ÓBUDA UNIVERSITY

REJTŐ SÁNDOR FACULTY OF LIGHT INDUSTRY AND ENVIRONMENTAL ENGINEERING

A MAGYAR TUDOMÁNY ÜNNEPE

Az MTA programsorozata

IJCELIT 2023

BOOK OF PROCEEDINGS

IJCELIT 2023

Book of Proceedings of the 9th International Joint Conference on Environmental and Light Industry Technologies [PDF]

IJCELIT 2023. BOOK OF PROCEEDINGS OF THE 9TH INTERNATIONAL JOINT CONFERENCE ON ENVIRONMENTAL AND LIGHT INDUSTRY TECHNOLOGIES [PDF]

ISBN 978-963-449-350-1

A MAGYAR TUDOMÁNY ÜNNEPE
Az MTA programsorozata

MAGYAR TUDOMÁNYOS AKADÉMIA · 1825 ·

ÓBUDA UNIVERSITY
REJTŐ SÁNDOR FACULTY OF LIGHT INDUSTRY AND ENVIRONMENTAL ENGINEERING

IJCELIT 2023

10 NOVEMBER 2023

ONLINE

IMPRESSUM

It is a Book of Proceedings of the 9th International Joint Conference on Environmental and Light Industry Technologies held online on 10 November 2023. IJCELIT aims to bring together researchers, engineers, and creative artists from basic research to industry applications working on light industry areas. IJCELIT 2023 comprised three simultaneous events, the Workshop on Graphic Communications Technology (GCTW), the International Symposium on Design and Innovative Technologies (ISDIT) and Workshop on Environmental Sciences and Engineering (WESE). Each event showcased selected scientific papers highlighting emerging technologies. The joint plenary session highlighted the latest technology trends in the field of the TCLF industry. The conference was organised in the framework of the Hungarian Scientific Season.

This publication, carried out by the Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University, is available on the conference website: https://rkk.uni-obuda.hu/ijcelit-2023/

The papers appearing in this book compose the technical conference proceedings cited on this volume's cover and title page. Papers were selected by the organising committee to be presented in oral or poster format and were subject to review by the programme committee.

IJCELIT 2023. Book of Proceedings of the 9th International Joint Conference on Environmental and Light Industry Technologies [PDF]

ISBN 978-963-449-350-1

Edited by: Dr. Edit Csanák

Publisher: Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University, **Budapest**, 1034 Doberdó út 6, Hungary

Year of publishment: 2024

Please use the following format to cite materials from this book: Author/s, "Title of paper", in IJCELIT 2023. Book of Proceedings of the 9th International Joint Conference on Environmental and Light Industry Technologies [PDF], pp. page numbers.

TABLE OF CONTENTS

COMMITTEES

Patron: **Prof. Dr. Levente Kovács**

Rector, Óbuda University

General Chair: **Dr. habil. László Koltai**

Dean, Óbuda University Sándor Rejtő Faculty of Light Industry and Environmental Engineering

Co-chair: **Dr. Edit Csanák DLA**

Vice Dean, Óbuda University Sándor Rejtő Faculty of Light Industry and Environmental Engineering

ORGANIZING COMMITTEE

Dr. Ákos Borbély

Dr. Rita Kendrovics

Prof. Dr. Marianna Halász

Lászlo Berek

Eszter Bartha

Coordinator
Andrea Tóth, Óbuda University, Hungary

MEMBERS OF THE SCIENTIFIC COMMITTEE:

Dr. Rita Bodáné-Kendrovics, Óbuda University RKK, Associate Professor

Dr. Edit Csanák DLA, Óbuda University RKK, Associate Professor

Prof. Dr. Márta Kisfaludy DLA, Óbuda University RKK, professor

Prof. Dr. Marianna Ágnes Halász, Óbuda University RKK, professor

Prof. hc. Dr. Csaba Horváth, Óbuda University RKK, honorary professor

Prof. Dr. Hosam Bayoumi Hamuda, Óbuda University RKK, associate professor

Dr. habil Róbert Németh, Óbuda University RKK, associate professor

Dr. Ákos Borbély, Óbuda University RKK, associate professor

Dr. Tamás Csiszér, Óbuda University RKK, associate professor

Dr. Krisztina Demény, Óbuda University RKK, assistant professor

Dr. Csaba Ágoston, Óbuda University RKK, assistant professor

FULL PAPERS

ADVANCED MACHINERY FOR GARMENT FINAL PRESSING

Ineta NEMEŠA[1], Marija PEŠIĆ[1], Nadiia BUKHONKA[1], Inese ZIEMELE[2], Valentina BOZOKI[1]

1 Technical faculty "Mihajlo Pupin", University of Novi Sad, Zrenjanin, Serbia

2 Riga Technical University, Latvia

Abstract

The garment finishing covers operations required to complete a garment: final pressing, folding and packing. The final pressing is done to increase quality and visual appearance of ready goods at garment factories, industrial laundries and dry-cleaners. Unwanted creases are removed by different style and productivity steam finishers and finishing tunnels. Flat single or double leg presses and contoured topping presses are used to get final look and needed creases on trousers. Wide variety of molding machinery is available to create 3D shapes in separate parts of ready garments. Four trends are actual in further development of finishing equipment: increased application, automation, digitalization and energy saving. Automation makes the finishing machinery highly programmable and reduces the need for manual labour. The machines can be connected to customer ERP networks to monitor and control work process in real time on-line. The finishing equipment becomes multi-functional and modular for wider range of applications in medium and small capacity production sites. Heat recovery systems and improved air and steam flow principles help to reduce energy consumption of advanced finishing machinery.

Keywords: *garment finishing, final pressing, steam finishers, finishing tunnels, shaping presses*

1. INTRODUCTION

During apparel manufacturing process flat 2D textile materials are cut in separate parts to be joined in 3D garments. The garment creation process is long and complicated, cut components and semi-finished articles are processed in different departments of sewing factory, transported from one work station to another and short time stored in between separate operations in smaller of larger bundles [1][2][3]. All these manipulations affect processed goods also negatively - semi-finished garments get wrinkled, coved with industrial dust and cut thread ends. During finishing operations the negative impact of industrial manufacturing process has to be removed and the appearance of ready garments has to be improved maximally to give them qualitative look and make them attractive to potential customers.

The garment finishing in apparel manufacturing process covers all the last operations required to complete a garment [4]. They can be divided in three main groups: final pressing, folding and packing.

2. FINAL PRESSING OF GARMENTS

The *final pressing* is done to increase quality and visual appearance of ready garments at clothing factories, shops, as well as, at industrial laundries and in dry-cleaning industry. The final pressing has several functions and machinery which helps to fulfil its stated tasks [5][6]:

- *removal of unwanted creases* - creases which are obtained during garment production process: cutting material, handling, holding and storing semi-finished goods. To remove unwanted creases shirt finishers, trouser finishers and finishing tunnels are used.
- *creation of needed creases* - in accordance with the design of a style different kind of creases use to be pressed on trousers, skirts, shirts, others. Special flat legger presses are used to process trousers with creases.
- *molding/shaping of ready garments* - creation of 3D shape by help of shrinkage or stretching of the fabric in separate parts of a garment. It is mostly used in men suit manufacturing processes. Pressing machines for different parts of a garment - for a front, a back, elbow seams, shoulder seams, a collar, others - are used for this purpose.

The most well-known manufacturers of final pressing machinery are: Veit Group (Germany), Macpi (Italy), Fimas (Italy), Pony (Italy), Rotondi (Italy), Sankosha (Japan), Oshima (Japan), Hoffman (USA), Forenta (USA), Weishi Machinery (China).

2.1. Machinery for crease removal

2.1.1. Shirt finisher (upper part garment finishers)

This machinery use to be called as a *steam air bag*, a *form press* or a *'dolly' press* or just simply a *steam finisher* (see Fig.1) [7]. It is formed from a base carrying a steam distribution system, compressed air distribution system and a pressing form/dummy - a canvas bag in the approximate shape of the upper part of a human body with no hand part on it. There is control system to apply steam and air, timers to perform certain length steaming and drying cycles. This equipment can remove accidental creases and refinish the fabric on such garments as: shirts, blouses, t-shirts, light blazers. If the form/doll is made longer, dresses can be finished, too [7][8][9][10][11][12][13].

Methodology: The operator puts the processed garment on to a doll. He fixes its hem line, front line and sleeves, by help of additional devices – a padded clamps which hold the separate sections of garment in place and a spring-loaded attachment for sleeves. Then the garment is expanded to its full size by help of steam which is blown through it from the inside. When the steaming is finished, hot air is blown from inside to dry the processed garment.

a  b 

Figure 1: Shirt finisher 484 by Barbanti (a) and trouser finisher 8741 by VEIT Group

The shirt finisher can be use together with a press for collars and cuffs to perform continues finishing process. Then while a shirt finisher processes a shirt, an operator can place the next shirt on a press for collars and cuffs.

2.1.2. Trouser finisher (topper):

Trouser finishers are used to remove creases from jeans and casual trousers which do not have wanted creases. Trouser finishers also have a base which carries a steam distribution and compressed air distribution system. A pressing form/doll is different - it has a shape of a human body's lower part on which the trousers are worn. It represents a extendable waist and hips of a human body. Computerized system controls application of steam and air in needed amount and time [7][11][14].

The trouser finisher can be also carousel type when a single machine is equipped with 4-5 finishing mannequins (see Fig.2). Then while an operator put on the trousers on a new form, other trousers are already steamed and dried on other work stations. The carousel type of trouser finisher can be used together with an automatic un-loader which takes off the processed trousers and place them on a conveying surface one by one or in pre-set bundles.

Figure 2: Automatic Four Station Unit for Trouser finishing Macpi 320

Methodology: The operator puts the processed trousers on a doll. Additional devices are used to fix in place and also iron a waistband-fly part, front pockets and side parts of the trousers. There are spring-loaded attachment for legs of the trousers in which the hems are fixed and moved down to stretch the legs in their real length. The trouser leg tensioning clamps can be adjusted in various position to fit better to different trouser styles. After it extension of a leg part, steaming and drying of a trousers follow.

2.1.3. Finishing tunnel

A finishing tunnel also removes creases by help of steam and air without applying a pressure to garments. Ready garments on hangers are moved through a multi-section tunnel on a motorized rail. They pass through sections with steam and are they dried by blowing air (see Fig.3,4). Gravity or tension pulls out the wrinkles and the turbulence of air creates additional energy to relax wrinkles in fabrics. Some finishing tunnels use infrared drying which gives better results. The parameters of steaming and drying processes in the tunnel can be set different for different quality fabrics. T-shirts and other knitwear use to be processed on special flat frames to pass through the tunnel on a conveyor belt. Operators only load and unload the garments [15][16][17].

Figure 3: The VEIT TF 57 Tunnel Finisher

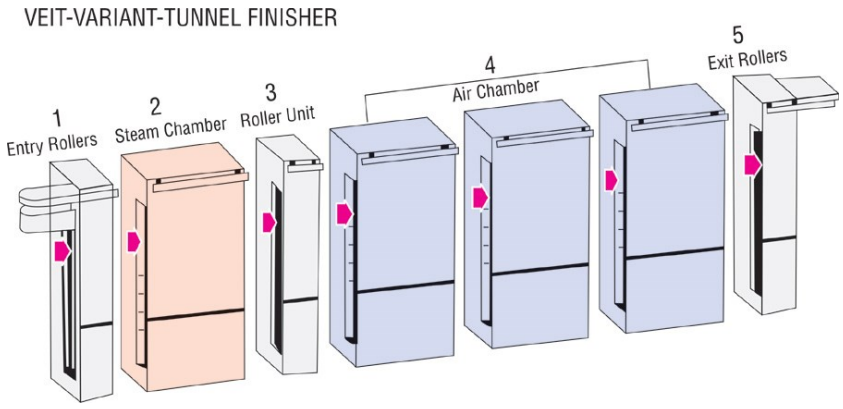


Figure 4: modular system of VEIT TF 57 Tunnel Finisher

2.2. Machinery for creation of needed creases

This machinery is used for final pressing and pleat creations on different style trousers. Traditionally trouser pressing is carried out in two operations on two different finishing machines:

- *flat legger press* - used to fix side seams and create needed creases (see Fig.5a).
- *contoured topping press* - used to press top/body part of trousers (see Fig.b).

2.2.1. Legger press for trousers

A flat legger press can be developed for single or double leg simultaneous processing (See Fig.5a). Press closing system can be vertical or scissor closing. The vertical top closing system ensures more even distribution of pressure onto the pressing surface and prevents displacement of the garment. Separate suction for lower plate and a swing frame are used to make the positioning of the trouser legs easier and more precious. To avoid impressions and gloss at the side seam, a split head action (with a vertically acting top plate) applies steam to the whole leg but no pressure to the seam area [11][12].

To increase productivity and ensure continues work process, carousel type flat legger presses can be used. They have two work stations and an automatic un-loader of processed trousers.

Methodology: An operator put trousers on a bottom press plate so that a body part of them stays in between two press plates for right and left leg. By help of bottom suction system trousers are smoothed and crease lines are placed precisely. Canvas plate is lowered on the trousers smoothing their top fabric layer. The top plate of a press is lowered applying stream and pressure. At the end of work cycle the top plate opens and the suction system takes way left moisture.

a b

Figure 5: Double Legger Trouser Press 8940 (a) and Trouser topper pressing machine BRI 231 SC (b) by company VEIT Group

2.2.2. A contoured topping press for trousers

A contoured topping press is used to press and iron top/body part of trousers (see Fig.5b). It has 3D top and bottom surfaces and a hand iron to press most difficultly reachable places of trousers manually. During the work process an operator works on separate areas replacing trousers on a bottom surface of a press.

2.3. Machinery for molding/shaping of ready garments

Different pressing machines are available to create needed 3D shapes on separate parts of ready garments (see Fig.6). Manufacturing men jackets the pressing is divided in two stages - under pressing and final pressing. Both of them use specially shaped presses. For example, there are available finishing machines for pressing collars, shoulders, jacket and sleeve hem and other parts of a jacket. Work principles are similar to methodology of trouser pressing [10][18][19].

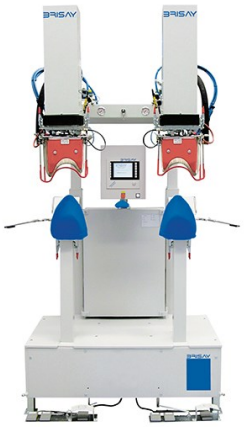
a  b 

Figure 6: Collar finishing press BRI 710/101 (a) and shoulder finishing press BRI 1920/101 (b) by VEIT Group

3. LAST TRENDS IN FINISHING MACHINERY DEVELOPMENT

The offer of finishing machinery is large, the equipment differ not only in application, but also in the technologies that increase its performances. Currently manufacturers of finishing machinery point out 4 main trends in development of their products, there are: increased application, automation, digitalization and energy saving [2][3][4].

3.1. Automation

Mechanization and automation for finishing equipment are not new, they have been used for decades. By help of mechanization manual ironing and pressing were replaced by machine labour. Automation has made the finishing equipment programmable, increased its functionality and ergonomics, reduced the need for manual labour. Pressing and finishing parameters have to be easy changeable during the

working day to make finishing machinery maximally flexible in application, increasing its processing quality and productivity.

3.2. Digitalization

Digitalization of the finishing equipment is the next development step after automation. The computer controlled finishing machines can be connected to customer ERP networks. Pressing parameters - pressure, temperature and the moisture content of steam can be controlled using appropriate software integrated into a network. By help of real time monitoring of finishing machinery it is possible:

- to modify the work process parameters for single or needed number of finishing machines in accordance with a new garment style and its material qualities;
- in real time to view the production status of a whole finishing equipment or a single press;
- to detect probable obstructions in production process (bottle necks, similar);
- to collect and analyze intelligent data and, by help of them, improve productivity of a production process;
- to receive maintenance notifications for finishing machines.

3.3. Energy saving

It is well known fact that pressing and finishing equipment uses a lot of energy and its manufacturers have always tried to develop their products with the lowest energy consumption. During the last years because of the world energy crises the task to produce energy-efficient machinery has become even more actual. Manufacturers of finishing equipment use:

- heat/hot air recovery systems - by help of new extraction concepts recycled hot air released during processing and re-use it reducing energy consumption by 20-30%. The heat exchanger dries the humidity obtained drying the fabric. This increases the drying temperature which leads to shorter processing time [20].
- improved air and steam flow - automatic drying sensors are used to control garment's dryness and switches off the blower as soon as the garment is completely dry. It helps to shorten processing cycle time to ensure maximum steam savings.

3.4. Increased application

In fast fashion dominance conditions, when garment orders are smaller in quantities but more different in design and materials used, finishing machinery becomes more flexible - multi-functional, modular for wider range of applications, easy controlled and programmed, developed for small and medium production units, laundries and drycleaners.

Figure 7: Narrow body tunnel finishers for dry-cleaned garments SkinnyMac CFS by Colmac

4. CONCLUTIONS

Advanced finishing technologies and equipment were researched and described in the paper. Following general conclusions were found:

1. Finishing operations have to remove negative impact of manufacturing process to ready garments and make them qualitative and attractive to potential customers. By help of final pressing unwanted creases are removed, needed pleats and creases are created and separate garment parts are pressed to obtain 3D shapes.
2. In fast fashion dominance conditions final pressing has become even more important. Often ready garments are delivered to shops in folded way to reduce transportations costs. The garments have to be pressed to remove unwanted creases directly in their sell place.
3. Different type and productivity steam finishers and finishing tunnels are developed to remove unwanted creases from ready garments. They are used at sewing factories, industrial laundries and dry cleaners. Processing trousers flat legger presses and contoured topping presses are used to get final look and needed creases. Wide variety of molding/shaping machinery is available to create 3D shapes in separate parts of ready garments.
4. Currently manufacturers of finishing machinery point out 4 main trends in development of their advanced products: increased application, automation, digitalization and energy saving.

REFERENCES

[1] Nayak R, Padhye R: *GARMENT MANUFACTURING TECHNOLOGY,* WOODHEAD PUBLISHING, ISBN: 978-1-84569-295-7, CAMBRIDGE, (2015)

[2] Fairhurst C.: DEVELOPMENT IN PRESSING TECHNOLOGY FOR GARMENT FINISHING, IN *ADVANCES IN APPAREL PRODUCTION*, WOODHEAD PUBLISHING, ISBN: 978-1-78242-232-7, CAMBRIDGE, (2008), PP.250-265

[3] Nayak R, Padhye R: INTRODUCTION IN AUTOMATION IN GARMENT MANUFACTURING, IN *AUTOMATION IN GARMENT MANUFACTURING*, WOODHEAD PUBLISHING, ISBN: 9780081011331, CAMBRIDGE, (2017), PP.1-25

[4] Fergusson S. M.: GARMENT FINISHING TECHNIQUES, IN *GARMENT MANUFACTURING TECHNOLOGY*, WOODHEAD PUBLISHING, ISBN: 978-1-84569-295-7, CAMBRIDGE, (2015), PP.250-265

[5] PRESSING AND GARMENT FINISHING TECHNIQUES, *AVAILABLE FROM*: https://www.styleliquid.com/2020/03/pressing-and-garment-finishing-technique.html ACCESSED: 2023.09.27.

[6] CONSISTENCY IN THE FINISHED RESULT, *AVAILABLE FROM*: https://www.laundryandcleaningnews.com/features/featureconsistency-in-the-finished-result-6881734/ ACCESSED: 2023.09.27.

[7] Khalil E.: ADVANCED APPAREL FINISHING MACHINERY, *AVAILABLE FROM*: https://textilernd.com/advanced-apparel-finishing-machinery/ ACCESSED: 2023.09.27.

[8] Jana P.: EVOLUTION OF TECHNOLOGY: PRESSING & FINISHING, *AVAILABLE FROM*: https://apparelresources.com/technology-news/manufacturing-tech/evolution-of-technology-pressing-finishing/ ACCESSED: 2023.09.27.

[9] MACPI, QUALITY AND INNOVATION ON DISPLAY AT EXPODETERGO INTERNATIONAL 2022, *AVAILABLE FROM*: https://www.detergo.eu/en/cover-story-macpi-quality-and-innovation-on-display-at-expodetergo-international-2022/ ACCESSED: 2023.09.27.

[10] FINISHING EQUIPMENT, *AVAILABLE FROM*: https://www.veit.de/en/products/finishing-equipment ACCESSED: 2023.09.27.
[11]PANTS FINIHER, *AVAILABLE FROM*: https://www.veit.de/en/products/pants-finisher/ ACCESSED: 2023.09.27.
[12]FINAL PRESSING, *AVAILABLE FROM*: https://macpi.it/prodotti/ironing-finishing-technology/shirt/final-pressing/?lang=en ACCESSED: 2023.09.27.
[13] SHIRT FINAL PRESSING, *AVAILABLE FROM*: https://www.rotondigroup.com/en/shirts/ ACCESSED: 2023.09.27.
[14] TROUSERS AND JEANSS, *AVAILABLE FROM*: https://www.rotondigroup.com/en/trousers-and-jeans/ ACCESSED: 2023.09.27.
[15] THE IDEAL SOLUTION FOR REFINISHING GARMENTS AND UNRIVELED FINISHING RESULTS, *AVAILABLE FROM*: https://www.veit.de/en/products/tunnel-finisher/tunnel-finisher-veit-8657/ ACCESSED: 2023.09.27.
[16] INDUSTRY 4.0: THE NEW MACPI FINISHING TUNNEL, *AVAILABLE FROM*: https://macpi.it/en/single-news.php?id=4061 ACCESSED: 2023.09.27.
[17TUNNEL FINISHERS… MAKING THE GARMENTS WRINKLE-FREE https://in.apparelresources.com/technology-news/manufacturing-tech/tunnel-finishers-making-garments-wrinkle-free/
[18] IN-LINE PRESSING OF FORMAL JACKET AND BLAZER, *AVAILABLE FROM*: https://apparelresources.com/technology-news/manufacturing-tech/line-pressing-formal-jacket-blazer/ ACCESSED: 2023.09.27.
[19] MEN'S JACKET OFFPRESSING, *AVAILABLE FROM*: https://www.rotondigroup.com/en/mens-jacket-offpressing/ ACCESSED: 2023.09.27.
[20] SHIRT FINISHER: WEIT 8326 PREMIUM, *AVAILABLE FROM*: https://www.newclothmarketonline.com/executive-pages/shirt-finisher-veit-8326-premium/ ACCESSED: 2023.09.27.

CORRESPONDING AUTHOR:

Dr. Ineta NEMEŠA
Department of basic and applied sciences, Technical faculty "Mihajlo Pupin", University of Novi Sad
Đure Đakovića bb, 23101, Zrenjanin, Serbia
E-mail: inetavil@gmail.com

COMMUNICATING SCIENCE AND HEALTH. MOTIVATION PROTECTION THEORY, COMMUNICATION DESIGN AND COVID-19

Manuela ZAMBIANCHI, Lorenzo VOLPE

University Institute ISIA, Faenza, Italy

Abstract

The communication of science represents nowadays an emerging issue. Social Representation Theory evidenced the socio-cognitive and emotional processes involved in the transformation of a scientific theme into a common social representation. Fundamental in our society is the figuration of knowledge, being iconic communication at the core of public messages. Health Psychology can give a contribution through models on psychological determinants of safe behaviours. A study was conducted based on theoretical models of Health Psychology and the principles of Communication Design in order to create a set of protective messages against Covid-19.

A research testing the efficacy of two of these messages involved 101 Italian participants (m. age 42.16; DS = 20.68). They filled in two self-report questionnaires and three single item asking the preferred media sources of information for Covid-19. Results confirmed the persuasive efficacy of both messages, the former about facial mask and the latter about vaccination. The perceived efficacy of both two messages shows positive Pearson's correlations with the four components of the Protection Motivation Theory. Results obtained encourage this research avenue, with the integration of communication design creativity with psychological science for the promotion of health at individual and community level for Covid-19 and for future sanitary crisis.

Keywords: *Social Repres entations, Health Psychology, Covid-19, Graphic design, Typography, Health Communication*

INTRODUCTION

At the end of the 2019 year, a new virus started its sudden diffusion from the Region of Wuhan (China) to the world, spreading across all the nations, giving life to the so called Covid-19 pandemic. Its quick diffusion, the threat posed to the health of the population, the high level of contagion brought to the forefront the question of the scientific communication of the evolution of the virus, the vaccine, and the other actions for reducing its diffusion.

The communication of science (its models, methodology, paradigms, results) become for this reason a central issue of our society. The advent of Covid-19 pandemic has demonstrated the fundamental role of science for reducing its destructiveness but, at the same time, it has highlighted in the population a growing skepticism and, sometimes, the refusal, or even denial of its discoveries (eg. the efficacy of the vaccine against Covid-19, the mounting presence of vaccine hesitant and vaccine resistant among the population). Understanding the causes of this skepticism, the determinants of the adoption of safety behaviours, constitutes an essential starting point for reaching through effective messages the population

and safeguarding its health. This pandemic therefore can be seen as a crucial event for rethinking the issue of communication about health and prevention of this (and not only) new planetary challenge.

Communicating science and health: the role of Social Representation Theory. Reified universes and Consensual universes: the language of science and the language of common sense.

This pandemic, due to its planetary diffusion and threatening for life and health highlighted the following questions:

How to make scientific discourse, scientific discoveries, scientific theories accessible to the widest public when a problem becomes global, of public domain, as in the case of Covid-19? How can one translate the technical, specialist, abstract and probabilistic language of science into a language that is authoritative, credible but also accessible to the widest possible public? How can we promote the protection of as many people as possible through authoritative and effective communication?

Social Representation Theory, [1, 2, 3, 4] was elaborated as an attempt to explain the processes involved in the "translation of a scientific model into a language understandable to non specialists". [1] Social Representations are defined as cognitive systems, with their own logic and language through which the individuals construct the social reality. Their genesis is favored by the emergence of new events, far from common knowledge and experience (the "*unfamiliar"*), generating fear and a sense of threat. They are thought as the basis of individual attitudes [5, 4]. Social Representations, contrary to official science (the "*reified universes*"), are defined as "*consensual universes*", characterized by the search for meaning, instead of scientific, probabilistic explanations of the problem or the event. Two main cognitive processes are involved in their genesis: the *anchoring* process (the new information is anchored to previous, ancient information, so that the new can be understandable), the *objectification* process (the new, abstract information is turned into a concrete image).

Moscovici [1] De Rosa ([3, 5] for their genesis, evidenced also the growing relevance on information diffusion, especially in the contemporary society dominated by mass-media and social media, that are often redundant but don't deepen the issues that are of growing interest for the society (as in the case of Covid-19 pandemic). A central concept of the Social Representation Theory is the "*figuration of knowledge*", that is the predominance of iconic dimensions with respect to logic-verbal dimension.

As stated by Cohen et al. [6] "the main characteristic of visual material is that it generates emotions". They maintain that the process of objectification (use a concrete object for clarifying abstract contents),

Covid-19 vaccination campaign poster in Budapest, 2021

central in the construction of social representations, leads them to acquire a figurative core, making communication easier among members of social groups.

This predominance of iconographic dimensions nowadays is reinforced by the digital media, based especially on iconographic communication, and this can lead to a growing difficulty in disentangling and comprehending the argumentative explanation of complex concepts such as those of bio-medical nature and epidemiology. [7, 8] The use of the figuration of knowledge is ancient, almost in epidemiology, as can be seen from the paintings depicting the first vaccinations against smallpox such as Eugène Ernst Hillemacher (1884). It provided information in a social context with low level of verbal competencies and high level of illiteracy, highlighting in this case the central role of the doctor, the authority in science, surrounded by the whole family. These painting was not only artistic masterpiece, but instead a messages that had the aim of reassuring the population about the efficacy of this new discovery, the vaccine.

The social communication of protective behaviours such as the vaccine against Covid-19 utilized this type of mass communication widely, together with short verbal messages (see figure 1) in some cases from authoritative scientists, known to the general public (see figure n.

1. Vaccine works, Hungary Works
2. Italian Vaccine Brand Identity by Studio Boeri Architecture

The Social Representations are, in the conception of Jaspars & Fraser, as stated above, at the basis of individual attitudes. As we can see below, the attitudes toward a question or a health issue are at the core of relevant models of Health Psychology for primary prevention. For this reason the study in depth of social representations of a health treat such as the Sars-Cov-2 constitutes a fundamental premise for subsequent interventions aimed at modifying the biased or untrue common models for the pandemic, the virus and the preventive actions such as taking the vaccine.

Social communication of health can be thought as a “bridge” between official science and social perception of the scientific question. For reaching this important objective a multidisciplinary approach has to be adopted.

Health Psychology and the determinants of protective behaviours

Health Psychology is an area of research and application within the psychology field that focuses on how social, psychological, and biological factors combine to influence human health. It focuses both on primary prevention, and on secondary prevention (the reduction of damages and the coexistence with chronic diseases), at individual, groups and social level. [9, 10, 11] For the primary prevention, research conducted in several decades in Health Psychology leads to understanding that:

Information is necessary, but not a sufficient condition for producing a desired protective behaviour against health risks. Adherence to health protective behaviours over time is the result of numerous psychological and psychosocial factors. Research has elaborated several models for preventive behaviours. One of the most relevant Is the Motivation Protection Theory (PTM). [12, 13, 14, 10]

The Protection Motivation Theory maintains that the adoption of protections for safeguarding health is the result of four steps, or factors:

a) The problem is severe (**Perception of gravity of the problem**). for protection, people have the necessity to perceive the problem as severe

b) You have to perceive yourself as vulnerable (P**erceived vulnerability to the problem**). To adopt the protections, after having considered the problem to be serious, one must perceive oneself as vulnerable to the problem.

c) Effective actions/protections exist (**Efficacy of the protections available**). After recognizing that the problem is serious and believing that we can be involved in it, it is essential to know that there are effective actions and behaviours for avoiding the damage.

a) You feel yourself able to use these protections (**Perception of self-efficacy and contro**l). Having effective systems available to, request a good self-efficacy for adopting them.

This model has been extensively adopted by scientific international community for exploring the determinants and predictors of protective behaviours against Covid-19, eg. [15, 16, 17].

Design Communication and Health promotion

The term Communication Design indicates an area of design research and intervention that, through creativity and a series of more or less conventional tools—ranging from print to digital platforms [18, 19]—seeks to "tell" and enhance an object, a message, or a story [20, 21]. Therefore, it is not so complex to observe that everything around us in the human realm is the result of a designer's planning. Whether an object is complex or simple, whether it is a pen or a web page, a book, or a poster, it will always be the result of creative thinking [19]. The world of design is characterized by a strong interdisciplinary and multidisciplinary vocation because the creation of products and messages requires the presence of multiprofessional teams with diverse perspectives and skills to realize them. Any respectable professional in the field of design, when dealing with complex communicative issues such as social problems or health threats, must possess numerous and complex skills. Above all, a broad knowledge and mastery of analog tools and digital graphic design software are required. Only in this way can one express their ideas with quality and speed, leveraging the great technological resources available today. Depending on the type and purpose of the project, the first step is to grasp the best way to convey a specific message, evaluating whether to use mediums such as illustration, photography, 3D modeling, or animation.The scope of the creative profession is very vast and includes various specificities, such as that of Social Communication Design: a design area where, through creative and innovative thinking, an attempt is made to sensitize a specific target audience to accept, reject, or modify a certain behavior that could harm the individual or their community [22]. There are numerous factors that can positively or negatively impact the correct or ineffective efficacy of social communication, and consequently, on the possibility of actual change by individuals or the community. A first point is the so-called visual hierarchy of a message. When creating a message, it is necessary to arrange elements in a way that allows reading in a prioritized order of conceptual importance. Several determining factors come into play: color, position, and size of elements in the layout [23]. Another essential theme in social marketing design is the readability of an element; it should lead to a process of viewing, recognition, and understanding regarding a given phenomenon. Whether it's text or an image, what we want to communicate to our audience must be clear and easily interpretable. Otherwise, communication would lose its purpose and effectiveness. These may seem like basic considerations, but it is precisely through

their correct implementation that the success or failure of a communication campaign can occur. Returning to the concept of readability, one of the points of major reflection and work for a communication expert is the correct choice and use of a font.The term "font" refers to a typeface, which represents the most important and widespread design invention in the world. Underestimating the choice of font type, for example in an advertising campaign, can alter the perceived tone of voice through the textual message [24, 25, 26]. The selection of a serif font, with upper and lower extensions in the letters, as opposed to a sans-serif font with more linear traits, can give the creative message a different identity, influencing possible interpretations [27, 28]. Two very well-known typefaces, which are certainly not unfamiliar to readers, are Helvetica and Times New Roman. The first is a sans-serif font with a modern design, widely appreciated for its readability, used in a wide range of applications, from design magazines to metro tickets, corporate brands, and websites. Times New Roman, on the other hand, is a serif font with a design reminiscent of Roman characters, characterized by serifs and x-height that favor smooth reading, making it ideal for the composition of books, essays, or articles with large amounts of text [29]. This distinction is just the tip of the iceberg, considering that there are hundreds of thousands of fonts, historically divided into categories such as Renaissance, Baroque, Modern, and Postmodern fonts [30]. In other words, distinctions in typography go well beyond the simple question of "Which font is more readable?" Health Psychology [9] teaches us that information alone, related to a health threat, is not sufficient to generate the desired protective behavior. For this reason, relying on the principles of Communication Design becomes a key element in combating fake news or erroneous beliefs on topics such as Covid-19 vaccination or the use of health protective devices [31]. Throughout history, numerous socio-health information campaigns have been conducted in various formats, from posters to announcements on social networks such as Facebook or Instagram [32, 33]. In addition to choosing the platform to disseminate the message, it is important to distinguish the different goals that messages can have, aiming to increase awareness of a phenomenon, change behaviors that could negatively impact the community, or counter opinions on unfounded beliefs, as in the case of vaccine misinformation [34, 35]. To develop persuasive messages on the threat of Covid-19, the authors conducted an in-depth study of numerous national and international social campaigns [36, 37, 38, 39] [40, 33], analyzing the basic design and its reception by the population. They also examined other social campaigns, seemingly unrelated to Covid-19 but with effective design structures, such as cases of Nike and IKEA, focused on communication against racial and sexual discrimination [40, 41]. In Italy, health authorities tried to raise awareness among the population about the danger of Covid-19 through Stefano Boeri's "Primula" campaign, which was supposed to become the symbol of the Italian vaccination campaign. However, the graphic management was criticized for questionable choices and low-quality tools in message creation, deemed too distant and cold by the public [42, 43, 44, 45]. The analysis reveals the complexity in constructing valid social communication, highlighted by the four steps illustrated by Pietrantoni and Prati [22]:

1 Target planning: Identify the target population for messages so that social and/or health communication is effective, considering psychographic and structural variables such as gender, age, and education.
2 Development of messages and communication materials: Base choices on the target and the selected media for communication, taking into account the best graphic medium for the image.

The study: objectives and hypotheses

The research started during the acute phase of the pandemic (2020-2022); the diffusion of the Sars-Cov-2 indeed generated the necessity to identify effective strategies of communication on protective behaviours (facial mask, hand gel, social distance, vaccine) that science was gradually discovering as effective in reducing the mortality and the contagion. This study represents an attempt to integrate two areas of research, Health Psychology for its knowledge about the predictors of healthy behaviours and Communication Design for its capacity to creatively translate these psychological factors coming from scientific models into effective communication for health promotion. The main model of Health Psychology that was chosen for the study is the Protection Motivation Theory.

METHODOLOGY

The study has been developed in two steps.

The first step consisted in creating of a series of messages based on Protection Motivation Theory and Design Communication principles for specific targets: young people, adults and old people.

The second step consisted in an experimental study on the perceived efficacy of two messages that was created (the former for encouraging the adoption of facial mask and the latter for the adherence to vaccination campaign). For this study, 101 people took part in it (66 males and 35 females, m. age = 42.16; SD = 20.68; range: 18-87). They filled in the Questionnaire on Motivation to Protect against Covid-19 (Zambianchi, 2021) and a *purpose-built* questionnaire on the perceived efficacy of the two messages (Zambianchi, 2022). Both Questionnaires highlighted good psychometrics properties (Cronbach Alpha). Three single item explored the sources of information on Covid-19 evolution (traditional mass-media; social media; specialistic journals).

RESULTS

Pearson's Correlations between the perceived efficacy of the two messages and the PTM factors

The Pearson's Correlations matrices show that there are positive correlations between the perceived efficacy of both messages and the dimensions of Protection Motivation Theory. Negative correlations has been found, on the contrary, between mistrust in Political Institutions and mass-media and the efficacy of the two messages.

Table 1: Zero order correlations between the perceived efficacy of facial mask messages, PTM dimensions and mistrust in Political Institutions and media

Variabile	Perceived efficacy ms. mask	Mistrust in Institutions and mass-media	Perceived gravity and vulnerability	Efficacy of protections	Beliefs on vaccine
Perceived efficacy ms. mask	---------				
Mistrust in Institutions	-0.21*	----------			
Perceived gravity and vulnerability	0.39***	-0.38***	----------		
Efficacy of protections	0.41***	-0.44***	0.39***	----------	
Beliefs on vaccine	0.45***	-0.50***	0.61***	0.54***	----------

** p< 0.05; *** p< 0.001*

Table 2: Zero order correlations between the perceived efficacy of vaccine messages and PTM and the mistrust in Political Institutions and mass-media

Variabile	Perceived efficacy ms. vaccines	Mistrust in Institutions and mass-media	Perceived gravity and vulnerability	Efficacy of protections	Beliefs on vaccine
Perceived efficacy ms. vaccines	---------				
Mistrust in Institutions	-0.22*	----------			
Perceived gravity and vulnerability	0.56***	-0.42***	----------		
Efficacy of protections	0.38***	-0.30**	0.37***	----------	
Beliefs on vaccine	0.63***	-0.38***	0.58***	0.41***	----------

** p< 0.05; *** p< 0.001*

Both messages are positively correlated with traditional mass-media as sources of information (mask message: 0.30; p< 0.001; vaccine message: 0.41; p< 0.001).

DISCUSSION

Results obtained encourage this research avenue, with the creative integration of Communication Design with Psychological Health Science for the promotion of protective behaviours and health at individual and community level (Volpe, Zambianchi, 2022). The pandemic can be seen as a starting point for new paths for prevention in case of future sanitary crises.

REFERENCES

1. Moscovici. S.: *La psychanalyse, son image et son public*. Paris: PUF. (1961)
2. Farr, R.; & Moscovici, S.: Rappresentazioni sociali. Il Mulino ed. ISBN 88-15-02319.4 (1989)
3. de Rosa, A. S., & Mannarini, T. Covid-19 as an «invisible other» and socio-spatial distancing within a one-metre individual bubble. Urban Design International, 26, 370-390. https:// doi.org/10.1057/s41289-021-00151-z. (2021)
4. Galli, I. *Rappresentazioni Sociali*. Il Mulino ed. Bologna. (2012)
5. Livolsi, M. (200). Manuale di Sociologia della Comunicazione. Laterza ed. Bari. ISBN 20-6147-6.
6. Cohen, G., Bessin, M., & Gaymard S. *Social representations, media, and iconography: A semiodiscursive analysis of Facebook posts related to the COVID-19 pandemic.* European Journal of Communication 2022, 37(6) 629–645. DOI: 10.1177/0267323122109633. (2022).
7. Bucciarelli, M. *Meccanismi psicologici alla base del disprezzo del sapere scientifico, Giornale Italiano di Psicologia* 2, 335-350, doi: 10.1421/102686. (2021)
8. Zambianchi, M.:Dalla Letteratura Scientifica all'Intervento Formativo. La Pandemia di COVID 19 tra crisi individuale e sociale:per un approccio formativo improntato alla complessità. Counseling. Giornale Italiano di Ricerca e Applicazioni, 3, 21-36. doi: 10.14605/CS1532202, (2022)
9. Gremigni, P. *Comportamenti di Salute: Modelli e Teorie di Riferimento.* In Ricci Bitti P. E., & Gremigni, P. (ed). *Psicologia della Salute. Modelli Teorici e Contesti Applicativi.* Carocci ed. Roma. ISBN. 978-88-430-7020-6. (2013)
10. Zambianchi, M.: Covid-19, *La teoria della Motivazione a proteggersi. Il Sole 24 Ore*. / May, (2003).https://www.ilsole24ore.com/art/covid-teoria-motivazione-proteggersi-vaccino-contro-nuove-pandemie-AEXw5zPD.
11. Zanin, L., & Zambianchi, M. : *Anziani, Prospettiva Temporale e Pandemia di COVID-19*. Counseling, 15 (2), 37-62. DOI: 10.14605/CS1522203.
12. Rogers, R. W. : A protection motivation theory of fear appeals and attitude change. Journal of Psychology, 91(1), 93-114. DOI: 10.1080/00223980.1975.991583 (1975).
13. Rippetoe, P. A., & Rogers, R. W.: *Effects of components of protection-motivation theory on adaptive and maladaptive coping with a health threat.* Journal of Personality and Social Psychology, 52, 596-604. https://doi. org/10.1037/0022-3514.52.3.596 (1987)
14. Milne, S., Sheeran, P., & Orbell, S.: Prediction and intervention in health related behavior: A Meta-Analytic Review On Protection Motivation Theory. Journal of Applied Social Psychology, 30(1), 106-144. DOI: 10.1111/j.1559- 1816.2000.tb02308 (2006)
15. Eberhardt., J., & Ling J.: *Predicting COVID-19 vaccination intention using protection motivation theory and conspiracy beliefs. Vaccine*, 39 (42), 6269-6275. doi: 10.1016/j.vaccine.2021.09.010. (2021)
16. Ezati, R. A. D., Mohseni, S., Takhti, H. K., Azad, M. H., Shahabi, N., Aghamolaei, T., & Norozian, F. : Application of the protection motivation theory for predicting COVID-19 preventive behaviors in Hormozgan, Iran: A cross-sectional study. BMC Public Health, 1-11. https://doi.org/10.1186/s12889-021-10500w (2021)
17. Zambianchi, M.: (2022). *The young and the pandemic. A pilot study testing a questionnaire onpsychological motivation to protect against Covid-19. Counseling,* Giornale Italiano di Ricerca Applicazioni, 15(1), 86-106. DOI: 10.14605/CS1512206

18. Newsroom.: *WWF shakes up the rules of Fortnite with eco-friendly #NoBuildChallenge by We Are Social,* https://marcommnews.com/wwf-shakes-up-the-rules-of-fortnite-with-eco-friendly-nobuildchallenge- by-we-are-social/ accessed (2023-05-22).
19. Norman, D.: *La caffettiera del masochista. Psicopatologia degli oggetti quotidiani,* Giunti, Firenze, (1990).
20. De Bono, E.: *Sei cappelli per pensare. Manuale pratico per ragionare con creatività ed efficacia,* Rizzoli, Milano, (2013)
21. Munari, B.: *Design e comunicazione visiva. Contributo a una metodologia didattica*. Laterza, Bari, (2017)
22. Pietrantoni, L. & Prati, G.: *Perché accadono gli incidenti,* Carocci, Roma, (2013)
23. Falcinelli, R.: *Cromorama,* Einaudi, Torino, (2017).
24. Beier, S.: *Type Tricks: Your Personal Guide to Type Design,* BIS Publisher, Amsterdam, (2017)
25. Garfield, S. *Sei proprio il mio typo. La vita segreta dei caratteri tipografici,* TEA, Milano, (2015)
26. Hochuli, J.: *Il dettaglio in tipografia*, Lazy Dog Press, Milano, (2018).
27. Tracy, W.: *Letters of Credit: A View of Type Design*, D.R. Godine, Boston, (2004)
28. Gerard, U.: *Il gioco della lettura*, Stampa Alternativa, Roma, (2006)
29. Gerard, U.: *La teoria del type design*, Ronzani Editore, Vicenza, (2020)
30. Bringhurst, R.: *Gli elementi dello stile tipografico*, Edizioni Sylvestre Bonnard, Milano, (2001)
31. Volpe, L. & Zambianchi, M.: *Design dentro e oltre la pandemia. Il valore della comunicazione sociale,* Homeless Book, Faenza (2022).
32. Garcia, A., & Eirò Gomes, M.: *Health communication in times of pandemic: The perspective of Portuguese National Health Service users.* Comunicação y Sociedade, 40,189-203. doi: 10.17231/comsoc.40 (2021).3250, (2021)
33. Wirz, C. D., et al.: *Science communication during COVID-19: When theory meets practice and best practices meet reality*. Journal of Science Communication, 21(3), N01. https://doi.org/10.22323/2.21030801, (2022).
34. Riva, G.: *Fake News. Vivere e sopravvivere in un mondo post-verità.* il Mulino, Bologna, (2018).
35. Agrifoodtoday.: *La notte è dei vaccinati-lo spot dell'Heineken fa infuriare i no-vax*. https://www.agrifoodtoday.it/attualita/la-notte-e-dei-vaccinati-lo-spot-dell-heineken-fa-infuriare-i-no-vax.html, accessed: 2021-06-21.
36. Bertolucci, L.: *Oliviero Toscani è un magnifico fallito?* https://www.ilfatto-quotidiano.it/2019/05/15/oliviero-toscani-e- un-magnifico-fallito/5177120/, accessed: 2022.07.26.
37. Burgio, R.: *Comunicazione sociale: La pubblicità per fare del bene,* https:// lagazzettadelpubblicitario.it/branding/inclusion-%20diversity/comunicazione-sociale/, accessed: 2022.09.27.
38. Palazzo Chigi. *La stanza degli abbracci, campagna di comunicazione per la Vaccinazione anti-Covid-19*,[Video], https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiyven6q--DAxUN9gIHHe4XDKYQwqsBegQIDRAG&url=https://www.youtube.com/watch?v=NRymX7aOy6w&usg=AOvVaw01603p65s6NdIJaiSyAWF1&opi=89978449, accessed: 2022.08.18.

39. Sica, J.: *Colin Kaepernick e il suo inginocchiamento durante l'inno: così 5 anni fa il giocatore di football aprì la strada alla protesta nello sport*. Retrieved from https://www.ilfattoquotidiano.it/2021/08/26/colin-kaepernick-e-il-suo-inginocchiamento-durante-linno-cosi-5-anni-fa-il-giocatore-di- football-apri-la-strada-alla-protesta-nello-sport/6303001/, accessed: 2022.08.27.
40. IKEAitalia: #FATELOACASAVOSTRA, [Video], https://www. youtube. com/watch?v=boGe6J8B8No, accessed: 2022.08.27.
41. Giorgi, G.: *Primule? No grazie. I padiglioni di Arcuri rifiutati dalle Regioni. Rischio focolai e menzogne eco-friendly dietro il flop,* https://www.open.online/2021/02/07/covid-19-vaccini-primule-no-grazie-i-padiglioni-di-arcuri-rifiutati-dalle-regioni/, accessed: 2021-02-07
42. Il Portale Degli Italiani Emigrati: *Covid, flop pazzesco per lo spot vaccinale con la primula.* https://italianiemigrati.com/covid-flop-pazzesco-per-lo-spot-vaccinale-con-la-primula/, accessed: 2022-08-27.
43. Ministero Salute: *Facciamolo per noi*, [Video], https://www.youtube.com/watch?v=5VUss9DtQJg, accessed: 2022-08-27.
44. Ottomanelli, A.: *La Primula di Stefano Boeri sui padiglioni dei vaccini. Operazione poco comprensibile.,* https://www.artri- bune.com/progettazione/architettura/2020/12/primula-padiglione-vaccini-boeri/, accessed: 2022-12-16.
45. Kowalski, R. M., et al.: *Protection Motivation Theory and Intentions to Receive the COVID-19 Vaccine,* Health Promotion Practices. doi: 10.1177/15248399211070807, (2022).

AKNOWLEDGEMENT

Authors thank the "Dalle Fabbriche Multifor Foundation" for funding the research

CORRESPONDING AUTHORS:

Manuela ZAMBIANCHI PhD
University Institute ISIA, Faenza, Italy
Corso Giuseppe Mazzini, 93, 48018 Faenza RA
40129, Bologna, Italy
E-mail: zambianchi_manuela@isiafaenza.it

Lorenzo VOLPE
University Institute ISIA Faenza, Italy
E-mail: volpe_lorenzo@isiafaenza.it

THE INFLUENCE OF PACKAGING ON FOOD PRODUCT SHELF LIFE: REDUCING FOOD WASTE AND EXPLORING ENVIRONMENTALLY SUSTAINABLE APPROACHES

Teodora GVOKA, Gojko VLADIĆ, Gordana BOŠNJAKOVIĆ, Magdolna PÁL, Gala GOLUBOVIĆ, Katarina MARIČIĆ

University of Novi Sad, Faculty of Technical Sciences, Department of Graphic Engineering and Design, Novi Sad, Serbia

Abstract

Although world hunger remains a pressing problem, unfortunately, a significant amount of produced food is thrown away, resulting in environmental waste. Although food waste may seem less noticeable compared to other forms of environmental pollution, it is a major environmental challenge. The impacts of food waste go beyond its outward appearance and include excessive energy consumption, resource depletion, and more. At the same time, food packaging, often perceived as a significant environmental burden, is ubiquitous in public spaces around the world. Nonetheless, packaging performs indispensable functions: It protects food from external hazards, extends its shelf life, facilitates grouping, and preserves its essential properties. This paper aims to highlight the extent of food waste and its negative impact on the environment. It also attempts to propose possible solutions to this problem through innovative packaging solutions. This paper discusses various materials suitable for food packaging and their potential to have a positive impact on the environment.

Keywords: *Food Waste, Sustainable Packaging, Food Packaging*

1. INTRODUCTION

According to the Food and Agriculture Organization (FAO), the prevalence of global hunger remains significantly higher than the levels recorded prior to the onset of the COVID-19 pandemic. Projections indicated that in 2022, between 690 and 783 million individuals worldwide confronted hunger, marking an increase of 122 million people compared to the period preceding the pandemic [1]. On the other hand, although the percentage of world hunger is extremely high, a significant amount of food is thrown away into the environment every day. In 2019, approximately 931 million metric tons of food, constituting 17% of the total food supply accessible to consumers, found its way into the waste streams of households, retailers, restaurants, and various food service establishments. This revelation comes from recent research conducted by the United Nations to support worldwide initiatives aimed at reducing food waste by 50% by the year 2030. The primary contributors to food waste are households, responsible for 47 million tons (with a margin of ± 4 million tons), and the processing sector, accounting for 17 million tons (with a margin of ± 13 million tons). Of the remaining 28% of food waste, food service is responsible for 11 million tons (12%), primary production for 9 million tons (10%), and wholesale and retail sectors for 5 million tons (5%) [2]. To put it in perspective, one in every four food calories intended for human consumption ultimately goes unconsumed [3]. On a global per capita basis, an average of 121 kilograms of consumer-grade food is squandered annually, with households accounting for 74

kilograms of this total. It's worth emphasizing that the food lost or wasted has the potential to provide nourishment for 1.26 billion people suffering from hunger each year [4].

Worldwide, the food and beverage industry plays a substantial role in driving climate change and various other environmental challenges. In the European Union (EU), food production stands out as a principal driver of consumption-related environmental consequences. The primary cultivation of food necessitates the utilization of a diverse range of resources, including fossil fuels, land, freshwater, and raw materials, each of which carries economic and environmental impacts [6, 5]. Despite the ongoing shortfall in climate action, approximately 8% to 10% of global greenhouse gas (GHG) emissions are linked to unconsumed food when accounting for losses before reaching the consumer level. According to the Environmental Protection Agency (EPA), the annual carbon dioxide equivalent GHG emissions resulting from food loss and waste, spanning from production to consumption, amount to 170 million metric tons. This quantity is equivalent to the annual CO_2 emissions generated by 42 coal-fired power plants. This calculation does not encompass the significant methane emissions arising from food waste decomposition in landfills [4].

1.1 Food packaging and the environment

Packaging has become ubiquitous, from parcels for online shopping to coffee-to-go cups. Every product offered on the market requires adequate packaging. The consumption of packaged foods has seen a significant surge in recent decades. With an annual growth rate of 5%, the global packaged food market was valued at $1.9 trillion in 2020, and it is anticipated to reach $3.4 trillion by 2030 [7]. In 2021, the European Union produced 188.7 kilograms of packaging waste per capita, marking a substantial increase of 10.8 kilograms per person compared to 2020, the largest rise in a decade, and nearly 32 kilograms more than in 2011. In total, the EU generated 84 million tons of packaging waste, with paper and cardboard accounting for 40.3% of this waste. Plastic constituted 19.0%, glass 18.5%, wood 17.1%, and metal 4.9% [8]. A significant portion of plastic waste polluting the environment is attributed to food packaging plastics [9]. In 2021, the average per capita plastic packaging waste generated by individuals in the EU was 35.9 kilograms, with 14.2 kilograms being recycled. Compared to 2020, both the generation of plastic packaging waste and recycling increased: generation rose by 1.4 kilograms per capita (4.0%), and recycling increased by 1.2 kilograms per capita (9.5%) [8].

The world is currently grappling with three pressing issues: the problem of global hunger, the problem of food waste, and the pervasive challenge of single-use plastic waste. A substantial portion of single-use plastic waste is attributed to the realm of food packaging. Regrettably, most food packaging is designed for single use and lacks a recycling framework. Following product consumption, this packaging typically undergoes improper disposal, frequently ending up in locations ill-suited for its management, such as landfills, riverbanks, oceans, meadows, and forests. This haphazard disposal of food packaging poses a significant hazard to both aquatic and terrestrial ecosystems [10, 11]. A notable consequence of this inadequate disposal is the substantial contamination of waterways, as illustrated in Figure 1a, posing a grave threat to aquatic life. Ingestion of plastic materials by marine creatures can prove fatal, contributing to the annual demise of 100,000 marine animals due to pollution caused by waste. Alarmingly, a staggering 693 distinct marine species have been observed to ingest or become ensnared in ocean-bound plastic waste [12]. Beyond water pollution, food packaging also engenders other environmental concerns, including air and soil pollution, as depicted in Figure 1b.

Figure 1: Examples of pollution caused by food packaging: a) water pollution, b) land pollution

There is a concerted effort to reduce the quantity of packaging employed and the resultant packaging waste. However, this endeavor to minimize, and in certain cases, eliminate packaging, carries the potential for heightened product damage and increased waste generation. This unintended consequence may counteract the environmental benefits sought through changes in packaging. It is worth noting that the ecological footprint stemming from food and beverage waste often surpasses that of the packaging itself when considering the comprehensive array of resource inputs, including water and fossil fuels, as well as the associated emissions and waste outputs associated with the sourcing of raw materials, transportation, product manufacturing, distribution, usage, and eventual waste disposal [5].

2. THE IMPACT OF PACKAGING ON FOOD PRODUCT SHELF LIFE

Although discarded packaging is a significant problem for the environment, packaging itself is still necessary to preserve food products. Food packaging includes any material used for wrapping and packaging food products. It primarily includes various boxes, canisters, bottles, bags, sacks, and tubes, as well as various foils and wrapping films. The packaging should safeguard its contents from external environmental influences, including water, water vapor, gases, odors, microorganisms, light, dust, shocks, vibrations, compressive forces, and so forth [14,15]. Depending on the characteristics of the product itself, food packaging can be made of different materials, such as paper and cardboard, metal, glass, and plastic. According to Robertson [13], the main functions of packaging are to contain food, protect it from adverse external effects and damage, facilitate storage, and communicate with consumers by offering information about its content. In addition to the previously stated, the extension of the shelf life and freshness of the product, along with the reduction of waste generation, is a very important role of packaging. In order to extend the life of food products and preserve their freshness and other important properties, while preventing the creation of new food waste and other hazards resulting from it, it is necessary to choose natural, ecologically sustainable and acceptable, and at the same time creative solutions. Some of these solutions include the use of intelligent and active packaging, as well as the use of environmentally sustainable packaging materials, in order to replace harmful packaging materials and, where possible, apply a zero-waste policy.

2.1 The use of active and intelligent packaging

While traditional food packaging techniques have played a significant role in advancing food delivery systems, there has been a recent recognition that these methods may not consistently align with the increasing expectations of consumers. Notably, conventional packaging systems face certain limitations, particularly in terms of extending shelf-life and ensuring food safety [16]. When it comes to extending the shelf life of food products and preserving the freshness of food products, active packaging, and intelligent packaging have proven to be extremely effective solutions. Active packaging (AP) (Figure 2b) involves packaging systems designed to intentionally incorporate components that release or absorb substances into or from the packaged food or the surrounding environment [17]. This is the type of packaging that directly interacts with the content of the packaging in order to improve product quality during storage. The main task of this packaging is to remove unwanted components from food or its environment, such as moisture, oxygen, carbon dioxide, and other gases, and odors, or to add components to food, such as antioxidants, antimicrobials, flavors, et cetera (Figure 2a) [18]. This approach leads to a decrease in food waste and enhances the quality of food products, consequently leading to an extended shelf life. Precisely because of its advantages, this type of packaging has found wide application in the packaging of fresh products and high perishable foods, such as fruit and vegetables, meat, fish, and the like. As an illustration, when it becomes imperative to govern and oversee the degree of ripening in fresh fruits and vegetables, the inclusion of specific substances, such as activated carbon, silica gel, or potassium permanganate within the packaging, proves influential in addressing this issue. [18, 19]. Depending on the food product for which they are intended, active packaging can provide optimal conditions, such as humidity level, gas permeability, sterility, and many others.

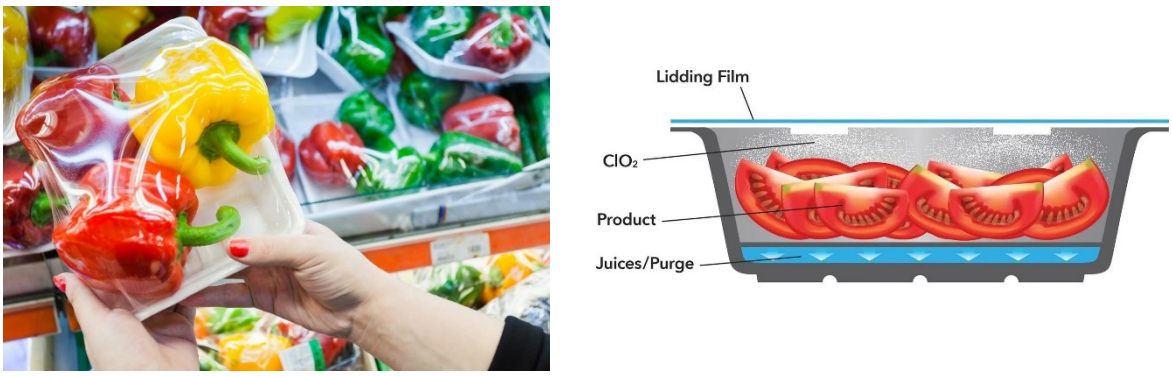


Figure 2: Active packaging: a) example of active packaging application, b) elements of active packaging

Furthermore, active packaging contributes to sustainability by diminishing both food waste and potential packaging waste. Embracing novel materials, optimizing existing materials, and introducing innovative processes and technologies could significantly contribute to the reduction of food waste while concurrently meeting consumer expectations and needs [18, 20].

Intelligent packaging (Figure 3a) implies packaging materials that provide the possibility of additional consumer information about the packaged product itself, as well as about the environment that surrounds

it, without physical contact between these materials and the food product [17, 21]. Those materials can sense environmental changes, as well as internal changes in packaged food, and in turn, inform users about these changes. Intelligent packaging (IP) systems incorporate a specialized component or device within or on the packaging that responds to kinetic changes associated with the quality of the food or its environment [22]. These devices can be categorized into three groups. The first category comprises external indicators (Figure 3b), affixed outside the package, such as time-temperature indicators and physical shock indicators. The second category consists of internal indicators, positioned within the package, either in the headspace or attached to the lid. Examples include oxygen leak indicators, carbon dioxide indicators, microbial indicators, and pathogen indicators. The third category encompasses devices designed to enhance information flow and facilitate effective communication between the product and the consumer. This includes special barcodes storing information on food product details such as usage and expiration dates. Devices for product traceability, anti-theft measures, anti-counterfeiting features, and tamper-proof mechanisms are also included in this classification [21, 22].

Figure 3: Intelligent packaging: a) example of external indicator, b) example of intelligent packaging

Due to the rapid development of this technology in recent years, the development of information technologies and artificial intelligence technologies, intelligent packaging has an increasingly wide application [23]. Utilizing this technology has the potential to prevent numerous health hazards, such as food poisoning, extend the food product's shelf-life, and consequently alleviate the issue of food waste to a manageable minimum.

2.2 The use of environmentally sustainable packaging materials

The solution to the problem of plastic waste, whenever possible, certainly lies in replacing plastic packaging with paper-based packaging. Paper is a widely available material that can be recycled up to four times without significantly losing its characteristics. Packaging based on paper and cellulose fibers (Figure 4a) plays a significant role in the storage and transportation of goods. In such applications, cellulose fibers often contribute greatly to the strength and structural stability of the packaging [24, 26]. It is significantly cheaper to produce, is completely biodegradable, and has no harmful effects on the physical, chemical, and mechanical properties of food products. Cast paper pulp presents itself as an ecologically sound substitute for packaging, derived from recycled raw materials. These materials

provide a renewed purpose to paper waste, thereby diminishing the reliance on virgin paper in packaging production to an acceptable minimum [25]. Paper pulp has increasingly found applications in various sectors of food packaging (Figure 4b), encompassing fast food products, beverages such as juices and water, eggs, fruits, vegetables, and other related domains.

Figure 4: Paper-based food packaging

Paper pulp packaging enables the reproduction of graphic elements, and by adding environmentally sustainable colors to the paper mixture, it is possible to change the color of the packaging, making it more attractive to consumers. It is also possible to imprint important graphic elements into the packaging material itself directly in the manufacturing process, which makes it significantly cheaper than other packaging solutions in terms of production and additional processing.

The agri-food industry produces a substantial volume of waste and by-products, accounting for 40–50% of the overall discard, encompassing various components derived from plant sources, including peels, pulps, skins, pomaces, shells, roots, stems, stones, leaves, seeds, et cetera [27]. These waste parts, rich in nutrients and natural polymers, are suitable for the production of various biopolymer packaging and films for food product packaging. Some of the most common waste materials from which these packaging are made are citrus peels, most often oranges, limes and lemons, banana peels, pomegranate peels, as well as vegetable peels such as potato peels, cucumber and zucchini peels, and many others. The utilization of biodegradable packaging (Figure 5a) employing biopolymer materials yields several advantages, including cost-effectiveness, non-toxicity, and transparency in contrast to conventional plastics. These materials exhibit film-forming capabilities and function as carriers for antimicrobial and antioxidant compounds [27]. Furthermore, they demonstrate resistance to mechanical damage, possess water vapor permeability beneficial for packaging fresh fruits and vegetables, and feature water absorption capacity along with a low friction coefficient. Biodegradable packaging serves as a barrier to odors, aromas, fats, and oils [27, 28]. A recent and promising trend involves the incorporation of natural additives, extracts, and by-products from food processing, such as phenolic acids, tannins, proanthocyanidins, or flavonoids, to augment the performance of food packaging [27].

Figure 5: Biopolymer packaging: a) biopolymer food packaging, b) fruit and vegetable peel edible films

The inclination is towards edible packaging materials (Figure 5b) that encompass additional functionalities, such as antioxidant, antimicrobial, and nutritional properties. The main difference between conventional and edible packaging is that edible packaging is made from natural, fruit or vegetable-based biopolymers, and unlike conventional packaging, is integrated with the food product itself, so it could be consumed together, without having to throw away the packaging. Edible packaging stands as a sustainable solution to mitigate both food waste and environmental pollution [28, 29]. All these advantages contribute to the preservation of food products, extend their shelf-life, and do not pose a threat to human health and the preservation of the environment.

3. CONCLUSIONS

Although food waste may not always command the immediate attention that other forms of environmental pollution do, it nevertheless represents a significant and intricate ecological challenge. Addressing this challenge requires a comprehensive approach that acknowledges both the environmental impact of food waste and the indispensable role that packaging plays in ensuring the longevity and quality of food products. While packaging waste poses a significant threat to the environment, it must be acknowledged that packaging serves irreplaceable functions in preserving food. It acts as a shield, protecting food from external threats, extending its shelf-life, simplifying its organization, and maintaining its essential characteristics. Striking a balance between minimizing packaging waste and ensuring the functionality of packaging is essential in creating sustainable solutions for the future.

Effective solutions to the complex issue of food waste involve not only technological advancements but also public awareness and education. By fostering an understanding of the environmental implications of food waste and promoting responsible consumer behavior, it is possible to collectively work towards reducing waste at the source. Moreover, the implementation of defined environmental measures, including recycling programs and waste reduction initiatives, is crucial. Encouraging industries to adopt sustainable practices and invest in research for eco-friendly packaging materials will contribute significantly to mitigating the environmental impact of packaging waste. The utilization of appropriate, environmentally sustainable materials and technologies in the production of food packaging presents a promising avenue. By embracing innovations that prioritize eco-friendly alternatives and exploring

methods to reduce the ecological footprint of packaging materials, it is possible to pave the way for a more sustainable future.

REFERENCES

FAO: THE STATE OF FOOD SECURITY AND NUTRITION IN THE WORLD 2023 - URBANIZATION, AGRIFOOD SYSTEMS TRANSFORMATION AND HEALTHY DIETS ACROSS THE RURAL-URBAN CONTINUUM, FAO, ISBN 978-92-5-137226-5, ROME, (2023)

FUSIONS EU: *ESTIMATES OF EUROPEAN FOOD WASTE LEVELS*, SWEDISH ENVIRONMENTAL RESEARCH INSTITUTE, ISBN 978-91-88319-01-2, STOCKHOLM, (2016)

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R. & Searchinger, T: REDUCING FOOD LOSS AND WASTE, *WORLD RESOURCES INSTITUTE WORKING PAPER 1*, (2013), PP. 1-40

UNITED NATIONS ENVIRONMENT PROGRAMME: *UNEP FOOD WASTE INDEX REPORT 2021*, UNEP, ISBN 978-92-807-3868-1, NAIROBI, (2021)

Coles, R: INTRODUCTION, IN *FOOD AND BEVERAGE PACKAGING TECHNOLOGY*, BLACKWELL PUBLISHING LTD., ISBN 978-1-4051-8910-1, LONDON, (2011), PP. 21-49

Scherhauer, S. et al.: ENVIRONMENTAL IMPACT OF FOOD EASTE IN EUROPE, *WASTE MANAGEMENT*, **VOL.** 77 (2018), PP. 98-113, ISSN 0956-053X

Kan, M. & Miller, S.: ENVIRONMENTAL IMPACT OF PLASTIC PACKAGING OF FOOD PRODUCTS, *RESOURCES, CONVERSATION AND RECYCLING*, **VOL.** 180 (2022), ISSN 0921-3449

Eurostat Statistic Explained: EU PACKAGING WASTE GENERATION WITH RECORD INCREASE, *AVAILABLE FROM*: HTTPS://EC.EUROPA.EU/EUROSTAT/WEB/PRODUCTS-EUROSTAT-NEWS/W/DDN-20231019-1 *ACCESSED*: 2023.10.12.

Ncube, L.K. et al.: ENVIRONMENTAL IMPACT OF FOOD PACKAGING MATERIALS: A REVIEW OF CONTEMPORARY DEVELOPMENT FROM CONVENTIONAL TO POLYLACTIC ACID BASED MATERIALS, *MATERIALS*, **VOL.** 13, NO. 21 (2020), PP. 1-24

Rhodes, C.J.: PLASTIC POLLUTION AND POTENTIAL SOLUTIONS, *SCIENCE PROGRESS,* **VOL.** 101 (2018), NO. 3, PP. 20-260

Zhuo, Y. et al.: A REVIEW ON TAKEAWAY PACKAGING WASTE: TYPES, ECOLOGICAL IMPACT, AND DISPOSAL ROUTE, *ENVIRONMENTAL POLLUTION*, **VOL.** 337 (2023), ISSN 0269-7491

UNEP: BEAT PLASTIC POLLUTION – OUR PLANET IS CHOKING ON PLASTIC, *AVAILABLE FROM:* HTTPS://WWW.UNEP.ORG/INTERACTIVES/BEAT-PLASTIC-POLLUTION/?GCLID=CJWKCAIA3AEQBHBZEIWAXFIOBR2CLYVBTPUSP4PMHOPJFBYSO9IYXWZVN4RW-6N18KWZZ9LCYNAKGBOCLI0QAVD_BWE *ACCESSED*: 2023.10.12.

Robertson, G.L.: INTRODUCTION TO FOOD PACKAGING, IN *FOOD PACKAGING – PRINCIPLES AND PRACTICE,* TAYLOR & FRANCIS GROUP, ISBN 978-1-4398-6242-1, BOCA RATON, (2013), PP. 1-9

Robertson, G.L.: PACKAGING AND FOOD AND BEVERAGE SHELF LIFE, IN *THE STABILITY AND SHELF LIFE OF FOOD*, ELSEVIER LTD., ISBN 978-0-08-100435-7, AMSTERDAM, (2016), PP. 77-107

Brown, M.: PROCESSING AND FOOD AND BEVERAGE SHELF LIFE, IN *FOOD AND BEVERAGE STABILITY AND SHELF LIFE*, ELSEVIER LTD., ISBN 978-1-84569-701-3, AMSTERDAM, (2011), PP. 184-243

Ozcan, A.: NEW APPROACHES IN SMART PACKAGING TECHNOLOGIES, *PROCEEDINGS OF 10TH INTERNATIONAL SYMPOSIUM ON GRAPHIC ENGINEERING AND DESIGN*, Dedijer, S. (ED.), PP. 21-38, ISBN 978-86-6022-303-8, NOVI SAD, NOVEMBER 2020., FACULTY OF TECHNICAL SCIENCES, DEPARTMENT OF GRAPHIC ENGINEERING AND DESIGN, NOVI SAD, (2020)

EUR-LEX: COMMISSION REGULATION (EC) NO 450/2009 OF 29 MAY 2009 ON ACTIVE AND INTELLIGENT MATERIALS AND ARTICLES INTENDED TO COME INTO CONTACT WITH FOOD, *AVAILABLE FROM*: HTTPS://EUR-LEX.EUROPA.EU/LEGAL-CONTENT/EN/ALL/?URI=CELEX%3A32009R0450 *ACCESSED*: 2023.10.12.

Limbo, S. & Khaneghah, A.M.: ACTIVE PACKAGING OF FOODS AND ITS COMBINATION WITH ELECTRON BEAM PROCESSING, IN: *ELECTRON BEAM PASTEURIZATION AND COMPLEMENTARY FOOD PROCESSING TECHNOLOGIES*, WOODHEAD PUBLISHING, ISBN 9781782421009, SAWSTON, (2015), PP. 195-217

Yildirim, S., Rocker, B., Pettersen, M.K., Nilsen-Nygaard, J., Ayhan, Z., Rutkaite, R., Radusin, T., Suminska, P., Marcos, B. & Coma, V.: ACTIVE PACKAGING APPLICATIONS FOR FOOD, *COMPREHENSIVE REVIEWS IN FOOD SCIENCE AND FOOD SAFETY*, **VOL.** 17, NO. 1 (2018), PP. 165-199, ISSN 1541-4337

Bose, I., Roy, S., Pandey, V.K. & Singh, R.: A COMPREHENSIVE REVIEW ON SIGNIFICANCE AND ADVANCEMENTS OF ANTIMICROBIAL AGENTS IN BIODEGRADABLE FOOD PACKAGING, *ANTIBIOTICS*, **VOL.** 12 (2023), PP.1-20, ISSN 2079-6382

Han, J.H., Ho, C.H.L., & Rodrigues, E.T.: INTELLIGENT PACKAGING, IN *INNOVATIONS IN FOOD PACKAGING*, ELSEVIER LTD., ISBN 978-0-12-311632-1, AMSTERDAM, (2005), PP. 138-155

Yucel, U.: INTELLIGENT PACKAGING, IN REFERENCE MODULE IN FOOD SCIENCE, ELSEVIER LTD., ISBN 9780081005965, AMSTERDAM, (2016), PP. 1-5

Tiekstra, S., Dopico-Parada, A., Koivula, H., Lahti, J. & Buntix, M.: HOLISTIC APPROACH TO A SUCCESSFUL MARKET IMPLEMENTATION OF ACTIVE AND INTELLIGENT FOOD PACKAGING, *FOODS*, **VOL.** 10 (2021), PP. 1-22, ISSN 2304-8158

Yanqun, S., Bo, Y. Jingang, L., Bo, S.: PROSPECTS OF REPLACEMENT OF SOME PLASTICS IN PACKAGING WITH LIGNOCELLULOSE MATERIALS: A BRIEF REVIEW, *BIORESOURCES NORTH CALIFORNIA*, **VOL.** 13, NO. 2 (2018), PP. 4450-4476

Gvoka, T., Vladić, G., Kašiković, N, Maričić K. & Bošnjaković, G.: APPLICATION OF CAST CARDBOARD PACKAGING IN THE TEXTILE INDUSTRY, *PROCEEDINGS OF FIFTH INTERNATIONAL CONFERENCE ''CONTEMPORARY TRENDS AND INNOVATIONS IN TEXTILE INDUSTRY''*, Urošević, S. (ED.), PP. 333-340, ISBN 978-86-900426-4-7, BELGRADE, SEPTEMBER 2022., UNION OF ENGINEERS AND TEXTILE TECHNICIANS OF SERBIA, BELGRADE, (2022)

Gurav, S.P., Bereznitski, A., Heidweiller, A., Kandachar, P.V.: MECHANICAL PROPERTIES OF PAPER-PULP PACKAGING, *COMPOSITES SCIENCE AND TECHNOLOGY*, **VOL.** 63, NO. 9 (2003), PP. 1325-1334, ISSN 0266-3538

Bazram, B., Ozkan, G., Kostka, T., Capanoglu, E. & Esatbeyoglu, T.: VALORIZATION AND APPLICATION OF FRUIT AND VEGETABLE WASTES AND BY-PRODUCTS FOR FOOD PACKAGING MATERIALS, *MOLECULES*, **VOL.** 26 (2021), PP. 1-18, ISSN 1420-3049

Petraru, A. & Amariei, S.: A NOVEL APPROACH ABOUT EDIBLE PACKAGING MATERIALS BASED ON OILCAKES – A REVIEW, *POLYMERS*, **VOL.** 15 (2023), PP. 1-26, ISSN

Patel, P.: THE TIME IS NOW FOR EDIBLE PACKAGING, *AVAILABLE FROM*: THE TIME IS NOW FOR EDIBLE PACKAGING (ACS.ORG) *ACCESSED*: 2023.10.12.

CORRESPONDING AUTHOR:

Teodora GVOKA
Department of Graphic Engineering and Design, Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21000, Novi Sad, SERBIA
E-mail: teodora.gvoka@uns.ac.rs

SPECTRAL AND COLORIMETRIC EVALUATION OF LAMINATED DIGITAL PRINTS

Ákos BORBÉLY

Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

Abstract

Lamination is surface finishing by bonding a layer of material, which is typically plastic. The primary function of this layer is to protect the surface underneath. In case of printed documents the appearance of the colors will change. Light will interact the complex structure of the laminate and the print in a different way relative to the original print. It is extremely difficult to simulate this process, because the effect will be influenced by several factors: the surface structure, thickness and material of the plastic film; the type of paper and printing process, etc. If one would like to predict the optical properties of the outcome of the lamination one has to focus on the individual case. Measurements are needed to be able to define the transformation from the original to the laminated sample.

In this study the objective was to perform spectral and colorimetric measurements to investigate how lamination affects the colors of the printed sheet. Optical properties of the laminating film, the substrate and the print, as well as standard measurement parameters were considered in the experiments.

Keywords: *lamination, electrophotography, spectral measurement, color measurement, measurement modes*

1. INTRODUCTION

Laminates and films offer a wide range of advantages to printed media, including enhanced durability, structure, and unique visual and tactile effects. When used as a finishing technique, lamination consistently enhances the value of printed sheets, labels, digital photographs, packaging materials, etc. The application of various finishing processes on a printed piece will inevitably modify the visual appearance of the document. The utilization of UV coatings, thermal laminates, and films with wet adhesive will each yield distinct effects on the final appearance of the colors in the print.

The chromatic visual effect is primarily influenced by various factors, including the characteristics and response of multiple factors. In addition to the substrate and the ink, there are other important elements to consider. These elements encompass the type of plastic film employed, such as its opacity and transparency, as well as the surface structure and thickness. Additionally, the technology employed for applying the plastic film and the type and amount of adhesive used also play a significant role in determining the achieved visual effect. [1]

The lamination process may result in a variation in color between the printed sheet and the non-laminated sample. Typically, these differences are minimal and often imperceptible for the human eye, but the magnitude of color shifts are unpredictable, which makes it inevitable to be analyzed in every

case when accurate color reproduction is important. The presence of the plastic film attached to the printed sheet alters the path of the light that interacts with the sheet. Initially, the light directly impacts the printed sheet, but after lamination, it passes through the plastic film as well. As the path of light influences color perception, printers may encounter unintended consequences in terms of color accuracy.

There are two ways to handle the effect of lamination in the standard color management system of the printing process. The FOGRA 49/50 profiles offer characterization data for standardized printing conditions to precisely simulate the effect of lamination with glossy and matte foils. [2] If the print conditions do not match the requirements of the above then instead of using standard profiles, they have to be created. Individual profiles can be created for the printed document by printing the ICC profile target, laminating the prints, measuring the laminated prints, and generating an ICC profile. The optimal visual outcome is achieved when viewing the prints under the standard lighting conditions specified in the ICC profile. [3]

2. EXPERIMENTAL

Spectral and colorimetric measurements were performed by an Xrite Exact spectrophotometer with built-in white standard. The instrument has a directional measurment geometry with ring illumination (45ºa:0º) and 4 mm aperture, colorimetric data were obtained with D65 standard illuminant and the CIE 1931 2º standard colorimetric observer.

ISO 13655:2017 (former ISO 13655-2009) is a standard in the field of graphic technology which focuses on the spectral measurement and colorimetric computation for graphic arts images. [4] The standard defines different measurement conditions, each denoted by a specific code:

M0: This condition is suitable for any application where neither the substrate nor the colorants used in the image fluoresce.
M1, part 1: In this condition, either the substrate or the colorants, or both, may exhibit fluorescence.
M1, part 2: This condition is applicable when the imaging colorants used do not fluoresce.
M2: This condition is used when the paper used fluoresces, and it aims to eliminate this fluorescence effect.
M3: This condition focuses on minimizing first surface reflections and involves the use of polarization.
These different measurement conditions help to ensure accurate and consistent color reproduction in graphic arts. The spectrophotometer used in this study is capable to switch between the above modes and operate accordingly.

Three types of coated paper substrates (with grammages 80-240g/m^2) were used in the experiment each of them suitable for electrophotographic printing and contained optical brightening agents. A Ricoh C3004ex electrophotographic press was used to print the test charts, some prints were laminated with a transparent 100 micron foil at about 110ºC using a Heatseal h215 laminator machine.

A typical test chart was chosen with step wedges of the process (C, M, Y, K), overprinted (R, G, B) and chromatic gray (CMY) colors. Only 12 of the patches were chosen for investigation, they are shown on Figure 1.

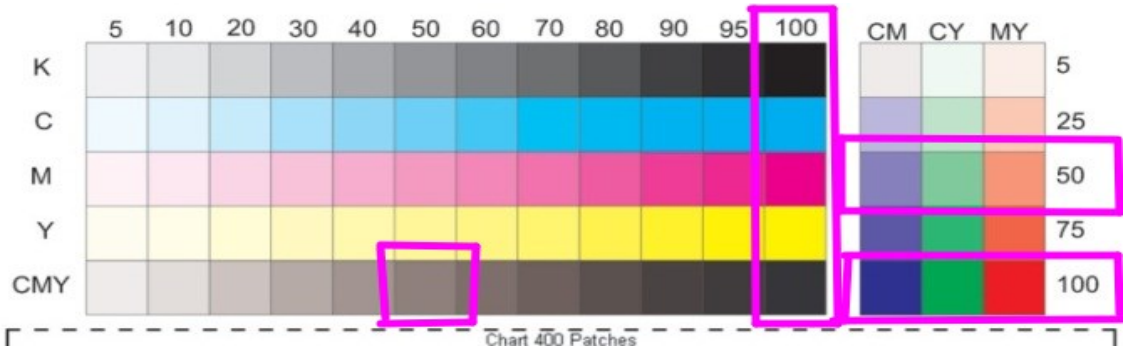


Figure 1: Measurements were performed on 12 patches (framed in pink color) of the test chart

3. RESULTS AND DISCUSSION

The spectrophotometer measured spectral reflectance of the samples and tristimulus values in the CIELAB color space were calculated. Figure 2. shows the reflectance spectra of the original and laminated white substrates (L) in the different measurement modes (M0, ...M3).

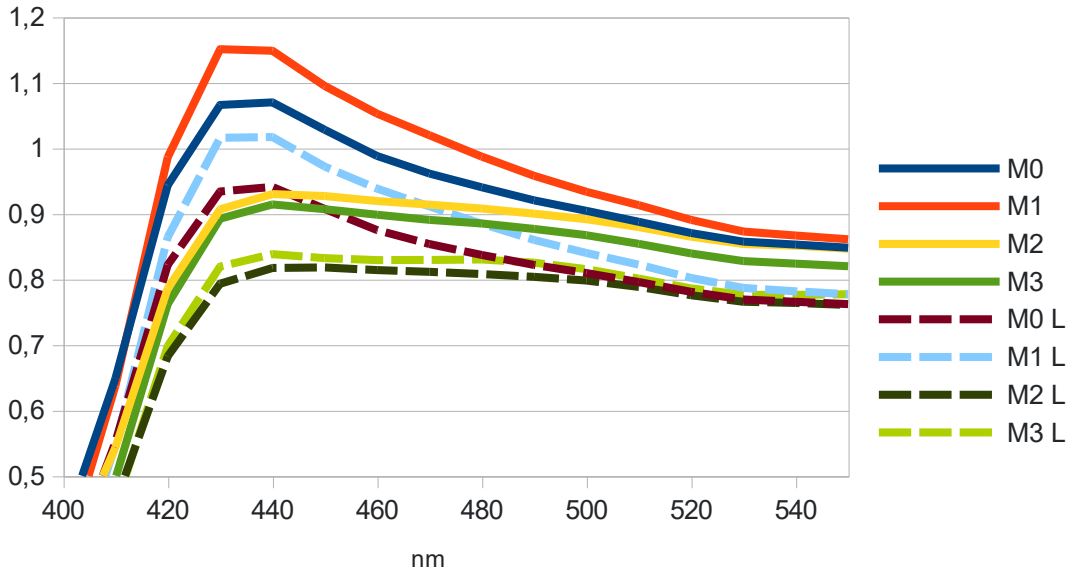


Figure 2: Spectral reflectance of the white substrate obtained with different measurement modes (M0, M1...) and its laminated pair (M0 L, M1 L ...) in the 400- 550 nm range

Figure 3 shows the spectral reflectance curves of overprinted halftone colors (R50, …) and chromatic grays (CMY50%) and their laminated pairs (R50 L, ... CMY50 L) obtained with M1 measurement mode in the 400- 700 nm range

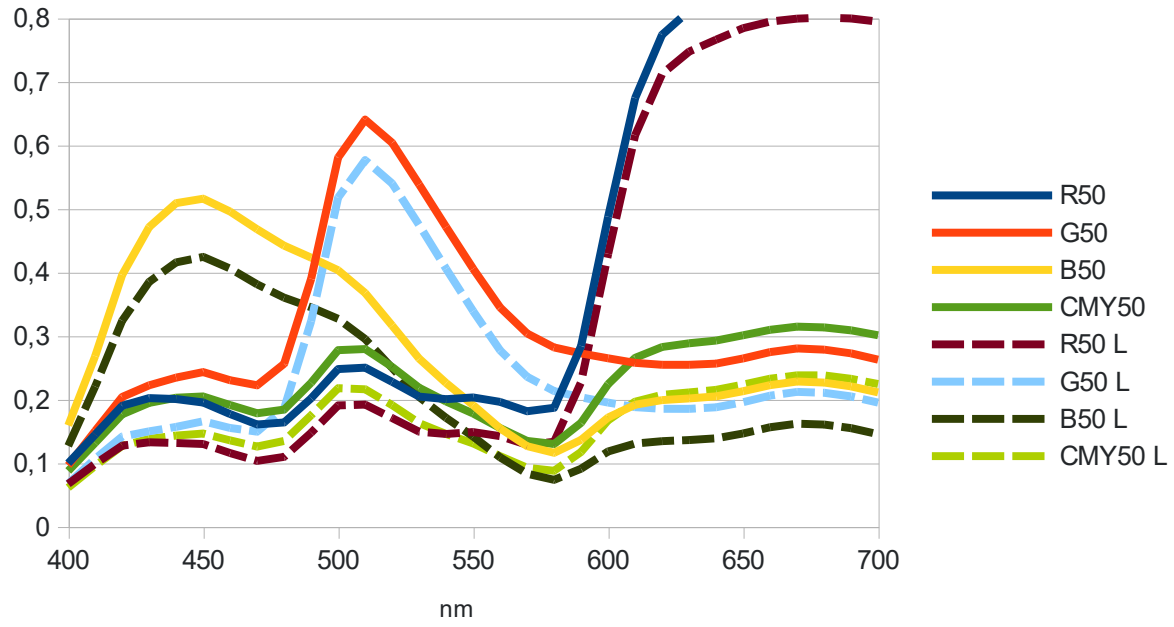


Figure 3: Spectral reflectance of halftones (R50, ...), chromatic greys (CMY50%) and their laminated pairs (R50 L, ... CMY50 L) obtained with M1 measurement mode in the 400- 700 nm range

The visual effect of lamination is characterized by the deviations of the metric color attributes between the original and the laminated prints. The lowest metric color difference (ΔE^*_{ab}) calculated between the original and laminated patches was experienced with measurement mode M3, followed by M1 and M2, and the highest was obtained with M0 mode for all substrates (tables 1-2).

Table 1: Color difference (ΔE^*_{ab}) values between the original and laminated samples of substrate 1 (W). full tone process colors and chromatic black (CMY) measured in different modes (M0...M3)

	W	C	M	Y	K	CMY
ΔE^*_{ab} M0	4.15	6.49	3.54	5.31	3.85	4.21
ΔE^*_{ab} M1	4.06	6.34	3.55	5.3	3.85	4.21
ΔE^*_{ab} M2	4.01	6.72	3.4	5.38	3.64	3.74
ΔE^*_{ab} M3	2.54	5.05	1.93	4.49	1.4	0.36

The largest color difference was observed in case of the 50% green halftone (CY50%) for all substrates. The patch producing the smallest color difference was red (MY) except in the M3 mode.

If the set of samples is divided into three groups according to chromatic content (full tone process colors: C, M,Y; overprinted colors: R, G, B; and achromatic: K, CMY) the difference between the mean ΔE^*_{ab} of the groups are around the unit color difference (e.g. in case of substrate 1, in M0 mode mean ΔE^*_{ab} was 5.11; 6.29 and 5.01). The color shift of the substrate caused by the lamination is always smaller than the mean shift of the three groups defined above.

Table 2: Color differences between the original and laminated samples of samples R, G, B and 50% R, G, B and CMY measured in different modes (M0...M3)

	R	G	B	R50	G50	B50	CMY50
ΔE^*_{ab} M0	3.82	5.58	3.37	8.24	9.64	7.11	6.96
ΔE^*_{ab} M1	3.8	5.56	3.37	8.06	9.32	7.69	6.9
ΔE^*_{ab} M2	3.56	5.74	3.16	8.35	9.6	6.74	6.81
ΔE^*_{ab} M3	2.01	2.34	2.07	6.44	7.74	5.17	5.09

The metric color difference (ΔE^*_{ab}) values can be split into the lightness difference (ΔL^*). the chroma difference (ΔC^*) and the hue difference (ΔH^*) for further analysis. In our results ΔH^* is the least significant, it is an order of magnitude smaller than the lightness or the chroma difference in all cases. On average the lightness difference is 40-60% larger than the chroma difference except for the M3 mode for all substrates. Using the M3 mode lightness values drop for the darker non-laminated samples (especially in case of the process and chromatic black) due to the use of polarization, which makes the average lightness difference 10-40% lower than the chroma chroma shift and also decrease color difference considerably.

The use of polarization helps to reduce specular reflections; possibility arises that it may compensate the effect of lamination to some extent. The combination of the measurement modes where the non-laminated sample is measured with M0, M1, M2 and the laminated sample is measured in M3 mode resulted in mean color differences 6.97, 7.72, and 5.98. Therefore the combination of different measurement modes is not beneficial in the prediction of the colorimetric values of the laminated prints.

4. CONCLUSIONS

In this study spectral and colorimetric measurements were performed to investigate how lamination affects the colors of the printed sheet. Three coated substrates were printed with an electrophotographic press and finished with a heat laminator. Spectral reflectance curves and colorimetric properties of the original and laminated prints were measured in different modes of the ISO 13655:2017 standard. The choice of measurement mode affected the color difference values at threshold level except for the M3 mode, which caused measured color shifts to decrease significantly.

Large mean color differences were found ($5 < \Delta E^*_{ab} < 10$), lightness difference values were about 50% larger than the chroma shifts except for the M3 mode; hue differences were negligible. The combination

of different measurement modes for the original and laminated samples did not contribute positively to the prediction of the appearance of the laminated prints.

REFERENCES

[1] R. Tomerlin, M. Tomiša, D. Vusić: THE INFLUENCE OF PRINTING, LAMINATION AND HIGH PRESSURE PROCESSING ON SPOT COLOR CHARACTERISATION, *TEHNIČKI GLASNIK* 13, 3(2019), p. 218-225, ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)

[2] European Color Initiative: Collaboration between ECI, Fogra und bvdm: New print characterizations FOGRA 48/49/50, (2012) (http://www.eci.org/en/colorstandards/offset)

[3] International Organization for Standardization: ISO 15076-1:2010 - *Image technology colour management* (2010)

[4] International Organization for Standardization: ISO 13655:2017 *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images* (2017)

CORRESPONDING AUTHOR:

Dr. Ákos BORBÉLY
Institute of Light Industry and Media Technology, Óbuda University
Doberdó u. 6, 1034 Budapest, Hungary
E-mail: borbely.akos@uni-obuda.hu

ANALYSIS AND COMPARISON OF ARTIFICIAL INTELLIGENCE LOGO GENERATORS

Ivana TOMIĆ, Nemanja KAŠIKOVIĆ, Rastko MILOŠEVIĆ, Ivan PINĆJER

University of Novi Sad, Faculty of Technical Sciences, Department of Graphic Engineering and Design, Serbia

Abstract

The use of artificial intelligence-powered tools for generating visual content is growing exponentially over time. These tools offer fast and economical solutions for creating various products, including business cards, banners, letterheads, posters, and even entire websites or marketing campaigns. However, a question arises regarding authenticity of these creations and whether they can compare to the output of a human designer. In this work, we tested various online logo generators based on artificial intelligence to evaluate the options these tools offer and their outcomes. We assessed two different approaches: in the first case, we specified all the parameters for logo creation (such as color, style, keywords), while in the second, we kept the creation process unconstrained, i.e., let the software choose all the logo elements without our intervention. The results indicate that artificial intelligence logo generators are efficient tools for creating logos when all the input variables are clearly specified. Nevertheless, the outcomes are not unique and are usually very generic. Hence, at this stage of their development AI logo generators can be used as aids in design process, and not as a replacement for a human designer.

Keywords: *logo design, artificial intelligence, logo generators, logo makers*

1. INTRODUCTION

In the last couple of years, there has been a rapid growth of artificial intelligence (AI) tools in almost every sector of human activity. In graphic design, AI is used for different tasks – image processing, font and color selection, creation of different layouts and compositions, user research and personalization, automation and many more [1].

Of particular interest to those in the field of graphic design is generative AI. This term refers to a class of artificial intelligence systems with the ability to generate new content [2, 3]. Often based on deep learning architecture, those systems can analyze patterns from large datasets and generate images, illustrations, and entire designs that can mimic desired style [3].

In this work, we were interested in AI logo generators. Sometimes referred to as 'logo makers', these software tools leverage the power of AI to create logos based on user requirements. AI logo generators typically employ Generative Adversarial Neural Networks trained on large datasets [4-6] and conditioned on specific characteristics, such as color [5]. Users input a set of parameters—criteria used to select data and condition the model, including color, style, industry sector, etc.—and the generator produces various results.

At present, there are a lot of AI logo generators in the market [7-14]. All of them are web-based, and some even free for use. The goal of this paper is to evaluate the functionalities offered by these tools

and the quality of the logos they generate. A lingering question in the graphic design sector pertains to whether AI has the potential to replace designers in the near future. We sought to address this query by examining the capabilities of AI in the context of a seemingly straightforward yet inherently demanding task—logo creation.

2. EXPERIMENTAL

For this study, we tested various AI logo generators [8-14] before narrowing our focus to three. The criteria for selecting the software to focus on were related to the options available during the creation process and the quantity/quality of the obtained solutions.

To begin with, we put ourselves in a position of users lacking design experience. Therefore, our objective was to find software capable of generating logos without the need to specify additional parameters such as style, colors, or ideas to be transmitted. On the other hand, we also wanted to have the flexibility to define all those parameters and to customize the final solution. It was crucial for the software not only to avoid randomly assigning symbols and fonts, as observed in some tested software, but also to produce a meaningful variety of solutions. Additionally, we prioritized the convenience of creating logos without the necessity of logging in or making advanced payments.

Software that fulfilled all the above-mentioned criteria were BrandCrowd AI logo generator [8], Logoai [11] and Looka [13]. In the remaining tested software, the steps in the creation process closely resembled each other. Therefore, the selected software can be viewed as typical representatives of AI logo generators currently available in the market.

The task assigned to the software was to create a logo for our department, namely, a higher education institution in the field of graphic engineering and design. We chose not to use only the abbreviation of our department's name (GRID) but also the word 'education' in an attempt to determine whether the software could “understand” that the logo should be designed for an educational institution, even without explicit specification.

In each of the chosen software we created logos by testing two approaches. First, we assessed unconstrained creation process where none of the parameters apart from the name of the institution (GRID education) were specified. In the second scenario, we defined the sector (university or education, as available), dominant color (blue, as in a current logo), style (modern) and four keywords (university, graphic design, printing, education).

3. RESULTS

All logo generators we tested have a very similar user workflow. The first step requires entering the business name and sector and, in some cases, also keywords (in order to describe the business in more detail, and define ideas and messages to be conveyed through the design). If keywords are not defined in the first steps, they are usually used to choose symbols later on.

In the following steps, a user defines logo style (either by choosing it by name or from the provided examples) and the predominant color(s). In some cases, the user can also select symbols (by entering keywords or choosing from the predefined options based on a sector). The user is then presented with solutions and can choose one or more. The chosen solutions can be further modified and, in the final step, downloaded. Modifications may include changing text (font type, style, color, etc.), symbols (replacing or changing colors), layout, background color, adding or deleting slogan, etc. In the following sections we describe options in each of the chosen AI generator and present their outcomes.

3.1. BrandCrowd AI Logo Generator

The BrandCrowd AI Logo Generator has a very simple interface where all the parameters are defined in the same window (Figure 1). The user first enters the description, business name and keywords, and then chooses the logo style and predominant colors. For styles, BrandCrowd offers different logo types (mascot, emblem, and wordmark) and only a few options to actually stylize the logo (abstract, vintage, and classic). After defining all the parameters, logos are created by clicking on the 'Generate' button. Slogan is added by default, but can be changed or removed later on.

In the first tested scenario, we only entered description and the business name (Figure 1). Keywords input field could not be left empty, so in order to bypass that requirement we entered a dot. However, after clicking on 'Generate' button keywords 'Innovation, Expertise and Inspiration' were automatically added, and generated solutions contained a lot of logos that represented those keywords. Only after we deleted those keywords and clicked on 'Search' button the process was done without keywords defined. Some of more than 300 created solutions are presented in Figure 1.

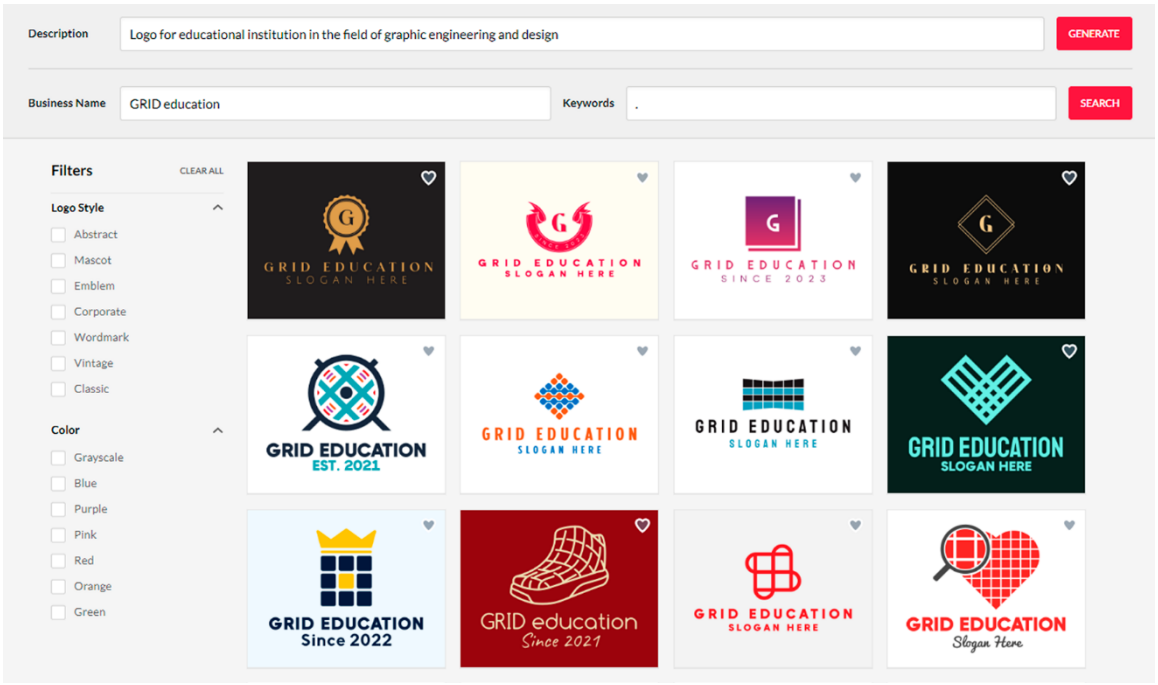


Figure 1: Results obtained in BrandCrowd when additional parameters for logo design were not specified

What is evident is that the software interpreted the abbreviation of our department as the word for mesh or a matrix, so most of the obtained logos contained symbols representing those terms. Only a few solutions, like the one in the first row, for example, featured a book or another symbol related to education. In any case, the obtained results are all very generic, and most of the symbols are also used for other businesses.

In the second scenario, we entered the keywords and selected a blue color from the given list (Figure 2). There was no option to choose the modern style, and since none of the remaining options represented that idea, we skip to define style. Some of more than 300 solutions obtained this way are shown in Figure 2.

It can be seen that the results are much better in conveying the intended meaning, as there are symbols representing education, learning, and printing. However, since we did not have the option to choose the style, most of them are quite conventional.

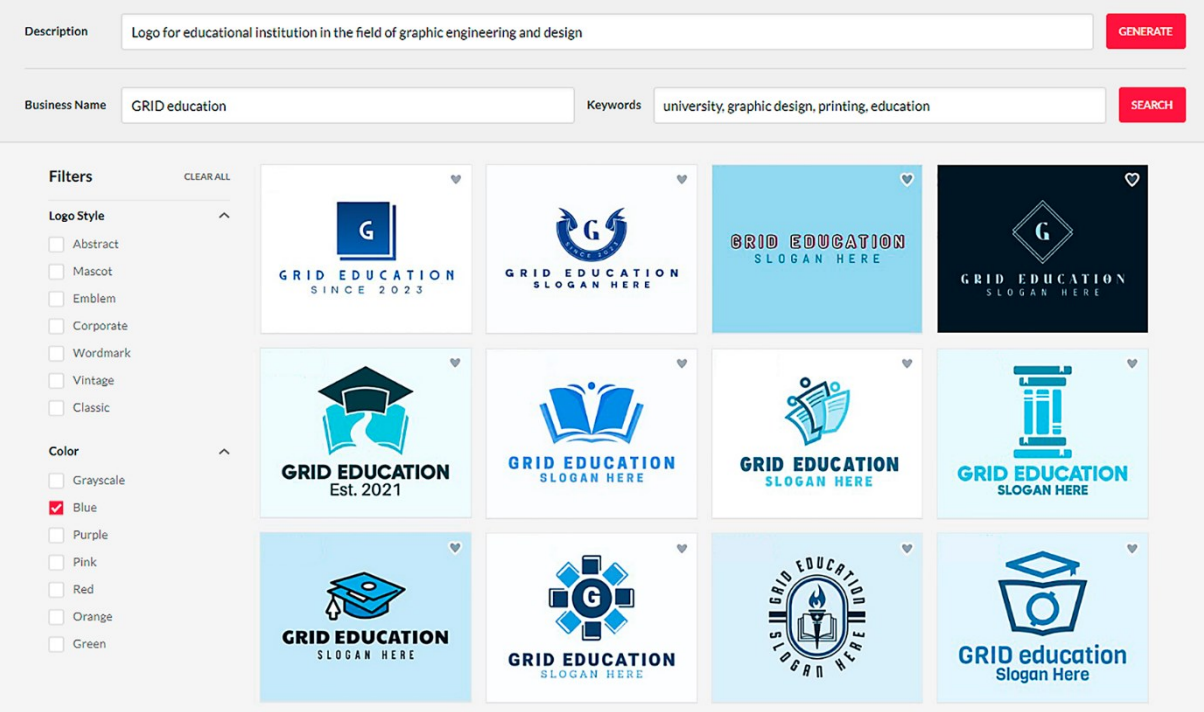


Figure 2: Results obtained in BrandCrowd when parameters for logo design were specified

When we chose a logo to customize, there was a plethora of editing options for text. It was possible to delete the slogan and change the font for the name, as well as its text size, position, curvature, outline, and color (Figure 3). We could change the layout and the background, while the grid in the background allowed us to accurately position all the elements. It was also possible to choose different colors and gradients for each part of the symbol, delete the symbol or add a new one. However, the choices were very limited and basic, as seen from Figure 3 (right).

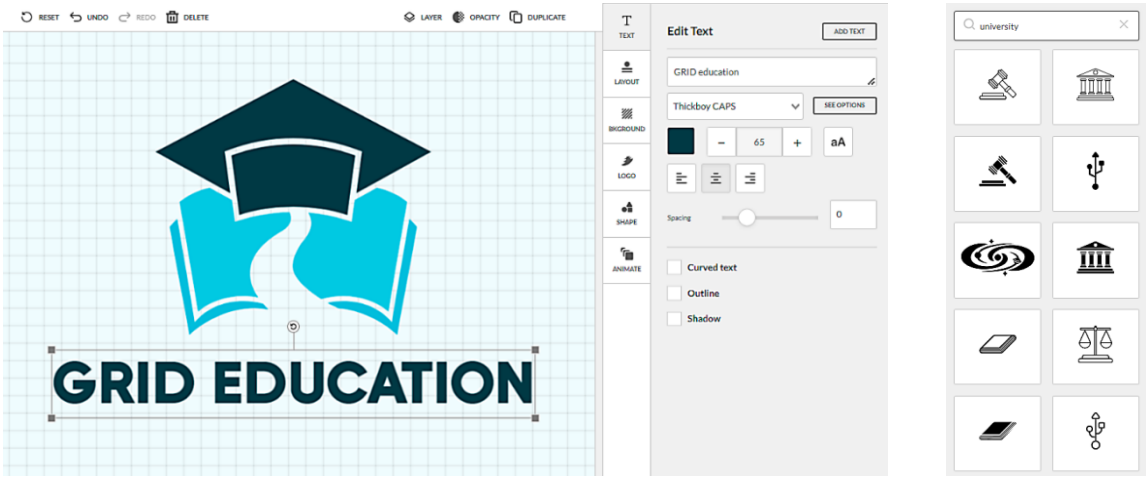


Figure 3: Customization options for text (left), choosing new symbol by entering keyword (right)

3.2. Logoai

In Logoai, the first step is to define business name and choose industry sector from the given options. Some of the 21 options include travel, retail, sport, finance, medical, restaurants, events, and so on. In the next step, the user is asked to define the logo color scheme, with the available combinations shown in Figure 4. When one of them is selected, an explanation about its meaning is provided, which can be very useful for users without design background. The last step allows the user to choose a symbol by entering keywords. In Logoai there is no option to choose a specific logo style; instead, the style is automatically defined based on the chosen industry.

Solutions this software generated when we only entered business name are shown in Figure 5. All of them are very generic and do not convey any idea or a concept.

In the case where we defined the sector (education), color scheme (cold, as marked in Figure 4), and chose some symbols based on our keywords, the results were slightly better (Figure 6). However, it is clear that the solutions are created by placing the chosen symbols in different layouts, so they were not stylized in any way. Additionally, in most cases the defined color palette was ignored — even when we chose the cold palette, many solutions contained warm colors (Figure 6).

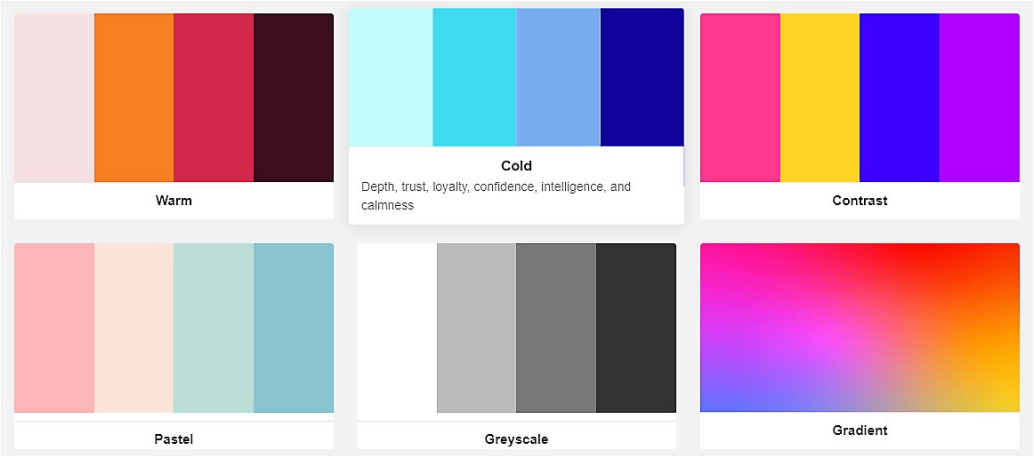


Figure 4: Color schemes in Logoai

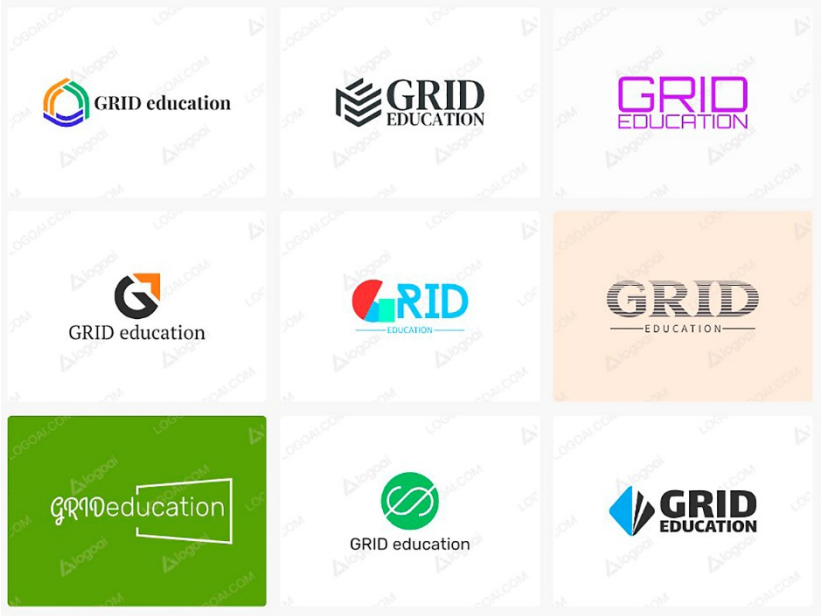


Figure 5: Results obtained in Logoai when additional parameters for logo design were not specified

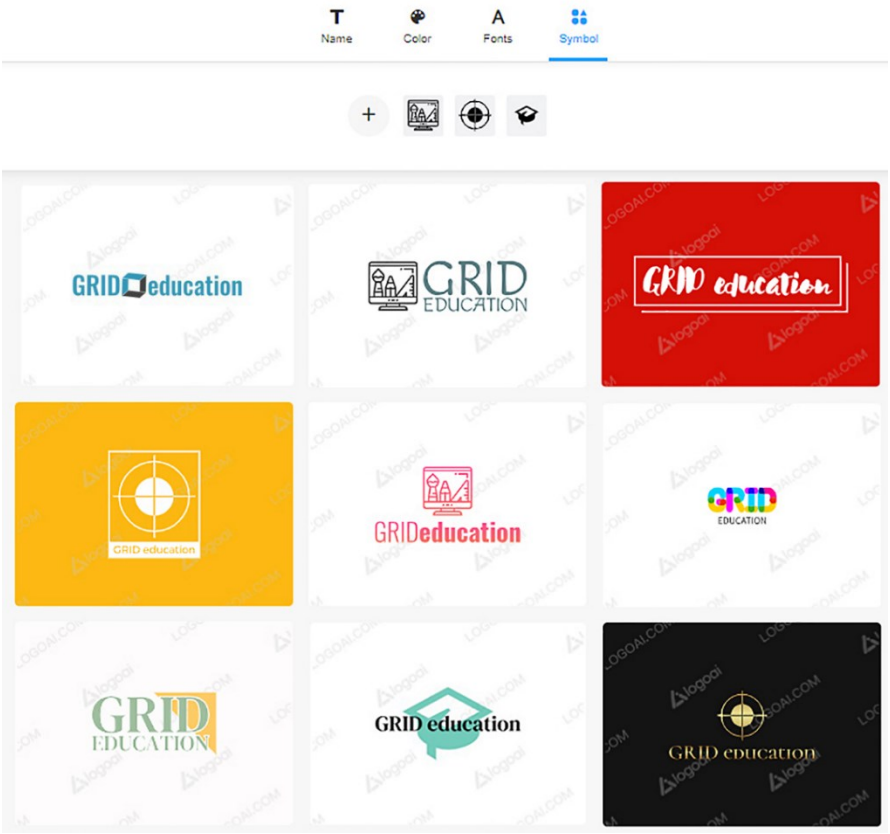


Figure 6: Results obtained in Logoai when all the parameters for logo design were specified

Logoai has many options to modify the chosen solution. As in the previous case, we could change the layout, font, colors, and symbol. The options for symbols were much more extensive in comparison to BrandCrowd. Also, in beta version of this software, there is a possibility to add AI-generated symbols.

3.3. Looka

In Looka, the creation process is very similar to Logoai. Upon entering the business name, the user has to choose an industry and select different solutions to define logo style. In the next step, there are options to choose dominant colors from the typical hues, and pick symbols by entering keywords. However, most of the symbols offered in this step are very detailed and, therefore, not suitable for logo design. Additionally, many resemble icons made for operating systems (Figure 7).

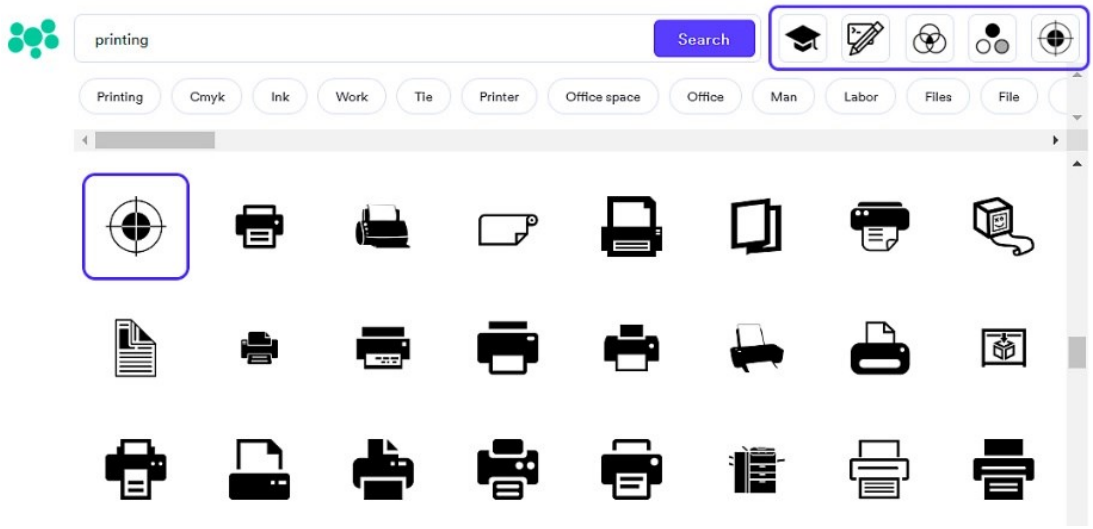


Figure 7: Choosing symbols in Looka

The unconstrained design process ended up with many different results, some of which are presented in Figure 8. Again, none of them resembles anything related to education or a university, and all the solutions are quite simple and generic.

Figure 8: Results obtained in Looka when additional parameters for logo design were not specified

When we defined industry (university), style, colors (blue), and symbols based on our keywords (chosen symbols are marked in blue in Figure 7), the results were much more refined (Figure 9). Even though some of them did not follow the predefined style, the majority satisfied the requirements and can be used with minor modification. The rest needed further refinements.

Selected logos can be modified in the same manner as in the previously described software. Looka also offers a preview of the chosen logo on different media and products, allowing the user to see how it would look on mobile screens, websites, business cards, and so on (Figure 10). This option is useful since the solution can be further modified to better fit the desired communication channel.

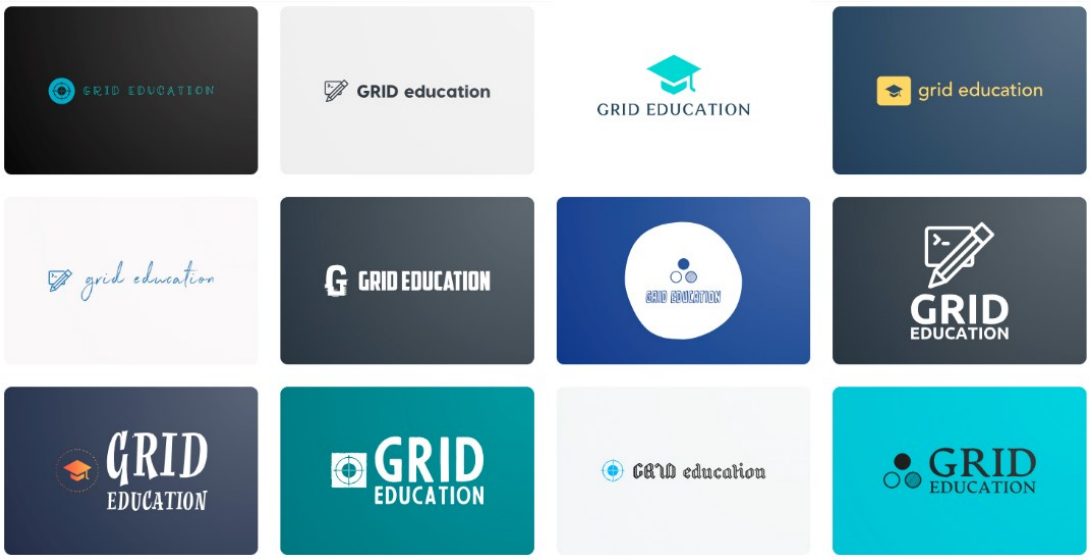


Figure 9: Results obtained in Looka when all the parameters for logo design were specified

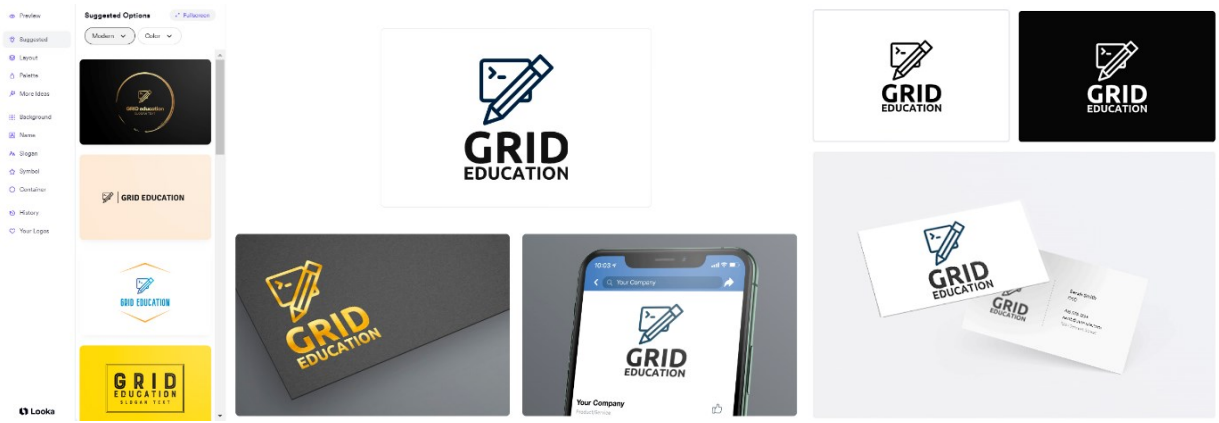


Figure 10: Preview of the selected solution on different media and products

4. DISCUSSION

Table 1 summarizes advantages and disadvantages we noticed when testing chosen software.

Table 1: The benefits and drawbacks of the tested software

Software	BrandCrowd	Logoai	Looka
Benefits	• Simplicity • Plethora of editing options • Large number of different solutions	• Color meaning clearly explained • Possibility to choose symbols	• Color meaning clearly explained • Possibility to choose style based on examples • Possibility to choose symbols • Logo preview on different media/products
Drawbacks	• Limited styles • Limited options for changing the symbol during customization	• Not possible to define style • Colors do not match the defined palette	• Not all symbols are suitable for logos

Apart from the factors typical for each software, speed can be defined as the major plus of all AI logo generators. The creation process is very fast - after defining all the parameters, more than 100 solutions can be obtained right upon the click.

Nevertheless, those solutions are not unique and are, therefore, unoriginal. The same symbol can be used many times, so the user can never be sure that the design obtained from the generator has not been used for another business as well. Additionally, if users without any design knowledge are creating a logo with the help of an AI generator, they might choose fonts and colors that are not suitable for the desired application. In some of the tested software color meaning is explained, but nothing similar exists for fonts. The wrong choice of fonts can convey the wrong message, and the use of such logos can be brought into question.

5. CONCLUSIONS

In this work, we tested different AI logo generators in order to determine whether they can replace human designers in the task of logo creation. What is evident is that all of them enable fast and efficient logo design, so in terms of speed, human designers would never be able to compete with those tools. The best results were obtained when all the parameters were precisely specified. In that case, some of the software generated logos that can even be satisfactory to less demanding users.

On the other hand, logos created by AI generators are not unique, and may even convey the wrong message. Most software creates logos by altering the layout and combining various fonts with predefined symbols, limiting the stylization. As a result, different users may end up with similar or even identical logos.

Taking all into account, we strongly believe that in this stage of their development, AI logo generators cannot replace human designers. They are powerful tools for testing initial ideas and can be used to inspire designers and help them in case of creative block. But, unlike human designers, they lack creativity. The absence of this important characteristic limits them in creating original solutions, those that will stand out in the market and effectively serve its purpose.

ACKNOWLEDGMENTS

This paper has been supported by the Serbian Ministry of Science, Technological Development and Innovation through project no. 451-03-47/2023-01/200156 “Innovative scientific and artistic research from the FTS (activity) domain”.

REFERENCES

Tomić, I. et al.: ARTIFICIAL INTELLIGENCE IN GRAPHIC DESIGN, *PROCEEDINGS OF 54 ANNUAL SCIENTIFIC CONFERENCE OF THE INTERNATIONAL CIRCLE OF EDUCATIONAL INSTITUTES OF GRAPHIC-MEDIA TECHNOLOGY AND MANAGEMENT,* PP. 85-93, ISBN 978-618-81734-4-6, Wuppertal, Germany, September 2023, Helgramed, Athens, (2023)

Mitchel, M.: *ARTIFICIAL INTELLIGENCE: A GUIDE FOR THINKING HUMANS*, Farrar, Straus And Giroux, Isbn 9780241404843, New York, (2019).

TRASK, A.W.: *GROKKING DEEP LEARNING*, MANNING, ISBN 978-1617293702, Shelter Island, (2019).

Goodfellow, I. et al.: GENERATIVE ADVERSARIAL NETS, IN ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 27 (NIPS 2014), ISBN 9781510800410, (2014), PP. 1-9. *AVAILABLE FROM* https://arxiv.org/pdf/1406.2661.pdf *ACCESSED:* 2023-06-11

Mino, A., Spanakis, G.: LOGAN: GENERATING LOGOS WITH A GENERATIVE ADVERSARIAL NEURAL NETWORK CONDITIONED ON COLOR, *PROCEEDINGS OF 17TH IEEE INTERNATIONAL CONFERENCE ON MACHINE LEARNING AND APPLICATIONS (ICMLA)*, PP 965-970, DOI 10.1109/ICMLA.2018.00157, Orlando, Fl, Usa, December 2018, Ieee, (2018).

Sage, A. et al.: LLD - LARGE LOGO DATASET - VERSION 0.1, *AVAILABLE FROM* https://data.vision.ee.ethz.ch/cvl/lld, (2017) *ACCESSED:* 2023-06-15

Balderson, K.: 10 Best AI Logo Generators in 2023 [Free & Premium] *AVAILABLE FROM* https://mspoweruser.com/best-ai-logo-generator/ *ACCESSED:* 2023-08-25

BrandCrowd: BrandCrowd AI Logo generator, *AVAILABLE FROM* https://www.brandcrowd.com/ai-logo-generator *ACCESSED:* 2023-06-11

BrandMark: Create a unique, professional logo for your business, *AVAILABLE FROM* https://brandmark.io/ *ACCESSED:* 2023-09-01

DesignsAi: Create your unique logo, *AVAILABLE FROM* https://designs.ai/logomaker/start *ACCESSED:* 2023-08-26

Logoai: New Logo and Brand Design, *AVAILABLE FROM* https://www.logoai.com/ *ACCESSED:* 2023-08-25

Logomaster.Ai: Make a logo in 5 minutes, *AVAILABLE FROM* https://logomaster.ai/ *ACCESSED:* 2023-08-25

Looka: Make a logo with Looka, *AVAILABLE FROM* https://looka.com/logo-maker/ *ACCESSED:* 2023-09-01

Zarla: Create a Free Logo with Zarla, *AVAILABLE FROM* HTTPS://WWW.ZARLA.COM/ *ACCESSED:* 2023-09-01

CORRESPONDING AUTHOR:

Ivana TOMIĆ
Department of Graphic Engineering and Design, Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad, SERBIA
E-mail: tomic@uns.ac.rs

ADSORPTION MECHANISM OF MAGENTA FLEXOGRAPHIC PRINTING DYE ON ACTIVATED CARBON

Vesna GVOIĆ, Saša PETROVIĆ, Živko PAVLOVIĆ, Gordana BOŠNJAKOVIĆ, Miljana PRICA

Department of Graphic Engineering and Design, Faculty of Technical Sciences, University of Novi Sad, Serbia

Abstract

Since printing dyes are characterized by a high solubility in water, a considerable part of them ends up in wastewater. Due to their numerous harmful effects, they can cause various health problems for humans and the aquatic ecosystem. Therefore, the removal of dyes from wastewater is important. To date, numerous studies have been conducted in the field of wastewater treatment for the removal of dye molecules, and it has been shown that there is no single method that can be applied to all types of wastewater from the printing industry, as the different nature of the colouring substances must be taken into account. The aim of this work is to optimize the adsorption process and investigate the adsorption mechanism of Magenta flexo dye (in synthetic solution and real wastewater) on activated carbon. It was found that the mass of adsorbent, pH and reaction time were statistically significant parameters that contributed most to the removal efficiency of Magenta dye. In addition, the adsorption treatment resulted in 98% and 68% efficiency in removing the dye from the synthetic solution and real wastewater, respectively. Finally, it was found that the adsorption of printing dye on activated carbon is best described by the Langmuir model.

Keywords: *Magenta flexo dye, activated carbon, adsorption mechanism, optimization*

1. INTRODUCTION

As printing dyes are characterized by high water solubility, a significant proportion of them end up in wastewater after the dyeing process [1]. Due to numerous harmful effects on the environment, printing dyes can cause various health problems for humans, but also for the entire aquatic ecosystem. Dyes, various solvents, dioxins, pesticides, polychlorinated biphenyls, acids, bases, heavy metals, surfactants and very hazardous and toxic substances are found in the wastewater produced after the printing process. Such wastewater is characterized by high pH and temperature values, high conductivity, high content of suspended solids, high total organic carbon, high chemical oxygen demand (COD), low biological oxygen demand (BOD) and low COD/BOD ratio, which indicates a high content of non-biodegradable organic matter in the wastewater [2]. Therefore, the removal of dyes from wastewater from the printing industry is extremely important before it is discharged into the environment. To date, numerous studies have been conducted in the field of wastewater treatment for the removal of dye molecules, and it has been shown that there is no single method that can be applied to all types of wastewater from the printing industry, as the different nature of the dyes must be taken into account. An ideal treatment method should allow a large amount of dyes to be efficiently removed in a short time without causing secondary pollution, so that the treated water can be reused [3, 4].

Adsorption is an effective technique that has been successfully used to remove various pollutants from wastewater. In adsorption, a solid adsorbent is used to attract a dissolved component to its surface to

eventually remove it from an aqueous solution through the formation of physical or chemical bonds. There are active, high-energy sites on the surface of the adsorbent that can interact with the solute due to their specific electronic and spatial properties. The interaction between adsorbate and adsorbent, the ratio of the amount of adsorbent and adsorbate in the system, the pH value of the solution, the temperature at which the process takes place, the dynamics and the duration of the process are just a few examples of the many factors that can influence the efficiency of the adsorption process. In order to successfully carry out the adsorption process to separate substances from aqueous solutions, it is important to consider and investigate the effects of all these parameters. In addition, the process parameters must be optimized, as this offers the possibility of predicting the behaviour of the overall system at different values of the process parameters [5 - 7].

The aim of this work is to optimize the adsorption process and to investigate the adsorption mechanism of Magenta flexographic printing azo dye (in synthetic solution and real wastewater) on commercial activated carbon. Commercial activated carbon was used as the adsorbent, and wastewater containing Magenta dye was produced after the flexographic printing process.

2. EXPERIMENTAL

2.1 Materials and chemicals

The following chemicals were used in the experimental section: Activated carbon (AC, Norit Row 0.8 Supra), Magenta flexographic printing dye (Flint), sodium hydroxide (> 98.8% POCH, Poland) and hydrochloric acid (> 96%, J.T. Baker) - Fischer Scientific, USA). Deionized water and chemicals from *pro analysi* purity were used to prepare all working solutions at the desired concentrations. Commercially available activated carbon with the following physical and chemical properties was used as adsorbent: iodine number (1050 mg/g); specific surface area (1150 m^2/g); ash content (7%), moisture content (2%); pH 4.6; density (390 kg/m^3). Activated carbon is a highly porous carbon material whose amorphous framework consists of microcrystals with a graphite lattice. The efficiency of adsorption on activated carbon depends on the type and concentration of organic matter to be removed, the presence of other organic compounds competing for the available active sites on the surface of the adsorbent and the properties of the solution [7].

In the adsorption experiments, samples of a synthetic solution of Magenta flexographic printing dye, which belongs to the group of azo dyes, and a sample of the wastewater collected after the flexographic printing process (real wastewater) were used as adsorbate. The basic properties of the Magenta printing dye are: Dye index (PR57:1), CAS number (5281-4-9), chemical formula ($C_{18}H_{12}N_2O_6$), molecular weight (352 g/mol), λmax (573 nm). The concentration of Magenta dye in the real wastewater sample, 88.56 mg/L, was determined based on the calibration curve method. Based on the measured dye concentration in the wastewater, model systems with different dye concentrations of 20 mg/L, 100 mg/L and 180 mg/L were produced in the experimental part of the work. In this way, a broader spectrum of the influence of different dye concentrations in wastewater samples on the effectiveness of the applied treatment could be investigated.

2.2. Experimental design

The statistical method DSD (Definitive Screening Design) was used to optimize the experiment and to investigate the influence of the process parameters on the adsorption treatment process and its effectiveness. By using DSD, it is possible to significantly reduce the number of experiments carried out and at the same time achieve maximum precision [8, 9]. The selected software JMP 13 (SAS Institute, USA) was used for the experimental design and the complete statistical processing of the obtained results. In this work, DSD analysis was used to investigate the influence of four process parameters: initial dye concentrations (20 mg/L, 100 mg/L and 180 mg/L), adsorbent mass (0.01 g, 0.055 g and 0.1 g), pH (2, 6 and 10) and reaction time (1 min, 30.5 min and 60 min). The range of investigated variables was determined based on previous studies [10 - 12] and based on the determined dye concentration in a sample of real wastewater produced after the flexographic printing process.

2.3. Adsorption treatment in the removal of synthetic dyes

The adsorption experiments were carried out under batch conditions of the system, where activated carbon of a certain mass (0.01 - 0.1 g) was added to a 50 mL sample volume of a synthetic dye solution of a certain concentration (20 - 180 mg/L), and then the pH of the reaction medium (2 - 10) was adjusted by adding HCl or NaOH (0.1 M). After preparation of the adsorbent/matrix suspension, the reaction mixture was run on a rotary shaker (IKA, KS 130) for the specified time (1 - 60 min) at a speed of 240 rpm and an ambient temperature of 23 °C. After mixing, the samples were filtered through a cellulose acetate membrane filter with a porosity of 0.45 mm and the equilibrium dye concentration was determined using a UV/VIS spectrophotometer (Genesys 10S, Thermo Fisher) [4]. The adsorption treatment of the real wastewater was performed in the same way, but the initial dye concentration was not adjusted, but a coloured wastewater sample obtained by the flexographic printing method was used, and the dye concentration was determined by the calibration curve method (88.56 mg/L). The efficiency of the adsorption treatment was monitored by evaluating the dye removal from the synthetic solution and the real wastewater using the following formula (1):

$$E\ (\%) = \frac{A_0 - A}{A_0} * 100 \qquad (1)$$

where: A_0 - the initial absorbance of the aqueous synthetic solution and real wastewater, and A - the absorbance of the solution after the adsorption treatment.

The adsorption mechanism of Magenta printing dye on activated carbon was determined by means of adsorption isotherm experiments. During the experiment, seven different initial dye concentrations were mixed (1, 5, 25, 50, 100, 150 and 200 mg/L), with a constant adsorption mass of 0.1 g. After mixing, the samples were filtered through a cellulose acetate membrane filter with a porosity of 0.45 mm and the equilibrium concentration of the dye was determined using a UV/VIS spectrophotometer (Genesys 10S, Thermo Fisher) [13]. The results obtained were modeled using the Freundlich and Langmuir models.

3. RESULST AND DISCUSSION

3.1. DSD model evaluation and optimization of adsorption process

For the four numerical factors, the software JMP 13, which was used for the statistical analysis of the data in this study, created a table with 13 experiments and two central elements (Table 1). Optimizing the adsorption treatment, using the statistical DSD method, by selecting a combination of process parameters (initial dye concentration, adsorbent mass, pH, reaction time) makes it possible to achieve the highest degree of decolourization of the treated samples. Table 1 shows the results of Magenta removal efficiency from the synthetic solution, where the effective range of adsorption treatment was 13.19 - 95.71%.

Table 1: DSD experimental design and obtained removal efficiency

Sample	Dye concentration (mg/L)	Adsorbent mass (g)	pH	Time (min)	Removal efficiency (%)
1	100	0.1	10	60	68.06
2	100	0.01	2	1	92.36
3	180	0.055	2	60	88.80
4	20	0.055	10	1	47.14
5	180	0.01	6	1	17.05
6	20	0.1	6	60	30.00
7	180	0.1	2	30.5	95.29
8	20	0.01	10	30.5	34.29
9	180	0.1	10	1	27.27
10	20	0.01	2	60	95.71
11	180	0.01	10	60	36.04
12	20	0.1	2	1	81.43
13	100	0.055	6	30.5	13.19
14	100	0.055	6	30.5	16.32
15	100	0.055	6	30.5	17.36

The coefficient of determination ($R^2 = 0.975$) and the adjusted coefficient of determination (R^2 Adj = 0.955) were used to evaluate and select the regression model that best describes the process used. High values of these descriptive factors indicate a good approximation of the experimental data with the selected model, and a very small difference between these two coefficients indicates that the model was not over-fitted to the data.

Based on the estimated value of the parameters and the standard error, the factors with statistical significance (Table 2) that contribute most to the efficiency of Magenta dye removal in the adsorption process were filtered out. Based on the value of $p < 0.05$ (bold values), it is found that the mass of adsorbent, pH and reaction time are statistically significant parameters that contribute most to the efficiency of Magenta dye removal from the synthetic solution.

Table 2: Evaluated regression coefficients

Parameter	Evaluated value	Standard error	t value	Probability > |t|
Dye concentration (mg/L)	-2.412	2.166	-1.110	0.298
Adsorbent mass (g)	0.496	0.671	0.740	**0.048**
pH	-24.079	2.166	-11.120	**<0.0001**
Reaction time (min)	5.336	2.166	2.460	**0.039**

Dye concentration has a negative effect (-2.412) on the adsorption efficiency, which is consistent with the assumption that a higher adsorbate concentration saturates the active sites on the surface of the adsorbent faster. Consequently, increasing the mass of the adsorbent has a positive effect on the dye removal efficiency (0.496), as a larger number of free active sites on the surface of the adsorbent improves the binding of the dye. The pH has a significant negative effect on the dye removal efficiency (-24.079), which is due to the use of activated carbon with an acidic surface (pHPZC = 4.6) [14]. Finally, the reaction time has a positive effect (5.336) on the adsorption process, indicating that a longer period of time favours the removal of the printing dye.

In this work, the application of statistical DSD analysis brought the greatest advantage with regard to the optimization of the adsorption treatment, as the number of experiments could be considerably reduced compared to the previously applied standard statistical analyses, such as CCD (Central Composite Design). The optimization diagram shown in Figure 1 gives a clear insight into how the efficiency of the adsorption process changes depending on one variable while the other variables remain constant. In this way, the highest efficiency of the applied treatment of 98% was proposed to remove the Magenta dye under optimal process conditions: dye concentration 20 mg/L, adsorbent mass of 0.1 g, pH 2.4 and reaction time 60 min. Thus, it was found that the maximum efficiency of the process is achieved at the minimum dye concentration and maximum adsorbent mass with the longest treatment time.

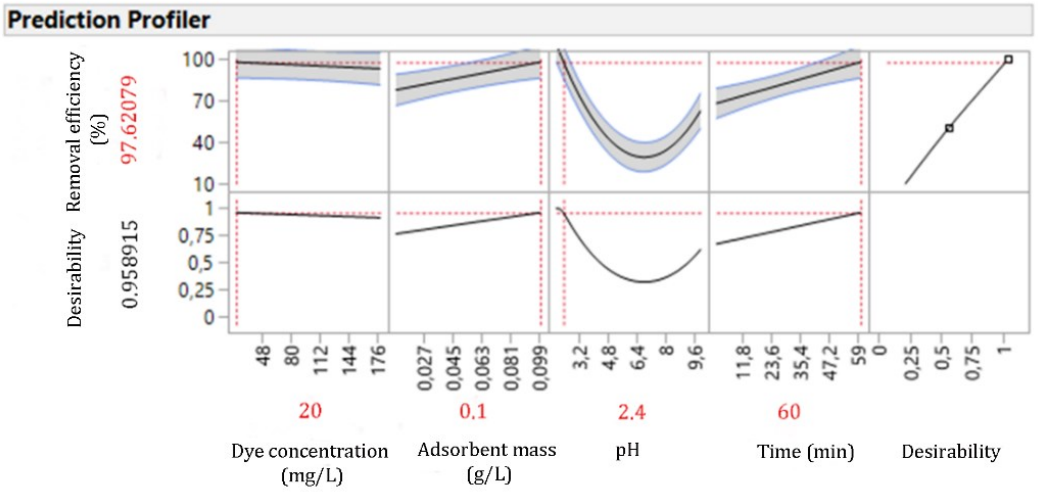


Figure 1: Optimization diagram

The optimization diagram clearly shows the pronounced influence of pH, reaction time and mass of adsorbent on the performance of the adsorption process, which is consistent with the estimated regression coefficients in Table 2. At the same time, the change in dye concentration was found to have the least influence on the change in adsorption process efficiency.

3.2. Treatment of printing wastewater under optimal conditions

In order to determine the possibility of using the optimized adsorption treatment, the real wastewater produced after the printing process was subjected to the same treatment at the optimum values determined for the process parameters (adsorbent mass 0.1 g, pH value 2.4 and reaction time 60 min). The Magenta dye concentration of 88.56 mg/L in the real wastewater was previously determined using the calibration curve method. Figure 2 shows the decolorization efficiency of the Magenta dye from the real wastewater sample as a function of reaction time. The highest decolorization efficiency of 68 % was achieved in the 75th minute of the reaction, which confirms the lower activity of the activated carbon in the treatment of the real wastewater compared to the synthetic solution.

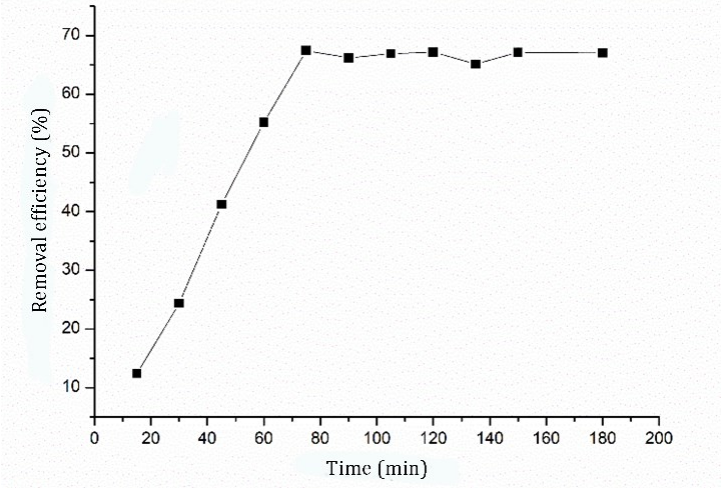


Figure 2: Decolorization efficiency of printing wastewater by application of optimized adsorption process

The lower decolorization performance of the printing wastewater compared to the decolorization performance of the synthetic Magenta dye solution is due to the fact that it is enriched with numerous organic and inorganic compounds such as dibenzofuran, pesticides, polychlorinated biphenyls, heavy metals, surfactants, additives [4], etc. beside the dye molecules. In addition, a longer reaction time of 75 minutes was found compared to the results of other studies [10], which showed that a contact time of 5 to 10 minutes is sufficient for maximum dye removal, but the mentioned study did not include printing dyes but textile dyes. Nevertheless, the experiments conducted in this work confirm that activated carbon has a satisfactory potential for the removal of organic dyes in the adsorption process.

3.3. Adsorption mechanism

When analysing the samples of the treated solution, the equilibrium concentration of the dye Ce (mg/L) was determined and then the equilibrium adsorption capacity of the substance Qe (mg/kg),

which is required for drawing the adsorption isotherms, was calculated (Table 3). The adsorption mechanism of the printing dye on activated carbon was investigated using the Freundlich and Langmuir models.

Table 3: Adsorption isotherms of printing dyes on activated carbon

Sample	C_0 (mg/L)[a]	Ce (mg/L)[b]	Qe (mg/kg)[c]	log Ce (mg/L)	log Qe (mg/kg)	1/Ce (l/mg)	1/Qe (kg/mg)
1	1	0.784	2.160	- 0.105	0.334	1.275	0.462
2	5	3.782	12.180	0.577	1.085	0.264	0.082
3	25	14.692	103.075	1.167	2.013	0.068	0.009
4	50	22.410	275.900	1.350	2.440	0.044	0.003
5	100	32.550	674.500	1.512	2.828	0.030	0.001
6	150	50.700	993.000	1.700	2.996	0.019	0.001
7	200	66.200	1338.000	1.820	3.126	0.015	0.001

[a]initial dye concentration; [b]equilibrium dye concentration; [c]quantity of adsorbed dye

By plotting the graphical dependencies of logQe (mg/g) as a function of logCe (mg/g) for the Freundlich adsorption isotherm (Figure 3a) and of 1/Qe (g/mg) as a function of 1/Ce (l/mg) for the Langmuir adsorption isotherm (Figure 3b), linear equations were obtained, which were used to calculate the constant values of the adsorption isotherms (Table 4).

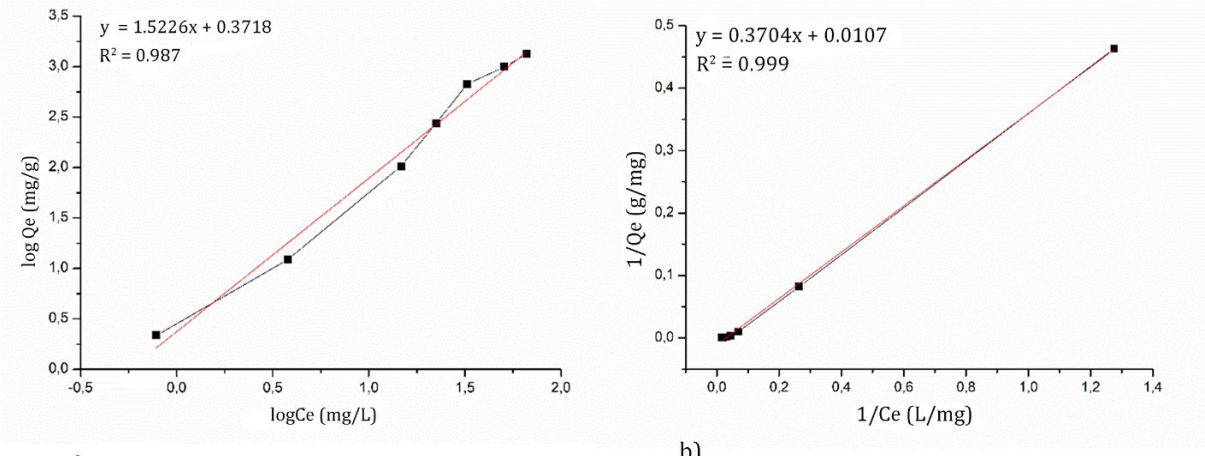


Figure 3: Adsorption isotherms: a) Freundlich, b) Langmuir

Table 4: Freundlich and Langmuir adsorption isotherm constants

Adsorption isotherm model	Adsortpion isotherms constant	Adsortpion isotherms constant
Freundlich	R^2	0.987
	K_F[a]	2.353
	n_F[b]	0.656
Langmuir	R^2	0.999
	Qmax[c]	93.460
	K_L[d]	0.029

[a]Freundlich constant; [b]Freundlich coefficient showing how much adsorption is favored; [c]maximal amount of adsorbate that can be adsorbed per unit mass of adsorbent; [d]Langmuir equilibrium constant indicating the affinity of the adsorbent towards the adsorbate

The comparison of the correlation coefficients showed that the adsorption of printing dye on activated carbon is better described by the Langmuir model ($R^2 = 0.999$). The good agreement with the Langmuir model indicates that there are chemical interactions in the activated carbon/dye system, i.e. that chemisorption takes place, which is primarily due to the presence of numerous functional groups on the surface of the activated carbon that have a high affinity for the dye. A high value of the Langmuir constant, Qmax, justifies the maximum adsorption capacity at equilibrium. At the same time, at high dye concentrations in the solution, the surface of the activated carbon becomes saturated and adsorption ends with the formation of a monolayer of adsorbed particles. On the other hand, the lower value of the correlation coefficient for the Freundlich model ($R^2 = 0.987$) shows that the adsorption behaviour of the investigated system does not correspond to the assumptions on which the Freundlich model is based. Similar results were found in the work of Azaman et al. [15], who investigated the adsorption of malachite green dye on activated carbon from coconut shells.

4. CONCLUSIONS

The results show that the mass of adsorbent, pH and reaction time were statistically significant parameters that contributed most to the efficiency of Magenta dye removal from the synthetic solution. In addition, the adsorption treatment resulted in 98% and 68% efficiency in the removal of printing dye from the synthetic solution and printing wastewater, respectively. The adsorption of printing dye onto activated carbon was best described by the Langmuir model, indicating the presence of chemical interactions in the activated carbon/printing dye system, i.e. the chemisorption mechanism was confirmed by the presence of numerous functional groups on the surface of the activated carbon, which have a high affinity for dyes. Further research should be directed towards the development of ideal purification methods that allow fast and efficient removal of dyes from printing industry wastewater without causing secondary contamination. This approach would enable the reuse of treated water and help to preserve the environment and protect human health and aquatic ecosystems. It seeks research and innovation to develop sustainable technologies for the purification of wastewater from the printing industry, which would help to minimize the negative impact on the environment.

ACKNOWLEDGEMENT

The authors acknowledge financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-47/2023-01/200156).

REFERENCES

MALIYAPPA, M. et al.: SYNTHESIS, CHARACTERIZATION, PHARMACOLOGICAL AND COMPUTATIONAL STUDIES OF 4,5,6,7-TETRAHYDRO-1,3-BENZOTHIAZOLE INCORPORATED AZO DYES, *JOURNAL OF MOLECULAR STRUCTURE*, **1179**. (2019) PP. 630-641, ISSN 1872-8014

Natarajan, S.; BAJAJ H. & TAYADE R.: RECENT ADVANCES BASED ON THE SYNERGETIC EFFECT OF ADSORPTION FOR REMOVAL OF DYES FROM WASTE WATER USING PHOTOCATALYTIC PROCESS, *JOURNAL OF ENVIRONMENTAL SCIENCES*, **65**. (2018) PP. 201-222, ISSN 1001-0742

Pekarovicova, A. & HUSOVSKA V.: PRINTING INK FORMULATIONS, *PRINTING ON POLYMERS*, **3**. (2016) PP. 41-52, ISBN 9780323375009

GVOIĆ, V.: INVESTIGATION OF FENTON-PROCESS APPLICATION IN THE TREATMENT OF DYE WASTEWATER IN PRINTING INDUSTRY, PhD THESIS, (2019) FACULTY OF SCIENCES, UNIVERISTY OF NOVI SAD.

Katheresan, V.; KANSEDO J. & LAU S.: EFFICIENCY OF VARIOUS RECENT WASTEWATER DYE REMOVAL METHODS: A REVIEW, *JOURNAL OF ENVIRONMENTAL CHEMICAL ENGINEERING*, **6**. (2018) PP. 4676-4697, ISSN 2213-3437

BOUDECHICHE, N. et al.: COMPARATIVE STUDY ON REMOVAL OF TWO BASIC DYES IN AQUEOUS MEDIUM BY ADSORPTION USING ACTIVATED CARBON FROM ZIZIPHUS LOTUS STONES, *MICROCHEMICAL JOURNAL*, **146**. (2019) PP. 1010-1018, ISSN 1095-9149

HARRACHE, Z. et al.: THERMODYNAMIC AND KINETICS STUDIES ON ADSORPTION OF INDIGO CARMINE FROM AQUEOUS SOLUTION BY ACTIVATED CARBON, *MICROCHEMICAL JOURNAL,* **144**. (2019) PP. 180-189, ISSN 1095-9149

Jones, B. & NACHTSHEIM C.: DEFINITIVE SCREENING DESIGNS WITH ADDED TWO-LEVEL CATEGORICAL FACTORS, *JOURNAL OF QUALITY AND TECHNOLOGY*, **45**. (2013) PP. 121-129

FIDALEDO, M. et al.: APPLICATION OF A NOVEL DEFINITIVE SCREENING DESIGN TO DECOLORIZATION OF AN AZO DYE ON BORON-DOPED DIAMOND ELECTRODES, *INTERNATION JOURNAL OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY*, **13**. (2016) PP. 835-842, ISSN 1735-2630

SUHAIMI, A. et al.: PRODUCTION OF LARGE SURFACE AREA ACTIVATED CARBON FROM A MIXTURE OF CARROT JUICE PULP AND POMEGRANATE PEEL USING MICROWAVE RADIATION-ASSISTED $ZnCl_2$ ACTIVATION: AN OPTIMIZED REMOVAL PROCESS AND TAILORED ADSORPTION MECHANISM OF CRYSTAL VIOLET DYE, *DIAMOND AND RELATED MATERIALS*, **130**. (2022) PP. 109-456, ISSN 1879-0062

BOULIKA, H. et al.: DEFINITIVE SCREENING DESIGN APPLIED TO CATIONIC & ANIONIC ADSORPTION DYES ON ALMOND SHELLS ACTIVATED CARBON: ISOTHERM, KINETIC AND THERMODYNAMIC STUDIES, MATERIALS TODAY: PROCEEDINGS, **72**. (2023) PP. 3336-3346, ISSN 2214-7853

RAJI, Y. et al.: HIGH ADSORPTION CAPACITIES OF CRYSTAL VIOLET DYE BY LOW-COST ACTIVATED CARBON PREPARED FROM MOROCCAN MORINGA OLEIFERA WASTES: CHARACTERIZATION, ADSORPTION AND MECHANISM STUDY, *DIAMOND AND RELATED MATERIALS*, **135**. (2023) PP. 109-834, ISSN 1879-0062

TUBIĆ, A. et al.: SORPTION POTENTIAL OF MICROPLASTICS FOR AZO- AND PHTHALOCYANINE PRINTING DYES, *DYES AND PIGMENTS*, **209**. (2023) PP. 110884, ISSN 1873-3743

LAROUS, S. & Meniai, A.: ADSORPTION OF DICLOFENAC FROM AQUEOUS SOLUTION USING ACTIVATED CARBON PREPARED FROM OLIVE STONES, *INTERNATIONAL JOURNAL OF HYDROGEN ENERGY*, **41**. (2016) PP. 10380 - 10390, ISSN 1879-3487

AZAMAN, S. et al.: REMOVAL OF MALACHITE GREEN FROM AQUEOUS PHASE USING COCONUT SHELL ACTIVATED CARBON: ADSORPTION, DESORPTION, AND REUSABILITY STUDIES, *JOURNAL OF APPLIED SCIENCE AND ENGUNEERING*, **21**. (2018) PP. 317-330, ISSN 1560-6686

CORRESPONDING AUTHOR:

Vesna GVOIĆ
Department for Graphic Engineering and Design, Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21000, Novi Sad, Republic of Serbia
E-mail: kecic@uns.ac.rs

INNOVATIVE MULTIPURPOSE GIFT PACKAGING

Andreja POGAČAR[1], Diana GREGOR-SVETEC[2]

1 Dodopack, Trbovlje, Slovenia
2 University of Ljubljana, Faculty of Natural Sciences and Engineering, Ljubljana, Slovenia

Abstract

The objective of our research was to design sustainable multipurpose gift packaging. Packaging made from a corrugated cardboard was designed in a way to attract the consumer with a unique shape that conveys the comprehensive brand image through the packaging's form rather than its graphic design. This approach underscores that unique packaging shapes can also make a brand recognizable, even when the graphic design is of secondary importance. Elements of multifunctionality and the possibility of re-use the packaging were added. With adding a handle, to avoid the use of gift bag, and with the construction that enables storing of different products, multifunctionality of packaging was provided. An exhibition product display that can be assembled from several package units, which can be used instead of promotional stand, is another multipurpose feature of the packaging. After serving its purpose, packaging can turn into a nesting box for solitary bees, enabling a re-use of the packaging. The substance that attracts bees was tested to obtain the right consistency for screen-printing. Finally, the survey provided insights into how consumers perceive the enhancement of sustainable packaging through various multifunctional features.

Keywords: *Packaging, eco-design, corrugated cardboard, multifunctionality, re-use.*

1. INTRODUCTION

Packaging is designed to protect and preserve the product from the producer to the consumer and has a significant impact on factors such as economic, social, and environmental [1]. It can offer additional features and provide social prestige and advantage over the competition with apperance, however with thoughtful design it can also reduce the negative impact on the environment [2]. Sustainable eco-design is a concept that focuses on creating products with consideration of the environmental impacts of the product throughout its entire life cycle, including design, production, use, and disposal. Steps in the eco-design promote the reduction of energy and material consumption, reuse of products or its components, upgrading used products, recycling of materials, including waste material generated in production and energy recovery [3]. Azzi et al. [4] recommended that in sustainable packaging design, packaging waste should be completely eliminated, material consumption reduced, packaging reused or recycled at the end of its life cycle, and used material returned as a raw material for reuse. Disposal at landfill is the worst option and is something we strive to completely avoid in sustainable approach. For successful implementation of sustainable design in a company, it is first necessary to create an environmentally friendly product that meets the needs of the customer and can be produced efficiently [5].

Thoughtful design of gift packaging and all additional elements is extremely important. The use of sustainable materials is important, as well as a limited use of print and avoiding use of materials that give a luxurious appearance (lamination, foils, adhesives, UV varnish) as they result in causing poor or unusable recyclate. In eco-design of packaging, the mass of the packaging, the ratio of mass and volume

of the packaging and product, packaging waste, and the amount of recyclable materials are considered [6-8]. It is also important to consider the ratio of used renewable and non-renewable materials and resources, the degree of processing and returnability [9]. Graphic design is also important, implying alternatives to print, such as cut-outs or embossing without foils or UV varnish. The innovative design approach to optimize packaging efficiency and create reusable or multipurpose packaging are, besides employing eco-friendly materials, important steps to sustainable packaging. The objective of our research was to design sustainable multipurpose gift packaging.

2. METHODS

2.1 Packaging design

A single wall E-flute corrugated cardboard made from recycled board was used. The guiding principle for several construction solutions was eco-design, with emphasis on a multi-purpose and reusable packaging. Versions of structural design differ also in the number of layers that make up one side of the box (Table 1). Structure designs were constructed by using ArtiosCAD version 12.0 software.

Table 1: Structural design of seven versions of packaging construction

Version	Layers	Description
A	4	FEFCO 0427 with modification
B	6	FEFCO 0331 with modification
C	6	FEFCO 0331 with modification + insert for bottles
D	1	Self-drawn
E	3	Self-drawn, closing FEFCO 0427
F	3	Self-drawn, closing FEFCO 0427, modified E
G	3	Version F with added perforation

2.2 Preparation and testing of suspension of pollen

Several combinations of suspension of pollen were prepared by mixing water, sugar syrup and pollen in different states (whole grains, crushed grains, powder prepared by dissolving in water and drying) and in different ratios. Following suspensions were prepared: - water and pollen (powder), - sugar syrup of different densities and pollen (whole grains), - sugar syrup of different densities and pollen (crushed grains), - sugar syrup of different densities and pollen (powder).

The fluidity, wettability and absorption into the material of various mixtures applied to corrugated cardboard was visually assessed. The viscosity of suspension was determined using Brookfield Ametek DV-1 Viscometer (Ametek, ZDA) according to ISO 2555.

The selected suspension of pollen, water and sugar syrup was applicated on back side of corrugated cardboard by screen printing using a GOK screen printing machine, model VSM B2. The suspension was applied four times, without drying in between.

2.3 Survey

In the survey, we focused on consumers and collected their opinions about gift packaging and its functions. Quality, efficiency, affordability, usability, visual appeal and satisfaction with the product as a whole were evaluated. An online questionnaire entitled "Sustainable packaging" was used as a data collection tool. The questionnaire was divided into three parts: the first part investigated the socio-economic situation of the respondents, the second part focused on the design of the gift packaging and the third on the multifunctionality and reuse of the packaging. The questionnaire was constructed with multiple-choice questions and a 5-point Likert scale from 1 (poor quality/cheap/less attractive/useless/irrelevant) to 5 (high quality/most expensive/most attractive/very useful/very important). The target population were citizens of Slovenia over the age of 16. The invitation to participate in the survey was distributed via e-mail, social networks and various communities. Respondents remained anonymous, no personal data or identifiers were collected in accordance with the GDPR. We received and analyzed a total of 207 valid questionnaires, in which we got answers to all questions.

3. RESULTS AND DISCUSSION

3.1 Design of packaging

The basic packaging design was taken from the FEFCO Style Boxes collection. A folder-type 0427 and telescope-type 0331 box that was modify to strengthen the box on one side, or at bottom/top were selected. Seven versions of packaging were designed in such a way that no additional gluing was needed. First packaging (A) is a folder-type box, which consist of only one piece of board. The bottom of the box is hinged to form all side walls and the cover. Second and third design (B and C) are telescope-type boxes, that consist of two pieces and are characterised by a lid telescoping over the body of the box. Fourth packaging (D) was created by drawing with parametric components from only one piece of board and then further modified to more complex shape (E). For developing packaging E the starting point was the unconventional shape of packaging D, with adding structural elements of packaging A. It consists of three pieces and is easy to assemble without gluing. Packaging F is an upgrade of packaging E by changing the position of closure and handle. Packaging G is an upgrade of packaging F with added perforation. Prototypes of packaging A to F are shown in Figure 1 and structure designs of boxes are presented in Figure 2.

Figure 1: Packaging – versions A, B, C, D, E and F

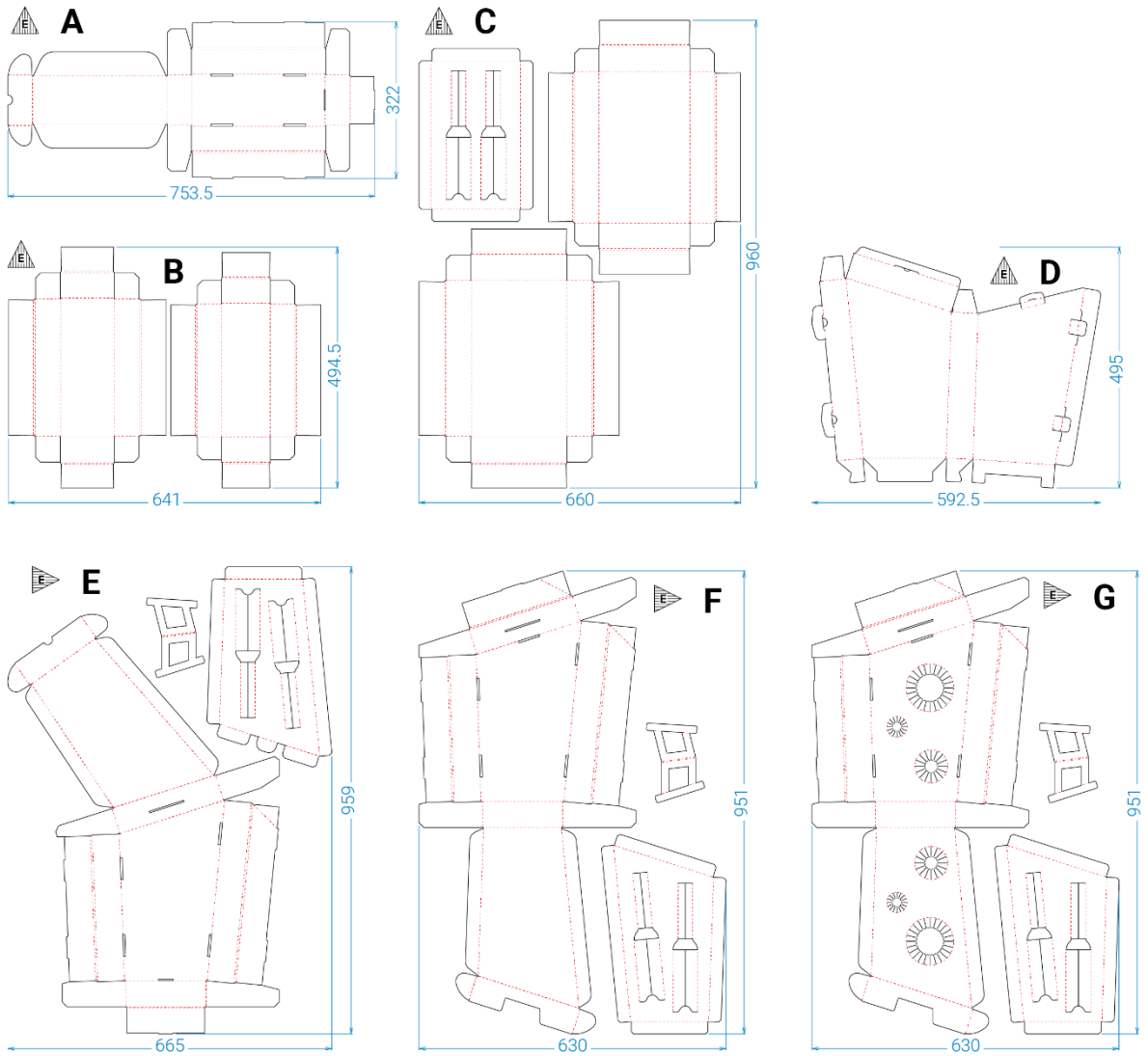


Figure 2: Structure design of boxes

The technical data presented in Table 2 are needed for the production of packaging. The boxes are of different dimensions, and as a result, the consumption of material differs, except for packages F and G, which have the same dimensions, differing only in the perforation added at packaging G. Two boxes can be cut from a B1 size for versions A, B and D, and one for the others. The best material utilization is at B, C and D. The minimum waste at die-cutting is at packaging B, and the largest at packaging A. Packaging E, F and G have the largest volume, while packaging A has the smallest. From the volume, we can see how much space the packaging will take up and what volume of products can be packed in it. The cheapest package is D (taking into account the initial cost of the die-cutting tool), and the most expensive is packaging G. The price difference is around 20%.

Table 2: Technical data for production of packaging for seven versions

Packaging		A	B	C	D	E	F	G
Sheet dimensions [mm]		322 × 753.5	641 × 494.5	660 × 960	592,5 × 495	665 × 959	630 × 951	630 × 951
Format size [mm]		707 × 1000 (size B1)						
Pieces/format size [pcs]		2	2	1	2	1	1	1
Surface efficiency [%]		51.2	68	61.7	61.7	53.8	54.4	54.4
Material resude [%]		48.8	32	38.3	38.3	46.2	45.6	45.6
Cuts [m]		3.4	3.6	6.1	3	7.1	7.2	9.6
Creases [m]		2.9	5	8.4	2.4	6.1	6.3	7.6
Total rule length [m]		6.2	8.5	14.5	5.5	13.2	13.5	17.2
Volume of packaging [cm^3]		1555.6	1691	3425.5	3634.3	3653.5	3653.5	3653.5
Price/pcs [€ excl. VAT]	order 500 pcs	0.4051	0.4051	0.5135	0.4051	0.5135	0.5135	0.5135
	order 1000 pcs	0.3564	0.3564	0.4596	0.3564	0.4596	0.4596	0.4596
	order 2000 pcs	0.332	0.332	0.4327	0.332	0.4327	0.4327	0.4327
Tool price [€ excl. VAT]		264	361	560	234	521	521	664

3.2 Multipurpose and reuse of packaging

Implementing the eco-design was the guiding principle for construction solutions. At the same time a multipurpose and reusable packaging was designed. A handle made of corrugated cardboard was added to the basic shape of the packaging (E). The gift packaging was designed in such a way that it can be used to pack several different products, simply by adding different interior fitments. With different shapes, volumes and dimensions of boxes, an exhibition product display was constructed which can be used instead of promotional stand (Figure 3). After serving its purpose, packaging can turn into a nesting box for solitary bees, enabling a reuse of the packaging (Figure 4). This was made by adding perforations in the front and back side of packaging (G).

Figure 3: 3D visualization of promotion stand, representing the silhouette of the mountains the Julian Alps

Figure 4: Packaging G turned into the nesting box for solitary bees

Nesting boxes are artificial structures designed to provide nesting sites for solitary bees. In order to attract solitary bees to enter the nesting box the suspension of pollen is used. Different suspensions of water, sugar syrup and pollen in different states (whole grains, crushed grains, powder) were used and applied to corrugated cardboard. When a larger amount of water was present in the suspension, the wettability and absorbency were too high. Mixtures that contained more dry matter, i.e pollen, have dried faster. The most optimal mixture, especially for screen printing, was a combination of pollen with sugar syrup with less water, for quick drying and good adhesion to the surface. When the mixtures were completely dry, the surface was hard and non-sticky.

After a visual assessment, the viscosity of two different sugar syrups solutions was tested. The results are shown in Table 3. With a viscosity of around 2700 mPa.s, solution B has a significantly higher viscosity than solution A. For printing an equal amount of powdered pollen was added to each solution. Solution B, which was more viscous, applied better and more evenly on cardboard with screen printing and dried faster. For production of gift packaging a more viscous suspension was screen printed on inside of the packaging.

Table 3: Viscosity and composition of sugar syrup samples

	Sugar syrup composition		Speed (RPM)	Viscosity [mPa.s]
	Water	Sugar		
A	43%	57%	20	32.0
			50	51.5
			100	70.0
B	23%	77%	20	2680.0
			50	2736.0
			100	2718.7

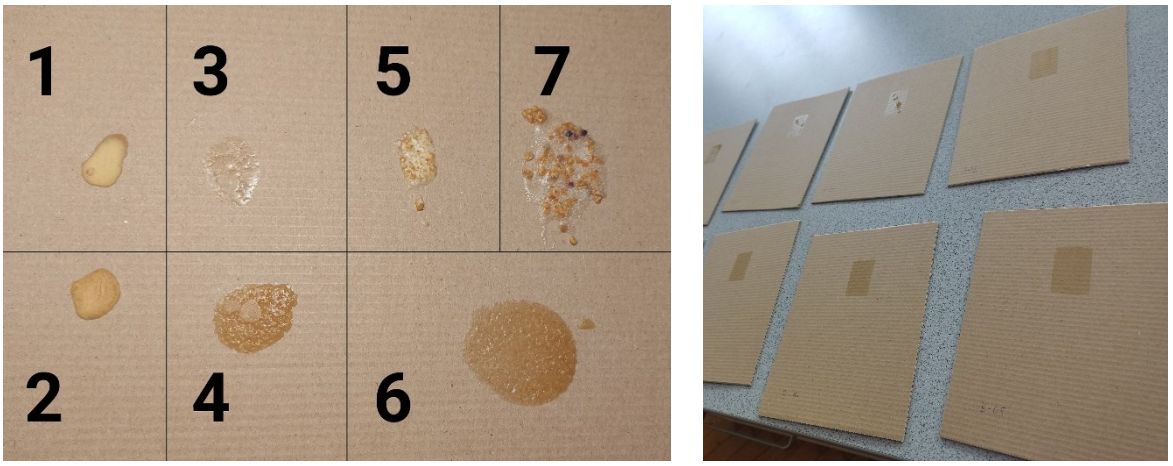


Figure 5: Left - testing combinations with varying amounts of ingredients, water, sugar and pollen; Right - sugar syrup solutions with powdered pollen printed on cardboard with screen printing

3.3 Survey results

In survey respondents evaluated the structural design of packaging B, A and F, shown in Figure 6. The average score about structural design according to socio-economic factors is presented in Table 4.

Figure 6: Images of packaging B, A and F presented in the survey

Respondents of generations X and Y recognized packaging F as the best quality and visually attractive, while the youngest and oldest (Z and Baby boomers) recognized packaging A and B as the highest quality. Packaging F was rated as the highest price class, and packaging the most useful B followed by packaging A, socio-economic factors in this case had no effect on perception. In general, it can be seen that respondents with (in)completed primary school gave higher marks on average for all items. The summary of the respondents' opinions is as follows. Respondents express different preferences regarding the design of the packaging, emphasizing simplicity, practicality, multi-purpose use, minimal material consumption, aesthetic appearance, product protection, easy opening and closing, and the desire for better folding and organization of the packaging after use. Some also express concerns about the practicality, design and suitability of packaging for certain products.

Table 4: On-line survey: average score of structural design according to socio-economic factors

	n	Quality			Price range			Visual attraction			Usability		
		B	A	F	B	A	F	B	A	F	B	A	F
Average rating	207	3.6	3.6	3.5	2.9	2.9	3.9	3.5	3.3	3.3	3.9	3.8	3.0
STD		0.23	0.22	0.19	0.14	0.22	0.24	0.35	0.31	0.29	0.08	0.16	0.21
CV [%]		6.27	5.93	5.38	4.81	7.42	6.22	9.86	9.03	8.55	2.03	4.26	6.86
Age													
generation Z	72	3.7	3.7	3.3	2.8	2.9	4.0	3.8	3.3	3.0	3.9	3.9	2.9
generation Y	46	3.2	3.4	3.7	2.8	2.9	4.1	3.2	3.3	3.4	3.8	3.8	3.3
generation X	65	3.6	3.5	3.7	3.0	2.7	3.9	3.4	3.1	3.6	3.9	3.7	3.0
Baby boom	24	3.9	4.1	3.5	2.8	3.3	3.4	3.6	3.8	3.4	4.0	3.8	3.0
Level of education													
Elementary school	7	4.0	4.1	3.7	3.1	3.4	3.9	4.3	4.4	3.6	4.1	4.1	3.1
High school	59	3.4	3.6	3.3	2.6	2.8	3.8	3.2	3.3	3.2	3.8	3.9	3.0
University	117	3.7	3.6	3.6	3.0	2.9	4.0	3.6	3.2	3.4	3.9	3.7	3.0
Master's degree, Ph.D	23	3.5	3.3	3.5	2.8	2.8	4.0	3.5	3.3	3.3	3.9	3.9	3.1
Employment status													
Unemployed	5	4.0	3.8	3.4	2.8	2.4	3.4	4.4	3.6	2.8	3.8	4.4	2.6
Pupils or students	66	3.7	3.7	3.3	2.9	2.9	4.0	3.8	3.4	2.9	3.9	3.9	2.8
Employed	119	3.4	3.5	3.6	2.9	2.8	4.0	3.3	3.2	3.6	3.9	3.7	3.1
Retired	15	3.7	4.0	3.7	2.8	3.2	3.3	3.2	3.9	3.5	3.9	3.8	3.3
Average monthly income (net)													
up to 800 €	55	3.8	3.6	3.2	3.1	3.0	3.8	3.8	3.4	2.9	3.9	3.8	2.9
801 – 1300 €	36	3.3	3.6	3.5	2.7	2.9	3.9	3.2	3.4	3.6	3.8	3.8	3.2
1.301 – 1800 €	42	3.4	3.4	3.8	3.0	2.8	4.1	3.4	3.2	3.8	3.9	3.8	3.2
from 1801 €	45	3.6	3.7	3.7	2.8	2.9	4.0	3.4	3.3	3.4	3.9	3.7	3.1

The respondents evaluated the various functionalities of the gift packaging. They evaluated the usefulness and importance of the following functions: a handle for the packaging - we do not need an additional gift bag, one packaging - intended for several different products, and the reuse of the packaging, which can be turned into a nesting box for solitary bees with a few simple steps (Figure 7). In Table 5 average score for multipurpose and reuse of packaging is given according to socio-economic factors. The respondents perceived the most useful and important multi-functionality, as packaging is suitable for packing several different products. This is immediately followed by the added handle. They rated the possibility of reuse for the nesting box less useful and important. Among the respondents' opinions, the advantages of multi-functionality, reuse of packaging, care for nature and innovation are

highlighted. There are also concerns regarding the aesthetics, the stability of the handle, the suitability of the material for bee hives and the usability of the packaging according to its original function. The need for personalization, reduction of waste and concern for the use of environmentally friendly colors and materials are also mentioned.

Figure 7: Image of packaging G turned into nesting box for solitary bees.

Table 5: On-line survey: average score of multipurpose function and reuse of packaging according to socio-economic factors

	n	Usability			Importance		
		Handle	For different products	Nesting house	Handle	for different products	Nesting house
Average rating	207	4.1	4.2	3.6	3.9	3.9	3.4
STD		0.18	0.21	0.18	0.15	0.15	0.27
CV [%]		4.53	5.10	4.91	3.95	3.66	7.83
Age							
generation Z	72	4.2	4.3	3.6	3.9	4.0	3.2
generation Y	46	4.1	4.3	3.8	3.9	4.0	3.2
generation X	65	3.9	4.0	3.5	3.7	3.8	3.6
Baby boom	24	4.0	3.9	3.5	4.1	4.0	3.7
Level of education							
Elementary school	7	4.3	4.4	4.1	4.0	4.3	3.9
High school	59	4.1	4.2	3.3	3.9	3.8	3.0
University	117	4.1	4.2	3.7	3.8	4.0	3.5
Master's degree, Ph.D	23	4.0	3.7	3.8	4.1	3.7	3.6

Employment status							
Unemployed	5	3.4	4.0	3.6	3.6	4.2	3.8
Pupils or students	66	4.2	4.4	3.7	3.8	4.0	3.2
Employed	119	4.1	4.1	3.6	3.9	3.9	3.4
Retired	15	4.0	3.9	3.5	4.2	4.1	4.0
Average monthly income (net)							
up to 800 €	55	4.1	4.2	3.5	3.7	3.9	3.3
801 – 1300 €	36	4.1	4.0	3.4	4.0	3.9	3.1
1.301 – 1800 €	42	4.2	4.4	3.8	4.0	4.0	3.7
from 1801 €	45	4.1	4.0	3.6	3.8	3.9	3.4

4. CONCLUSION

Besides using sustainable material such as corrugated cardboard, the packaging's construction itself has a great influence on the environmental function of the packaging. When designing sustainable packaging, it is also necessary to consider the possibility of reuse and the multi-purpose nature of the packaging. In our case, with adding a handle, to avoid the use of gift bag, and with the construction that enables storing of different products multifunctionality of packaging was provided. With the special design of the gift packaging, we communicate the overall image of the brand that it represents. With adding boxes from the same packaging family of unconventional shapes, to the original gift packaging we designed first (F), we achieve the effect of creating a promotional layout that resembles the silhouette of the mountains, the Julian Alps. After its initial use, the packaging can transform into a nesting box for solitary bees, demonstrating a commitment to reuse and sustainability. When developing packaging, consumer opinion is also an important aspect. The opinions obtained in our research confirmed that packaging with a special design is visually attractive, high-quality and useful, and that upgrading it with multifunctionality adds added value. This approach not only meets sustainability requirements but also coincides positively with consumers opinion.

REFERENCES

Snoj, B.: *EMBALAŽA-SESTAVINA POLITIK IZDELKOV IN KOMUNICIRANJA V MARKETINGU*, ČGP DELO, LJUBLJANA, (1981)

Dreyfuss, H.: *DESIGNING FOR PEOPLE*, ALLWORTH PRESS, ISBN: 9781581153125, NEW YORK, (2003)

Brezet, H.: DYNAMICS IN ECODESIGN PRACTICE, *INDUSTRY AND ENVIRONMENT*, **20** (1997) PP. 21-24

Azzi, A. et al.: PACKAGING DESIGN: GENERAL FRAMEWORK AND RESEARCH AGENDA, *PACKAGING TECHNOLOGY AND SCIENCE*, **25** (2012) 8, PP. 435-456

Pigosso, D.C. et al.: ECODESIGN MATURITY MODEL: A MANAGEMENT FRAMEWORK TO SUPPORT ECODESIGN IMPLEMENTATION INTO MANUFACTURING COMPANIES, *JOURNAL OF CLEANER PRODUCTION*, **59** (2013) PP. 160-173

González-García, S. et al.: SUSTAINABLE DESIGN OF PACKAGING MATERIALS. IN *ENVIRONMENTAL FOOTPRINTS OF PACKAGING*, SPRINGER, ISBN: 9789812879134, SINGAPORE, (2016), PP. 23-46

Radonjič, G.: *OBLIKOVANJE IN RAZVOJ OKOLJU PRIMERNEJŠE EMBALAŽE*, FAKULTETA ZA KEMIJO IN KEMIJSKO TEHNOLOGIJO, ISBN: 9612484171, Maribor, (2014)

Samanta, K.K. et al.: POTENTIALS OF FIBROUS AND NONFIBROUS MATERIALS IN BIODEGRADABLE PACKAGING. IN *ENVIRONMENTAL FOOTPRINTS OF PACKAGING*, SPRINGER, ISBN: 9789812879134, SINGAPORE, (2016), PP. 75-113.

Radonjič, G. et al.: *EMBALAŽA IN VARSTVO OKOLJA: ZAHTEVE, SMERNICE IN PODJETNIŠKE PRILOŽNOSTI*, ZALOŽBA PIVEC, ISBN: 9789616494632, MARIBOR, (2008)

CORRESPONDING AUTHOR:

Diana GREGOR-SVETEC
Department of Textiles, Graphic Arts and Design, Faculty of Natural Sciences and Engineering
Snežniška 5, 1000 Ljubljana, Slovenia
E-mail: diana.gregor@ntf.uni-lj.si

INFLUENCE OF ARTISTIC STYLES ON CONTEMPORARY DESIGN

Róbert NÉMETH, Éva HOTTÓ, Márta KISFALUDY

Product Design Institute, Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

Abstract

The impact of the arts in all walks of life is endless and provides an inexhaustible source of inspiration for new generations. Coupled with technological innovation, new fields of visual expression are opening up. What are the most popular and well-known styles, the trends that most influence today's design culture, architecture or even the film and games industry? These are the questions the authors seek to answer, based on the work of well-known designers and the preferences of students.

Keywords: *Art, design, technological innovation, visual expression*

1. INTRODUCTION

The arts are a way of expressing culture and history, developing our identity and promoting understanding between societies with different values. The arts of the past, as well as the ever-changing contemporary trends, have a multifaceted impact on our daily lives.

Art affects us all, wittingly or unwittingly, because it provokes emotions, evokes memories, generates involuntary comparisons, conveys new values and encourages us to form our opinions.

None of the arts can be confined to a specific boundary because they are expressive and creative. The purpose of art is to express emotions or ideas through means such as colour, texture, line, composition and form. It can evoke a wide range of emotions from joy to sadness or from contemplation to identification. In design, products or spaces that have an emotional impact on people create an intimate connection with the user, creating a sense of loyalty to the designer, brand or style. A good piece of art conveys complex ideas and messages, while also helping to create an aesthetic appreciation of beauty and form.

The arts are often a source of inspiration for designers. Colours, shapes and patterns can generate new design ideas and motivate creative thinking, whether in interior design, graphic design or industrial design.

Art plays a multifaceted role in our lives and in the design process. It influences our emotions, inspires creativity, conveys messages and enriches the human experience. Understanding and harnessing the essence of art can lead to innovative design concepts and spectacular products.

The influence of artistic styles on contemporary design is a significant, complex and dynamic relationship that is constantly present, providing inspiration, influencing design principles and reflecting the current cultural, technological and social context of our time.

Today's designers often draw inspiration from different artistic movements of the past, such as Art Nouveau, Art Deco, Cubism or the Bauhaus movement. Elements of these styles are reinterpreted and incorporated into their work, so that the achievements of the past are constantly renewed.

For example, minimalist art movements and conceptual art have had a lasting influence on contemporary design. The principles of simplicity, functionality and the reduction of design elements to basic shapes are present in many contemporary products and spaces. Later, postmodern art and design movements rejected the rigidity of modernism and focused on eclecticism, colour and humour.

Contemporary design, moreover, often incorporates elements from different cultural artistic traditions, reflecting the multicultural nature of today's society. Such a fusion of styles and influences from around the world can be seen in architecture, interior design, fashion and other areas of object design.

The digital age has created new forms of artistic expression, and this has had a major impact on contemporary design. Digital tools and technologies allow designers to use new forms and materials in their creations and to explore interactive experiences. Augmented Reality (AR) and Virtual Reality (VR), Artificial Intelligence (AI), high-tech and eco-friendly materials, as well as the widespread adoption of the internet, are also having a positive impact on designers' creations. Contemporary design thus offers more opportunities for individual expression, with designers often combining multiple styles, materials and technologies to create unique and personalised works.

2. MOTIVATING FACTORS FOR DESIGN

There are many sources of inspiration for design, and it often depends on the type of design project you are working on. Without being exhaustive, we can mention the eternal source, nature, with all its wholeness and detail, landscapes, plants and wildlife. The historical periods of artistic movements also occupy a prominent place among the sources of inspiration, with their different styles, techniques and means of expression. The reinterpretation of design as inspiration plays an important role in the perpetuation of different cultures and traditions.

In this article, we explore the preferences of historical periods in relation to design from an artistic perspective. It has long been known how, almost from season to season, clothing from art-historical periods inspires contemporary fashion. The distinctive stylistic features also give a clear character to contemporary clothes, whether they are Renaissance, Elizabethan, Baroque, Rococo or turn-of-the-century. These styles have influenced and continue to influence design and architecture. New stylistic trends and reflections on social phenomena are most quickly manifested through clothing, and fashion is thus expressively linked to the visual spectacle of the arts. (*Figure 1-3.)*

Figure 1. Elsa Schiaparelli and S., Dali's Lobster Dress (1930s). [1]

Figure 2. Painting of Sonia Delaunay: Simultaneous Dresses and a Simultaneist's Dress from 1920. [1]

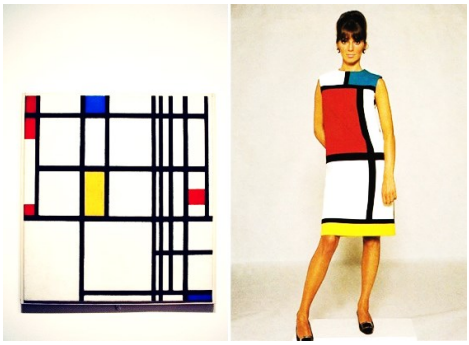


Figure 3. Piet Mondrian painting and a model from Yves Saint Laurent's 1965 collection. [2]

Already at the end of the 19th century, the visual arts had a strong influence on the world of fashion. French designer Paul Poiret's models brought a spectacular change in both silhouettes and patterns. In the 20th century, the Italian-born Elsa Schiaparelli was the first to be inspired by surrealism, as she maintained friendly relations with many of its exponents. [3]

The changes since then have only intensified this trend and the fashion industry, equipped with the latest technologies, has become a keen user of artistic prints on clothing. The Hungarian brand The Four has produced a Botticelli-print collection, but there are also a number of Hungarian collaborations representing this trend, such as the Kattizoob brand and prints by Anna Lesznai, Nubu and Dóra Maurer, or paintings by Márta Kucsora.

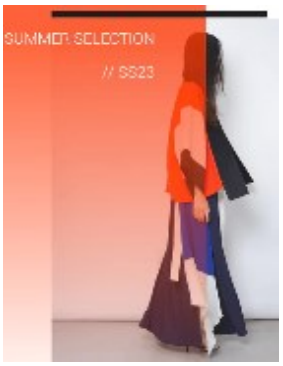


Figure 4. Nubu and Dóra Maurer collaboration, 2023. [4]

Figure 5-6. Kati Zoob and Anna Lesznai exhibition, 2018. [5]

3. RESEARCH WORK

We conducted a questionnaire survey of people who had studied art history, so that they could be a little closer to understanding this field and who have been emotionally touched by the different great periods.

Of the 96 respondents, 76.8% were women, 23.2% were men, 72.9% were aged between 18 and 25, 14.6% were aged between 26 and 32, and the rest were aged above these ages. (Figure 7.)

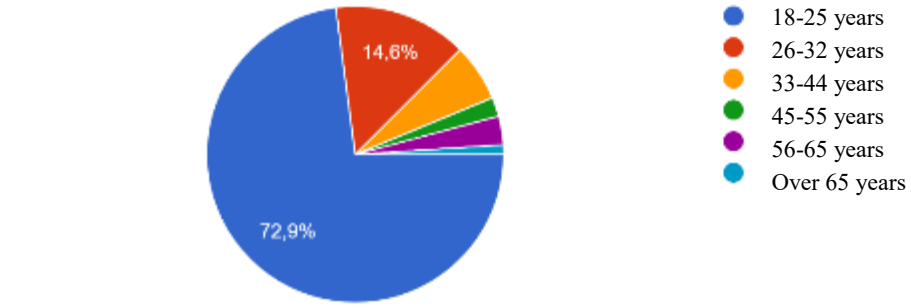


Figure 7. Age distribution of respondents

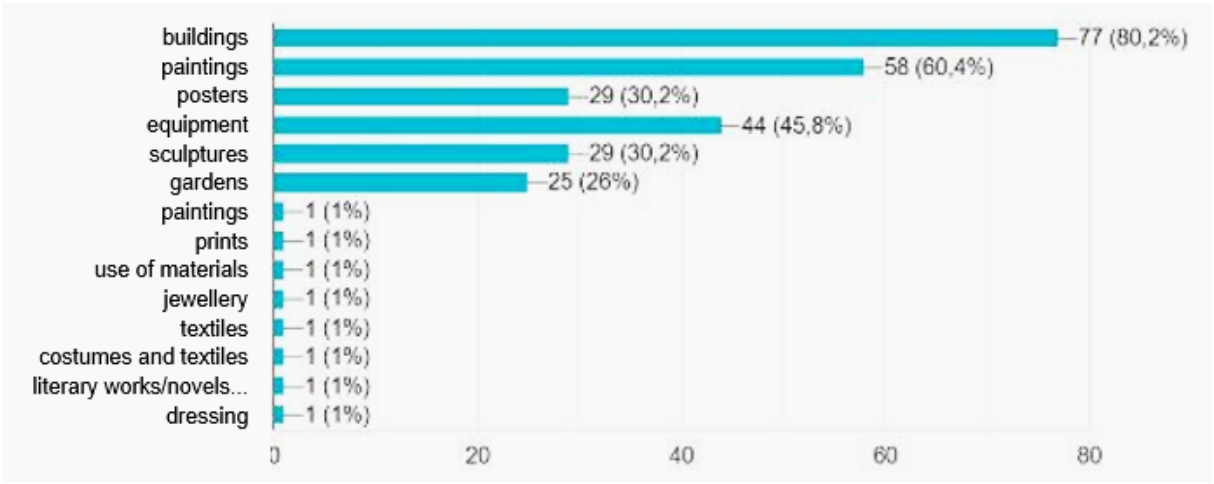


Figure 8. The most popular sources of style inspirations

Of the contemporary works that conveyed the style, buildings were the most popular (77 people, 80.2%), followed by paintings (58 people, 60.4%) and then furnishings (44 people, 45.8%). These were most often cited for the atmosphere (71 people, 74.7%), colours (70 people, 73.7%) and shapes (67 people, 70.5%) suggested by the style. (Figure 8.)

We listed styles that are well known and typical, but there was also an option to add others to see which is the most popular. The answers covered a wide range of major periods in art history. For their own designs, however, three trends were the main sources of inspiration: Art Deco (53 respondents, 55.2%), Bauhaus (39 respondents, 40.6%) and Art Nouveau (37 respondents, 38.5%), with Art Deco coming top of the popularity list. *(Figure 9.)*

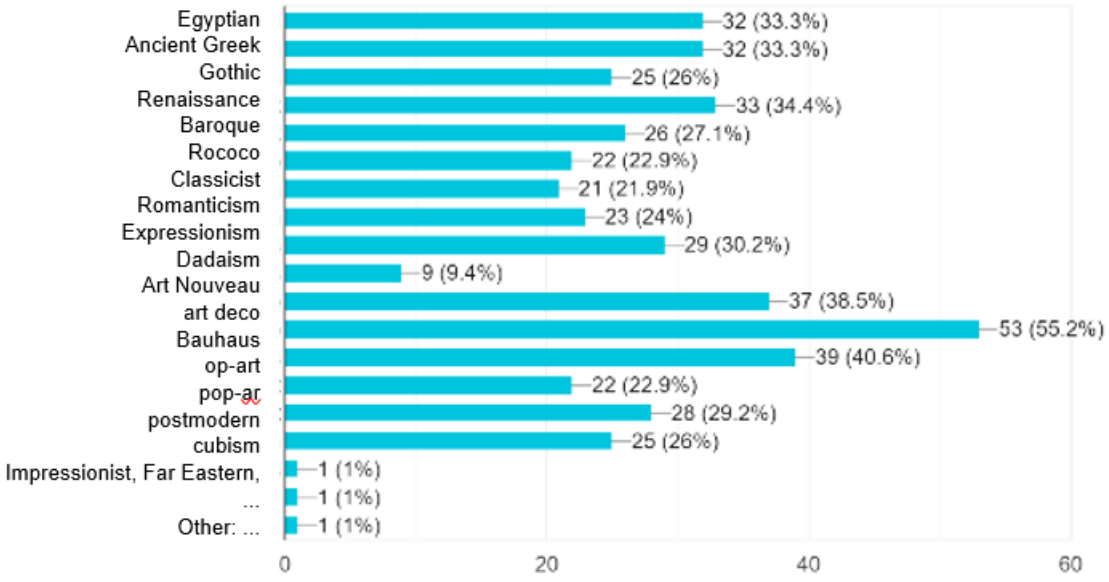


Figure 9. The popularity of the great style eras

4. THE EMERGENCE AND EXPANSION OF ART DECO

The origins of Art Deco can be found in the years following World War I, when a variety of artistic styles, historical eras, and cultural influences came together. Art Deco[1] first appeared at the *1925 International Exhibition of Modern Decorative and Industrial Arts* in Paris, which featured a mix of traditional craftsmanship and contemporary industrial processes. After reaching its peak in 1925 it spread rapidly around the world. Although it originated in Europe, Art Deco quickly became popular in the United States as well. However in the 1930s, during the Great Depression, luxury and opulence became less emphasized. (Figures 10-14) [11]

[1] The name "Art Deco" (from *art décoratif*) was later coined by art critic Bevis Hillier in 1968. In its own time, it was referred to primarily as "Art Moderne" or "zigzag decoration," as this form was one of its most commonly used motifs.

Figure 10. Chrysler Building, New York. [6]

Figure 11. Guardian Building, Detroit. [7]

Figure 12. Tamara de Lempicka, self-portrait in a Green Bugatti, 1929. [8]

Figure 13. Art deco space divider. [9]

Figure 14. Art deco interior.[10]

Art Nouveau was characterized by curved forms, asymmetrical elements, and the use of winding, vine-like, colorful plant motifs and female figures. It was also more closely associated with late romanticism and naturalism. In contrast, Art Deco emerged after the spread of avant-garde movements. It turned its back on nature and emphasized the shaping by human hands. It used symmetry and angular forms. The style became one of the expressions of luxury and elegance, influencing all areas of life, including fashion and advertising of the time. The visual language of Art Deco is distinguished by geometric shapes, symmetrical patterns, and luxurious materials. Geometric elements like zigzags, chevrons, and stepped forms became Art its trademarks. The use of expensive materials such as exotic woods, chrome, glass, and lacquer contributed to the style's luxury. The movement embraced various mediums, including architecture, visual arts, fashion, and industrial design. The Empire State Building and the Palais de Chaillot are two notable examples of dramatic, sleek constructions with ornamentation.

New materials and alloys appeared, such as polished chrome, stainless steel, and bakelite, which could be polished to a mirror finish. The dominance of the style ended with World War II, but it regained popularity in the 1960s and remains fashionable to this day (for example, in interior design). The Machine Age, Cubism, Fauvism, and ancient civilizations like Egypt served as sources of inspiration for the movement. Egyptian themes became popular after Tutankhamun's tomb was found in 1922, which influenced the style of Art Deco. The movement's design also reflected the streamlined forms of modern technology-inspired cars and aircraft.

Art Deco inspired both clothing and accessories in fashion. Flappers embraced the dramatic style of the trend, wearing lowered waists, fringe detailing, and geometric designs. The beauty of the trend extended to jewelry, which featured diamonds, platinum, and vivid gemstones. As a significant fashion movement of the 20th century, Art Deco had an impact on design, architecture, and the arts. Bold geometric shapes, vivid colors, and sense of glamour defined it. The optimism and excitement of the years following World War I were reflected in it also. Additionally, it was a style that was adopted by people worldwide, both common shoppers and wealthy clients. [11][12]

Artists like Tamara de Lempicka reflected the era's elegance and appeal in the visual arts, while graphic design embraced bold lettering and geometric designs. Prominent figures in the Art Deco movement included Jean Carlu, Paul Colin, and A.M. Cassandre (Adolphe Jean-Marie Mouron). Renowned for their distinctive posters marked by geometric shapes, vibrant colors, pioneering typography, and an emphasis on luxury and modern aesthetics, these designers aimed to produce visually impactful and refined works. Their creations significantly influenced the aesthetic of the Art Deco movement, leaving an enduring imprint on graphic design and the visual arts of the era.

Despite its early 20th-century origins, Art Deco is still in style today for a number of reasons. It is renowned for having a sophisticated and glamorous look. People who appreciate traditional and refined design are drawn to the sophisticated and timeless feel that is created by the use of bold patterns, geometric shapes, and expensive materials. There is a universal appeal to the strong emphasis on geometric shapes and symmetry. A sense of order and aesthetic harmony that appeals to modern design sensibilities is created by the balanced compositions and clean lines. It is also a flexible style that works well in a range of design settings. [13]

The Art Deco style can be adapted to suit a variety of interests and preferences by incorporating its features subtly or boldly into architecture, interior design, fashion, and graphic design. In addition, a lot of individuals are captivated to the nostalgia that comes with Art Deco, particularly because it is a unique historical period. Due to the style's retro appeal, both consumers and designers are reviving interest in it and blending its aspects into contemporary adaptations. Art Deco is known for its use of exquisite, luxurious materials including marble, brass, chrome, and exotic woods. Its ongoing appeal among people who value quality and attention to detail is partly due to the appreciation for craftsmanship that has persisted over time, as well as the use of premium materials. It has had a profound impact on popular culture, inspiring modern art and design as well as movies and TV series. Its continuous popularity has been assisted by its visibility in a variety of media outlets. With origins in many cultures and places, including Europe, the US, and beyond, it also has a global impact. Its universal appeal and ability to connect with a wide range of people have led to its continued success. [3] [14]

The preference for elegant art deco style among young people can be attributed to a number of factors, with a combination of geometric patterns, bold colours and luxurious fabrics that feel both contemporary and retro. Young people often appreciate the nostalgic, timeless and classic appeal of such designs. Its easily recognisable, distinctive style sets it apart from mainstream design trends and makes it versatile for use on a variety of products. The sophisticated, detailed craftsmanship and the use of high quality materials are favoured by environmentally conscious young people because the products are long-lasting and do not need frequent replacement as is the case with lower quality mass-produced products. The metal and glass, the black colour, accented with gold, blend perfectly into the contemporary urban environment.

5. THE CONTEMPORARY TRENDS

The current design culture is heavily influenced by technological advances, new sustainable materials, social changes, individual design, and the impact of the emergence of styles that change from time to time. Today's most popular, clean minimalist design may be replaced by a more vibrant, colourful style, only to be replaced later by a simpler trend. In such a cycle, art deco can provide a distinctive look, but it seems to be more than just a fast-changing element of design inspiration. Clean lines, minimalist design and simple aesthetics have a strong influence in particular on product design and interior design. Looking at today's design offerings, we found many contemporary interior design pieces with art deco inspiration. Everyday furnishings, coffee tables, vases or other utilitarian items such as gift boxes or sinks also appear in the repertoire. (Figure 15.)

The use of the characteristic art deco features on these design products always creates an elegant effect. Elegance creates a sense of refined quality, beauty and tastefulness, often through a harmonious balance of simplicity, aesthetics and functionality, which is appreciated by all. This style is found in many areas of life, including fashion, design, art, language, behaviour and many more. In design, elegance means a clean and harmonious aesthetic, often involving simplicity, balance, and symmetry to create a visually pleasing yet functional product or space.

Figure 15: Art deco design products [15]

6. EXPERIMENTS ON DESIGN CONCEPTS

In the course of solving the project tasks, it was clear that if the students were given a choice of given style inspirations, they would decide in favour of art deco. Interestingly, they are able to identify well with this trend and there is little misunderstanding of the use of formal features, stylization, colour harmony and balance elements. Product design and packaging design students alike have been able to innovate with this inspiration, so that everything from tableware to redesign lamps, clothing to box and food plates show signs of Art Deco style and form.

In the design and realisation of the cake takeaway box, many spectacular and innovative solutions were created, while of course adhering to the packaging specifications for cakes and cake slices. For restaurant menus, the choice of fonts and the proportionate distribution of the list of offerings were also successfully chosen. Strips and line thickness variations were used to divide the paper surfaces. (Figure 16.)

Figure 16: Menus and cake boxes in ART-DECO style. Henrietta Kiss, Nikolett Bartók, Fruzsina Miskolczi [16]

For festive, elegant tableware, the main focus was on decorative tablecloths, runners, placemats and other accessories. Strips were applied with appliqués in the right places, but there were also students who layered individual geometric elements as if they were just shaping a building. The skyscraper-shaped lamp is also made up of layers of white, yellow and black plexiglass scraps. (Figure 17-18.)

Figure 17: Works of students. Dinner in art deco style: Fruzsina Heinrich, Boglárka Varga [16]

Figure 18: Works of students. Lamps and table decoration in art deco style: Krisztina Halász, Nóra Szeleczky, Zsófia Bagi [16]

Black, gold and bone colours also dominated the stitching of the clothes, with interesting combinations and manipulations of materials to recreate the pure geometry of art deco, known for its careful attention to detail and craftsmanship, which is reflected in the precise pattern cut-outs, beveled edges and unique shapes. (Figure 19.)

Figure 19: Dresses in art deco style from students: Viktória Farkas, Melinda Sinkovics, Lilla Kontra, Rebeka Farkas [16]

7. CONCLUSION

Artistic styles have a significant impact on contemporary design by providing inspiration, influencing design principles and reflecting the cultural, technological and social context of the present. Artworks convey complex ideas and messages and help the viewer to develop aesthetic sensibility and to

appreciate beauty and form together. Whatever the inspiration for a design, the methodology is built in the same way. But students will be more willing to go through the design process if they have a starting point, inspiration and experience, such as the arts, close to them.

Fine and applied arts, as well as architecture, furnishings, paintings, sculptures, textiles and clothing, are a rich source of inspiration for research. However, it is advisable to set tasks and projects that are relevant to the perceived/actual needs of the students, so that the end result is innovative and successful. This will ensure that they will approach the next assignment with similar intensity when they are working in a company/enterprise where innovation, social and economic utility are expected.

REFERENCES

[1] *https://nlc.hu/trend/20220712/kepzomuveszet-divat/*
[2] *https://contextus.hu/yves-saint-laurent-divatvilag-piet-mondrian/*
[3] Lussier, Suzanne: ART Deco Fashion. London, Bulfinch Press, 2003.
[4] *https://nubustudio.com/collections/nubu-x-maurer-dora*
[5] *https://www.kattizoob.hu/news---lifestyle/esemenyek/lesznai-anna---ki-latott-engem*
[6] *https://www.architecturaldigest.com/story/new-york-chrysler-building-sells-less-than-purchased-decade-ago*
[7] *https://detroit.curbed.com/2015/9/18/9919700/iconic-detroit-building-of-the-week-guardian-building*
[8] *https://www.artchive.com/art-movements/art-deco/*
[9] *https://roomlybox.cafeblog.hu/2014/10/02/igy-dekoralj-art-deco-stilusban/*
[10] *https://fineline.com.sg/exploring-the-art-deco-interior-design-style/*
[11] Charles, Victoria: *ART DECO.* New York, Parkstone Press International, 2019.
[12] Bevis, Hillier: *ART DECO OF THE 20S AND 30S*. New York, E.P. Dutton, 1968.
[13] Benton, Tim (ed.); Benton, Charlotte (ed.); Wood, Ghislaine (ed.): *ART DECO 1910-1939.* London, Bulfinch Press, 2003.
[14] Wood, Ghislaine: Essential *ART DECO.* London, Bulfinch Press, 2003.
[15] *https://kofurhomeshop.hu*
[16] Works of students of interior/fashion design

CORRESPONDING AUTHOR:

Dr. habil Róbert NÉMETH
Institute of Product Design, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University
1034, Budapest, Doberdó u. 6. Hungary
E-mail: nemeth.robert@rkk.uni-obuda.hu

DESIGN AND PRODUCTION OF INTERMINGLED HYBRID YARN ON WINDING MACHINE

Ayşe TÜRKTAŞ ALİ[1]*, Gonca YILDIZ PABUŞÇU[1], Timur ATİK[1], Fatma GÖKTEPE[2]

[1]Gülle Integrated Textile Enterprises Eml. Dan. San. Tic. A.Ş., Tekirdağ, Türkiye

[2]Tekirdağ Namık Kemal University, Department of Textile Engineering, Tekirdağ, Türkiye

Abstract

In this work, an approach to produce a different type of intermingled hybrid yarn is described by combining short-staple spun yarns with synthetic multifilament yarns on a winding machine. For this purpose, a conventional yarn winding machine was modified by implementing an intermingling air-jet so that these two different yarn types are combined into a resulting hybrid yarn. On this modified system, ten different types of intermingled hybrid yarns were produced by combining 100% cotton or cotton/polyester blended yarns (Ne 30/1) with polyester multifilament yarns (75, 87 and 168 denier) to analyse the effect of nozzle pressure (2.5 and 4.0 bar) and effect of winding speed (500 and 750 m/min) on resulting yarn structure and colour. Also, single-jersey knitted fabrics were produced by using these yarns and the effect of nozzle pressure and winding speed on texture of the fabrics were analysed. The results show that the distance between mingling points increases as the winding speed increases and this leads to more visible filaments on knitted fabric surface while the mingling effect weakens as the nozzle pressure decreases and in general multifilaments become more visible on the fabric surface.

Keywords: *Intermingled yarns, hybrid yarns, winding machine, air-intermingling, melange fabric*

1. INTRODUCTION

In intermingled yarns, the filaments are intermingled or entangled in order to avoid their separation during processing. Intermingling of filaments is a substitute for twisting operations and yarn looks tight at the mingle points which are distributed at regular intervals along the yarn length as the mingle points hold the filaments together. In the mingling process, rapidly moving air in an air jet is used to generate entanglements in and among filaments. When filaments of the same type are entangled, the yarn is known as an intermingled yarn; and when filaments of two or more types, e.g. carbon and polyester, are mingled together, the yarn is known as commingled yarn [1].

Intermingling process changes the arrangement of fibers so that surface structure and reflection properties of the yarn vary and this can be used to obtain special effects on yarn and therefore fabric appearance. In literature, there are some works investigating the effect of intermingled yarn surface structure caused by difference in number of nips on colour parameters of knitted fabrics [2]. In another work, the effect of yarn speed (150, 300, 450 m/min) and air pressures (3, 5, 6 bar) on yarn strength, breaking elongation and the number of nips were evaluated [3]. It is also shown that production speed has significant effect on intermingled yarn and fabric parameters by using nylon and polyester textured yarns to produce melange effect on fabrics [4]. The effect of air pressure on properties of polyester/nylon

intermingled yarn and melange fabric with special reference to fabric appearance was also investigated [5].

The main aim of this work is to create special effect on yarns and therefore fabrics by using mingling principle. For this aim, a staple yarn of natural fibers has been used as one component instead of using synthetic filaments at both components (Figure 1) and a conventional yarn winding machine was modified by implementing an air-jet so that these two different yarn types are combined into a resulting hybrid yarn having special colour effect. Then, the effect of yarn speed, air-pressure and yarn type on the effect of yarn and fabric appearance was investigated.

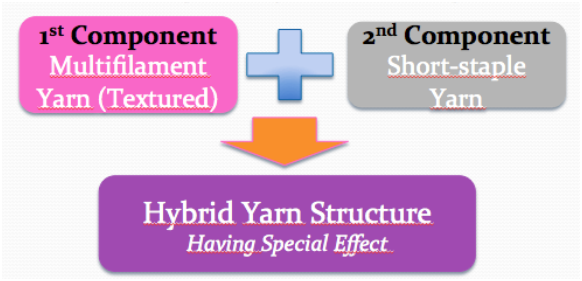


Figure 1: Hybrid yarn structure aimed in this work

2. MATERIAL AND METHOD

For the aim of this work, a conventional yarn winding machine (Murata V7 2000) was modified as the main working principle of this modified winding machine has been described briefly in Figure 2a and 2b. Then, the effect of air-pressure and winding speed were analysed following yarn production according to the experimental plans given at Table 1 and 2, respectively.

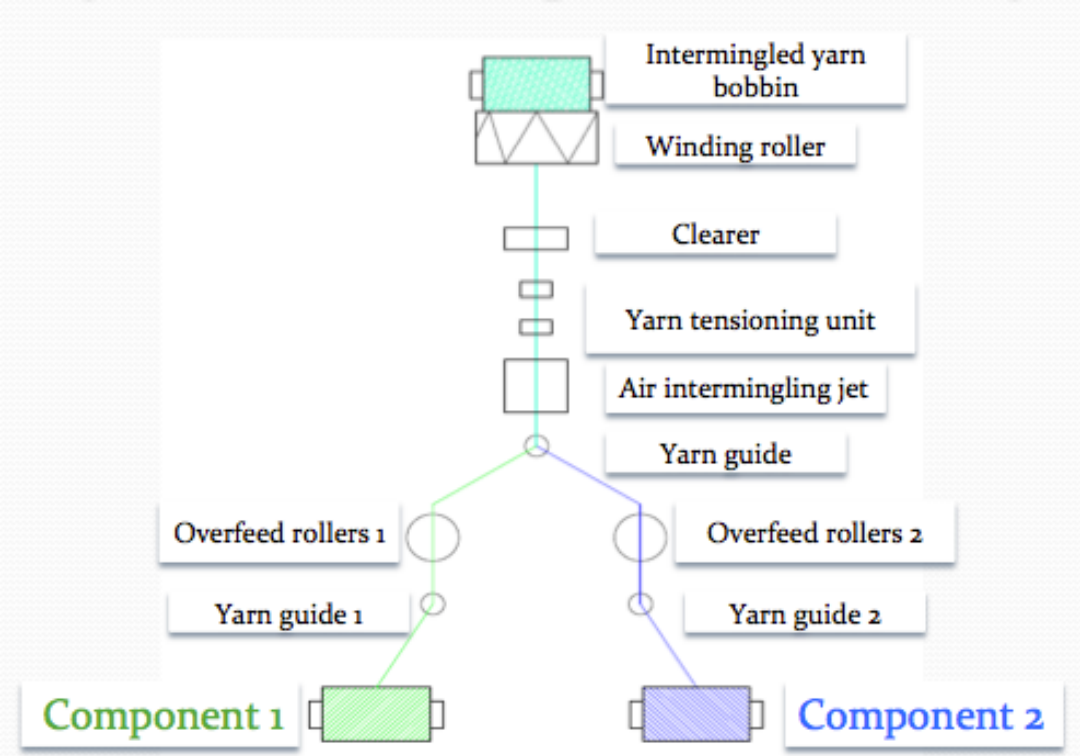
Table 1. Yarns produced by polyester filament and short-staple spun yarns (Part I)

Yarn Code	1.Component	2. Component	Air-pressure	Yarn Speed (m/min)
Y1	%100 Polyester (75den f36)	Cotton/Polyester (Ne 30/1)	2.5	500
Y2	%100 Polyester (87 den f36)	100% Cotton (Ne 30/1)	2.5	500
Y3	%100 Polyester (168 den f48)	100% Cotton (Ne 30/1)	2.5	500
Y4	%100 Polyester (75 den f36)	Cotton/Polyester (Ne 30/1)	4	500
Y5	%100 Polyester (87 den f36)	100% Cotton (Ne 30/1)	4	500
Y6	%100 Polyester (168 den f48)	100% Cotton (Ne 30/1)	4	500

Table 2. Yarns produced by polyester filament and short-staple spun yarns (100% Cotton) (Part II)

Yarn Code	1.Component of Yarn	2. Component of Yarn	Air-pressure	Yarn Speed (m/min)
Y7	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	2.5	750
Y8	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	4	750
Y9	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	2.5	500
Y10	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	4	500

Following yarn production, nip points per unit length of yarn and nip size were determined. For each yarn type, 50 different samples of one meter were taken and their mingle points were counted. At the same time, the length of mingle points were measured manually (in mm). Regarding the stability of nip points, the controls were made in the way of separating the yarn by hand. Also, we produced knitted fabrics for visual analysis. For this aim, single jersey knitted fabrics were produced by using a circular knitting machine (30 pus; 28 fine).



(a)

(b)

Figure 2: Main working principle on a modified winding machine (a) and a sample of hybrid yarn produced by two different components (b)

3. RESULTS AND DISCUSSION

Ten different yarn samples produced in this work have been shown below (Figure 3).

The analysis results show that, as the air pressure increases, the nip size increases. As the number of filaments within the filament yarn increases, short staple yarn is embedded into the filaments in a better way, as expected and mingle points have became more durable at these yarns (Table 3). Regarding the yarn samples of Part II, the results indicate that both nip number per m. and nip size decreases as the yarn winding speed increases (Table 4).

Figure 3. The hybrid yarn samples produced in this work

Table 3. Analysis results of yarn samples (for Part I)

Yarns Produced by Using Polyester Filament Yarn + Short-staple Spun Yarn						
Yarn Code	1.Component	2. Component	Air-pressure	Winding Speed (m/min)	Nip number per m	Nip size (mm)
Y1	%100 Polyester (75 den f36)	Cotton/Polyester (Ne 30/1)	2.5	500	22	12
Y2	%100 Polyester (87 den f36)	100% Cotton (Ne 30/1)	2.5	500	20	12
Y3	%100 Polyester (168 den f48)	100% Cotton (Ne 30/1)	2.5	500	21	12
Y4	%100 Polyester (75 den f36)	Cotton/Polyester (Ne 30/1)	4	500	19	18
Y5	%100 Polyester (87 den f36)	100% Cotton (Ne 30/1)	4	500	20	18
Y6	%100 Polyester (168 den f48)	100% Cotton (Ne 30/1)	4	500	21	18

Table 4. Analysis results of yarn samples (for Part II)

Yarns Produced by Using Polyester Filament Yarn + Short-staple Spun Yarn (100% Cotton)						
Yarn Code	1.Component	2. Component	Air-pressure	Winding Speed (m/min)	Nip number per m	Nip size (mm)
Y7	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	2.5	750	15	11,7
Y8	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	4	750	14	19
Y9	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	2.5	500	20	13,6
Y10	%100 Polyester (Black) (75 denier, f36)	100% Cotton (Ne 30/1)	4	500	21	20

The views of knitted fabrics produced from these yarns are also show the effect of air-pressure and winding speed clearly (Figure 4).

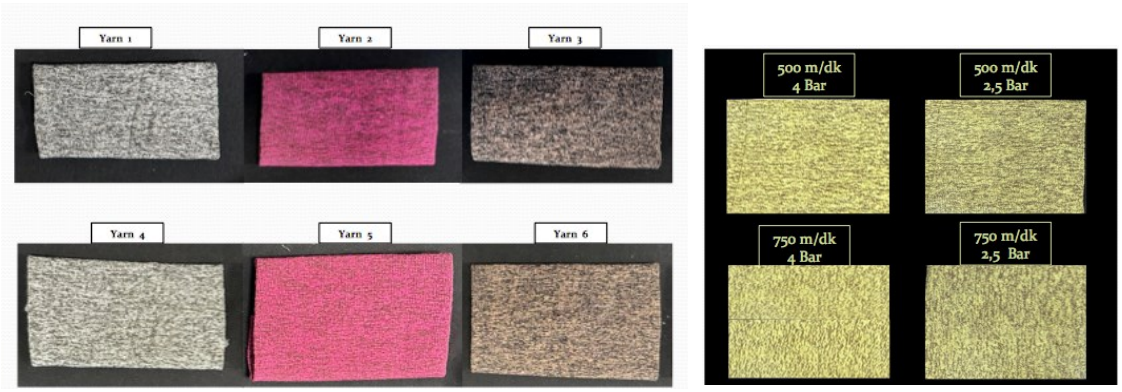


Figure 4: The effect air-pressure and yarn winding speed on fabric visual appearance: (left) Fabrics produced by yarns of Part I, (right) Fabrics produced by yarns of Part II

4. CONCLUSION

In this work, hybrid intermingled yarns were produced by combining short-staple spun yarns and multifilament textured yarns on a modified winding machine. Then, the effect of main working parameters such as yarn winding speed, air-pressure were analysed and main findings are summarised below:

The Effect of Yarn Winding Speed
The results show that as the yarn speed increases (500 and 750 m/min), the distance between nip points increases as expected. This resulted in a more emphasized view of filament yarns on hybrid yarn surface and therefore the knitted fabric surface.

The Effect of Air-Pressure
The results show that as the air pressure decreases (from 4 bar to 2,5 bar), the mingling effect decreases and appearance of filament yarns on yarn surface increases.

The Effect of Yarn Components Used in Hybrid Yarn Production
As linear density of filament yarn increases and there are more filaments within yarn structure, the hybrid yarn becomes softer, nip points are stronger and they look more emphasized.

REFERENCES

[1] Alagirusamy, R. and Das, A., Technical Textile Yarns, Woodhead Publishing Limited, 2010, p.6 and p.416.

[2] Özkan, İ., Baykal, P. D., Özdemir, H., Effects of Intermingled Yarn Surface Characteristics on Knitted Fabric's Color Parameters, Tekstil ve Mühendis, Vol. 25 (2018), 112, 327-334.

[3] Baykal, P. D., Özkan, İ., The Effects of Intermingling Process Parameters and Number of Filaments on Intermingled Yarn Properties, The Journal of The Textile Institute, Vol. 104 (2013), No. 12, 1292–1302.

[4] Wickramasinghe, G. L. D. et al., Effect of Production Speed on Polyester/Nylon Intermingled Yarn and Melange Fabric Properties, International Journal of Clothing Science and Technology, Vol.34 (2022), No.1, 65-78.

[5] Wickramasinghe, G. L. D et al., Effect of Air Pressure on Polyester/Nylon Air Intermingled Yarn and Melange Fabric Properties, The Journal of The Textile Institute, Vol. 112 (2021), No. 4, 526–537.

CORRESPONDING AUTHOR:

Ayşe TÜRKTAŞ ALİ
Gülle Integrated Textile Enterprises Eml. Dan. San. Tic. A.Ş.,
Ulaş OSB Mah. 105 Sokak No: 44/1 Ergene-Tekirdağ, Türkiye
E-mail: ayse.turktas@gulletekstil.com.tr

FRUIT BASED SUSTAINABLE TEXTILE MATERIALS

Marija PEŠIĆ, Ineta NEMEŠA, Nadiia BUKHONKA, Valentina BOZOKI

Technical faculty „Mihajlo Pupin“, University of Novi Sad, Zrenjanin, Serbia

Abstract

The textile and clothing industry has been facing major changes in recent years. Considering that it is one of the biggest polluters, transformations in this industry are largely directed towards sustainable development. It seeks to transform the clothing industry based on value propositions that integrate ethics, aesthetics and innovation. In order to respond to these changes, one of the ways is the application of innovative sustainable textile materials. The use of fruit to extract fibers for fabric production represents a unique and innovative development in the field of fiber technology. Natural fibers such as cotton, wool, silk and linen have long been known to the textile industry, but the use of fruits such as orange, pineapple, sugar cane and banana to create environmentally friendly and sustainable fabrics is a relatively new trend. The advantages of the application of fruit-based materials are reflected in biodegradability, eco-friendly approach and renewability. The application of fruit-based materials such as materials obtained from pineapple, apple, orange, banana and others are discussed in this paper, as well as their advantages and disadvantages.

Keywords: *eco-friendly fabrics, sustainability, pineapple fiber, banana fiber, orange fiber.*

1. INTRODUCTION

In recent decades, the global interest in sustainability has been growing dramatically in the fashion world, so the textile and fashion industry is facing major changes and reforms that are planned to be implemented by 2030. The large consumption of clothing generates a large increase in the consumption of resources and the generation of waste, which places the fashion industry on the list of industries with the largest economy, but also with the big negative impact on society and the environment [1, 2].

The huge impact of textile industry on the environment by European Commission shows that [3]:

- Textile production doubled between 2000 and 2015 globally.
- About 5.8 million tonnes of textiles are discarded every year, which is equivalent to 11.3 kg per person.
- European consumption of textiles has a fourth highest impact on the environment and climate changes after food, housing, and mobility.
- One full truckload of textiles goes to landfill or incineration every second.

The textile industry has also been identified as industry with major contribution to oceans pollution. Washing clothes releases every year in ocean a half a million tonnes of plastic from synthetic textiles which is equivalent of roughly 50 billion of plastic bottles [1].

Consumers shape the fashion industry to a large extent, and lately their interest in sustainability has been increasing. Today's consumers are increasingly looking for information about who, where and how their

clothes are made. These requirements increasingly encourage the brands themselves to develop new business models based on the integration of ethics, aesthetics and innovation [1, 4]. Under innovation we can classify new biodegradable textile materials obtained from fruit. Natural fibers such as cotton, wool, silk and linen have long been known to the textile industry, but the use of fruits such as orange, pineapple, sugar cane and banana to create environmentally friendly and sustainable fabrics is a relatively new trend and these materials will be presented in this paper.

2. CIRCULARITY IN TEXTILE INDUSTRY

Currently, in the textile industry production dominates a linear system of production called "Cradle to grave". This model of production means that resources are extracted, processed into a product, sold and at the end eliminated. A circular economy aims at reusing consumed materials and ideally, product cycles become closed according to the cradle-to-cradle principle [1].

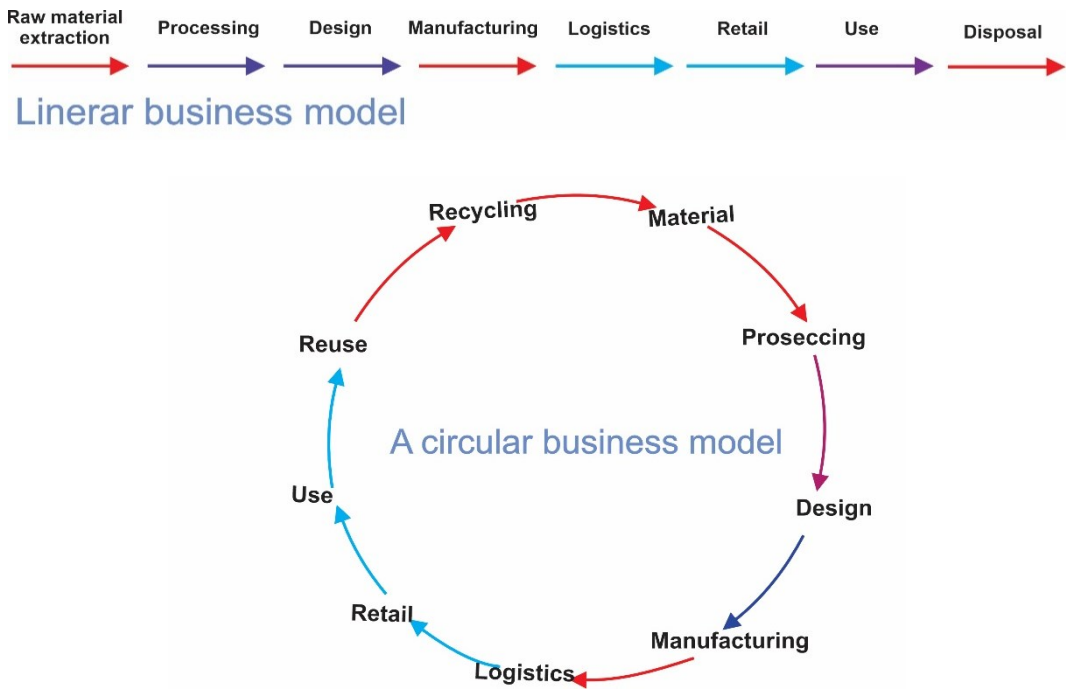


Figure 1: Linear, or „Creadle to grave"busines model and Cyrcular or „Creadle to creadle"business model [5].

Cradle to cradle system also means using textile raw materials that could be bio-based and biodegradable [1].

Bio – based means the use of biogenic raw materials for manufacturing of different types of products instead of fossil gas, coal, or petroleum as part of the bio-economy. Bio-degradable materials mean that materials can be degraded in the environment by microorganisms and physicochemical impact. And fruit based materials are biodegradable [6, 7]. Figure 2. Shows different types of fibers that can be created from various sources of food and fruit waste [8].

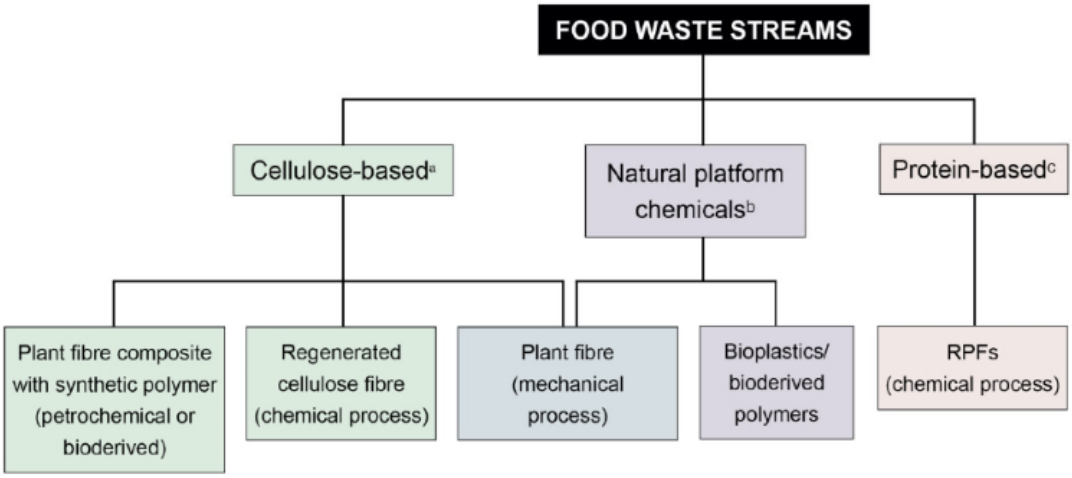


Figure 2: Types of textile materials from food waste. [8]

3. ORANGE FIBER TEXTILE MATERIAL

Every year in Italy 700 000 citrus by-product have to be disposed but it can be turned out into high-quality fabric that can respond to the need of sustainability and innovation of fashion brands [9]. Textile material made from orange is developed by The Orange Fiber Company based in Catania (Italy). It is obtained from citrus fruit pulp and as such it is biodegradable and it is able to decompose without generating new waste [10].

Figure 3: Textile material obtained from orange [10]

By transforming fruits into juices, jams and other products, local industries generate a large amount of waste that must be properly disposed of, with costs for both the processing industry and the environment. This waste is often exploited by generating energy through biogas plants. The productive process patented by Orange Fiber gives new life to remains of the citrus fruits after squeezing. The orange peel waste is processed with patented technology “Pastazzo” that separates the cellulose from the rest of the peel. The same process can be used to treat waste from oranges, lemons, mandarins and grapefruit [9, 11].

Orange Fiber fabrics are formed from a fine cellulose yarn that can be blended with other materials. Textile material made from 100% orange fiber is soft and has a silky hand-feel, it is characterized by lightweight and it can be opaque or shiny according to product needs. Considering that orange textile material has similar characteristic like viscose or rayon and it is suitable for producing high fashion clothing. The fiber extracted from citrus fruits is white and can be colored with natural dyes. Orange fiber can be blended with cotton or silk for getting poplin or satin material and also can be blended with elastane or pineapple fibers. Textile materials from orange fiber can be dyed and washed like any other conventional textile material [9, 10, and 11]. Orange fabric is used by designers and brands such us Salvatore Ferragamo, E. Marrinela and H&M [10].

4. TEXTILE MATERIAL FROM BANANA – BANANATEX

Bananatex is woven textile material that is made in the Philippines form Abaca banana plant. Abaca banana plant is growing without pesticides. Bananatex was developed by Swiss bag brand and material innovators QWSTION [12]. It can be harvested once a year and regenerate fully within one year. The first step is “topping”: cutting the leaves, then “tumbling” the stalks. Natural fertilizer is created by the natural decomposition of leaves. The stripping is handled at the harvesting site, and the fibers are “combed” to separate them from one another. The fibers are drying by air and after that they are sorting by a colour and nuance, which makes this process sustainable. The dryed fibers are boiling and pressing into sheets resembling cardboard. This Abaca sheets are then soaking in the water in order to make fibres after which the sheets is cutting into stripes and twisting in order to create a fiber. The obtained yarn is then woven into the fabric [12].

Textile material made from banana plant is very strong, durable, and lightweight, with good air permeability and water absorption. It has a smooth and distinctive hand feel. The chemical composition of bananas is rich in cellulose and lignin, but its lower fibre content relative to hemp results in reduced softness, and its high lignin contnt results in poorer spinnability [12].

Figure 4: a) Bananatex textile material, b) Product made from Bananatex by H&M

Bananatex is used for accessorise production like bags, wallets, tote bags, shoes, furnishing. Designers and brands are using this sustainable material and some of them are: H&M, Stella McCartney, Inuikii, Charlota Aman and etc [12].

5. TEXTILE MATERIALS FROM PINEAPPLE – PINATEX

Pinatex nonwoven textile material from pineapple leaves was created with purpose to replace fossil – based and animal based raw materials. Pinatex is made from an agricultural waste product, from pineapple leaf fiber [13].

After harvesting of pineapple fruit, the pineapple leaves are sorting and fibers are extracting from it using a semi automatic machines. The drying is conducting naturally by sun or during the rainy season in drying ovens. The dry fibers go through a purification process to remove any impurities. Pineapple leaf fibre gets mixed with a corn based polylactic acid (PLA) and undergoes a mechanical process to create Pinafelt, a non-woven mesh which forms the base of Pinatex materials. Depending of the final product pinafelt is dyed using a GOTS certified pigments and resin top coating in order to achieve additional strength, durability and water resistance. For metallic appearance it is used PU transfer coating [13].

This provides an opportunity for building a scalable commercial industry for developing farming communities with minimal environmental impact [13].

Sustainability of Pinatex textile material is reflected in facts that raw material for its production is obtained by waste product, which means that it is not needed extra land, water or pesticides for production. The use of leaves for the production of textile material prevents them from being burnt, which reduces CO^2 emissions into the atmosphere [13].

Figure 5: Pinatex nonwoven material

According the experiments conducted by M.Mayer, S. Dietrich, H.Schu and A. Mondschen, we can see that Pinatex leather has a lower tensile strength and tear resistance but water vapour absorption and water vapour permeability similar like leather [14].

The Pinatex textile material finds its use for shoes, bags, coats, accessories. An increasing number of designers and brands are using this sustainable material and some of them are: H&M, Hugo Boss, Mariam Al Sabai, Esere Vegano, Altiir, Guo Pei. Pinex finds application also in furnishing [14].

Figure 6: Guo Pei [14]

6. TEXTILE MATERIAL OBTAINED FROM APPLE – APPLESKIN

Apple Leather or AppleSkin is a fruit based leather obtained from apple waste and it is developed in Italian company Frumat. Considering that fruit producers leaves about 40% of their harvest in the fields, because it does not meet the cosmetic standards for the supermarkets, Apple leather is sustainable solution for the environment, textile and food industry. To make its products, Frumat recovers approximately 30 tons of apple waste a month from local companies which are therefore relieved of the cost of disposal and even receive payment for the waste materials [15].

AppleSkin is a coated textile with thin compact layers (PUR), a foamed layer (PUR) filled with organic particles and a PUR impregnated textile carrier, material made by coagulation process. After making apple juice, the pulp is usually thrown away. To make the leather, the apple waste, from apples cultivated in Italy, is dried and ground into powder. This powder turns into a flexible, leathery sheet that is then combined with Polyurethane to create the vegan leather, which is PETA-approved vegan. The material contains a minimum of 50% apple fibre. The tanning of the vegan leather is a lot cleaner and not as polluting, as the one used in conventional leather production so the toxins used in the tanning process is reduced [15].

Figure 7: Apple Leather, Frumat Italy [16].

According the experiments conducted by M.Mayer, S. Dietrich, H.Schu and A. Mondschen, we can see that Apleskin leather has a satisfactory tensile strength and tear resistance but water vapour absorption and water vapour permeability are lower [14].

Frumat Apple Skin is currently being used in the fashion and furnishing industry due to the product's ability to be worked into different textures. The softer fibre is ideal for textiles with a direct application in the clothing and apparel industry. The sturdier, thicker version PU leather alternative, made of 50% recycled apple fibre and 50% polyurethane (hence the name PU), is currently being used for shoes and luggage articles as well as furnishing and upholstery [15]. Brands that are using apple skin i.e. apple leather are Happy Genie, Verrah, Luxtra London and etc [15].

7. TEXTILE MATERIAL OBTAINED FROM MANGO

Mango grows in almost all tropical and subtropical regions of the world and about 27 million tons of this fruit are produced annually. Brazil alone produces about 5% of the mango consumed, being one of the eight largest producers in the world. The mango fruit that cannot be sold in a market can be converted into mango leather. Mango food waste often occurs when the consumer buys too much or because retailers reject the food due its unfavourable appearance. The processing of mangoes into mango skin is done by a company Fruit leather from Rotterdam [17].

Mango leather is made by mango pulp. The first phase in crating leather is making pulp from a mango fruit with addition of additives. After the draying and coating phase with resins mango leather can be used for making fashionable products. The type of the mango influences the colour of the leather. Palmer mango gives a brown colour while Keitt mango gives a more black colour. With embossing machine mango leather can have different texture on its surface [17].

Figure 8: Mango leather by company Fruithleather

Sustainability of mango leather is reflected in facts that raw material for its production is obtained by waste product, which means that it is not needed extra land, water or pesticides for production [17]. Further leather is a material which can be made into footwear, fashion accessories, upholstery, furnishing and more [17].

8. TEXTILE MATERIAL OBTAINED FROM GRAPE – VEGEA

Vegea is an innovative material characterised by the high content of vegetal, renewable and recycled raw materials: grape leftovers from winemaking, vegetal oils and natural fibers from agriculture [18].

Figure 9: Vegea, Grape leather [19]

It also referred to as 'wine leather' or 'grape leather', the making of it doesn't waste water and uses modified, existing machinery to transform what would otherwise create carbon dioxide when burnt. Considering that 26 billion liters of wine are produced worldwide every year, so the potential to transform the waste in big quantities is huge. It sustainability is reflected in use of renewable recourses as an alternative to synthetic textile materials. It can be made in various solutions, with different technical and aesthetic properties like thickness, finishing, texture and color [18].

According the experiments conducted by M.Mayer, S. Dietrich, H.Schu and A. Mondschen, we can see that Grape leather has a satisfactory tensile strength and tear resistance but water vapour absorption and water vapour permeability are little bit lower like in case of apple skin [18].

9. CONCLUSION

We can conclude that life of garment starts with a raw material and the production of textiles, and continues with design to production, transport, distribution, consumption and re-use and recycliing, and beacme a new textile or another product. In order to achive a cloosed loop cycle, it is essential for clothiogn to be made from biobased, renewable, recyclabe or biodegradable fibers. By choosing thypes of garment made from this materials it is possible to entail a minimal climat impact. Considering that synthetic fibers make up about 64% of the global fiber market, according to data from 2021 and considering that they have a very large negative impact on the environment, more and more should be invested in new biodegradable natural textile materials, such as fruit based textile materials presented in this paper.

Benefits of fruit based textile materials are reflected in fallowing:

- They are produced from food waste, which influence reduction in food, textilom and environmental pollution.
- There is not needed extra land, water or pesticides for production of fruit based textile materials.
- This kind of materials are recyclabe and biodegradable.

Good performances of orange fiber can be good solution for replacement of sithetic materials for garment manufacturing. On the another hand, fruit based leather alternatives can be a satisfactory and trendy solutuions for replacement of natural or faux leather despite a despite of some disandvantages in lower tensile strengts and additional work should be done to improve this performance.

We can conclude that ther is chalanges in front of fashion textile materials but also the opportunities that will change the fashion industry and help inproving the environment throu using the sustainable and alternatives textile matrial

REFERENCES

[1] F. R. Rinaldi, FASHION INDUSTRY 2030: RESHAPING THE FUTURE TROUGH SUSTAINABILITY AND RESPONSABLE INNOVATION, Bocconi University Press, Milano(2019)
[2] M. Pešić et al.,LASER APPLICATION IN TEXTILE AND APPAREL INDUSTRY, Conference Proceedings ICPAE 2023, , Zrenjanin, Serbia, 24th August – 26th August 2023.
[3]https://commission.europa.eu/index_en
[4] M. Pesic et al. THE RESEARCH OF CONSUMER AWARENESS OF SUSTAINABLE FASHION IN SERBIA, Donghua University (DHU), Shanghai China and College of Fashion and Design, Donghua University, China, 9-11 December 2020.
[5] https://si.se/en/
[6] J. Hldebrant, et al., THE CIRCULARITY OF PONETIAL BIO-TEXTILE PRODUCTION ROUTES: COMPARING LIFE CYCLE IMPACTS OF BIO-BASED MATERIALS USED WITHIN THE MANUFACTURING OF SELECTED LEATHER SUBSTITUTES, Journal of Cleaner Production, vol287, 2021.
[7] V. Rognoli, et al., MATERIALS BIOGRAPHY AS A TOOL FOR DESIGNERS EXPLORATION OF BIO-BASED AND BIO-FABRICATED MATERIALS FOR THE SUSTAINABLE FASHION INDUSTRY, Special Issue: Sustainable Redesign of the Global Fashion System, 2022.
[8] M.Stenton, et al., FROM CLOTHING RATIONS FO FAST FASHION: UTILISING REGENERATED PROTEIN FIBERS TO ALLEVIATE PRESSURES ON MASS PRODUCTIONS, Energies, 2021.
[9] https://www.textileworld.com/textile-world/features/2021/04/fiber-world-sustainable-alternative-plant-fibers-for-textiles/
[10] https://orangefiber.it/
[11] Aishwariya S. TEXTILES FROM PEEL WASTE. *Sci. Tech. Dev. J.;* 23(2):508-516.
[12] https://www.bananatex.info/index.html
[13]https://www.ananas-anam.com/about-us/
[14]M. Meyer, et al., COMPARISON OF THE TECHNICAL PEROFRMANCES OF LEATHER, ARTIFICIAL LEATHER AND TRENDY ALTERNATIVES, Coatings **2021**, *11*, 226.
[15]https://knowledge-hub.circle-lab.com/article/22219?n=Frumat-Appleskin---vegan-leather-from-discarded-apples-
[16] https://www.technofashionworld.com/frumat-the-leather-alternative-made-from-apples/
[17] https://fruitleather.nl/about-us/
[18] https://www.vegeacompany.com/company/
[19] https://www.pinterest.co.uk/pin/846324954949461853/

CORRESPONDING ADDRESS:

Dr. Marija Pesic
Department for Basic and Applied Sciences Technical Faculty “Mihajlo Pupin”, University of Novi Sad
Djure Djakovica nn, 23000 Zrenjanin, Serbia
E-mail: marija.stankovic.986@gmail.com

DEVELOPMENT OF AN ORTHOPEDIC UNLOADING INSOLE FOR PATIENTS WITH DISABILITIES USING ADDITIVE TECHNOLOGIES

Dariia KAPTIUROVA, Liliia CHERTENKO, Olexander UDOVENKO

Kyiv National University of Technologies and Design, Kyiv, Ukraine

Abstract

Since the war in Ukraine started, the number of people with lower limb amputations has increased significantly. After prosthetics in the case of unilateral amputation of the lower limb, during further walking, the load on the healthy leg is approximately twice as much as on the prosthesis. Therefore, it is advisable to use orthopedic unloading insoles for partial relief of a healthy leg.

This research looks at the advantages of manufacturing such insoles using additive manufacturing. Unlike traditional production, the production of printed insoles is automated and requires less human involvement in the processes. In traditional production, various orthopedic elements and layers of insoles use materials with different properties - EVA-pore, granitol, polymeric thermoplastic materials of different hardness.

This research addresses whether orthopedic insoles printed from one material (Flex filament) would meet the requirements, if the stiffness and elasticity of the insole zones were adjusted not by selecting another material, but by adjusting the filling of layers in the Ultimaker Cura slicer when slicing the model. FDM printing technology was used on an Anet Prusa i3 printer and Flex filament.

Keywords: *orthopedic insoles, FDM-printing, additive manufacturing, unilateral amputation*

1. INTRODUCTION

Today, a fairly large percentage of the population suffers from orthopedic foot problems of various origins. Previously, the vast majority of patients were elderly. However, since the beginning of the war in Ukraine, the number of people with gunshot wounds of various types has increased significantly. At the same time, according to statistical data, in 70% of cases, these are injuries to the limbs. Depending on the mechanism of gunshot wound formation (bullet, shrapnel, mine-explosive, etc.), such wounds can lead to bone fractures and significant soft tissue damage [1].

During clinical examination of the lower limbs in patients with unilateral lower limb amputation, the following observations were made: soft tissue injuries – in 82%, burns – in 64%, removed fragments in – 10%, and swelling – in 55%. As a result of single-leg loading during walking on the stumps of the examined individuals, the following were observed: calluses on the plantar surface – in 18%, calluses – in 36%, keratosis – in 10%, and consequences of foot abrasions – in 36% [2].

So when lower limb amputation occurs, even with prosthetic rehabilitation, a person's gait and weight distribution on certain areas of the foot change. Also there can be static foot deformities also occur as a result of unilateral amputation. These deformities disrupt a person's weight-bearing and kinematic

function, leading to the emergence of pain and calluses, causing rapid fatigue, reducing work capacity, and depriving the ability to use standard footwear [2].

Unilateral amputations of the foot or lower limb (complete or partial) during treatment, rehabilitation, and daily life, require protection of the healthy foot from the destructive effects of overloading. This need arises in the first days of treatment when patients are allowed to assume a vertical position and move independently. Moving with the support of crutches does not compensate for the overall area of lost support and disrupts the normal biomechanics of all foot and limb support elements. Overloading of the front and rear sections of the foot is a consequence of this process, resulting in specific changes in the foot, including widening of the front section, lowered arches, splaying of the foot, varus deformity of the ankle-foot, the formation of painful calluses, and more designed to improve the physical condition of the foot with impairments in function and pressure distribution, resulting from injuries and unilateral limb amputation.

Prevention of these changes can involve the use of individual functional foot orthoses or orthopedic insoles. Ready-made orthopedic correction devices available on the market do not always meet the specific needs of the patient. Considering this, a current focus is on researching the conditions of the feet after injuries and developing specialized footwear and adaptations that contribute to enhancing the biomechanics of the human musculoskeletal system.

The aim of the work is to develop orthopedic insoles designed to improve the physical condition of the foot with impairments in function and pressure distribution resulting from injuries and unilateral limb amputation.

1.1 Methods for analyzing foot relief for insole production

Modern methods for analyzing foot relief for insole production were empirically investigated.

Modern diagnostic tools such as baropodometry or dynamic plantography allow the objective assessment of changes in the foot and a clear determination of overloaded zones (Fig. 1). They also enable the evaluation of the load vector on various sections of the foot, among other parameters.

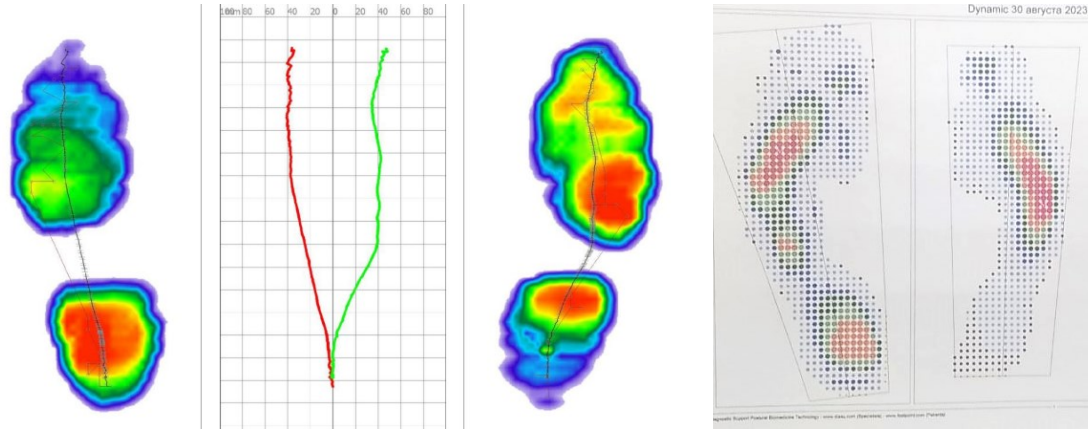


Figure 1: Results of foot diagnostics using baropodometry (a) and plantography (b)

Today the level of scientific and technological progress takes us the great opportunity to the use of 3D scanning to obtain initial information about the shape and dimensions of the foot.

Among the 3D scanners used to acquire anthropometric information about the foot, the InFoot 3D scanner has proven itself to be effective. However, the standard methodology for scanning the foot on a glass surface does not provide sufficiently comprehensive information about the relief of the plantar surface of the foot and the necessary adjustments that need to be considered in the development of orthopedic insole design [3].

So, one of the best and simplest ways to obtain information about the 3D shape of the plantar surface of the foot, including the affected foot, is to take an impression of the foot on a polymer foam.

A special polymer foam was used in the work for taking foot impressions, which accurately replicates the shape of the plantar surface of the foot, compressing soft tissues and visually highlighting the structural features of the foot.

The results of scanning the foot using the standard procedure on a 3D scanner and scanning the polymer foam with the foot impression demonstrated the necessity of using polymer foam. The standard foot scanning procedure on a 3D scanner does not provide as detailed information as the visualization on the polymer foam (see Fig. 2 and 3).

Figure 2: Obtaining information about the foot using the 3D scanner InFoot3D, creating a footprint on a polymer foam, and then scanning this polymer foam footprint

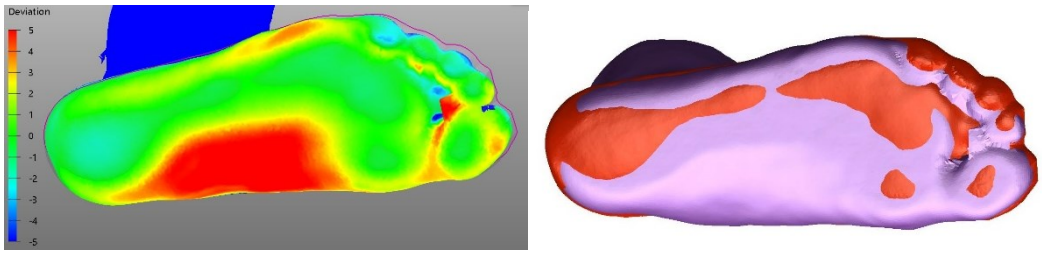


Figure 3: Comparison of a 3D scan of a foot under load and a footprint in polymer foam

1. 2 Analysis of traditional and additive methods for manufacturing custom insoles

3D printing of custom orthopedic insoles may offer advantages such as reduced time costs and automated production, potential long-term cost reduction through equipment use, and the ability to produce insoles that better match the contours of the foot [5, 6]. Additionally, there are preliminary studies indicating that orthopedic insoles manufactured using additive production are effective in reducing pain sensations in the heel area [7,8] and in altering the biomechanics of the lower limb [9,10].

In the research [11] participants were asked to walk along a corridor multiple times wearing textile sneakers without specialized insoles, in insoles made using traditional and additive methods. The survey revealed that both types of insoles significantly improved comfort compared to no insoles, with no significant differences noted between printed and traditional insoles. Measurements showed that the insoles produced via additive manufacturing were wider and had greater depth in the heel cup and higher longitudinal arch support. The difference in longitudinal arch support height was less than 2 mm, this difference did not affect insole comfort according to participant evaluations, but further investigation is needed to determine the clinical impact. One conclusion drawn from this study is the importance of further research comparing the biomechanical effects of insoles manufactured via additive and traditional methods.

In another study [12] for each participant, a plaster cast and a foot impression in a polymer foam box were made to gather initial information about the foot's relief. Based on this data, 4 pairs of individual orthopedic insoles were manufactured: a pair of supportive and regular insoles made traditionally from EVA, Poron, and XPE materials, and a pair of supportive and regular insoles made additively using the Object Connex 350 printer with a combination of TangoPlus and VeroClear materials.

The printed insole consisted of three layers:

- A base supportive layer made of three materials with varying stiffness in the heel, metatarsal, and arch areas.
- A load-distributing layer composed of small geometric cells.
- A thin top layer made of Plastazote material to give the insole a look similar to traditionally manufactured insoles.

Participants assessed forefoot and heel cushioning, arch support, overall insole condition, and overall shoe fit (size, width, etc.). No significant differences were noted between traditional and printed insoles at any stage of the study.

2. EXPERIMENTAL. DEVELOPMENT OF AN INSOLE PROTOTYPE BASED ON INDIVIDUAL FOOT PARAMETERS

2.1 Traditional methods of producing custom insoles and corrective orthoses

In this work we also analyzed recent researches about the production of orthopedic insoles using traditional subtractive and additive technologies. Their advantages and disadvantages were identified.

Classical methods of making orthoses/insoles will remain relevant for a long time. The layer-by-layer lamination of materials with different densities, followed by thermal and mechanical processing, requires relatively high material costs (a variety of materials and tools are needed) and proper technical equipment. The traditional process of making orthopedic insoles is on the Fig. 4.

Figure 4: Classical method of making individual insoles to prevent of deformities of the foot

We have crafted an orthopedic insole using the traditional method, incorporating layers of materials with varying elasticity and thickness. This will enable us to compare the comfort and effectiveness of the orthopedic insole produced through traditional methods with one created using modern innovative technologies.

Traditional manufacturing of custom-made orthopedic insoles is time-onsuming, labor-intensive process, and the quality and effectivness of the final product is largely dependent on the skill level of the manufacturing technician [4]. The production of a pair of insoles takes us approximately 2-3 hours, and apart from the duration of the process, we may face the challenge of finding specialists in this field. In the current conditions of war in Ukraine and the mobilization of the male population, this is a very important factor and a significant problem.

The designed insole can be manufactured using digital equipment through one of two primary methods:

1) Application of subtractive technologies (milling on a CNC machine with porous rubber);
2) Application of additive technologies (3D printing).

The use of CNC machines has long proven itself as a reliable method for manufacturing orthopedic insoles; however, it has several drawbacks (waste, noise, dust production etc.).

The idea of using 3D printing to create products with specific qualities from certain materials is not new but remains relevant.

In our work, we chose to focus on experiments with 3D printing to produce orthopedic insoles. By using a single material, our goal was to achieve different physical and mechanical properties in different areas of the product.

After analyzing previous information, tasks of the second part of the work, related to the manufacturing of orthopedic insoles through 3D printing were formulated. There are:

1. Development of a manufacturing technology for orthopedic products with specified properties using 3D design/modeling and 3D printing, employing thermoplastic materials based on domestic thermoplastic polyurethanes.
2. Development of technical recommendations and algorithms for the production of orthopedic products using accessible Fused Deposition Modeling (FDM) printing technology.
3. Optimization of production processes to reduce material, energy, and labor costs.

2.2 Designing the orthopedic insole using 3d modeling

By importing the scanned model of the impression surface into a 3D graphics program, we draw a horizontal plane through three points on the plantar surface: the point at the center of the heel, the point at the inner metatarsal arch, and the point at the outer metatarsal arch. The overall diagnosis of the foot, its alignment, and the position of anthropometrically significant points relative to the drawn horizontal plane indicate the necessary adjustments that should be considered in the design of the orthopedic insole: the parameters of the metatarsal bar (if needed), the shape of the bar to support the inner longitudinal arch, the need for pronators or supinators, and more (Fig. 5).

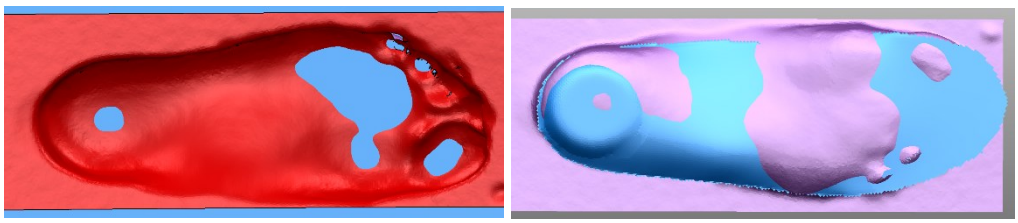


Figure 5: Preparing 3D data for the design of orthopedic insoles, comparing the patient's foot relief with the basic shape of an anatomical insole

The chosen design environment for the project is Rhinoceros 7 by McNeel with the Grasshopper plugin, which allows for algorithmization of specific actions and takes advantage of parametric modeling while automating the sequence of calculations.

The insole shape modeling was done in Rhinoceros according to the following algorithm:

1. Designing the upper surface of the insole based on the 3D scan of the foot impression on the polymer foam.
2. Fitting the constructed 3D surface into the contour of the inner sole of the footwear for which the insole is intended.
3. Aligning the resulting model with the foot pressure map to determine areas of extreme pressure.
4. Creating contours that delimit high-pressure zones.

5. Constructing surfaces to slice the 3D insole model into individual zones.
6. Saving the obtained separate zones of the insole.
7. Converting and importing them into the Cura slicer environment.
8. Setting printing modes in the Cura program for each zone.

The shape of the relieving insole has been adapted to the specific structural characteristics and needs of the patient, including the height and shape of the metatarsal arch, the height of support for the longitudinal arch, the depth and area of the heel bed, and so on (fig. 6).

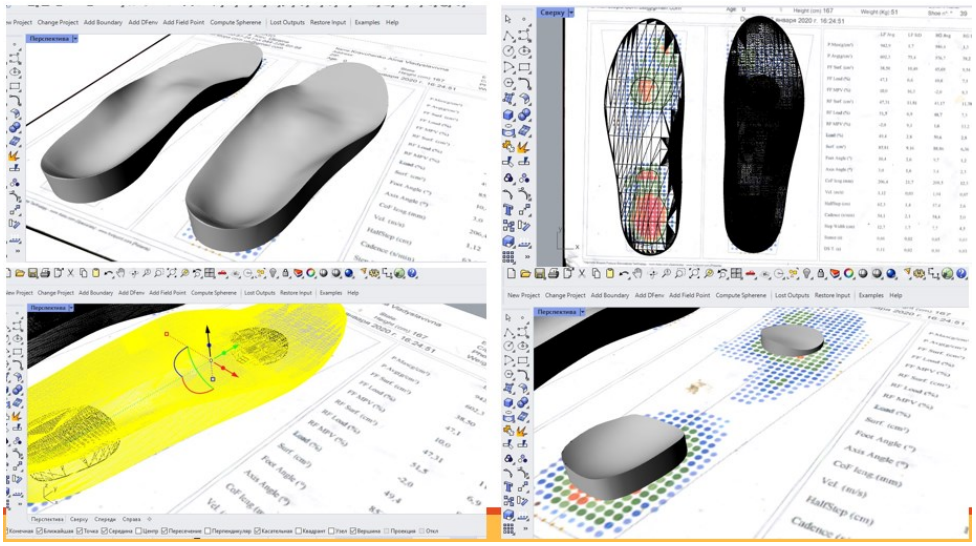


Figure 6: Designing insole in Rhinoceros 7

2.3 Insole manufacturing

We analyzed information from open sources regarding the results of experiments with different types of infill offered by the CURA slicer. In the initial stages of the experiments, a gyroid-based lattice structure was selected as the infill structure for the products. This is a natural structure found in biological objects, having the largest surface area and the lightest weight. Additionally, it offers high shear strength and other favorable properties. Although this structure can be challenging to model in CAD systems, it is present and easily implemented in most slicers, including CURA.

For CAM design, we use the CURA slicer version 4.6 and 5.4.0 by Ultimaker, which is the most accessible and free slicer available on the market (fig.7).

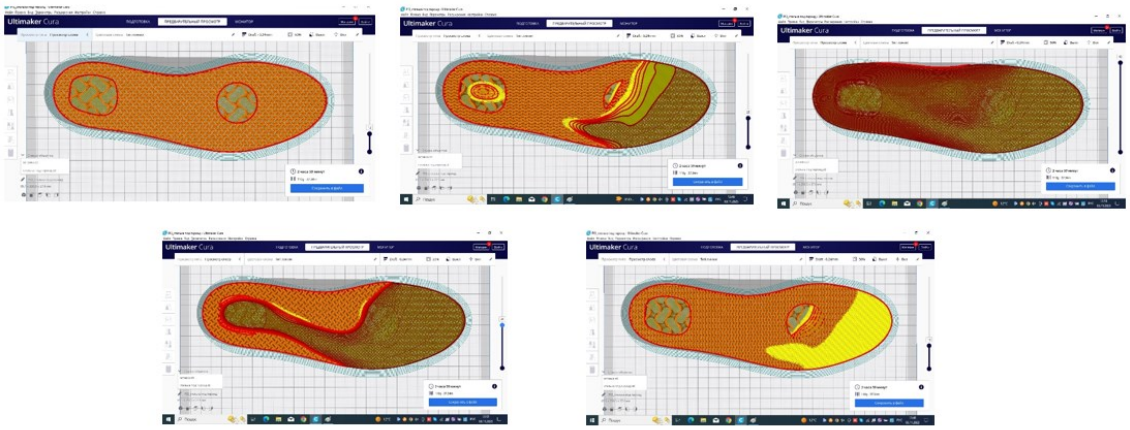


Figure 7: Configuring printing modes in the Cura software for each zone of the insole

To manufacture the products, we focused on using FLEX material from the domestic company Plexiwire.

3. DISCUSSION

During the study, samples of insoles were produced using traditional methods and 3D printing technologies.

A comparison of patients' subjective feelings from using both types of insoles led to the conclusion about the feasibility of applying additive technologies for the production of insoles to support arches, improve shock absorption during walking, reduce the load on the arches, heel, and, if necessary, other areas of the foot with calluses.

At the same time, the cost of manufacturing insoles using a 3D printer turned out to be lower compared to the traditional method of layer-wise addition of thermoplastic materials of varying stiffness. Due to the reduced time spent by the specialist on insole production and the lower quantity of materials used, additive manufacturing is economically more advantageous (the initial cost of equipment, such as the 3D-printer, was not taken into account).

The potential of this method for manufacturing insoles requires further research to determine the degree of therapeutic effectiveness and the possibility of using additive technology to produce insoles for patients with different types and levels of foot disorders and musculoskeletal pathologies. Further investigation is also needed into the methods and technology of insole production using 3D printing to identify the optimal approach, materials, and patterns of filling for achieving a satisfactory stabilizing, supporting, or therapeutic effect of customized insoles.

The creation of products with lattice structures and specified properties is a highly relevant issue today. FDM printing with rigid, flexible, and superelastic filaments is the most accessible method for experiments and obtaining guaranteed desired results.

Modeling lattice structures in CAD systems requires a lot of time, complex algorithms, and significant computing power. Our proposed method for preparing a model for 3D printing is quite simple, does not require extensive computing power, and can be easily implemented on basic CAD systems and freely available slicers (such as Ultimaker Cura).

We have proposed the following algorithm for the development process of a relieving insole by using types of input information such as a 3D scan of the foot, a 3D scan of the foot impression on polymer foam and a plantar pressure map. The process of collecting input data and designing insole is shown on the Fig. 8.

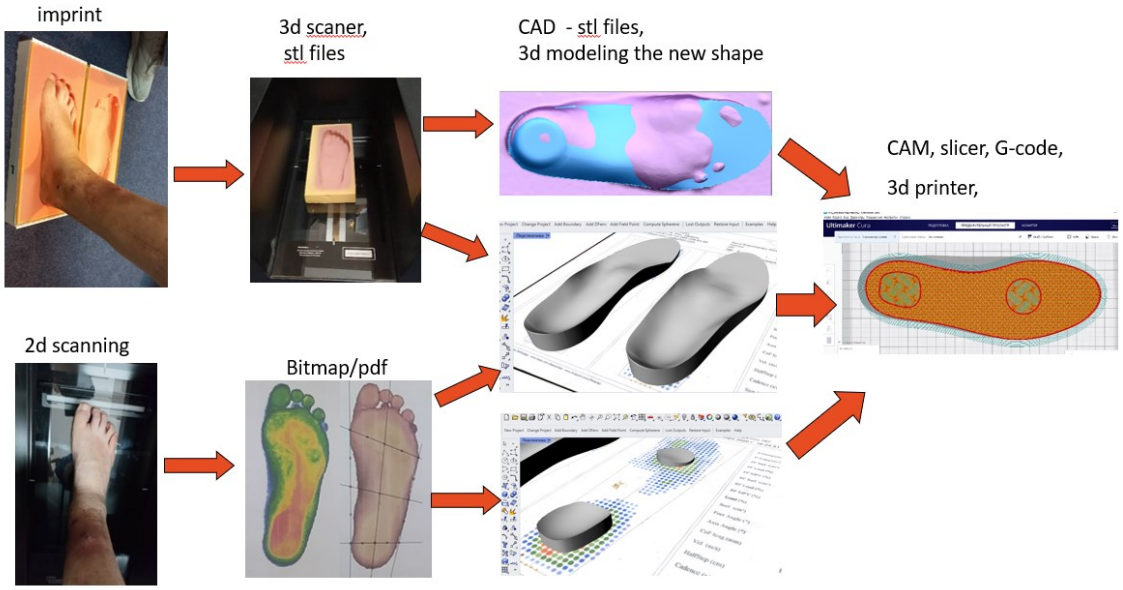


Figure 8: An algorithm of collecting input data and designing insole

1) Obtaining the initial information about foot (2D/3D scanning, imprinting orthopedic foam and 3D scanning, dynamic baropodometry)
2) Importing the primary data into the CAD environment, processing
3) Modeling the new shape of the orthotic using the insoles library files
4) Uploading orthotic model files to the CAM environment (Cura/Prusa slicer)
5) Obtaining g-code, starting 3D printing

During experiments, we had to adjust temperature settings, the printing speed of the insole model's casing and its infill, print height, various extruder nozzle diameters (Fig. 9).

Figure 9: Aditive made insole using FLEX material

High-quality FDM printing with elastomers is achievable on inexpensive printers with the simplest kinematics, even on open-type systems. A crucial rule is the use of direct extruders in 3D printers. Elastomeric materials may require some adjustments to the geometry of direct extruders, specifically reducing it to 0.3 mm and minimizing gaps between the feeder mechanism and the hotend of the extruder, reducing friction forces and resistance in the hotend, and using small heating blocks.

The manufactured insole shows printing defects such as filament residues due to retraction and color variations of the material. Therefore, it is necessary to establish optimal print parameters by reducing printing speed and temperature settings during model slicing. After some adjustments to the process parameters, we have achieved satisfactory results (fig.10).

Figure 10: Aditive made insole using FLEX material, second attempt

The insole turned out to be flexible and exhibits noticeably different levels of hardness in various areas. However, through experimental wear, we need to determine the operational and comfort characteristics of these insoles.

The total duration of the design and manufacturing process using this method was just over 6 hours (3D printing took 3 hours and 15 minutes). A significant advantage is the ability to produce several insoles simultaneously during this time without engaging the master's working hours (printing according to specified parameters occurs fully automatically). Further research is required to assess the comfort of wearing the insole and to determine the significance of its biomechanical effects.

4. CONCLUSIONS

Today, in Ukraine, the war continues, and unfortunately, the number of people with injuries is constantly increasing. This requires increased attention to improving the quality of life for people with injuries and limb amputations. Proper footwear is an element that can significantly improve the physical condition of patients with lower limb injuries. For the design of a specialized orthopedic insole designed to relieve pressure on the foot due to biomechanical disturbances resulting from severe injuries and unilateral limb amputations, a series of studies were conducted.

In this work, we initiated a series of experiments related to the production of orthopedic components with specified properties using digital technologies and 3D printing. To obtain the initial data, we used the InFoot 3D scanner and polyurethane foam to create foot impressions. Rhinoceros 7 and Cura slicer

were used for modeling and slicing, and FDM 3D printing technology with a Prusa i3 printer was used for the insole production.

The technology is promising and economically advantageous, however, it requires further research into the extent of its therapeutic efficacy.

REFERENCES

[1] Dorofieieva, O.; Yarymbash, K.; Skrypchenko, I. et al.: REHABILITATION DIAGNOSIS OF PATIENTS WITH MINE-EXPLOSIVE WOUNDS OF THE LOWER LEG BASED ON THE INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY AND HEALTH, *MEDICNI PERSPEKTIVI*, JUNE 2023, *23(2):143-149*, DOI: 10.26641/2307-0404.2023.2.283384

[2] Gondarchuk P.; Pervaiy N.; Vlasenko A.: THE STUDIES OF ANTHROPOMETRIC AND MORPHOLOGICAL PARAMETERS OF THE FEET OF WOUNDED WITH UNILATERAL AMPUTATION OF THE LOWER LIMB, *HERALD OF KYIV NATIONAL UNIVERSITY OF TECHNOLOGIES AND DESIGN. TECHNICAL SIENCES* №4 (112), 2017, ISSN 1813-6796

[3] CHERTENKO, L.; KAPTIUROVA, D.; BONDAR, O.: PRACTICAL ASPECTS OF 3D SCANNING RESULTS APPLICATION IN SHOE LAST DESIGN, *3DBODY.TECH 2023 - 14TH INTERNATIONAL CONFERENCE AND EXHIBITION ON 3D BODY SCANNING AND PROCESSING TECHNOLOGIES*, LUGANO, SWITZERLAND, OCTOBER 2023, DOI:10.15221/23.28

[4] Payne C.: COST BENEFIT COMPARISON OF PLASTER CASTS AND OPTICAL SCANS OF THE FOOT FOR THE MANUFACTURING OF FOOT ORTHOSES. *J AM PODIATR MED ASSOC* 2007; 41: 29-31

[5] Ciobanu O.; Soydan Y.; Hizal S.: CUSTOMISED FOOT ORTHOSIS MANUFACTURE WITH 3D PRINTERS. *IN: IMS 2012- THE 8TH INTERNATIONAL SYMPOSIUM ON INTELLIGENT MANUFACTURING SYSTEMS*. ISTANBUL, TURKEY. 2012.

[6] Spooner S.: 3D ORTHOTIC PRINTING: FAD OR GAME CHANGER? *PODIATRY TODAY,* 2016

[7] Xu R.; Wang Z.; et al.: EFFECT OF 3D PRINTING INDIVIDUALIZED ANKLE-FOOT ORTHOSIS ON PLANTAR BIOMECHANICS AND PAIN IN PATIENTS WITH PLANTAR FASCIITIS: A RANDOMIZED CONTROLLED TRIAL. *MED SCI MON INT MED J EXP CLIN RES* 2019; 25: 1392–1400

[8] Gatt A.; Chockalingam N.; Formosa C.: A PRELIMINARY STUDY ON THE EFFECT OF COMPUTER-AIDED DESIGN AND MANUFACTURED ORTHOSES ON CHRONIC PLANTAR HEEL PAIN. *FOOT ANKLE SPEC* 2018, 11: 112–116

[9] Dombroski C.; Balsdon M.; Froats A.: THE USE OF A LOW-COST 3D SCANNING AND PRINTING TOOL IN THE MANUFACTURE OF CUSTOM-MADE FOS: A PRELIMINARY STUDY. *BMC RES NOTES* 2014; 7: 443

[10]Mo S.; Leung SH.; Chan ZY.; et al.: THE BIOMECHANICAL DIFFERENCE BETWEEN RUNNING WITH TRADITIONAL AND 3D PRINTED ORTHOSES. *J SPORTS SCI* 2019; 37: 2191–2197

[11] Ho M.; Nguyen J.; Talbot K.; et al.: IMMEDIATE COMFORT PERCEPTION OF 3D-PRINTED FOOT ORTHOSES IN INDIVIDUALS WITH UNILATERAL HEEL PAIN, *PROSTHETICS AND ORTHOTICS INTERNATIONAL,* DOI: 10.1097/PXR.0000000000000068

[12] Walker K.; Przestrzelski B.; Kaluf B.; et al.: NOVEL 3D-PRINTED FOOT ORTHOSES WITH VARIABLE HARDNESS: A COMFORT COMPARISON TO TRADITIONAL ORTHOSES, *MEDICAL ENGINEERING AND PHYSICS*, APRIL 2023, HTTPS://DOI.ORG/10.1016/J.MEDENGPHY.2023.103978

CORRESPONDING AUTHOR:

Dariia KAPTIUROVA
Department of Fashion Technology, Faculty of Arts and Fashion, Kyiv National University of Technologies and Design
Mala Shyianovska (Nemyrovycha-Danchenka) Street, 2, 01011, Kyiv, Ukraine
E-mail: kadaria132000@gmail.com

ANALYTICAL STUDY ON THE BIOMECHANICAL EFFECTS ON THE FEET OF WEARING HIGH HEELS AND FOREFOOT SHOCK ABSORPTION STRATEGIES

Rui SHENG[1], Zhonghua CAO[2], Guoxiang YUAN[3,4]*

1 Shanghai Art and Design Academy, Shanghai, China
2 Guangzhou Lüpu Information Technology Co., Ltd., Guangzhou, Guangdong, China
3 Sustainable Futures – Fashion & Textile, Hong Kong
4 World Textile University Alliance, Shanghai, China

Abstract

This study examines the impact of high heels on women's foot structure, focusing on biomechanics. By analyzing structural changes in women's feet when wearing high heels, we reveal their effects on foot biomechanics. Research shows that high heels significantly increase pressure and impact forces on the forefoot, elevating injury risks due to altered pressure distribution. To mitigate this stress and reduce injuries, we propose a novel forefoot shock absorption method involving specially designed pads integrated into high heels. This approach lowers the force exerted on the foot, promising comfort and foot health for high heel wearers. This research enhances our understanding of biomechanical implications and introduces innovative solutions for more comfortable and healthier high heel designs. It not only opens new possibilities but also provides practical solutions to enhance comfort and reduce foot problems associated with high heels. Expectations are that this research will inspire further developments in creating healthier and more comfortable high heel designs. The passage now contains 200 words, within the requested range.

Keywords: *High heels, forefoot shock absorption, foot anatomical structure, foot tissue motion variation patterns*

1. INTRODUCTION

With the continuous improvement in people's quality of life and changes in lifestyle, consumers are placing increasing importance on comfort when choosing footwear. For female consumers, health and comfort have become equally important factors when purchasing shoes, rather than just focusing on style [1]. Women are increasingly aware that uncomfortable shoes can have adverse effects on foot health and even lead to foot-related problems [2-4]. Among the various demands related to shoe comfort, there is a growing emphasis on the type of cushioning performance in the forefoot of high-heeled shoes. Studies on the biomechanics of foot movement for high-heeled shoe wearers have found that the impact force on the feet during walking is much greater than when standing statically, especially in the heel and forefoot areas [5-7]. High heels shift the body's center of gravity and pressure point to the forefoot, increasing the pressure and impact on the forefoot, particularly as the heel height increases. Therefore, there are higher requirements for the material and functionality of the forefoot area of high-heeled shoes.

Currently, there is insufficient in-depth research on the cushioning performance of the forefoot for women's fashion leather shoes in China, and there are relatively few fashion shoe products with such excellent performance. Although there has been some research on the comfort and cushioning

technology of high heels, further investigation is still needed [8-10]. Therefore, this study aims to analyze existing methods of enhancing the comfort and cushioning performance of high-heeled shoes, starting from the biomechanical study of foot movement for high heel wearers. Through this research, we hope to provide valuable insights for the development of footwear with shock-absorbing and cushioning functions. The research findings of this paper are of great reference value for exploring shock-absorbing technology in high heels, providing consumers with a more comfortable shoe-wearing experience. To enhance the shoe-wearing experience for female consumers, further research on the comfort and cushioning technology of high heels is needed, along with the design of ergonomically sound shoes, and the widespread application of these technologies to improve both wearing experience and overall health.

2. EXPERIMENTAL

During the wearing of high heels, there are changes in the anatomical structure of the feet, thereby affecting the functionality and biomechanical characteristics of the feet (as shown in Figure 1). The stiffness of the feet is freely regulated through the rotational movement of foot joints and tensile stress in ligamentous tissues, with ligamentous tissues being the primary means of regulating foot stiffness. When wearing high heels, the bones, fascia, and ligamentous tissues of the feet experience varying degrees of tension and deformation, leading to alterations in foot stiffness and stability.

Figure 1: Infrared imaging under high-heeled shoe wearing

2.1 The impact of wearing high heels on foot biomechanics

When wearing high heels, the skeletal structure of the feet undergoes alterations, primarily characterized by an elevation in the rear part of the foot, creating a posture with a raised front and a lowered rear [11]. This posture leads to increased tensile stress on the plantar fascia, while also exerting pressure on the heel bone and the tarsal bones, limiting their downward movement. During walking and standing, the feet need to adapt to these changes by adjusting their stiffness and stability to maintain body balance.

2.2 Changes in foot ligament tissues

Foot ligament tissues play a crucial role in regulating foot stiffness and stability. When wearing high heels, these ligaments can experience varying degrees of tension and deformation, thereby affecting the foot's stiffness and stability [12]. The skeletal structure of the medial longitudinal arch and the plantar fascia form a bowstring-like structure. Wearing high heels causes changes in the height of the rear part of the foot, which in turn alters the tensile stress on the plantar fascia, subsequently impacting foot stiffness and stability.

2.3 Analysis of forefoot shock absorption mechanisms

Wearing high heels also affects the foot's ability to absorb shock in the forefoot region. Forefoot shock absorption refers to the cushioning capacity of the front part of the sole, which can effectively absorb the impact forces and vibrations experienced during walking, reducing their impact on the foot's skeletal structure [13-14]. In high heels, the forefoot area of the foot bears greater pressure and requires better shock absorption and support. Therefore, when designing high heels, it is essential to consider how to provide suitable shock absorption mechanisms in the forefoot area. Conversely, when wearing medium to low-heeled shoes, the forefoot's shock absorption capacity is better, effectively mitigating the impact on the foot and ensuring even force distribution. However, when wearing high heels, the forefoot's shock absorption capacity diminishes, leading to increased pressure and impact on the forefoot region.

Generally speaking, common shock absorption methods for high-heeled shoes involve the use of cushioning materials in the forefoot region, which primarily includes materials in the insole's forefoot area and the midsole's forefoot area. The materials in the forefoot region can reduce direct contact between the foot and the ground, thereby lowering the pressure on the foot. Additionally, they can create an air layer between the foot and the sole, providing additional cushioning, thus reducing the impact on the foot. Another shock absorption method is the use of soft sole materials. Soft sole materials can absorb the impact forces from the ground, reducing the pressure on the foot.

By using a thickened platform in the forefoot area, it's possible to effectively reduce the impact on the foot from the ground, significantly mitigating forefoot shock. Additionally, drawing inspiration from Nike's air cushion technology, the midsole of the platform can be designed as an airbag structure to enhance shock absorption in the forefoot. These technologies can offer improved shock absorption. Apart from cushioning materials in the forefoot region and midsole, and soft sole materials, the design of high-heeled shoes also needs to consider the shoe's structure. The material of the heel's midsole, the material of the shank, its position, length, and the material of the outsole all affect the stability and comfort of high-heeled shoes. Wearing high heels can impact the feet to some extent, so designing high-heeled shoes should take into account the biomechanics of the feet and shock absorption methods. Proper design can reduce pressure on the feet, provide better support, and enhance shock absorption, thereby improving the comfort and healthiness of wearing high heels. As shown in Table 1, there are typically four main shock absorption methods, including insole cushioning, arch support, sole materials, and shock-absorbing structures.

Table 1: Description of Forefoot Shock Absorption Methods

Forefoot Shock Absorption Method	Description
Insole Cushioning	Incorporating shock-absorbing materials in the insole, such as air cushions or shock-absorbing foam, to enhance the shoe's shock absorption capability and reduce pressure on the foot.
Arch Support	Proper arch support can distribute pressure in the forefoot area more evenly, improving forefoot shock absorption.
Sole Materials	Selecting suitable sole materials like rubber, EVA, etc., can also enhance the shoe's shock absorption capability.
Shock-Absorbing Structures	Some high-end athletic shoes feature complex shock-absorbing structures in the sole and insole, providing superior shock absorption effects.

Therefore, when designing and selecting high-heeled shoes, it's essential to consider the forefoot shock absorption methods and choose suitable insoles, sole materials, and shock-absorbing structures to enhance comfort during wear and reduce pressure on the feet.

3. RESULTS

3.1 Foot structure and its patterns of movement

The human foot structure is comprised of an arch-like formation made up of tarsal and metatarsal bones (as shown in Figure 2). This upward convex structure is formed collectively by the contractile force and resilience of elastic tissues such as the plantar fascia and ligaments. The foot arch takes on an arched shape, providing the foot with sturdiness, lightness, and elasticity, allowing it to withstand substantial pressure and cushion the vibrations generated during activities such as walking, running, and jumping. The foot arch can generally be divided into two parts: the transverse arch and the longitudinal arch.

Figure 2: Structure of longitudinal and transverse arches of the foot

The transverse arch is composed of the distal tarsal bones and proximal metatarsal bones. Besides ligaments, it also relies on muscles and tendons for crucial support apart from its lateral view. The longitudinal arch can be further divided into the lateral longitudinal arch and the medial longitudinal arch. Most people are familiar with the medial longitudinal arch, which is the more prominent of the

two. The lateral longitudinal arch is composed of the calcaneus, cuboid, and the fourth and fifth metatarsal bones. This arch has a relatively minor curvature and primarily serves as a stabilizer for the foot. The medial longitudinal arch, on the other hand, consists of the calcaneus, talus, navicular, cuneiform bones (medial, intermediate, and lateral), and the first, second, and third metatarsal bones (as shown in Figure 3). Among these structures, the most important is the spring ligament on the medial aspect of the foot, which acts as a bowstring. This arch has a greater curvature and excellent elasticity, making it suitable for activities like jumping and providing shock absorption. The medial longitudinal arch, also known as the "main foot arch," is crucial for maintaining balance, cushioning, and absorbing shock impact.

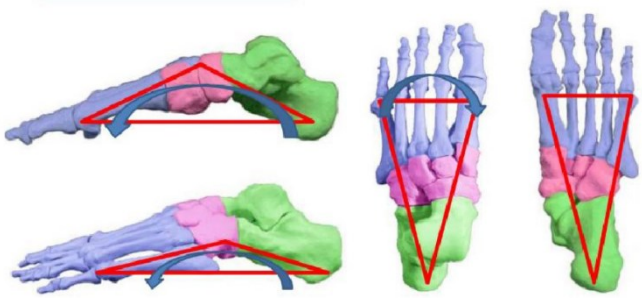


Figure 3: Structure of longitudinal and transverse arches of the foot

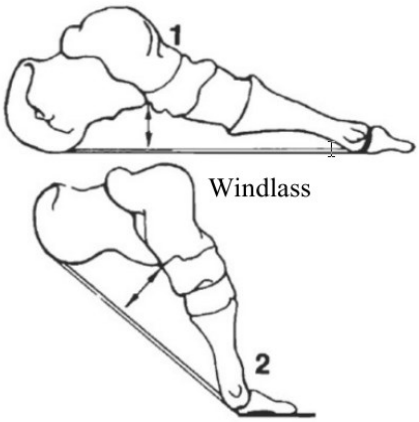


Figure 4: The winding effect of plantar fascia during dorsiflexion of the metatarsophalangeal joints

The human foot is an incredibly flexible structure that ensures the effectiveness of force transmission between the lower limbs and the ground through the interaction of numerous small joints. The foot arch is divided into the transverse arch and the longitudinal arch. During the support phase of walking or other activities, both arches undergo lengthening and compression and absorb impact loads as elastic strain energy within the foot arch. In the later stages of the support phase, as the metatarsophalangeal joints extend, the passive elastic recoil of the plantar fascia generates forward propulsion of the body. This compression-rebound process is referred to as the foot's spring mechanism. Additionally, through the winding effect of the foot (as shown in Figure 4), when the metatarsophalangeal joints extend, the plantar fascia is stretched, increasing the stiffness of the foot arch effectively, thereby enhancing gait

efficiency during the stride. With each footfall, the foot can store and subsequently release mechanical energy, further improving gait efficiency. Therefore, studying foot structure, gait formation patterns, and gait dynamics from a biomechanical perspective is highly valuable for researching the comfort of high-heeled shoes.

3.2 Changes in plantar pressure when wearing high heels

The alterations in plantar pressure distribution when wearing high heels have a significant impact on walking and human health. Research has shown that under normal circumstances, when standing barefoot in a static position, the body's weight is concentrated on the feet. In this situation, 82% of individuals experience peak plantar pressure in the heel area, with relatively low plantar pressure in the forefoot metatarsal region. However, when wearing high-heeled shoes with varying heel heights, there are notable changes in plantar pressure distribution. As the heel height of the high heels increases, plantar pressure shifts from the heel towards the first metatarsophalangeal joint in the forefoot, resulting in an increasing pressure on the forefoot. Consequently, the higher the heel, the further forward the center of gravity moves, leading to a gradual increase in pressure on the forefoot. The pressure distribution across different regions of the sole also changes significantly, with a substantial increase in pressure on the forefoot metatarsal area. This is one of the most significant reasons why high-heeled shoes can cause foot injuries (as shown in Figure 5).

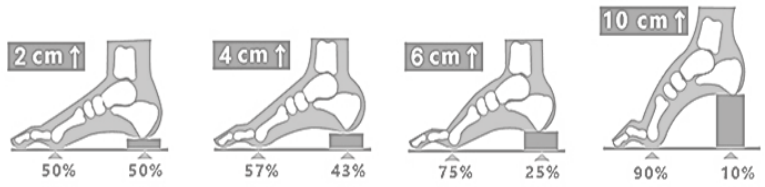


Figure 5: Weight distribution in individuals with different heel heights

Wearing high heels can indeed lead to an imbalance in plantar pressure, subsequently causing foot and lower limb joint issues, and even injuries. Studies have shown that when wearing high heels, the pressure center shifts forward, resulting in a significant increase in pressure on the forefoot area, and an apparent enhancement of arch support. Therefore, in the design of high heels, it's essential to consider the plantar pressure center and use shock-absorbing materials to compensate for the inadequate cushioning performance of the foot. Additionally, the sole should have sufficient flexibility and bendability, and the heel height should be moderate to alleviate foot fatigue and discomfort. The design of the shoe's upper should also take into account the physiological structure of the foot, avoiding excessive tightness or looseness that can cause pressure and discomfort. Furthermore, individuals wearing high heels should take measures to minimize the adverse effects on their feet, such as choosing the right shoe size and style, reducing the duration of wear, and using foot protection products. These measures can help reduce foot pressure and fatigue, as well as prevent foot-related conditions. In conclusion, the adverse effects of high heels on the feet are indeed real, but they can be effectively mitigated and alleviated through various means, including footwear design and personal protection. For individuals who regularly wear

high heels, it's especially important to prioritize foot protection and care to prevent the onset and exacerbation of foot-related issues.

4. DISCUSSION

There are various forefoot shock absorption methods for high-heeled shoes available in the market, encompassing a wide range of categories. These methods can be categorized into five basic forms: forefoot cushioning, arch support, midsole cushioning, shock-absorbing insoles, and forefoot cushion cores made from special materials.

4.1 Forefoot cushioning

The human foot has both medial and lateral arches, and the bottom of the forefoot consists of a smooth, contoured surface formed by the bones and muscles. Therefore, there should be a certain degree of concavity in the insole under the forefoot to accommodate the muscles and fat in the fore-mid-lateral aspect of the foot, ensuring comfort. However, when wearing high heels, the higher the heel, the tighter the tension in both arches, making the convexity of the forefoot more pronounced. This can affect the stability while walking in high heels. Research conducted abroad has shown that when the heel height of high heels exceeds 8 centimeters, the pressure at the ends of the fourth and fifth toe bones nearly disappears due to the irregularities in the medial and lateral arches. Furthermore, the pressure at the ends of the first and second toe bones is directly proportional to the heel height. If only soft insoles are added to the inner forefoot to alleviate the pressure in that area, it can result in a greater height difference between the inner and outer sides of the foot, exacerbating instability during walking. While adding cushioning in that area can alleviate pressure, the higher plane can lead to greater concentration of pressure on the forefoot, making it less conducive to pressure dispersion.

4.2 Arch support cushions

There is a popular type of arch support cushion on the market, as shown in Figure 6, also known as an arch cushion or metatarsal pad. It places a soft, elastic cushion in the arch area, primarily in the medial arch, aiming to provide support for the arch of the foot, distribute pressure, and correct flat feet. However, users of this type of arch support often report difficulties in achieving a proper fit with their arch height. Since everyone's arch height varies, placing the cushion in the arch area of high heels can either result in the cushion not reaching the arch or pressing against the top of the arch, failing to alleviate foot pressure. In reality, the design principle of this type of cushion is flawed as it doesn't account for the differences in arch height among individuals, especially when wearing high heels, where these differences can be magnified.

Figure 6: Common foot arch supports

While the current market offers arch supports that can provide some support to the medial arch to distribute pressure, these insoles exert external forces on the arch, causing the plantar fascia to remain in a stretched and tense state, leading to its relaxation and potentially exacerbating or causing the collapse of the arch. Therefore, the design of arch supports should take into consideration the biomechanical structure of the arch, avoiding excessive stretching of the plantar fascia.

4.3 Cushioned midsole

Research indicates that the impact force on the feet during walking is much greater than static gravity. Lack of a good cushioning system can lead to foot fatigue. Therefore, high heels use materials such as EVA with a certain degree of elasticity, high-density pulp, high-density sponge, etc., as midsoles to provide foot stability and shock absorption. At the same time, the outsole uses wear-resistant and non-slip materials like TPR, high-quality genuine leather outsoles, and rubber soles to offer foot protection and comfort.

4.4 Cushioned insoles

Cushioned insoles are designed to enhance shock absorption through material selection and consideration of movement patterns and foot characteristics (as shown in Figure 7). During walking, the feet experience significant impact, primarily concentrated in the heel, arch, and forefoot regions. To alleviate this impact, cushioned insoles are typically made from high-density, high-elasticity polymer materials capable of withstanding substantial pressure. Depending on the specific areas of force, materials of varying densities may be chosen to enhance shock absorption. For instance, some high-end athletic brands use special gel materials in their cushioned insoles, which can more effectively absorb impact and distribute pressure to protect the feet from injury. Additionally, some cushioned insoles come equipped with ventilation and antimicrobial features to enhance comfort and hygiene.

Figure 7: High-heeled shoe cushioning insoles

4.5 Other factors

The heel is a crucial component of shoes, responsible for bearing the body's weight. Therefore, materials like ABS, rubber plastics, metal, or hard wood are commonly used to make heels. However, high-heeled shoes often have thin soles, resulting in poor shock absorption. Many designers, therefore, focus on shock absorption in the midsole or heel structure. For example, a French designer showcased shock-absorbing high-heeled shoes with a spring-loaded heel at the 37th Geneva International Invention Exhibition. These shoes had an internal device that could adjust the spring's hardness based on the wearer's weight, catering to the dual needs of stability and shock absorption during walking (as shown in Figure 8).

Figure 8: Structure of spring shoe heels

Currently, our team is conducting research and testing on these pressure-distributing insoles, especially forefoot and arch supports. While increasing the flexibility of the sole can help reduce foot impact and distribute pressure, there are still some design issues that do not fully align with the principles of biomechanics. Different types of shoes may require corresponding adjustments to their shock-absorbing structures and materials. Additionally, individual differences in foot shape are significant and require research that considers both individual variability and commonalities within categories.

5. CONCLUSION

In conclusion, this research paper has explored the biomechanical effects of wearing high heels on the feet and presented strategies for forefoot shock absorption. The study emphasizes the growing importance of comfort and health in women's footwear choices, especially concerning high-heeled shoes. The findings indicate that high heels shift the body's center of gravity and increase pressure and impact on the forefoot, heightening the risk of foot injuries. To address this issue, the paper proposes innovative forefoot shock absorption methods, including specially designed pads and airbag structures in the forefoot area of high heels. These strategies aim to reduce the force exerted on the foot and enhance overall comfort. Furthermore, the research delves into the foot's structural organization, the impact of wearing high heels on foot biomechanics, changes in foot ligament tissues, and various forefoot shock absorption mechanisms. It identifies key methods such as insole cushioning, arch support, sole materials, and shock-absorbing structures, shedding light on the importance of proper footwear

design and selection. The study also discusses the alterations in plantar pressure distribution when wearing high heels and emphasizes the need for shock-absorbing materials, flexibility, and appropriate heel heights to mitigate foot-related issues. In light of these findings, it is evident that there is room for improvement in high-heel design, considering both biomechanics and comfort. This research serves as a valuable reference for future studies and the development of high-heeled shoes that prioritize both style and the well-being of wearers. Ultimately, the paper encourages further research and advancements in achieving healthier and more comfortable high-heel designs to benefit women's footwear experiences and overall foot health.

REFERENCES

Wang, Y.: CONSUMERS' PURCHASE INTENTIONS OF SHOES: THEORY OF PLANNED BEHAVIOR AND DESIRED ATTRIBUTES, *INTERNATIONAL JOURNAL OF MARKETING STUDIES*, 6 (2014) 4, 50

Guidozzi, F.: FOOT PROBLEMS IN OLDER WOMEN, CLIMACTERIC, 20 (2017) 6, 518-521

Hendry, G.J. et al.: FOOTWEAR EXPERIENCES OF PEOPLE WITH CHRONIC MUSCULOSKELETAL DISEASES. *ARTHRITIS CARE & RESEARCH*, 67 (2015) 8, 1164-1172

Wilson, O. et al.: THE EXPERIENCE OF FOOT PROBLEMS AND DECISIONS TO ACCESS FOOT CARE IN PATIENTS WITH RHEUMATOID ARTHRITIS: A QUALITATIVE STUDY. *JOURNAL OF FOOT AND ANKLE RESEARCH*, 10 (2017) 1, 1-11.

Lee, C.M., Jeong, E.H. & Freivalds, A.: BIOMECHANICAL EFFECTS OF WEARING HIGH-HEELED SHOES, *INTERNATIONAL JOURNAL OF INDUSTRIAL ERGONOMICS*, 28 (2001) 6, 321-326

Yu, J. et al.: BIOMECHANICAL SIMULATION OF HIGH-HEELED SHOE DONNING AND WALKING, *JOURNAL OF BIOMECHANICS*, 46 (2013) 12, 2067-2074

Zeng, Z. et al.: EFFECTS OF HIGH-HEELED SHOES ON LOWER EXTREMITY BIOMECHANICS AND BALANCE IN FEMALES: A SYSTEMATIC REVIEW AND META-ANALYSIS, *BMC PUBLIC HEALTH*, 23 (2023) 1, 726

Dinato, R.C. et al.: BIOMECHANICAL VARIABLES AND PERCEPTION OF COMFORT IN RUNNING SHOES WITH DIFFERENT CUSHIONING TECHNOLOGIES, *JOURNAL OF SCIENCE AND MEDICINE IN SPORT*, 18 (2015) 1, 93-97

Hong, W.H. et al.: INFLUENCE OF HEEL HEIGHT AND SHOE INSERT ON COMFORT PERCEPTION AND BIOMECHANICAL PERFORMANCE OF YOUNG FEMALE ADULTS DURING WALKING, *FOOT & ANKLE INTERNATIONAL*, 26 (2005) 12, 1042-1048

Yung-Hui, L. & Wei-Hsien, H.: EFFECTS OF SHOE INSERTS AND HEEL HEIGHT ON FOOT PRESSURE, IMPACT FORCE, AND PERCEIVED COMFORT DURING WALKING, *APPLIED ERGONOMICS*, 36 (2005) 3, 355-362

Flores, D.V. et al.: ADULT ACQUIRED FLATFOOT DEFORMITY: ANATOMY, BIOMECHANICS, STAGING, AND IMAGING FINDINGS, *RADIOGRAPHICS*, 39 (2019) 5, 1437-1460

Csapo, R. et al.: ON MUSCLE, TENDON AND HIGH HEELS, *JOURNAL OF EXPERIMENTAL BIOLOGY*, 213 (2010) 15, 2582-2588

Whittle, M.W.: GENERATION AND ATTENUATION OF TRANSIENT IMPULSIVE FORCES BENEATH THE FOOT: A REVIEW, *GAIT & POSTURE*, 10 (1999) 3, 264-275.

Zhang, R. et al.: THE BIONIC HIGH-CUSHIONING MIDSOLE OF SHOES INSPIRED BY FUNCTIONAL CHARACTERISTICS OF OSTRICH FOOT, *BIOENGINEERING*, 10 (2022) 1, 1

CORRESPONDING AUTHOR

YUAN, Guoxiang
Sustainable Futures - Fashion & Textile, Hong Kong
World Textile University Alliance, 2999 North Renmin Road, Shanghai, 201620, China
E-mail: yuanguoxiang@gmail.com

INNOVATION IN SKYDIVING CLOTHING

Orsolya NAGY SZABÓ[1], András KOLESZÁR[1], Zoltán DOLHAI[2]

1 Product Design Institute, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University

2 Intrudair Ltd.

Abstract

In this article, we present the development of sportswear for the ever-growing extreme BASE jumping and skydiving sports, from the clothing needs of beginners to professional competitors. Zoltán Dolhai, owner and managing director of Intrudair Ltd, manages a unique business in Hungary, manufacturing custom-made parachute and wingsuits for 25 years for skydivers all over the world. The research work was supported by the GINOP-2.1.2-8-1-1-4-16-2019-00901 grant, with the participation of colleagues from the Institute of Product Design of Obuda University.

In this article, we describe the difficulties of custom manufacturing and the digital options that have been developed to solve the problems that arise. The range of sportswear produced by the company is very wide, from parachute sports to wingsuits and their accessories, everything is made to measure. The experience of freefalling and flying is not only possible by jumping out of a plane, there is also the possibility to practice jumping in a wind tunnel. Every circumstance requires a different type of clothing. The athlete needs to feel the flow of air over his body, whatever way he flies, as it helps him to feel how much force he needs to move his body parts, where he needs to put force by tensing his muscles to keep his balance. The choice of materials used to make the garments is very important, as they need to be made from fabrics with good strength properties as well as those with high elasticity.

Keywords*: Skydiving sportwear, Formfitting clothes, Custom made wind tunnel suits, Custom made wing suits, dynamic movement*

INTRODUCTION

Parachuting is an extremely dynamic sport, which has led to the development of extreme sports, the development of which is a constant challenge for textile manufacturing and clothing companies. . Athlets also jump from a plane in a winged suit, but jumping off a high cliff is common. Base jumping is a jump from a relatively low height (compared to the minimum height of 800 meters for skydiving) and from fixed objects or natural formations, during which the jumpers use special parachutes, but different in terms of their opening and folding properties. For practicing jumping, the wind tunnel offers sports and entertainment opportunities. In this structure, everyone can try the experience of free fall with the lifelike feeling of a real fall. For practicing jumping, the wind tunnel provides sport and entertainment. In this structure, everyone can try the experience of free-falling with the realistic sensation of falling. In the wind tunnel, the wind force is adjustable, so people of different weights and with different flying skills can try freefalling in various positions. For practicing in the wind tunnel, we will show the technological development of the suits recommended for beginner flying, where an instructor will hold the student in the wind tunnel.

1. DEVELOPMENT OF WIND TUNNEL SUITS

The expansion of the wind tunnel market has increased the need to develop specialized competition clothing for extreme skydiving. The professional experience of the management and staff of Intrudair Ltd. and the market position of the Company enable it to be at the forefront of the world market for this type of product in the professional tunnel clothing segment. This product will be a more comfortable garment than ever before, even more conducive to high-speed wind tunnel flying, and will meet the increased high demands of this sport. With the development of technical garments, curved cut lines following the contours of the body are becoming increasingly important, making the garment more attractive to athletes from a design and ergonomic point of view.

In the wind tunnel sport, we keep several flight styles: Head up, Head down, Freestyle, Dynamic 2 way, Dynamic 4 way, FS 4 (formation skydiving) FS 8. Learner level or visitor flight. Different construction of clothes are used for each style, and the material composition of the clothes is also different. We develop prototypes for freestyle, dynamic fly, FS4, learner and tunnel passenger styles.

The construction of the clothing should basically fit the body, be comfortable and ensure the free flow of air around the athlete's body. This requires materials with suitable properties. The athlete must feel the flow of air over his entire body, abdomen, back and limbs, with the help of which he can feel the force with which he must move his body parts, his balance, and where he must apply force by tensing his muscles.

Wind tunnel suits for first fighter

Beginner students and visitors start to practice in "first-flyer" passenger clothes with professional trainers in the wind tunnel. These suits contain grips. Grips must be attached to these clothes so that the trainer can hold the student anywhere and anyway during the training. An important point is that the placement of the „grips" on the garment is adapted to the wearer's level of knowledge.

Requirements of first flyer passanger cloths

Ergonomic and physiological aspects:
The inflow of air is diverted around the body, preventing the suit from inflating and fluttering, making the user's flight unstable due to the altered undulating surfaces. The undulation of the fabric can affect the wearer's flight dynamics and posture, which in competitive sports is observed and assessed by scoring judges. In addition, its breathability allows sweat to escape to the outer surface of the garment, where it quickly evaporates in the flow.

Functional aspects:
- Comfortable, practical, can be worn even after several hours of active movement,
- Internal processing does not cause irritation and provides a second skin feeling.

Strength aspects:
The tensile strength of the materials must be adequate. When selecting seam types, we use those that have high tensile strength in the case of loading perpendicular to the seam, or with high elongation in the direction of the seam. (Fig. 1)

Figure 1: Front and back of the suit

2. TUNNEL SUIT CONSTRUCTION

The production preparation staff of Intrudair Kft. switched from manual editing to the use of a digital vector graphics program more than 5 years ago. This allows you to use the laser cutter. Tailoring samples for individual sizes are currently made with a general vector graphic program, so the tailoring is accurate and precise. (Fig. 2)

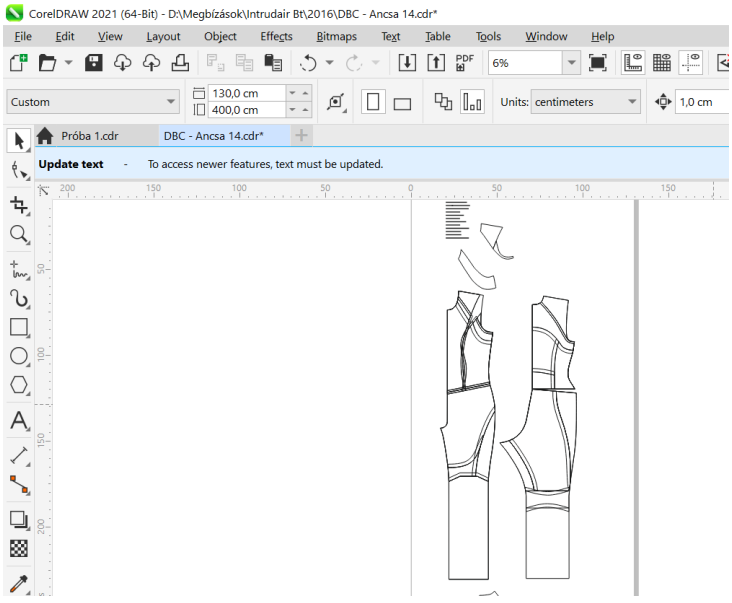


Figure 2: Pattern design with CorelDraw vector graphical system

Within the framework of the tender, a special Morgan CAD clothing industry production preparation program was purchased, so in addition to the unique, dimensional editing, the ready-to-wear production process is also easier and more efficient, which can be used for tunnel clothes in the case of orders from sports associations. Taking into account the geographical location of the customer and the average size type of the tourists who visit there in the largest number (EUR, Asia, USA), the design of the size chart is also a pivotal point in the case of clothes designed for ready-to-wear production. (Fig. 3)

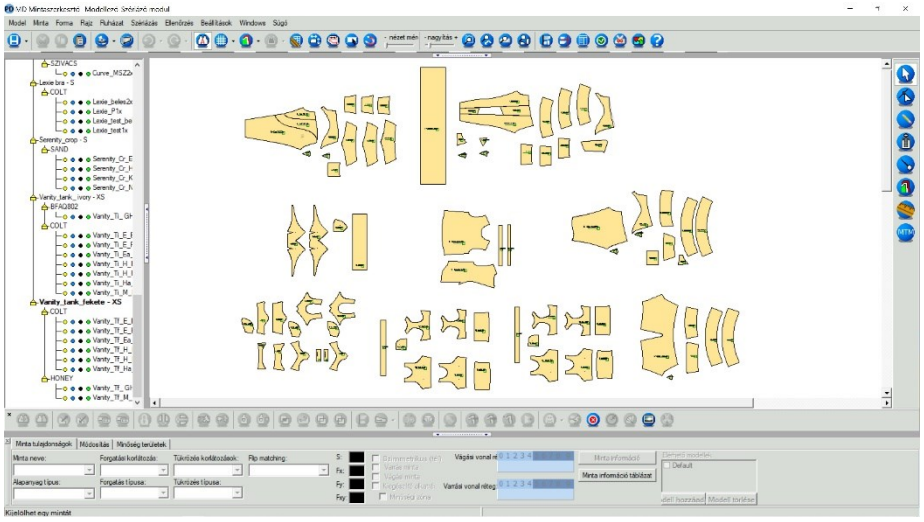


Figure 3: Pattern design with Morgan CAD system

Patterns and the accuracy of the cut have a major influence on the size of a tailor-made garment. As clothes are typically tailored individually for each customer, the use of a laser cutter is useful and justified. (Fig. 4)

Figure 4: Laser Cutting System

3. ASPECT OF TEXTILE SELECTION

We used 3 types of raw materials to develop the dress: A material called Brunico, the characteristic of which is that it is a soft, highly elastic material, in the neck area, wrists and places in contact with the skin. Teslan: lightweight material with high strength properties and low elasticity, Cordura: non-elastic material with high abrasion resistance and high tensile strength The development of the garment takes into account aesthetic and comfort aspects, with testing in a wind tunnel. During the development process, several products are made, the subjective evaluation of the test person is also taken into account for their further development. The final prototype is evaluated in detail in the documentation. (Fig. 5)

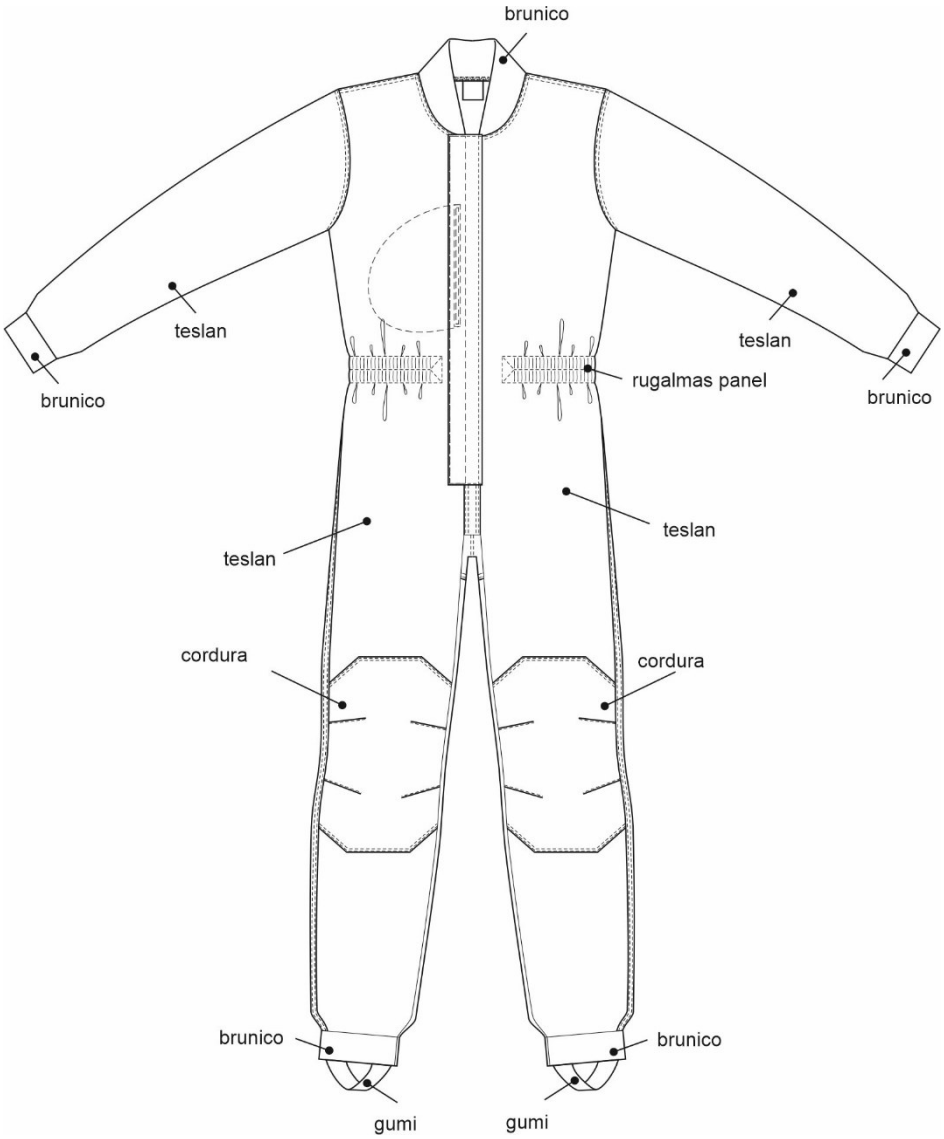


Figure 5: Technical drawing of first flyer suit

4. PLACEMENT AND DESING OF GRIBS

The way of fitting the grips is a key point for this type of garment, our aim is to create a "first flyer" garment for versatile and comfortable use in wind tunnels, with an optional grip design where the customer chooses the garment collection best suited to his/her educational theme, which is tailored to the wind speed and energy requirements and performance of the channel, both in terms of size range and the related generosity and thickness of the material. The grips should be easy to grip with strong anchor points, the centre of the sew-on is aligned with the position of the grip, this determines the direction from which the instructor grips the student to hold him, how deeply the fingers of the holding hand can grip the cylindrical or square shaped filler of the grip.

The size and density of the padding is also a critical point, cylindrical or square if required, too large handholds can flap in the wind, hurting the student's back and sides, interfering with flight, very fluttery parts wear out more quickly. Soft stuffing wears out even more over time, making it impossible to hold on firmly at critical moments, and too hard can cause injuries when flapping. Undersized grips or grips with inadequate centre grips can slip out of the instructor's hands and in an unfortunate case cause a serious accident. Collision with the glass of the channel or uncontrolled impact on the grating in an unfortunate position can result in serious limb or spinal injuries. (Fig. 6-7)

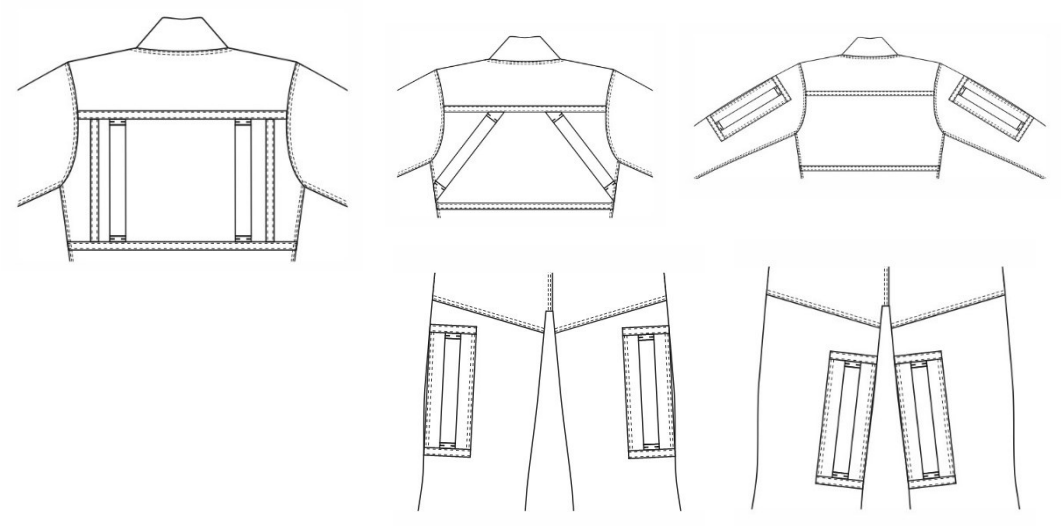


Figure 6: Placement of gribs

Figure 7: Design of gribs

5. STRENGTH TESTING OF GRIPS

The Gribs are made of Cordura material and are fixed in place through several layers of material where there is also Cordura material for adequate tensile strength. Wherever possible, one edge of the grib rail is sewn into a seam line, e.g. around the armholes, neck seams, double stitched to the base material, using a reinforcing ribbon which also serves as a decoration.

The tensile test was carried out at the Textile Laboratory of Óbuda University on the ZWICK Textenser. For the test, test strips of the appropriate material were cut out and the tensile strength of the raw materials was determined. For each type of fabric, 5 samples were torn in warp direction, as this is the guideline for tailoring the garment. The seam tensile strength was then tested in the direction perpendicular to the seam since this is the direction of greatest stress. For the seam breaking force test, all the test strips were performed on the same sewing machine with the same stitch density setting. The test bars were cut with hand scissors, taking into account the direction of the thread as worn. (Fig. 9)

The sewing circumstances are important to have an appropriate product. We use Groz-Beckert GEBEDUR® needles are coated with titanium nitride, making them better harder than standard needles. Especially in the point and eye area, they offer better protection against abrasion and damage, resulting in consistently good stitch quality and longer needle life. The stitch density: 30 stitch/ 10 cm, and we use Coats gral Tex 060 thread.

5.1 Tensile strenght of sewing tipes

To test the tensile strength of the grips, test samples were made using 3 different sewing techniques. (Fig. 10)

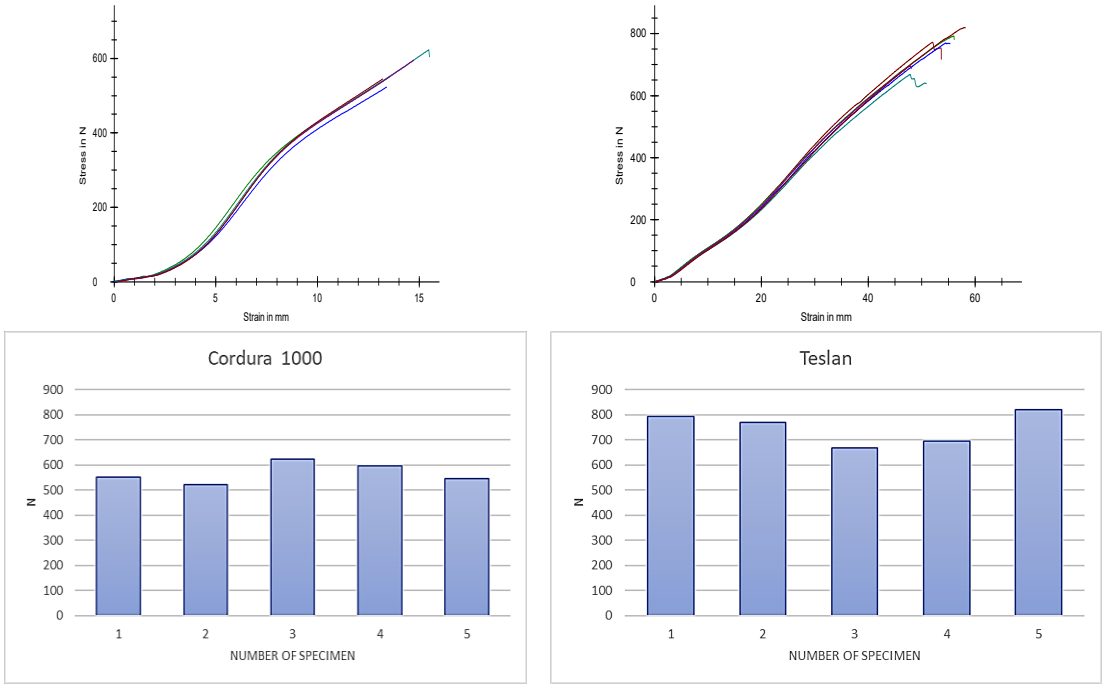
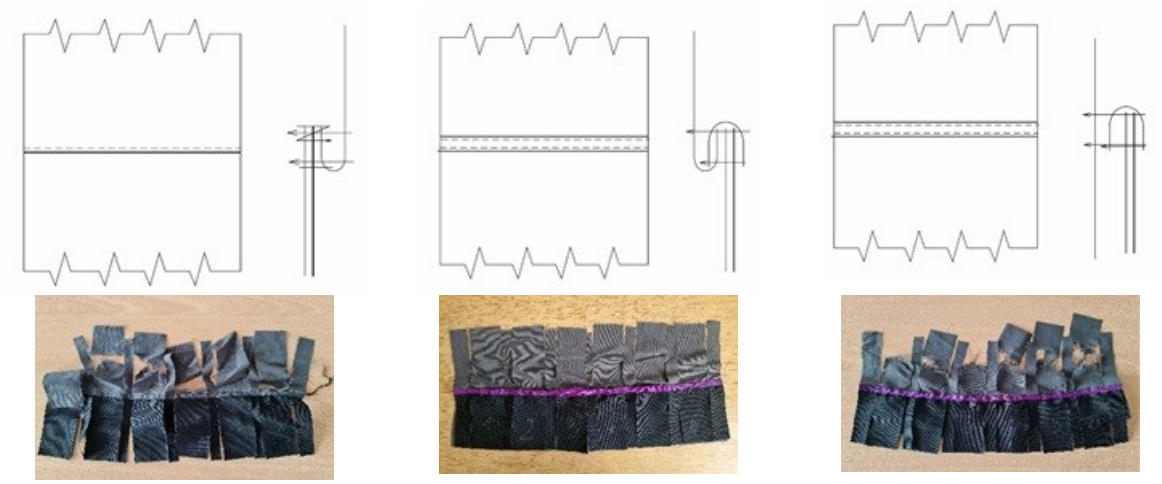


Figure 9: (left) Tensile test of Cordura; (right) Tensile test of Teslan



Sewing type 1. Sewing type 2. Sewing type 3.

Figure 10: Tensile strength of sewing types

Groz-Beckert GEBEDUR® needles are coated with titanium nitride, making them better harder than standard needles. Especially in the point and eye area, they offer better protection against abrasion and damage, resulting in consistently good stitch quality and longer needle life.

Figure 11: Equipment

Thred: Coats gral Tex 060, Gebedur titan-nitrid covered pin, stitch density: 30 stitch/ 10 cm.

6. EVALUATION

The test bars were torn at the Teslan material during tensile testing of seam tensile strength test specimens 1 and 3, which suggests that the seam does not reduce the tensile strength of the welded materials. Specimen 2 ruptured at the seam, and this seam type should therefore be excluded from the design technology of the grips. The study found that the tensile strength of seam type 3 exceeded the individual tensile strength of the materials, so design technology 3 is used. (Fig. 12)

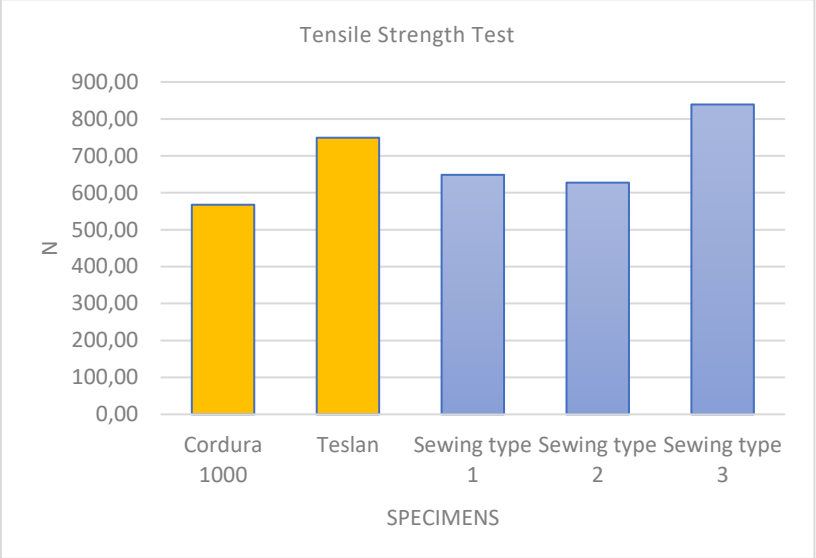


Figure 12: Tensile strenght of base materials and the 3 sewing tipes

REFERENCES

[13] Intrudair Gyártó, Kereskedelmi és Szolgáltató Kft. GINOP-2.1.2-8-1-4-16-2019-00901 Új generációs szárnyas, - illetve tunnelruhák kifejlesztése az Intrudair Kft - nél
[14] https://www.nah.gov.hu/hu/szervezet/innovatext-textilipari-muszaki-fejleszto-es-vizsgalo-intezet-zrt-dde5e332-4380-4ec0-86af-eb1154a0d735
[15] https://intrudair.com/product-selector.php

CORRESPONDING AUTHORS:

Orsolya NAGYNÉ Dr. SZABÓ
Product Design Institute, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University
Doberdó u. 6, 1034 Budapest, Hungary
E-mail: szabo.orsolya@uni-obuda.hu

Zoltán DOLHAI
Intrudair Kft.
4400, Nyíregyháza, Simai út 9.
E-mail: zoltan@intrudair.hu

INFLUENCE OF TEMPERATURE BEHAVIOR ON THE PROPERTIES OF EMULSIONS OF MODIFIED FATLIQUORING MATERIALS

Antonina ZAIETS, Olga ANDREYEVA

Kyiv National University of Technologies and Design, Kyiv, Ukraine

Abstract:

In leather industry, after the tanning process, the further formation of the structure and such important important properties of natural leather as strength, softness, and plasticity takes place at the stage of liquid finishing, first of all, process of fatliquoring. One of the most common methods of fatliquoring is the emulsion method, which involves processing the Wet Blue leather semi-finished product with water-fat emulsions. The effect of fatliquoring largely depends on the choice of fatliquoring materials and the stability of emulsions prepared on their basis. The purpose of this work was to study the properties of 5% and 25% emulsions of three modern commercial modified fatliquoring materials of natural and synthetic origin at room temperature (20°C) and in heating/cooling mode in the temperature range of 20-70°C/ 70-20°C. The properties of the emulsions were assessed visually by their appearance and analytically by particle size and zeta potential using a Malvern Zetasizer Nano ZS analyzer (Malvern Instruments Ltd, UK) and Zetasizer Software SOP Player 8.01.4906. The results of the research will be used in the creation of innovative technology for the production of leather of a modern assortment.

Keywords: *leather industry, modified fatliquoring material, emulsion, temperature behavior, properties.*

1. INTRODUCTION

The purpose of leather industry is to obtain leather from the animal skins, from which various items of wide use are made. At the same time, the hair cover, epidermis and subcutaneous tissue are removed from the skin, and the rest, in the form of dermis, is used for the manufacture of leather [2, 3, 11].

The main element of the structure of the dermis is the fibrous protein collagen. It is distinguished by a complex multi-level architecture, in which three main structures are recognized: molecular in the form of polypeptide chains and molecules, the size of which does not exceed 300 nm; supramolecular (macromolecules, fibrils) and suprafibrillar (primary and secondary collagen fibers, dermis) structures with dimensions over 300 nm. Each structural level forms capillaries and pores. Thus, the dermis is a porous material with pores of different sizes from 1 to 200 or more nm, due to which various structures are formed: microporous (pore up to 1 nm), mesoporous (pore from 1 to 200 nm) and macroporous (pore over 200 nm) [6]. The specified features of the collagen structure of the dermis allow for the purposeful formation of its fibrous structure during technological processes and operations, affecting the structural and physicochemical properties, taking into account the specific purpose of the skin [4-7].

After the tanning process, further formation of the structure and such important consumer properties of natural leather as strength, softness, plasticity and a number of others takes place at the stage of liquid

finishing. Fatliquoring is one of the decisive processes of liquid decoration, which involves the introduction of a certain amount of lubricating materials into the dermis, which significantly affects the formation of the spatial structure and consumer properties of the finished product. The effectiveness of fattening is determined by the nature of the penetration (diffusion) and fixation (binding) of fat in the collagen structure, which is determined by the processing method and the properties of the reagents. One of the methods of fatliquoring common in practice is the treatment of leather semi-finished products with emulsions, mainly of the "oil-in-water" type, which are dispersions of fat droplets in the liquid phase.

An important technological indicator of emulsions is their stability, which depends on many factors (the origin of the fat phase and the concentration of the emulsion, the presence of surface-active substances at the interface of the "fat-water" phases, the action of electrolytes and temperature, mechanical impact, etc.) and can manifest itself in the form of various phase transformations. During fatliquoring, the surface of the structural elements of the dermis is wetted with fatliquoring materials, as a result of which the micelles of the emulsifier pass from the surface of the emulsion particles into an aqueous solution and are sorbed on the structural elements with the formation of layers of emulsifier and layers of fat between them. The dispersion (particle size) of the emulsion determines the fat's ability to penetrate deep into the dermis, and the presence of active groups in the fat determines its interaction with collagen and other applied chemical reagents. Smaller particle size allows fat to more easily penetrate and distribute between dense collagen fibers. If the size of fat particles exceeds the size of the pores, fat is deposited on the surface of structural elements, which can reduce the effectiveness of fatliquoring. In addition, the presence and sign of the surface charge of the components of the colloid system "collagen-chemical material" is important for the latter.

It is known from the theory and practice of greasing that the smaller the difference in zeta potential between the surface of the collagen structural elements of and the particles of the fatliquoring emulsion, the deeper the greasing substances diffuse into the thickness of the semi-finished product. Fats of different nature and properties have different fattening effects, therefore, mixtures of fats are used to give the leather semi-finished product, and therefore the finished leather, the desired operational characteristics [4-7].

The purpose of this work was to study the properties of 5% and 25% emulsions of three modern modified fatliquoring materials of natural and synthetic origin at room temperature and in heating/cooling mode in the temperature range of 20-70°C/70-20°C.

2. EXPERIMENTAL PART

Modern commercial leather treatment products manufactured by Smit & Zoon (Netherlands) were used as modified fatliquoring materials: Sulphirol EG 60 – sulfited natural and synthetic fats; Synthol LC – natural and synthetic fats, sulfonated triglycerides, lecithin-containing mixture; Sulphirol C – sulphited oxidized fats based on marine fish fats. The specified materials have a liquid, fairly transparent consistency from yellow (Sulphirol EG 60, Synthol LC) to brown (Sulphirol C) in color (Fig. 1), without a sharp smell, capable of forming emulsions of the "oil in water" type, stable at pH 7,0-8,5 for 2 hours at room temperature [10].

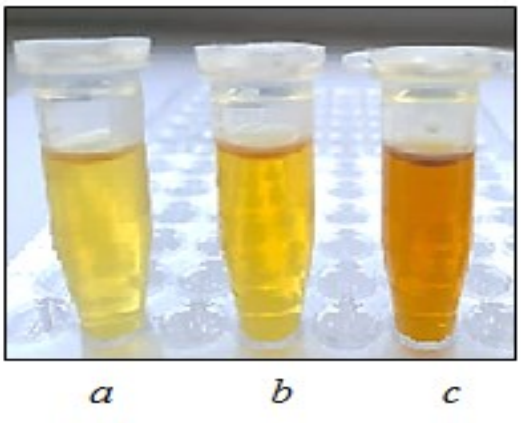


Figure 1: Modified fatliquoring materials:

a - Sulphirol EG 60; b - Synthol LC; c - Sulphirol C

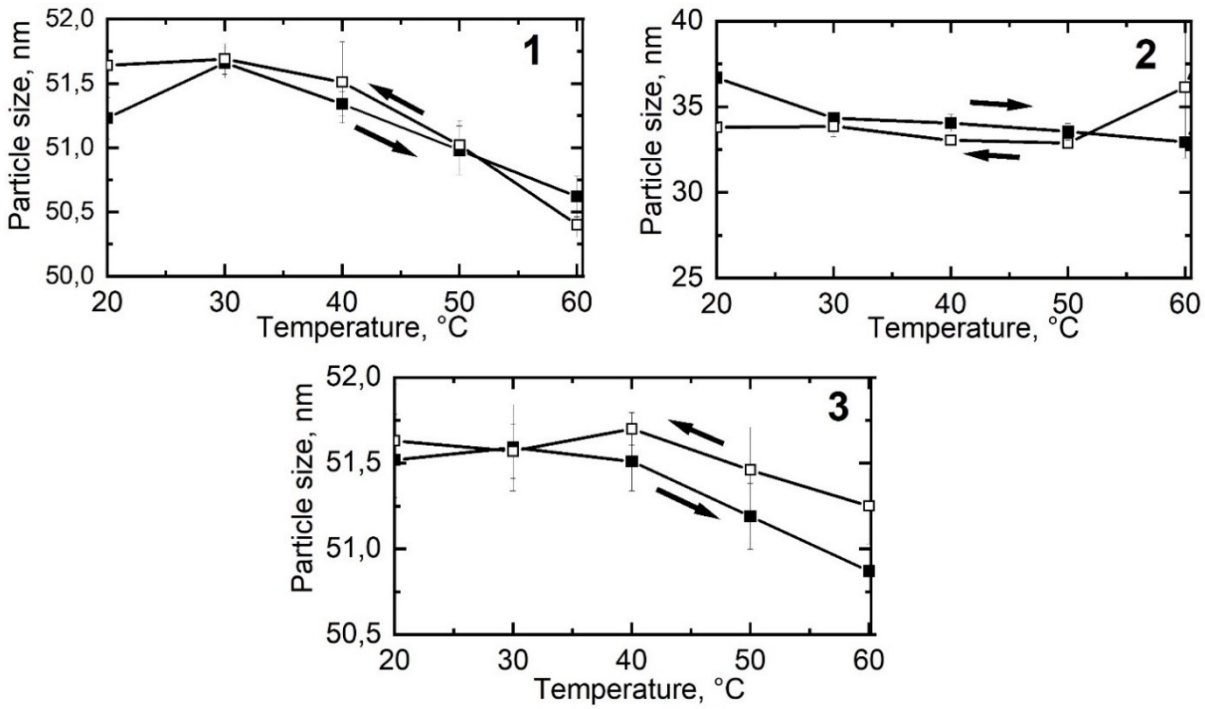
The particle size and zeta potential of fat emulsions were determined by DLS dynamic light scattering using a Malvern Zetasizer Nano ZS analyzer (Malvern Instruments Ltd, Malvern UK) and the Zetasizer Software 8.01.4906 SOP Player program. The measurement range of the device was 0,1-10000 nm. Emulsion samples were prepared at a concentration of 5% and 25% by diluting with water at a temperature of 60 °C with constant stirring. The properties of the obtained emulsions were controlled visually by appearance and analytically by particle size and zeta potential at room temperature, and by dispersion also in the "heating/cooling" mode. For this, the emulsions were gradually heated to 70°C, and then also gradually cooled to 20°C. The temperature regime was selected, and subsequently adjusted taking into account the acceptable conditions for the preparation of stable emulsions and the processing of leather (or rather, semi-finished leather Wet Blue).

3. RESULTS

As a rule, emulsions contain drops-particles of different sizes, so their properties are evaluated by the size and nature of the distribution of these particles. The presence and sign of charge is equally important for the state and behavior of emulsions. Based on the above, the properties of the investigated emulsions were determined using indicators of average particle diameter, polydispersity index, and zeta potential. The obtained results are shown in the table. 1-2 and Fig. 2-3.

Table 1: Characteristics of initial emulsions (temperature 20°C)

Fatliquoring material (emulsion concentration)	Average diameter (nm)	Index of polydispersity	Zeta-potential (mv)
Sulphirol EG 60 (5%)	51,23±0,162	0,121±0,008	-26,5±0,968
Synthol LC (5%)	34,69±0,214	0,403±0,008	-42,8±1,541
Sulphirol C (5%)	51,49±0,270	0,225±0,006	-46,6±1,192
Sulphirol EG 60 (25%)	95,10±1,865	0,418±0,055	-11,3±0,944
Synthol LC (25%)	108,2±3,016	0,607±0,028	-40,6±1,851



Sulphirol C (25%)	83,30±2,662	0,916±0,039	-15,2±2,263

Figure 2: Change in particle size of 5% emulsions of modified f fatliquoring materials in heating/cooling mode: 1 - Sulphirol EG60; 2 - Sulphirol C; 3 - Synthol LC

Table 2: Characteristics of emulsions (heating/cooling mode)

Fatliquoring material (emulsion concentration)	Average diameter (nm)	Index of polydispersity	Average diameter (nm)	Index of polydispersity
	Heating mode		Cooling mode	
	20°C		**60°C**	
Sulphirol EG 60 (5%)	51,23±0,162	0,121±0,008	50,40±0,096	0,124±0,003
Synthol LC (5%)	34,69±0,214	0,403±0,008	36,15±4,153	0,262±0,120
Sulphirol C (5%)	51,49±0,270	0,225±0,006	51,25±0,220	0,217±0,001
Sulphirol EG 60 (25%)	95,10±1,865	0,418±0,055	408,2±3,367	0,196±0,012
Synthol LC (25%)	108,2±3,016	0,607±0,028	159,7±8,589	0,579±0,046
Sulphirol C (25%)	83,30±2,662	0,916±0,039	92,38±6,197	0,673±0,129
	60°C		**20°C**	
Sulphirol EG 60 (5%)	50,62±0,157	0,112±0,008	51,64±0,208	0,118±0,008
Synthol LC (5%)	32,94±0,150	0,355±0,004	33,79±0,246	0,363±0,011
Sulphirol C (5%)	50,87±0,240	0,215±0,004	51,63±0,329	0,225±0,007
Sulphirol EG 60 (25%)	105,90±5,303	0,343±0,050	417,9±6,049	0,176±0,020
Synthol LC (25%)	100,2±3,736	0,551±0,029	157,5±1,200	0,622±0,009
Sulphirol C (25%)	82,05±6,015	0,687±0,152	95,47±1,746	0,600±0,029

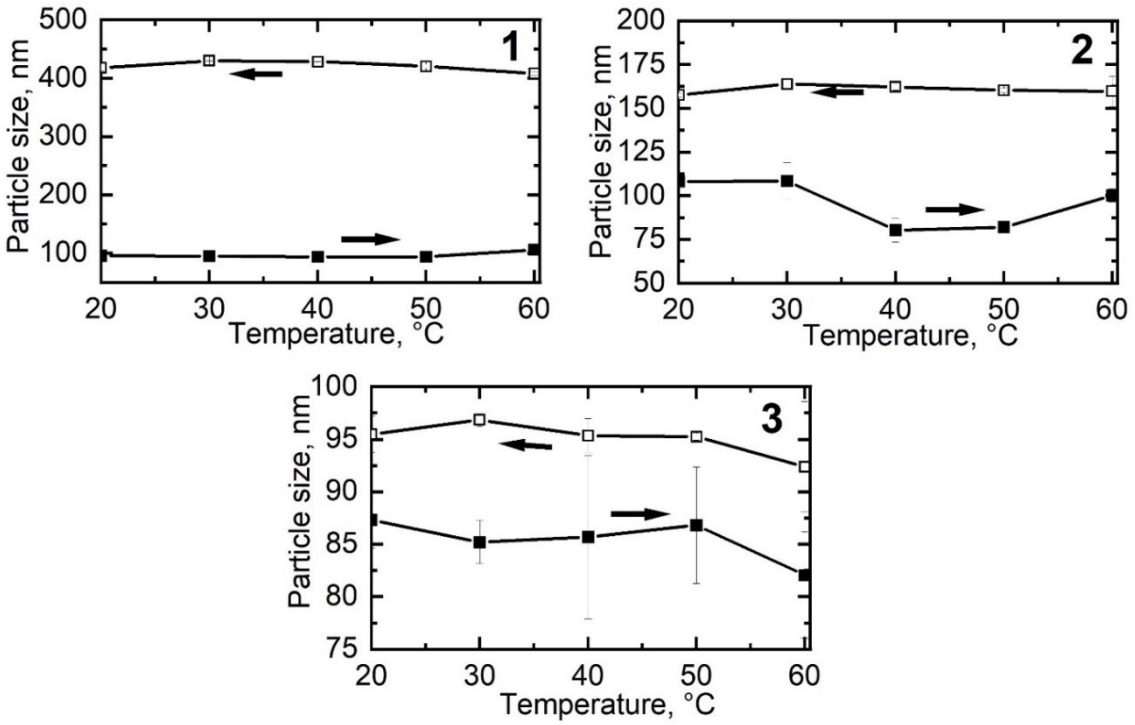


Figure 3: Change in particle size of 25% emulsions of modified f fatliquoring materials in heating/cooling mode: 1 - Sulphirol EG60; 2 - Sulphirol C; 3 - Synthol LC

4. DISCUSSION

The average particle size and zeta potential are considered important parameters in evaluating the stability of emulsions [1, 8]. In addition, the dispersion of the fat intended for the production of skin determines the effectiveness of lubrication of the structural elements of the dermis. If the particle size is reduced, the emulsions have a larger surface area per unit volume, which, in turn, facilitates the course of chemical reactions and increases the binding of fat to skin fibers [9].

Listed in the table. 1, the characteristics of the emulsions indicate that, in terms of particle size, the studied emulsions can be attributed to nanomaterials, since the indicator is at the level of 34,69-95,10 nm, with the exception of the 25% Synthol LC emulsion, where it is slightly larger (108,2 ±3,016 nm).

The distribution of particles in low-concentration Synthol LC and Sulphirol C emulsions is quite heterogeneous, which indicates the polydisperse nature of the system. The nature of the distribution of particles in the low-concentration Sulphirol EG 60 emulsion is monodisperse. When the concentration of emulsions is increased to 25%, an increase in the size of the particles by 1,62-3,12 times and a wider distribution of their size is observed (the polydispersity index increases by 1,51-4,07 times). However, even in this case, the fat emulsions have such particle sizes that will allow them to pass through the pores of the dermis deeper into the collagen matrix and be more evenly distributed in it, thus forming the desired properties (strength, softness, elasticity) and the yield of the skin by area .

Based on the results of the zeta potential analysis, it was established that low-concentration 5% Synthol LC and Sulphirol C emulsions have higher stability (–42,8 and –47,6 mV, respectively) than the identical Sulphirol EG 60 emulsion (-26,5 mV). When the concentration of emulsions increases to 25%, this indicator decreases for lubricating materials Sulphirol EG 60 and Sulphirol C, for Synthol LC it remains almost unchanged (about -40 mV).

Traditionally, the process of emulsion fatliquoring is carried out at a temperature not higher than 60-65°C. There are known methods of carrying out this process at different temperatures, for example, 50-55°C using a mineral- fatliquoring composition of natural fats and oils (including beef fat, as a product of leather processing), which were stabilized by modified montmorillonite dispersions [5], or 36-38°C in the case of chrome-emulsion tanning, when fat emulsions are used to treat the rind - a deashed, softened semi-finished product at the stage of pre-tanning and tanning processes [6].

Therefore, it was interesting to evaluate the properties of fatliquoring emulsions in a wider temperature range. For this purpose, the studied emulsions were gradually heated for 2 hours to a temperature of 70°C, holding for 2 minutes at a certain temperature for thermal stabilization, and similarly gradually cooled for 2 hours to a temperature of 20°C. The destruction of emulsions after two hours of heating to 70°C was visually determined. Because of this, in the future, the heating cycle was carried out in the range of 20-60 °C, and the cooling cycle in the range of 60-20 °C.

The results of the influence of the temperature regime on the size and nature of the distribution of particles in emulsions are shown in fig. 2,3 and in table. 2, which show a tendency to decrease the size of emulsion particles by 0,61-8,00 nm during heating, which is probably due to a decrease in the surface tension of fat.

An exception is the heating of 25% Sulphirol EG 60 emulsion, which caused the aggregation of particles, which was manifested in an increase in the size of the latter by 10,2%. The results of the influence of the cooling mode of emulsions on the size of particles are not so unambiguous, since in some cases there is an increase, in others - a decrease of this indicator. Attention is drawn to 25% Sulphirol EG 60 and Synthol LC emulsions, whose particle size index in the cooling mode is 3,85-4,39 and 1,46-1,59 times higher, respectively, than the index at the same temperature in the heating mode.

The influence of the heating/cooling regime on the distribution of particles in the emulsion volume is less significant: the difference in the polydispersity index for the initial and heated to 60 °C or cooled to 20 °C emulsions is within 0,01-0,08 abs. units, with the exception of 25% Sulphirol C emulsion. The high (0.916) polydispersity index of this emulsion at room temperature, that is, before heating, indicates significant heterogeneity of the system. which decreases after heating to 60°C by 1,33 times. When the sample of the specified emulsion is cooled to 20°C, an increase in the size of the particles is observed due to their merging with smaller particles.

The above can be explained by phase transformations that occur or, conversely, do not occur in the studied systems, which, in general, affects their properties.

5. CONCLUSIONS

As a result of the study of the properties of the emulsions of three modern, commercially available modified fatliquoring material, data were obtained on the dispersion, zeta potential, and character of the particle distribution of these emulsions at room temperature, as well as on the change in the size and character of the particle distribution in the heating/cooling mode in the temperature range of 20-70°C/70-20°C. Thus, it was established that under normal conditions, at room (20°C) temperature, 5% emulsions of modified fatty materials have an anionic, polydisperous (except for Sulphirol EG 60) character. All emulsions are quite stable (zeta potential at the level of -26,5-46,6 mv) and highly dispersed (average particle diameter in the range of 34,69-108,2 nm). Emulsions with such characteristics are able to penetrate through the pores of the dermis deep into the collagen matrix, and, reaching the elements of the supramolecular structure, adsorb and fix on their surface due to the presence of functional groups. Increasing the concentration of emulsions from 5 to 25% contributes to the thickening of emulsion particles, the formation of a polydisperse nature of their distribution, and a decrease in zeta potential, which, however, should not negatively affect the technological capabilities of these materials, each of which has its own characteristics. The influence of the heating/cooling regime in the considered temperature range on the properties of the investigated emulsions depends on the concentration of the emulsion and the type of fatliquoring material, the processing conditions. The results of the work will be used in further research on the creation of an innovative technology for the production of leather of a modern assortment using modified fatliquoring material.

REFERENCES

[1]. Zhuravsky, V., et al: *TECHNOLOGY OF LEATHER AND FUR,* STATE ACADEMY OF LIGHT INDUSTRY OF UKRAINE, ISBN 5-8238-0500-4, KYIV, (1996).

[2]. Andreyeva, O., Tsemenko, G.: *COMMODITY ANALYSIS OF LEATHER AND FUR RAW MATERIALS*, KONDOR, ISBN 978-966-351-399-7, KYIV, (2012).

[3]. Andreieva, O., et al.: *FEATURES OF LEATHER AND FUR RAW MATERIALS,* SVIT USPICHU, ISBN 978-617-7324-27-9, KYIV, (2019).

[4]. Danilkovych, A., Mokrousova, O: *EFFICIENT TECHNOLOGIES FOR FORMING THE PROPERTIES OF ELASTIC LEATHER MATERIALS*, FENIKS, ISBN 978-966-136-475-1, KYIV, (2017).

[5]. Gorbachev, A., et al: *FUNDAMENTALS OF CREATING MODERN TECHNOLOGIES FOR THE PRODUCTION OF LEATHER AND FUR*, KNUTD, ISBN 5-8238-0500-4, KYIV, (2007).

[6]. Danilkovic, A., et al: *ECOLOGICALLY ORIENTED TECHNOLOGIES FOR THE PRODUCTION OF LEATHER AND FUR MATERIALS FOR THE CREATION OF COMPETITIVE PRODUCTS*, PART 1, FENIKS, ISBN 8-66-651-54-5, KYIV, (2011).

[7]. Covington, A. *TANNING CHEMISTRY: THE SCIENCE OF LEATHER*, ROYAL SOCIETY OF CHEMISTRY, ISBN 978-0-85404-170-1, LONDON, (2009).

[8]. Zaiets, A., Andreeva, O: STUDY OF THE STABILITY OF EMULSIONS OF MODIFIED FATTENING MATERIALS, *PROGRESSIVE RESEARCH IN THE MODERN WORLD*, Proceedings of IV International Scientific and Practical Conference, Komarytskyy, M. (ED.), PP. 212-219,

ISBN 978-1-73981-125-9, Boston, USA, 28-30 December 2022, BoScience Publisher, Boston, USA, (2022).

[9]. Ali, Y.: EMULSIFICATION AND APPLICATION OF A THYMOL LOADED ANTIBACTERIAL FATLIQUOR FOR LEATHER INDUSTRY. *JOURNAL OF INDUSTRIAL TEXTILES*. **VOL.** 51 (2021) NO. 3., PP. 470–485, ISSN 1528-0837.

[10]. Lyu, B., et al.: PREPARATION AND APPLICATION OF CASTOR OIL/NANO-TiO_2 COMPOSITE FATLIQUORING AGENT VIA A PICKERING EMULSION METHOD. *JOURNAL OF CLEANER PRODUCTION,* **VOL.** 126 (2016), PP. 711-716, ISSN 0959-6526.

[11]. Murti, R. et al.: THE EFFECT OF PALM OIL SULFATATION TIME ON FATLIQUOR QUALITY AND FINISHED LEATHER PRODUCT, *JOURNAL OF THE AMERICAN LEATHER CHEMISTS ASSOCIATION*, **VOL.** 115 (2020) NO. 5., PP. 184-189, ISSN 29726.

CORRESPONDING AUTHORS:

Antonina ZAIETS
Department of biotechnology, leather and furs, Faculty of Chemical and Biopharmaceutical Technologies, Kyiv National University of Technologies and Design
Mala Shyianovska (Nemyrovycha-Danchenka) Street, 2
01011 Kyiv**,** Ukraine
zaiets.antonina888@gmail.com

Olga ANDREYEVA
Department of biotechnology, leather and furs, Faculty of Chemical and Biopharmaceutical Technologies, Kyiv National University of Technologies and Design
Mala Shyianovska (Nemyrovycha-Danchenka) Street, 2
01011 Kyiv**,** Ukraine
wayfarer14@ukr.net

WOMEN'S FASHION IN HUNGARY IN THE EARLY 20TH CENTURY, REFLECTED IN FASHION MAGAZINES[2]

Péterné KORONA, Virág NÉMETHY

Product Design Institute, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

Abstract

At the end of the 19th century and the beginning of the 20th century, one of the most significant literary, cultural, and fashion magazines was „Magyar Bazár - mint a nők munkaköre, a nőképző-, gazdasszony- és nőiparegylet hivatalos lapja". It provided Hungarian upper-class women with the opportunity to follow the literary life of the era and featured high-quality fashion illustrations. The fashion illustrations followed the latest Parisian fashion trends, accompanied by detailed descriptions. Contemporary marketing was also noteworthy, including advertisements related to the topic. Researching magazines that were published twice a month provides us with valuable insights into the women's attire of that era.

Keywords: *fashion paper, fashion magazines, fashion drawing, women's clothing, early 20th century*

1. INTRODUCTION

The Compromise of 1867, established on the principle of parity, created a constitutional monarchy that granted Hungary significant autonomy in political and economic aspects compared to the preceding period. The era of the Austro-Hungarian Monarchy was characterised by significant economic and cultural development, which manifested in the people's daily lives. During this time of peace, the aristocracy, the affluent middle class, and the bourgeoisie strengthened their positions, making Budapest, beyond the rural elite manors, the bustling centre of literary, cultural, and social life, now united under the name Budapest by the turn of the century.

Budapest's rapid development was evident in every aspect of life, and clothing sought to follow European trends, primarily Parisian fashion. While the wealthiest magnates participated in prestigious social events in London, Paris, Rome, and Vienna, not everyone had the opportunity to stay informed about lifestyle changes and new clothing trends abroad.

Fashion magazines of the time provided this opportunity for "ladies of high society."

[2] MAGYAR BAZÁR- MINT A NŐK MUNKAKÖRE, A NŐKÉPZŐ-, GAZDASSZONY- ÉS NŐIPAREGYLET HIVATALOS LAPJA

2. FASHION INSIGHTS FROM THE ISSUES OF THE „MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE" MAGAZINE FROM 1902-1904

In 1873, the magazine " Magyar Bazár, mint a Nők Munkaköre " was created through the merger of two publications, and it was marked by the influence of Wohl Janka (1846-1901) and Wohl Stefánia (1848-1889) for many years. The subtitle reveals the magazine's ars poetica: "The Gazette of Belles-Lettres, Society, and Fashion." Published twice a month, the fashion magazine, in line with the spirit of the time, served as a guiding light not only in matters of clothing but also in literary and social issues. In addition to their journalistic work, the Wohl sisters excelled in belles-lettres. The literary quality was guaranteed by the support of Arany János and Jókai Mór, who aided the magazine out of personal friendship. After Wohl Janka's death in 1901, the magazine continued under the editorial leadership of S. Hentaller Elma and Mrs. Lónyai Sándorné until the end of 1904. [1,2,3,4]

The magazine, in a relatively large format of 400 mm x 300 mm when closed, dedicated 8 pages to the fashion section in each issue. Its sophisticated typography, meeting the expectations of the time, along with readable yet high-quality articles and detailed model illustrations, made it popular among the "Ladies of High Society." Most readers were regular subscribers who could also take advantage of additional opportunities, such as purchasing discounted patterns for many showcased outfits. The 1st image depicts the elegant cover of the magazine's issue dated February 16, 1903. (Figure 1.)


XXXVIII. évfolyam. Ára: félévre 6 K., negyedévre 3 K. Budapest, 1903. február 16. Hivatkozni kell szám. 4. szám.

MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE

DIVAT.

Figure 1: „Magyar Bazár, mint a Nők Munkaköre", cover. February16, 1903 [5]

"In almost a duty for a woman to express the charm of her personality through her appearance, and in this, filtered through her individuality, she becomes a strong ally of refined fashion," – reads the November 16, 1902, issue of „Magyar Bazár, min a Nők Munkaköre". [„Magyar Bazár, min a Nők Munkaköre", November 16, 1902]. [7]

By the turn of the century, women sought to rid themselves of the hoops of skirts, the bustle (a cushion placed at the back of the hips under the skirt), and unrealistically puffy sleeves. A slender physique became fashionable, as evidenced by the drawings, and according to them, women had to adopt a new posture, with their breasts forward and their hips tilted backwards. The appropriate cuts of clothing slimmed the figure, but to achieve the slender line, the corset worn under the dress also contributed.

Magyar Bazár, as Nők Munkaköre, provided a general picture of fashion changes and served as a guide related to the current events of the seasons. The cold weather meant that aristocratic and affluent middle-class families closed their country estates and summer resorts, returning to their winter homes in bustling Budapest, representing the heart of life in the early 20th century. In the city, there were numerous opportunities for ladies to be seen showcasing their fashionable ensembles. On less chilly afternoons, they enjoyed strolling on Váci Street and the Danube promenade, chatting with acquaintances, and then stopping by an elegant pastry shop, such as Gerbaud, where ladies could meet their friends. Women regularly hosted reception days at their homes, where several visitors would come for "five-o'clock tea." They undoubtedly discussed important topics, but it was also essential to showcase their attire, carefully chosen as a significant part of the lives of upper-class ladies. On these occasions, they wore so-called "walking attire" or "visiting attire." The autumn-winter street outfits were made of warm, wool-type fabrics, velvet, or other fancy materials. The most common colours were grey, black, and grey with black patterns, dark blue, dark green, or darker shades of dappled. The long skirts, reaching to the ankle or sometimes longer at the back, were cut from 3 to 9 parts. This allowed the waist and hips to follow the body's contours and then expand forcefully. Techniques such as insets and pleating were also applied, presumably not using today's procedures. In other styles, the fullness of the skirt's bottom was created with horizontal lines and ruffles. The upper part of the dresses, the so-called "blouse-waist," typically made of the same material as the skirt, or for lighter-coloured blouse-waists, they also wore a short, bolero-like jacket made from the skirt's material. High-necked, almost collar-like necklines were common, which did not exclude the appearance of simultaneously present spreading or other ornate collars. The sleeves of the dresses were consolidated from the shoulder but very loose above the wrist, gathered with a narrow cuff. Even for these relatively everyday outfits, elegant decoration with various techniques and accessories was typical. They used embroidery, trimmings, velvet, or silk ribbons, passementerie cord, their own or different fabric ruffles, lace, enamel buttons, or even copper buckles on belts. A half-length coat with passementerie, ribbon, and embroidery was a complement to visiting ensembles, or in colder winter weather, a thicker felt coat. The fur worn around the neck—a fur-lined leather collar—also served as a kind of status symbol, as genuine noble furs cost significant amounts. (Figure 2.)

Figure 2: Casual dresses and overcoats, September 1, 1903. November 16, 1902. [6, 7]

Social life was found to be an important venue in the theatre, particularly opera performances, which were considered outstanding events where ladies showcased their beautiful dresses. According to the 3rd picture, these dresses had a silhouette like everyday attire, but the details, materials, and accessories greatly differed. The blouses were made of white or other light-shaded fabrics such as silk muslin, voile, silk, or tulle, and for decoration, they used passementerie borders, velvet ribbons, lace, beads, and embroidered inserts. While pairing a light top with a darker skirt harmonising in colour was acceptable, they also embraced dresses where the skirt and blouse sections were made from the same fabric. (Figure 3.)

The most significant message in the January issue was the commencement of the ball season. For this highly important social event, the noble ladies prepared splendid outfits. In the January 16, 1903 issue, the magazine primarily recommends attire for young women, accompanied by descriptions (Figure 4). The dresses are white, light blue, or other pale pastel shades. The materials include tulle, lightweight silk, silk muslin, and "crêpe de Chine." These luxurious, silk-shiny, softly flowing fabrics were richly decorated with lace, soft ruffles, silk ribbons, pearls, flower garlands, and more. The ethereal dresses featured open necklines in various designs, allowing for a beautiful décolletage. It was indicated which dresses were recommended for tall, slender ladies, emphasising their slimness. Among the showcased dresses, only one deviates from this line, gently expanding from the chest downward, reminiscent of the "reform attire," which evokes the empire silhouette. The ball gowns for older women were darker in colour and more subdued, yet they still utilised noble materials abundantly. (Figure 4.)

Figure 3: Ladies at the Theater. February 16, 1903. [5]

Figure 4: Ball Gowns, January 16, 1903. [8]

Following the spirit of the time, sports and physical activity became a new fashion, and women also had the opportunity to try it. In Budapest, the City Park Ice Rink welcomed skaters in January 1870, gaining great popularity by the early 1900s. The January 16, 1902, issue featured illustrations of ladies engaged in ice skating, accompanied by professional descriptions. These differ from what we would expect today as sports attire, but they differ from regular street clothes in that the skirts are narrower and shorter. They used winter-appropriate, thicker fabrics, and fur as a decorative element. Riding was accepted for women in earlier times, but the fashion of the attire varied. The riding outfit shown in Figure 5 was designed with an English skirt and a long frock coat.

Figure 5: Skating Outfits and Riding Attire [9,10]

The emergence and spread of the "automobile" brought about tremendous changes in every aspect of life. The magazine showcased the opportunities provided by the new "devilish vehicle" and the associated dress code. They recommended high-quality and warm clothing for car rides since these cars were open, making protective eyewear an essential accessory for the occasion.

Cycling was typically done in warmer weather, and women's bicycle attire was streamlined and sporty, with shorter yet adequately voluminous skirts to allow for unrestricted movement. (Figure 6)

Figure 6: Automobile attire and bicycle attire [11]

The spring and summer issues naturally assisted the readership with illustrations of clothing suitable for the weather and leisure activities. The silhouette of spring-summer attire fundamentally resembled the models analysed above; however, we observe differences in textiles. Lighter-coloured, often small-patterned, lighter summer fabrics such as linen, batiste, or silk were used, and ruffles, lace, and ribbons were abundantly applied on the skirt and blouse sections. The upper part of the dress was allowed to drape gently over the body, but a belt was mandatory at the waist, emphasising the ladies' narrow waistline. The term "wash dress" was often used for simple summer dresses, mostly made of batiste. This referred to their easy cleaning and washability, as dresses made of silk and other noble materials, richly decorated with lace and embroidery, were cumbersome. In the summer, ornate hats and parasols were essential accessories, protecting their skin from the sun. Tanning was not allowed, and the sleeves of the dresses remained long even on warm days. It was acceptable for women to opt for a more peaceful picnic rather than strolling on the promenade during the summer, with Margaret Island being the most popular spot in Budapest (Figure 7).

Figure 7: Summer Women's Outfits [12, 13]

From the hustle and bustle of Budapest, the affluent individuals travelled to the countryside in the summer, and those who could afford it spent their holidays at the seaside. Contemporary newspapers do not showcase what we now consider beach attire, but we can find so-called "seaside" outfits in the publications. Perhaps the boldest among them were the "bathing suits" intended for young girls, leaving the arms exposed and the shorter skirts revealing the legs covered with stockings. (Figure 8).

Figure 8: Beachwear and swimwear for young girls [14, 15]

Children, especially girls, can be seen alongside the women during the summer events. Little girls' dresses were shorter, reaching around the knees, typically with a cut not at the waistline but lower or expanding from the chest area. The cut of dresses for 12-13 year-old girls increasingly resembled that of adults. And for girls older than this, wearing almost full-length skirts became customary. The materials for children's clothing were batiste or less expensive, thicker fabrics decorated with silk, lace, velvet, or silk ribbons and trimmings. Boys' trousers reached below the knee, and the upper part was adorned with sailor-style collars, with minimal descriptions found about them.

Figure 9: Children's outfits [16, 17, 5]

As in fashion magazines, beautiful clothes are primarily recommended for young and slender, or so-called normal-bodied ladies, and this is the case here as well. The illustrations mostly depict the outfits on tall and slim ladies. The corset was still in use, hence the depiction of unrealistically narrow female waists. However, clothing was also shown for less slender ladies, such as an "Elegant reform outfit" with an embroidered scarf that was not cinched at the waist. Elegant clothes can also be seen for middle-aged and elderly ladies. The "reform outfit" was not only worn by less slender ladies; it represented the latest step in women's clothing reform. This silhouette did not require the forced narrowing of the waist with a corset, providing freedom for women in both a literal and figurative sense. (Figure 10)

Figure 10: Sophisticated Reform Outfits [8, 15]

The magazine presented the current fashion of various undergarments and accessories, allowing the elegant ladies to expand their repertoire. The lingerie may seem whimsical by today's standards, made of white or other pale shades of delicate batiste. Attention was paid to beautiful, delicate embellishments, including embroidery, various lace, and ribbons. The key piece among visible accessories was the hat, whose decoration knew no bounds. Depending on the weather and the occasion, hats varied in size, sometimes resembling a flowery basket with cascading flower garlands, occasionally even incorporating small birds. Hats adorned with tulle, lace, beads, or fur in winter were considered everyday wear. There were regulated or recommended fashions for the hairstyles under the headwear, and the magazine also provided instructions for this. Accessories such as the parasol, walking stick, or small purse, and in winter, the hand-warming muff, were important complements to women's attire. The above images illustrate the accessories that match the outfits.

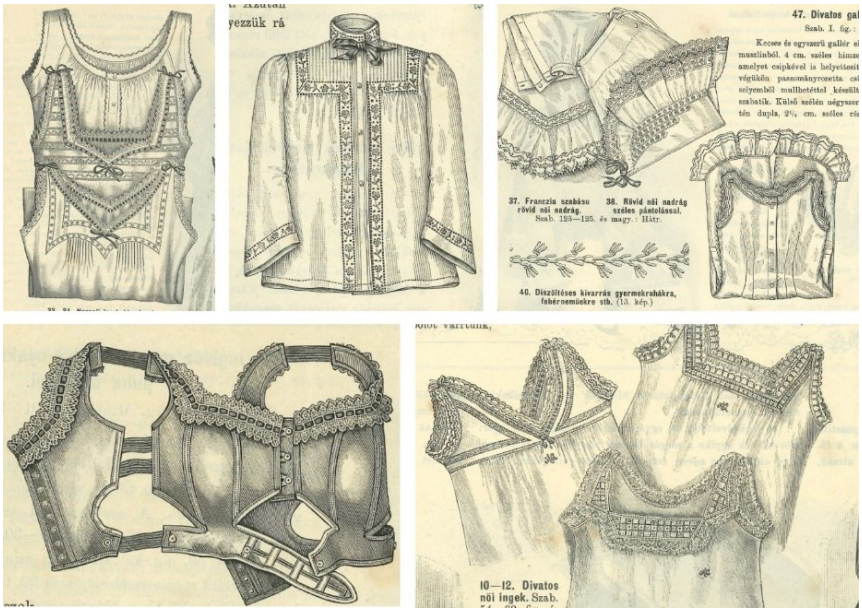


Figure 10: Contemporary Undergarments [13, 15, 17, 18]

Strangely, in the fashion sections of Magyar Bazár, men's attire is difficult to find. Throughout the study of numerous magazines, we only found one men's housecoat. While this is understandable for specifically women-oriented events, it leaves a sense of lack when it comes to formal events, where we miss seeing gentlemen's attire, as these were important social occasions.

In several issues, the "Monaszterly és Kuzmik" company was frequently mentioned in magazine pages, where ladies of high society could purchase their dresses. The store was located at Váci utca 15 and operated for years, considered one of the most elegant shops. They sourced information about the latest fashion and often the textiles themselves from Paris. It's not clear what kind of relationship existed between the magazine and the fashion store; there might have been a contractual agreement, as other advertisements also appeared in the magazine. Besides Montaszterly és Kuzmik, numerous other salons, milliners, lingerie and shoemakers ensured that beautiful Hungarian women could shine in stunning outfits.

3. SUMMARY

The magazine "Magyar Bazár, mint a Nők Munkaköre" played a significant role in informing upper-class ladies between 1873 and 1904. This encompassed both social and literary life, as well as fashion. Its appearance and graphics were of a similar high standard to prominent foreign publications of the time. The magazine successfully fulfilled its goal of elevating Hungarian intellectual standards, refining the mindset of women, and aspiring to be a friend to Hungarian noble families. It provided information to upper-class ladies about the latest fashion trends, procurement and solution options, which they enthusiastically welcomed. Magazines like this one contributed to establishing Budapest as the "fashion capital," following Paris.

REFERENCES

[1] F. Dózsa Katalin: *PESTI NŐ A SZÁZADFORDULÓN*, 1991. március 20.–aug 20. kiállítás ISBN 963-7421459
[2] https://sajtomuzeum.oszk.hu/forrasok/hirlapjaink/pdf/2_magyarbazar.pdf (Accessed: 14. September 2023.)
[3] Mészáros Zsolt: *A WOHL-NŐVÉREK NEMZETKÖZI FOGADTATÁSÁRÓL TRANSZNACIONÁLIS KONTEXTUSBAN,* EPA03580_Helikon_2017_3_418-429,
[4] Mészáros Zsolt: A MODERNITÁS ÉS AZ EMANCIPÁCIÓ HATÁRVIDÉKÉN A Magyar Bazár irodalmi vonatkozásai a Wohl-nővérek szerkesztése alatt (1873–1901) Irodalom a sajtóban, Acta Acad. Agriensis, Nova Series Tom XXXIX (2012)
[5] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE,* 1903. február 16. XXXVIII. Évf., 4. szám
[6] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1903. szeptember1. XXXVIII. Évf. 17. Szám.
[7] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1902. november 16. XXXVII. Évf. 22. szám.
[8] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1903. január 16. XXXVIII. Évf., 2. szám.
[9] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1902. december 16. XXXVII. Évf. 24. szám
[10] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1902. szeptember 1. XXXVII. Évf. 17. szám.
[11] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1903. március 16. XXXVIII. Évf. 6. Szám.
[12] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1903. augusztus 16. XXXVII. Évf. 16. szám
[13] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1902. augusztus 16. XXXVIII. Évf. 16. szám.
[14] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*,1903. július 16. XXXVIII. Évf. 14. szám.
[15] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1903. június 16. XXXVIII. Évfolyam, 12. szám.
[16] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1903. február 16. XXXVIII. Évfolyam, 4. szám.
[17] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1903. június 1. XXXVIII. Évf.11. szám.
[18] *MAGYAR BAZÁR MINT A NŐK MUNKAKÖRE*, 1902. március 1. XXXVII. Évf. 5. szám.

CORRESPONDING AUTHORS:

Péterné KORONA, Virág NÉMETHY
Product Design Institute, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University
Doberdó út 6, 1034 Budapest, Hungary
E-mail: korona.magdolna@rkk.uni-obuda.hu, nemethy.virag@uni-obuda.hu

TEXTURES AND TEXTS – MATERIAL IMPRINTS OF HUMAN EXISTENCE IN LITERATURE

Edit CSANÁK

Product Design Institute, Rejtő Sándor of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

Abstract

Traditionally, both clothing and architecture serve the human way of life. Textiles and architecture are connected straightforwardly and fundamentally. According to Plato, the Greek philosopher, "Our first and greatest need to live at all, to exist, is to get food. (...) Our second need is housing; the third is clothing, and so on." (Platón, 1988.) Textiles and fashion provide people with wearable clothes. Architecture provides a home for people to live in. Plato called weaving itself a "royal process," emphasising the importance of constructing clothing with balanced concern; the construction of clothing should be done with the same rigour and precision as the design of a building.

Although textiles, fashion and architecture are connected on several levels, and these areas mutually influence each other in terms of, for example, proportions, shapes, materials, colours, functions, and visual tools, this article does not focus on examining them and limiting itself to the discourse of textiles, highlighting that some exciting contemporary research has shed light on the presence of textiles in written sources and the diversity of descriptions related to textile making and dressing in literature. This study is in the early stages of research, and the investigation needs to be more comprehensive; it is more like a teaser.

Keywords: *textiles, clothing, weaving, sewing, embroidery, literature, arts and humanities, gender equality*

1. THE IMPORTANCE OF TEXTILES FOR HUMAN EXISTENCE

"We need houses as we need clothes; architecture stimulates fashion. It's like hunger and thirst — you need them both." Karl Lagerfeld

Textile production is one of the oldest cultural technologies. Textiles occupy an increasingly important place in the global economy and culture. This is proven by the marked social, art-historical, artistic and scientific interest in textiles as mediums, materials, technology and metaphors in the last decade. Many interdisciplinary research projects are interested in examining the historical meaning and functions of the textile medium in art and architecture from the Middle Ages to the present day. The discourse of textiles is a new, complex and challenging field of research involving other fields of science, such as literary studies and social history. It has resulted in many exciting research and publications in the last decade. [1] [2]

The history of mankind is intertwined with the history of textiles - the history of textiles is as old as civilisation itself. The origin of chemistry is rooted in the colouring and finishing of clothes. Selective breeding for the production of fibre marked the birth of agriculture. Textiles have created empires, fueled

inventions, and been the engines of industrial revolutions. They built trade routes and drew the borders of nations. Since the first thread was spun, fabric has driven technology, economics, politics and culture. From the Minoans, who exported wool fabric dyed with precious purple dye to Egypt, to the Romans, who wore wildly expensive Chinese silk, textile production and trade paved the way for the ancient world economy and culture. Like spices or gold, the trade in fabrics and dyes spurred sailors to cross seas and oceans, creating a globally connected world economy today. [3]

Textiles include rugs, bed linen, tablecloths, tapestries, linens, and blindfolds. They tell of a home created by a woman's hand and of life, birth, and death. Textiles surround and envelop us from birth to death: our swaddling clothes are made of them, our clothes are made of them, and our coffins will be lined with them. (Fig. 1)

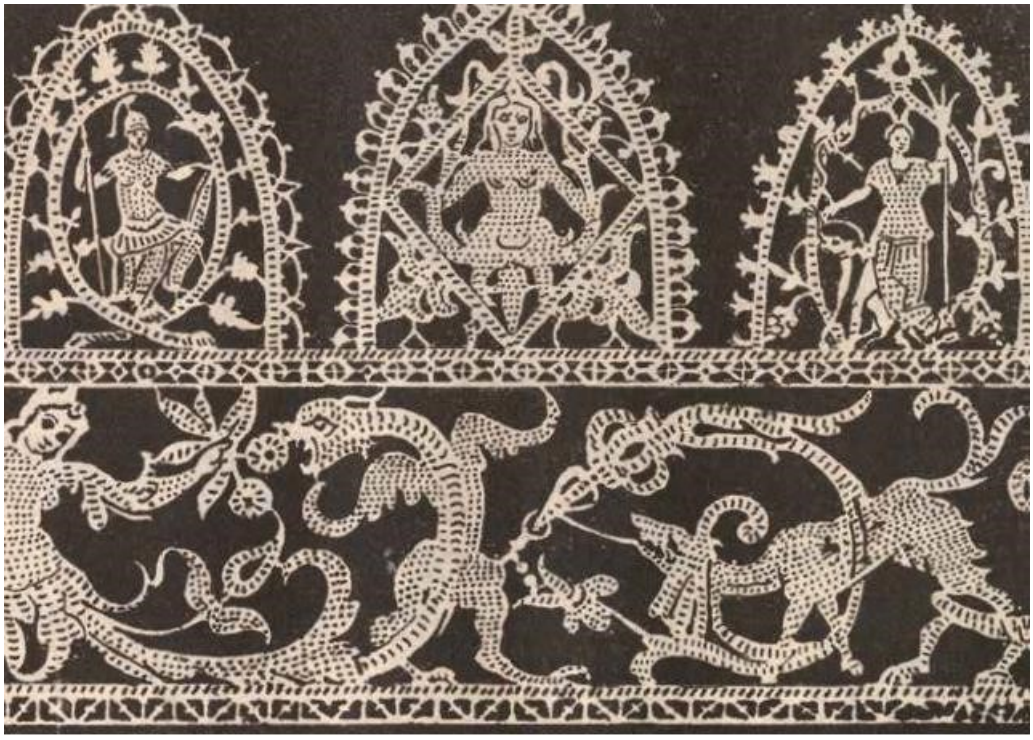


Figure 1: Lace pattern (detail), Cesare Vecellio, Corona delle nobili, e virtuose donne (Venice, 1592–1608).

Textiles are closely related to human survival and have lifelong significance – practical and symbolic. Textiles are a part of everyday life and affect all areas of human existence. The human body is covered by clothes made of woven, knitted or crocheted fabrics. Our homes are covered, lined and decorated with textiles; the textile provides warmth, comfort and protection against external forces. Textile clothing, beyond the biological need (see: protection of the body), indicates social belonging and individual identity through the characteristics of fabric and tailoring, design, and, especially in our time, the logo.

The colours and shapes of the flags and the symbols and decorations woven or sewn on them led the army in battle and defined national identity even today. National and folk costumes determine the

consciousness of nations, ensuring their identity and cultural sustainability. The global brands worn by young people are tools for individual self-expression and a sense of social belonging and identity. As a result, textiles are part of humanity's consciousness; they are imbued with historical, political, economic, personal, social, aesthetic and spiritual significance and contribute to the image of the world's cultures and linguistic representation.

From the beginning, the spinning and weaving of threads, the joining of threads, and the decoration of fabric interact with human life and the entanglements in human society. The descriptions of the processes related to textile production, which in some cases refer to the physical properties of the textile components and the textile manufacturing process, have significant semiotic and scientific value. To this day, it is accepted in the world's cultures that textiles have meaning and convey meaning.

2. MYTHS AND EPICS: CLOTHING DESCRIPTIONS, METAPHORS AND ARCHETYPES

The clothing has been described in literary sources since the beginning. In one of the first known literary works, the Epic of Gilgamesh (Gilgamesh, 2004), the following can be read:

"Gilgamesh washed out his long locks and cleaned his weapons; he flung back his hair from his shoulders; ***he threw off his stained clothes and changed them for new. He put on his royal robes and made them fast."*** *(...)"There he shall wash his long hair clean as snow in the water, he shall throw off his skins and let the sea carry them away, and the beauty of his body shall be shown, the fillet on his forehead shall be renewed, and* ***he shall be given clothes to cover his nakedness****. Till he reaches his city and his journey is accomplished,* ***these clothes will show no sign of age; they will wear like a new garment."*** [4] *"O Enkidu, all the people are dressed in their gorgeous robes; every day is a holiday, and the young men and the girls are wonderful to see." (...) "Ninsun went into her room,* ***she put on a dress becoming to her body, she put on jewels to make her breast beautiful, she placed a tiara on her head, and her skirts swept the ground."*** [5]

Texts have long used textiles as a medium for symbolic thinking. In his work The Republic, the philosopher Plato speaks to his contemporaries about friendship as ***"the finest and best of fabrics".*** Concerning "Beautiful style, beautiful morality, beauty, music, and love", Plato puts it as follows: *"Beautiful speech, beautiful tone, beautifully arranged form, beautiful rhythm are all adapted to beautiful morality (...) Do not young people have this in everything they have to follow if they want to fulfil their vocation? (...) "Good speech, then, good accord, and good grace,* [6] *and good rhythm wait upon good disposition, not that weakness of head which we euphemistically style goodness of heart, but the truly good and fair disposition of the character and the mind. And must not our youth pursue these everywhere if they are to do what it is truly theirs to do? And there is surely much of these qualities in painting* [7] *and in all similar craftsmanship –* ***weaving is full of them and embroidery*** *and architecture and likewise the manufacture of household furnishings and thereto the natural bodies of animals and plants as well. For in all these, there is grace or gracelessness. And gracelessness and evil rhythm and disharmony are akin to evil speaking, and the evil temper, but the opposites are the symbols and the kin of the opposites, the sober and good disposition."* [8]

Myths from many cultures create connections and archetypes between weaving and female deities. In this regard, we owe a lot to, for example, Greek mythology. Some of these myths reveal dangerous concepts and suggest subversive ideas.

In the myth Odyssey, Penelope embodies female loyalty, who waited for her husband, Odysseus, for twenty years until he could finally return home. For three years, she wove the death shroud for her father-in-law, Laertes, thus devoting herself to answering the suitors who harassed her in Odysseus's absence. What he weaved during the day, he broke down at night. (Fig. 2)

Figure 2: Penelope, the mythical weaver in a painting by John William Waterhouse (1912)

Other mythical figures are also strongly associated with textiles. The three monstrous Moria - Klotho, Lachesis and Atropos - who are called the goddesses of fate, the goddesses who "distribute portions" in Greek mythology, carry out the will of Zeus regarding the length of human life, weaving (Klotho), coiling (Lachesis) and cutting (Atropos) the thread of human life. In the illustrations, their working tools, the spindle, the yarn and the scissors, are always clearly depicted. Emphasising the elementary aspects of this female craft, the myth creates a symbolic connection between women's handiwork and human destiny. (Fig. 3)

Figure 3: Clotho, Lachesis and Atropos, the three messengers of Fate - Flemish tapestry (Brussels, c. 1510-1520), Victoria and Albert Museum, London

Textiles also inform language. In word images, we often use words that refer to the physical tasks of textile production or the properties of textiles (e.g. fabric, weaving, sewing, knitting, cloth, cloth, spinning, yarn). We string different ideas together, get entangled in our webs, and feel worn out. In early civilisations, textile metaphors were used as an analogy for creation and the lives of generations. These include the thread as a line and as a life path. *"Gladly surrender yourself to Clotho: let her spin your thread into whatever web she wills."* [9]

The linear aspects of the thread are interpreted as a line or path, and the entanglement and separation of the threads paradoxically represent the double value of togetherness and separation. Furthermore, the symbolic act of textile making, which practically creates something from nothing, is the generative and expansive activity associated with expansion, birth, and growth.

The Roman poet Caius Valerius Catullus sings of the marriage of Achilles' parents, Thetis and Peleus [10]:

"No house has ever sheltered such love,
no love has ever joined lovers in such a union,
even as harmony comes to Thetis and Peleus.
Fly, guiding threads: fly, spindle."

The famous chorus line ("Fly, guiding threads: fly, spindle.") indicates that the fate goddesses do not read the future from signs but determine it by weaving the thread of fate: their song informs the wedding party about what they are weaving for the young people.

In Norse mythology, the Norns spin the thread of life for all men. The strength and beauty of the threads are different: the thread is primarily grey and coarse, and only very rarely do the Norns spin a shiny golden thread for heroes or princes. (Fig. 4)

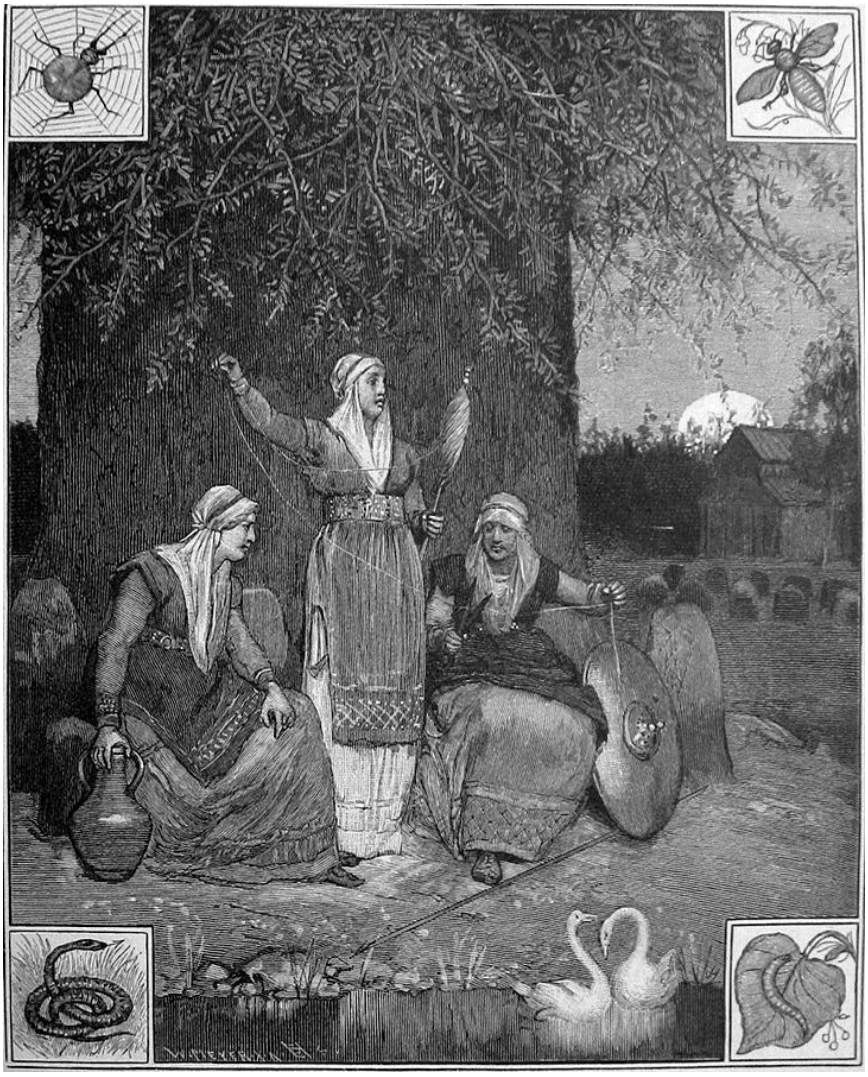


Figure 4: Norns weaving threads of fate at the feet of Yggdrasil, L. B. Hansen, 1893

3. THE MAGIC OF WEAVING, SEWIN AND THE CLOTHES IN FAIRY TALES

The mystery of women's needlework, the magic created by fragile hands, is also immortalised in countless tales. The creative power of textile work, its characteristic and ability to transform flimsy threads into material and works of art, is an act of magic. Folktales abound with stories of spinning, weaving, and sewing in which such magic is realised. There are many examples in the literature of spells produced by handwork and the realisation of spells in the form of protective talismans, amulets and clothes.

"Once upon a time in midwinter, when the snowflakes were falling like feathers from heaven, ***a queen sat sewing at her window, which had a frame of black ebony wood.*** *She looked at the snow as she sewed and pricked her finger with her needle. Three drops of blood fell into the snow. The red on the white looked so beautiful that she thought to herself, "If only I had a child as white as snow, as red as blood, and as black* ***as the wood in this frame.*** Soon afterwards, she had a little daughter (…) they called her Little Snow-White.*"* [11] (Fig. 5)

Figure 5: (left) Snow White's mother, from the Disney cartoon Snow White and the Seven Dwarfs. (Disney Archive); (right) Disney: Sleeping Beauty (1959) © AFP

In the Grimm Brothers fairy tale Sleeping Beauty, the Evil Queen[3] Maleficent cursed the baby princess, according to which a poisoned spindle will kill her on her sixteenth birthday. *"In the fifteenth year of her age,* ***the princess shall prick herself with a spindle and fall dead!*** *(...) The king, hoping to save his child even from this misfortune, commanded that* ***all spindles be burned.*** *This was done, but it was all in vain. (...) One day (...), she wandered about the palace and at last came to a little room at the top of a tower.* ***There, an older woman*** *(...)* ***sat spinning.***
"What are you doing, good old woman?" asked the princess.
*"****I am spinning****, my pretty child."*
"Ah," said the princess. "How do you do it? Let me see if I can spin also." She had just taken the spindle in her hand when (...) [12]

[3] Named in the 1959 Disney cartoon version Maleficent, a personification and incarnation of pure evil. (See Figure 5, right)

The tales make it clear that textiles and the activities related to their creation have characteristics that grow into metaphors and associations that later become diverse magical experiences. Clothes have mystical powers in fairy tales. According to the classic fairy tale topos, clothes change everything; such a dress allows Cinderella to attend the ball. [13]

"(...) Cinderella went to her mother's grave beneath the hazel tree and cried out:
Shake and quiver, little tree,
Throw gold and silver down to me.
Then the bird threw a ***gold and silver dress*** *down to her and* ***slippers embroidered with silk and silver****.*
She quickly put on the dress and went to the festival." [14]

Folktales talk more about clothes and clothing than we might think at first. Clothing typical of a fairy tale hero or character carries many different meanings. The reason for this is rooted in the unified worldview, according to which clothing reflects who the wearer is. Who does not know "The Emperor's New Clothes" by Hans Christian Andersen? It is a folktale about a vain emperor who exposes himself to his subjects. *"Many years ago, there lived an emperor* ***who loved beautiful new clothes*** *so much that* ***he spent all his money on being finely dressed****. His only interest was going to the theatre or riding in his carriage, where he* ***could show off his new clothes. He had a different costume*** *for every hour of the day. Indeed, where it was said of other kings that they were at court, it could only be said of him that* ***he was in his dressing room!*** *One day, two swindlers came to the emperor's city. They said they were weavers, claiming* ***they knew how to make the finest cloth imaginable.*** *Not only were the* ***colours and the patterns extraordinarily beautiful****, but this material also* ***had the amazing property*** *that it was to be invisible to anyone incompetent or stupid."(...)* [15] So the swindlers set up their looms and pretended to go to work, although nothing was on them. They asked for the finest silk and the purest gold, all of which they hid away, continuing to work on the empty looms, often late into the night.

In summary, many examples in the literature of magic take the form of hand-crafted protective talismans, amulets, and clothing. Folktales talk more about clothes and clothing than we might think at first. Clothing typical of a fairy tale hero or character carries many different meanings. The reason for this is rooted in the unified worldview, according to which clothing reflects who the wearer is. Further paradoxes in the interpretation of textiles can be found in the characteristics of the fabric's wearing and the description of the clothes; the textile is a material that wraps the body and represents the character.

2. FEMALE CHARACTERS AND TEXTILES IN WORLD LITERATURE

Women's intimacy and relationship with fabrics – the personal relationship between textiles and their makers – has always inspired writers from ancient times to the present day. In the majority of ancient cultures, women were responsible for making textiles, and it remained so for centuries. The relationship between the women involved in the textile production process has been one of the cornerstones of social norms for centuries. The value of women's needlework as a way of self-expression is reinforced by the number of recurring literary motifs, which descriptively demonstrate the ability of textile production to absorb the spirit of its maker and to contain the secrets of women. As a result, literature from different cultures and eras abounds with descriptive depictions of women engaged in textile production. The result is a rich archive of texts containing images and descriptions of women practising their craft skills in

various ways. The authors often describe such activities for the sake of authenticity and creating an atmosphere for each text, but at the same time, these texts are also rich in details regarding how the textiles are made.

The relationship between the women involved in the textile production process has been one of the cornerstones of social norms for centuries. The value of women's needlework as a way of self-expression is reinforced by the number of recurring literary motifs, which descriptively demonstrate the ability of textile production to absorb the spirit of its maker and to contain the secrets of women. As a result, literature from different cultures and eras abounds with descriptive depictions of women engaged in textile production.

Figure 6: Joshua Reynolds: Portrait of the Waldegrave Ladies, 1780.

The writers of the texts put the work of women's hands into a new dimension from the observer's perspective, identifying women's textile work with the woman herself. As a consequence of this association, the literary descriptions of women performing their textile activities provide a complex array of psychological elements while simultaneously serving as a complex expression of emotions

among the women undertaking these tasks. Such depictions offer insight into women's external and internal characteristics and lives, reflecting and highlighting the expected female characteristics and behaviour patterns. Such patterns ensure in literary works that depictions of women's handiwork can contribute to constructing a complex, often symbolic narrative. (Fig. 6)

Accounts of the past come primarily from male authors whose focus is on recording masculine achievements and activities. The State in Plato c. although in her work she carefully deals with the situation, rights and obligations of women and children, she summarises her opinion regarding women's tasks as follows: *"...let's mention weaving, making cakes and cooking vegetables, which the female gender is also good at, so it would be fun if even in this the men would boil me?"* [16][4]

Before the 19th century, women had few opportunities to participate in managing their lives. For generations, most women had limited access to education, which is why traditional women's handicrafts, such as spinning, weaving, knitting, sewing, and embroidery, met a particular need. On the one hand, these occupations offered women tools for communication and self-expression, refuting the expectations of women's passive role in society. A good part of the writings after the 19th century abound in female characters. In addition to portraying women, the descriptions still contain society's social judgment on women.

"But when she[5] heard he had a daughter, she began to make inquiries, and she learnt the Mademoiselle Rouault, brought up at the Ursuline Convent, had received what is called "a good education"; and so knew dancing, geography, drawing, how to embroider and play the piano. That was the last straw." [17]

"... Women are supposed to be very calm generally, but women feel just as men feel; they need exercise for their faculties and a field for their efforts as much as their brothers do; they suffer from too rigid a restraint, too absolute a stagnation, precisely as men would suffer; and it is narrow-minded in their more privileged fellow-creatures to say that they ought to confine themselves to making puddings and knitting stockings, to playing on the piano and embroidering bags. It is thoughtless to condemn them or laugh at them if they seek to do more or learn more than custom has pronounced necessary for their sex. (...) The one with red cheeks is called Miss Smith; she attends to the work and cuts out – for we make our clothes, our frocks, and pelisses, and everything (...) Miss Smith put into my hands a border of muslin two yards long, together with needle, thimble, &c., and sent me to sit in a quiet corner of the schoolroom, with directions to hem the same..." [18] [19]

[4] Translation by the Author.
[5] Madame Bovary junior

Figure 7: (left) Jean-Etienne Liotard: Portrait of a Young Girl Embroidering, 18th century; (right) Portrait of Catherine Brass Yates by Gilbert Stuart, 1793.

Yarn woven into the fabric, handwork created, and fabric taking shape in clothes are the "living" properties of textiles that can express the spirit of their creator or wearer in the material. The metaphors present the maker by conveying material fragility through the textile's ability to take over the creator's energy and spirit and how it can transform into the spirit of its creator or user. (Fig. 7)

"*A breath of love had passed over the stitches on the canvas; each prick of the needle had fixed there a hope or a memory, and all those interwoven threads of silk were but the continuity of the same silent passion."* [17]

The wearing of clothes occurs in countless writings as a word image or as a characteristic description; some of the following are just a teaser, leaving this task to be developed in the next phase of the research.

"Now, does he feel
His secret murders are sticking in his hands;
Now, minutely, revolts upbraid his faith-breach;
Those he commands move only in command,
Nothing in love. Now, does he feel his title
Hang loose about him, ***like a giant's robe***
Upon a dwarfish thief." [20]

Further paradoxes in the interpretation of textiles can be found in the characteristics of the fabric's wearing and the description of the clothes; the textile is a material that wraps the body and represents the character.

"(...) there was something ludicrous as well as painful in the little Parisienne's earnest and innate devotion to matters of dress." [19]

"She was elegantly dressed; she wore a muslin dress with full panels, a square Indian shawl embroidered at the corners with gold thread and silk flowers, a Leghorn straw hat and a single bracelet, one of those thick gold chains which were then just beginning to be fashionable." [21] (Fig. 8)

5. SUMMARY

As a result of the research, we gained more knowledge about how references to textiles and clothes influenced cultural discourse over the centuries, emphasising the importance of universal literature, myths, tales and novels in the broad explanation and celebration of textile culture. The research tried to shed light on the frequency of use of textiles, word images formed in connection with textiles, textile products and clothing production in literature and culture. The research article published as a result of the project tried to shed light on a wide range of topics related to fabric, with which this topic weaves the rich tapestry of human cultural development.

Figure 8: The Lady with the Camellia - poster by Alphonse Mucha for the theatrical version with Sarah Bernhardt (1896)

REFERENCES

[1] www.cordis.europa.eu, "The importance of textile in art and architecture," 2013.

[2] P. M. Poplett, "Textiles in Texts: Literary Representations of Women's Textile Crafts," kent.ac.uk, Kent, 2015.

[3] V. Postrel, The Fabric of Civilization: How Textiles Made the World, New York: Basic Books, 2020.

[4] [Online]. Available: https://k12.hillsdale.edu/k12/media/Resources/Documents/Upper%20School/History/The-Epic-of-Gilgamesh-Abridged.pdf. [Accessed 29. December 2023.].

[5] [Online]. Available: https://open.maricopa.edu/worldmythologyvolume2heroicmythology/chapter/the-epic-of-gilgamesh/. [Accessed 20. December 2023.].

[6] Perseus Digital Library, "Plato, Republic, Book 3," [Online]. Available: https://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0168%3Abook%3D3%3Asection%3D400d. [Accessed 5. December 2023.].

[7] Perseus Digital Library, "Plato, Republic, Book 3," [Online]. Available: https://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0168%3Abook%3D3%3Asection%3D400e. [Accessed 5. December 2023.].

[8] Perseus Digital Library, "Plato, Republic, Book 3," [Online]. Available: https://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0168%3Abook%3D3%3Asection%3D401a.[Accessed 5. December 2023.].

[9] M. Aurelius, Meditations, Suffolk, USA: Penguin Books, 2006.

[10] Poetry in Translation, "Catullus (c.84 BC–54 BC) - Complete Poems," [Online]. Available: https://www.poetryintranslation.com/PITBR/Latin/Catullus.php. [Accessed 22. March 2024.].

[11] J. a. W. Grimm, „Snow White and the Seven Dwarfs," in *A Favorite Collection of Grimm's Fairy Tales*, Singapore, Floris Books, 2015, pp. 43-58.

[12] J. a. W. Grimm, „Sleeping Beauty," in A Favorite Collection of Grimm's Fairy Tales, Singapore, Floris Books, 2015, pp. 139-154.

[13] A. Fehérváry-Ménes, „https://www.noklapja.hu/," 5. szeptember 2022. . [Online]. Available: https://www.noklapja.hu/aktualis/2022/09/05/amikor-a-ruha-teszi-az-embert-meses-atvaltozasok-a-filmvaszonrol/. [Accessed: 12. May 2023.].

[14] J. a. W. Grimm, „Cinderella," in *A Favorite Collection of Grimm's Fairy Tales*, Singapore, Floris Books, 2015, pp. 11-26.

[15] H. C. Andersen, „The Emperor's New Clothes," in *Hans Christian Andersen's Fairy Tales*, Stirlingshire, Penguin Books, 2010, pp. 21-29.

[16] Platón, Az állam, Budapest: Gondolat, 1988..

[17] G. Flaubert, „Madame Bovary," 1857. [Online]. Available: https://ocw.mit.edu/courses/21l-472-major-european-novels-fall-2008/25cdbb0df3de2a938ed0b9cadf4e4978_madame_bovary.pdf. [Accessed: 22. March 2024.].

[18] C. Brontë, Jane Eyre, Budapest: Európa, 1991.

[19] C. Brontë, Jane Eyre, 1847.

[20] W. Shakespeare, Macbeth, N.A.: Independently published, 2020., ca. 1606, p. 80.

[21] A. Dumas, Lady of the Camellias, London: Penguin Books, 2013.

CORRESPONDING AUTHOR:

Dr Edit CSANÁK DLA
Product Design Institute, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University
Doberdó út 6, 1034 Budapest, Hungary
E-mail: csanak.edit@uni-obuda.hu

ANALYSIS OF THE LEVEL OF CONSUMER AWARENESS OF SUSTAINABLE FASHION AND TEXTILE MATERIALS

Valentina BOZOKI, Ineta NEMEŠA, Marija PEŠIĆ, Nadiia BUKHONKA

Technical faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, Zrenjanin, Serbia

Abstract:

Sustainable fashion has become a significant concept in the textile and fashion industry, widely influencing new fashion trends and also consumer behaviour. This paper deals with the analysis of consumers' knowledge about the concept of sustainable fashion, sustainable textile materials and garment manufacturing methods which support actual sustainable fashion concept. The survey was done amount 106 potential female and male garment consumers. The analysis showed that surveyed people have different shopping habits, they use to put attention to fabric content, quality of the purchased garments and their country of origin. More than half of respondents devote their unwanted garments to other people. However, they are weekly informed about fast fashion, slow fashion and sustainable fashion concepts and their shopping and garment wear habits are not based on the support of one of these actual business models. The results of survey showed that it is necessary to raise awareness of our population about current environmental problems created by textile industry and on bases of it to change garment shopping and wear habits supporting sustainable fashion concept.

Keywords: *fast fashion, slow fashion, sustainable fashion, organic textile materials, shopping habits*

1. INTRODUCTION

During the last decade "fast fashion" business model has become part of our society. There are two reasons of its very serious influence to our everyday life: all of us we are consumers of fashion industry and the same time we are responsible for problems raised by business model. Fast fashion use to copy garment styles of well-known brands and by help of fast production and low quality materials presents cheap goods to the consumers. Unfortunately, all of it results with adverse impacts to the environment, human well-being. Keeping in mind the bad properties of fast fashion, it is only matter of time when something completely opposite to it would be developed. By analogy with food - slow food- the definition of slow fashion, known to us as "sustainable fashion" is developing. Slow fashion is a completely different, holistically conceived, more balanced and sustainable business strategy. According to it, all professionals in the field of fashion (designer, retailer, consumer) should take into account the different dimensions of the fashion industry, as well as, the possibilities to change them visibly for the better. [1,2]

By help of this research it was tried to see consumption habits of individuals and their awareness and knowledge connected to such terms as "sustainable fashion" and "fast fashion". As "fast fashion" carries malignant socioeconomic, moral and environmental consequences, serious public involvement is necessary to changes current consumer habits.

3. CONSUMER AWARENESS ABOUT SLOW FASHION

"Slow fashion", better known today as "sustainable fashion" is a logical reaction to mass production of "fast fashion" products - low-priced and low-quality fashion garments produced and bought by consumers in large quantities. The market is already saturated, the designers ran out of ideas as well as the natural materials that were used in various blends with synthetic fibers or in the production of "fast fashion" collections. [1, 3]

The entire fashion industry today operates according to the "fast fashion" business model, which is based on the excessive use of natural resources. All this leads to a huge amount of pollution - so the fashion industry is in second place for land use, fourth for water use, fifth for greenhouse gas emissions and first for releasing microplastics into waterways. Therefore, it is a completely unsustainable system by nature. Statistics tell us that today we buy 400% more than 20 years ago, and all the clothes we buy we throw away incredibly quickly. Sustainable shopping represents a move away from the excessive purchase of clothes through redesign, when the life of the product is extended and giving to it new look, the production of clothes from new sustainable or recycled materials that have special conditions and methods of production, such as organic cotton, organic wool, orange textile material bark, hemp, linen, lyocell and many other sustainable textile materials that are used today as an alternative solutions, as well as by buying goods in increasingly popular "second hand" stores, which also extends the life of the product etc., like we can see on Figure 1. which presents an infographic for sustainable fashion. [2,4,7,8]

Figure 1: Sustainable fashion infographic

The global problem of this mass production, in addition to the above, is the pollution of our environment. Not all clothing items are disposed in the prescribed manner in order to be recycled. Some of them are recycled or donated, some are burned, but in most cases the clothing items end up in landfills or in running water where it directly affects our living environment and human health. Also, the fact that at least 2700 litters of water is used to produce one cotton T-shirt is also scary. We can imagine how much natural resources are used producing just one piece of garment, without even selling it. These problems are the main drivers of a new business model called "slow fashion" [2, 5, 6].

The focus in "slow fashion" is on quality and smaller production because it's about good quality garments that can be worn for a long time. Production is slower and therefore everyone involved in production works in humane conditions in every respect, from realistic standards to solid incomes. The result is that the final product is of higher quality but also more expensive. As it is more sustainable for producers, it is also more sustainable for customers because they buy qualitative goods that they can wear a long time [2, 5, 6].

In the world, the trend called "sustainable fashion" is slowly but surely strengthening, and consumer awareness is slowly rising. It can be said that the customers have not yet been directly informed about this term. However, they have noticed that their favourite retail stores are no longer supplied with that much of clothing as before. Now stores start to release collections in traditional way, without micro-seasonal collections. There are more and more second-hand shops in their cities. Consumers have noticed that something is happening. These changes were greatly influenced by the coronavirus pandemic, which slowed down production and gave time for the textile industry to "slow down" a bit and take a break from the chaos it created before it. Consumers have noticed that something is happening, but we will see whether it has an impact on their purchase habits already through this research [4, 7, 8].

4. DISCUSSION ON THE CONDUCTED RESEARCH - PRESENTATION OF THE RESEARCH RESULTS

A total of 106 respondents participated in the conducted survey and answered the questions in the questionnaire. Based on the conducted survey, certain results were obtained which will be explained in a further research.

3.1 Demographic structure

First, the demographic structure of the survey was investigated. The gender structure of the respondents was rather equal - The 56.6%, of respondents are women while the male respondents were 43.4%. The age structure of the respondents was diverse. A four-group classification was made as an expedient solution: a) respondents under 18, b) respondents from 18 to 30, c) respondents from 31 to 45 and d) respondents older than 46. Regarding the age structure in the conducted survey, we can see that respondents who are between 18 and 30 prevail with their 55.7%, followed by respondents older than 46 with 18.9%, followed by respondents between 31 and 45 with 17.9% and respondents under 18 with 7.5%. In all age groups, the number of women is higher than men, except in the age group 31 to 46, where the number of male respondents is slightly higher, as shown in Figure 2.

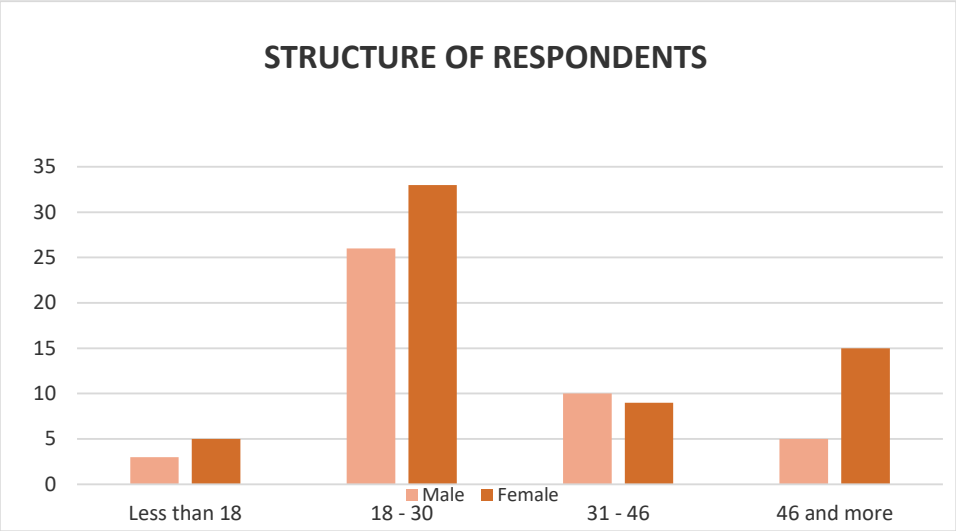


Figure 2: Structure of respondents

3.2 Shopping habits

After the presented demographic structure of the respondents, shopping habits of the respondents were researched. They answered the questions: how often do they buy clothes, whether the textile material composition is important to them and what do they pay attention to buying clothes. After the collected data, it was observed that the shopping habits are quite diverse. The most part of the respondents (27.4%) do shopping *once a month*, slightly less respondents (25.5%) answered that they buy clothes *sometimes*, less respondnts (17%) do shopping *several times a month*, while 11.3% of respondents buy clothes *once a week*. The same number of respondents (6.6%) declared that they buy clothing *for special occasions* and *a couple of times a year*. 5.7% of respondents enjoy shopping *several times a week*, see Figure 3.

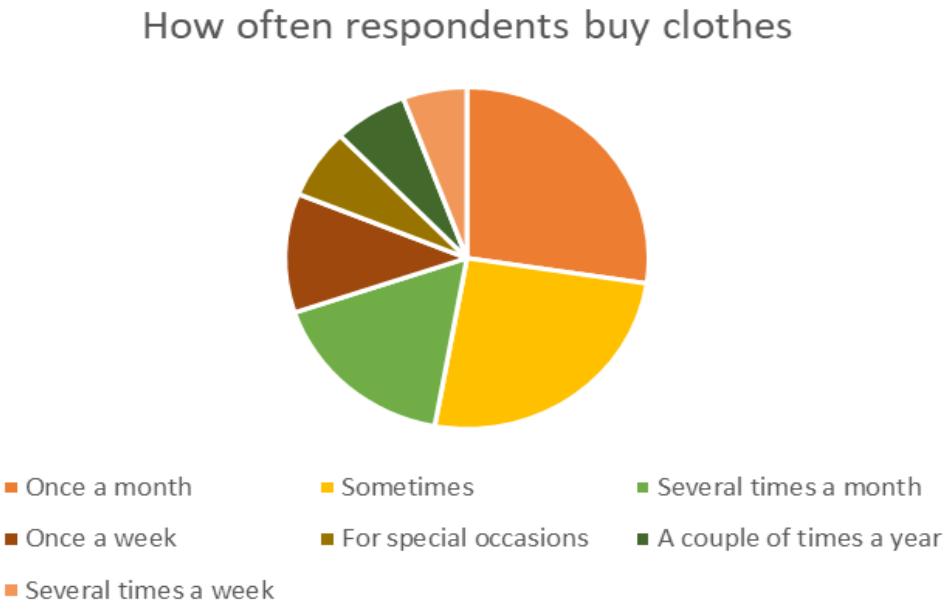


Figure 3: How often respondents buy clothes

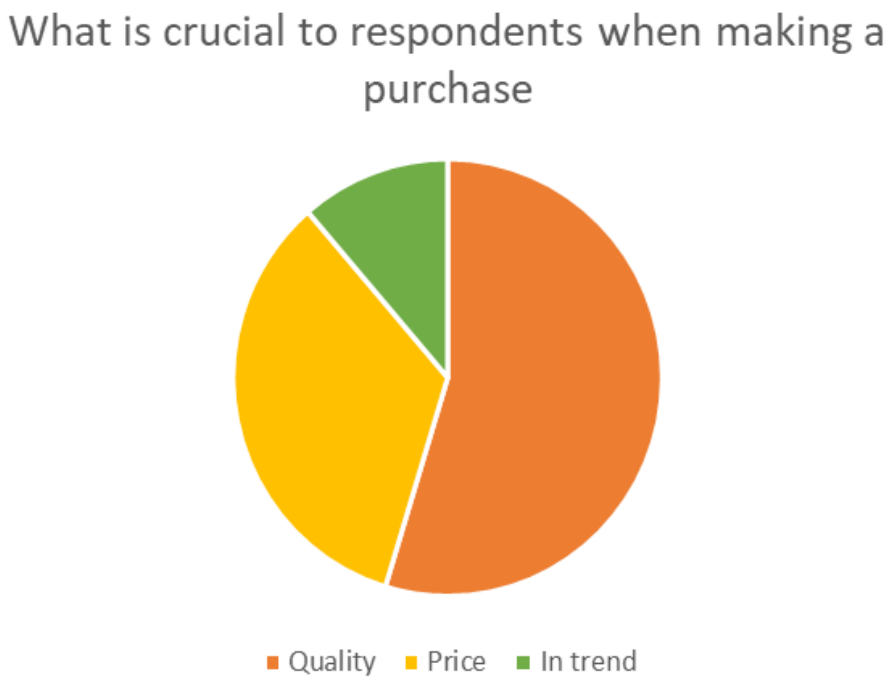


Figure 4: What is crucial to respondents when making a purchase

According to the results obtained from the survey, it is seen that the majority of respondents firstly look for the *quality of the product* (54.7%), only after - for *price of the product* (34%). For smaller group (11.3%) it is more important that the *item is in trend*, these results can be seen in Figure 4.

When it comes to the textile material composition, the majority of the respondents (65.1%) answered that the material *composition is important* to them buying clothes, while 34.9% of the respondents answered that they *do not put attention* to the origin of the material purchasing new garments.

3.3 Awareness of the concept of sustainable fashion

After the basic questions about shopping habits, the survey continued to checked knowledge of respondents connected with the terms "fast fashion" and "slow fashion". It was important to get an idea of how the respondents are informed about consequences of the fast fashion, how do they understand terms fast and slow fashion. Parallel to data collecting, the questions also had to inform respondents about existing environmental problems. The questions were put in the certain way - *do you know that...*

It was observed that the half of respondents (51.9%) are not familiar with the term "fast fashion" while other half (49.1%) have heard about this trend. Also many respondents (63.2%) are not familiar with the term "sustainable fashion" and only third part of them (36.8%) know the idea of this term (see Figure 5). From the answers of the respondents it was concluded that knowledge of our population about "fast fashion" disadvantages is minimal and the reason of this situation is a lack of general information about it. The majority of respondents are not informed about sustainable fashion concept and its aims. The research showed that the current trends in fashion industry which are actual in society are not much noticed by the respondents.

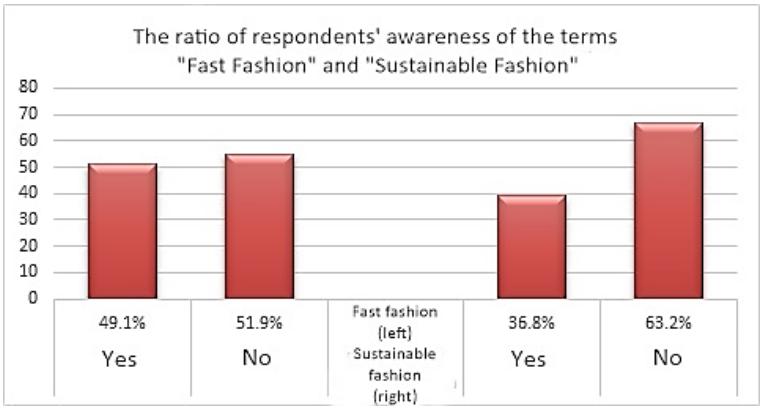


Figure 5: The ratio of respondents' awareness to "Fast Fashion" and "Sustainable Fashion"

There were group of questions which had to check respondents' awareness about the need to *slow down* textile and fashion industry. By help of questions "Do you know that..." the respondents were informed about the huge amount of water used in textile production, the fact that the most part of our clothes end up in wild landfills and what it means the sustainable fashion. Only 27.4% of respondents know that huge amount of water is needed to produce cotton T-shirts, while other part of them did not know this information. The half of respondents (51.9%) did not know where our clothes end up, other 48.1% of respondents were aware of current situation. The Figure 6. shows the analysis of obtained data from questions connected to ecological textile materials: manufactured from bamboo, pineapple, eucalyptus and orange peel.

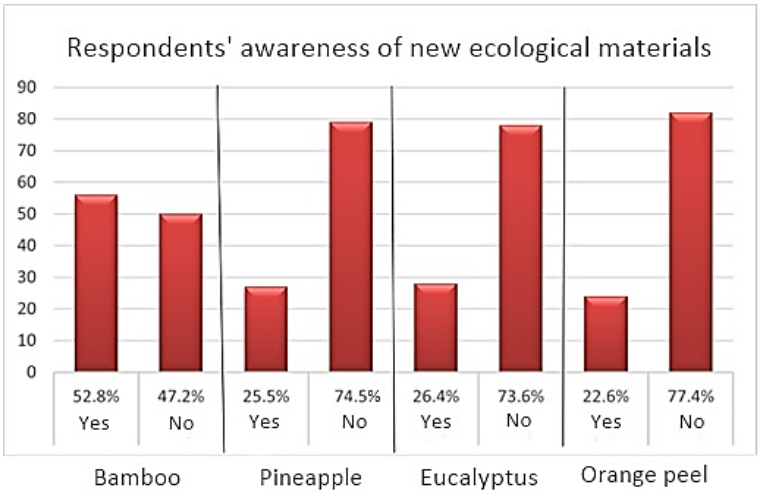


Figure 6: Respondents' awareness of new ecological materials

According to the results, the bamboo textiles were the most familiar ecological material to the respondents (52.8%), it was followed by eucalyptus textiles (26.4%), pineapple textiles (25.5%) and textiles manufactured from orange peel (22.6%). Respondents had the option to add in the list of sustainable materials one more known by them. The respondents added: recycled cotton, recycled polyester, organic cotton, organic wool, some have heard of kombucha, banana, apple skin and even coconut fiber textile material. By help of the survey, it was tired to researched would this new information had an impact to the further purchase habits of the respondents and how much this survey

had increased knowledge of respondents about the actual problems in textile industry. The majority of respondents (91.5%) were satisfied with the survey and the information they received answering to the questions. They valuated the survey with mark 5. 5.7% of respondents gave mark 4, while 1.9% of respondents rated the survey with a mark 3 and only 0.9% - with mark 2. Evaluation of the survey showed that it was successful and respondents obtained new awareness about current actual problems in fashion industry.

3. CONCLUSION

Summarizing all the results obtained from the survey, it was seen that the respondents are active users of the "fast fashion" products, however they do not have reasonable knowledge about "fast fashion" concept and ecological problems which this business model is creating to environment. The respondents are weakly familiar to "sustainable fashion" concept and because of it knowingly do not support this concept searching for recycled or ecological products. The respondents are generally content with the survey and new information obtained by help of it, there are going to change their shopping habits putting more attention to the origin of the textile materials. It was concluded that it is necessary to educate and raise public awareness about "sustainable fashion" by help of mass medias and different character educational campaigns.

REFERENCES

Palić, Ž; Purgar, K: *"THEORY AND CULTURE OF FASHION - DISCIPLINES, APPROACHES AND INTERPRETATIONS"*, Faculty of Textile Technology, Zagreb (2018)

Tumasović, J.: WHAT IS FAST FASHION AND WHY IS IT HARMFUL?, *AVAILABLE FROM* HTTPS://KRPICA.INSPIRINGCHANGE.RS/BRZA-MODA/ Accessed: 2023-10-18

Yinyin Wang, T.: CONSUMER BEHAVIOR CHARACTERISTICS IN FAST FASHION, *AVAILABLE FROM* https://www.diva-portal.org/smash/get/diva2:1312256/fulltext01.pdf Accessed: 2023-10-18

Hambleton, H.: HOW CAN CONSUMER BEHAVIOUR CHANGE THE FASHION INDUSTRY?, Available from: https://textileconsult.wordpress.com/2017/04/28/how-can-consumer-behaviour-change-the-fashion-industry/ Accessed: 2023-10-18

N.N.: SUSTAINABLE FASHION, Available from: https://www.renovablesverdes.com/sr/moda-sostenible/ Accessed: 2023-10-18

N.N.: WHAT IS SUSTAINABLE FASHION?, Available from: https://blog.digitalfashionacademy.com/sr/what-is-sustainable-fashion/ Accessed: 2023-10-18

N.N.: WHAT IS SUSTAINABLE FASHION AND HOW TO APPLY ITS RULES IN PRACTICE?, Available from https://bujanovacke.co.rs/2022/02/25/sta-je-odrziva-moda-i-kako-da-primenite-njena-pravila-u-praksi/ Accessed: 2023-10-18

Pandey.D.: EMBRACING SUSTAINABLE FASHION: A PATH TOWARDS A GREENER WARDROBE, Available from: https://medium.com/@divisha.pandey1233/embracing-sustainable-fashion-a-path-towards-a-greener-wardrobe-32392dd06dd1 Accessed: 2023-10-18

CORRESPONDING AUTHOR

Valentina BOZOKI
Department of Basic and Applied Sciences, Technical Faculty "Mihaljo Pupin", University of Novi Sad
Đure Đakovića bb, 23000, Zrenjanin, Serbia
valentina.bozoki10@gmail.com

FROM GRADING TO TAILOR-MAKING

Marianna HALÁSZ[1], Péter TAMÁS[2]

[1] Institute of Product Design, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

[2] Department of Mechatronics, Optics, and Mechanical Engineering Informatics, Faculty of Mechanical Engineering, Budapest University of Technology and Economics, Budapest, Hungary

Abstract

The appearance of computer systems significantly accelerated the ready-to-wear industry's production-preparation process. At the Faculty of Mechanical Engineering of BME, we have been developing a computer-aided system for the clothing industry since 1985. During the work, we developed the pattern gradation and the cutting layout design applications and then the software for producing patterns to individual sizes. In connection with this, we designed and built our body scanner. A related software creates a 3D model of the examined person's body based on the scanned data and determines the individual body measurements required for cloth design. By projecting the 3D garment surface created on the 3D body model to the plane, we have developed a completely new method for making patterns to individual sizes. For the 3D virtual representation of the clothes on the 3D body models, we developed a particle drape model and worked out a special method for determining the necessary fabric data of the drape model. The article shows our developments for the clothing industry.

Keywords: *clothing industry, computer-aided design, body scanner, draping measurement, body model, material simulation*

1. INTRODUCTION

In the second half of the last century, the clothing industry gained more and more space with ready-to-wear clothes according to size charts. In mass production, changing needs had to be served more and more quickly due to rapid changes in fashion. During production, the preparation processes require most of the time. Computer technology offered the opportunity to solve this problem. The appearance of computer systems significantly accelerated the ready-to-wear industry's production-preparation process. At the Faculty of Mechanical Engineering of BME, we have been developing a computer-aided system for the clothing industry since 1985. During the work, we developed the pattern gradation and the cutting layout design applications and then the software for producing patterns to individual sizes. In connection with this, we designed and built our body scanner. A related software creates a 3D model of the examined person's body based on the scanned data and determines the individual body measurements required for cloth design. By projecting the 3D garment surface created on the 3D body model to the plane, we have developed a completely new method for making patterns to individual sizes. For the 3D virtual representation of the clothes on the 3D body models, we developed a particle drape model and worked out a special method for determining the necessary fabric data of the drape model. The article shows our developments for the clothing industry [1-3].

2. DEVELOPMENT STEPS OF COMPUTER SYSTEM

The following chapters present the successive phases of developing our computer-aided system for the clothing industry.

2.1 Pattern gradation

We started working on the system in 1985 by the pattern gradation. This first element of the system operates according to the manual grading procedure that developed over a long period [2, 4-5].

The first task was the geometric modelling of the planar tailoring patterns. First, we determined the method of selecting the defining points located on the outline of the pattern. The selected points were stored using a digitizing board. For the virtual presentation of the tailoring pattern, the digitized points were connected with them by B-spline interpolated curves similar to the original tailoring pattern. (Fig. 1).

To grade the tailoring patterns according to the size chart, we created a database of grading rules (Fig. 2). The grading rules move to the new location of the characteristic points of the tailoring pattern. We developed a mathematical method for shifting the curve sections between the characteristic points. The shifted points are connected by B-spline curves, like the original bounding curves of the pattern.

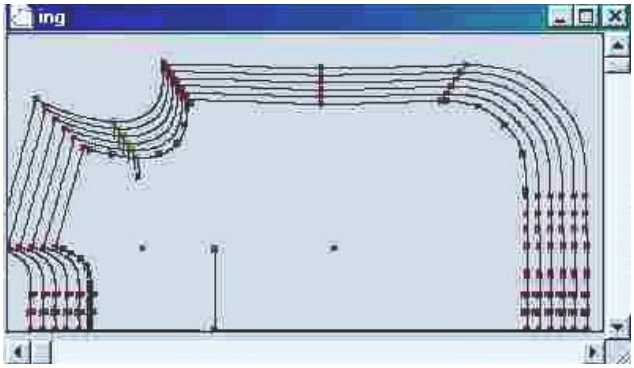


Figure 1: Grading of the front part of a shirt

Figure 2: Grading rule

We have also developed the necessary machine drivers for drawing and cutting out tailoring patterns. A special application was designing shirt patterns to individual sizes. The software automatically calculated the grading rules considering individual body measurements [6-7].

2.2 Cutting layout design

We soon expanded the system with the cutting layout design module [8-11]. The width, length, pattern, and washing shrinkage of the material can be specified in the design program. While the program ensures compliance with the predefined limits, the pattern parts to be laid can be arranged on the fabric strip in two ways (Fig. 3):

- automatically, when the recursive algorithm arranges the pattern parts based on their enclosing rectangle without human intervention,
- interactively, when the designer can arrange the parts by shifting, rotating, mirroring, and colliding the parts.

Meanwhile, the program continuously calculates again the material ratio to find the most economical arrangement.

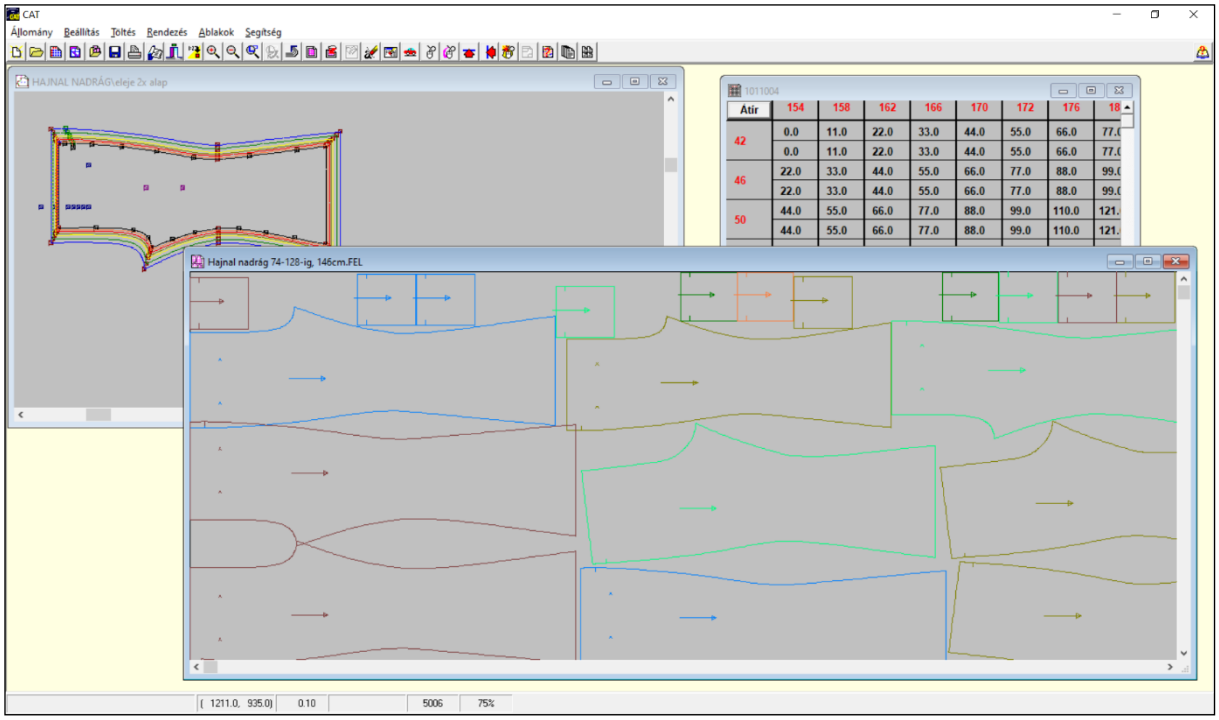


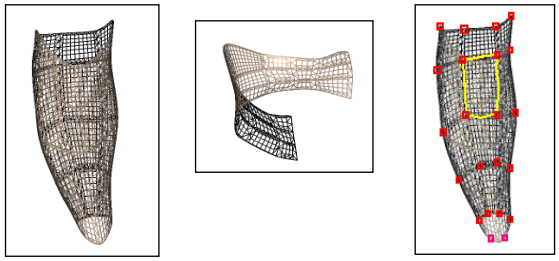
Figure 3: Cutting layout of trousers

Our software, including the pattern gradation and cutting layout designing modules, named **CAT for Windows** (Computer-aided Textile for Windows), has spread in clothing industry vocational schools in Hungary.

2.3 Parametric body model

3D rendering of clothing models requires a model of the human body. In our system, the model of the surface of the human body is composed of body part elements [1, 3, 12-19]. We described the surface of each body part with interpolation surfaces characterized by control points parameterized by body data. The Catmull-Rom surface model is created from connected Bezier patches. The control points are functions of body dimensions.

To compose the tube-like and half-tube-like surface elements (Fig. 4), we built the simplified model of the skeleton (Fig. 5). The joint points of the skeleton model are the characteristic initial points of the body parts. As a result, anyone's body can be modeled with this parametric body model (Fig. 6) if the main anthropometric dimensions of the person's body are given (Fig. 7).



a) b) c)

Figure 4: Tube (a) and half tube-like (b) body parts, control points, and surface patches (c)

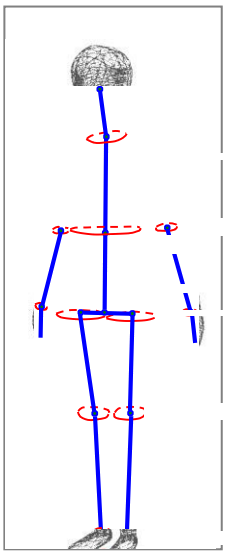


Figure 5: Simplified model of the skeleton with the joint point of body parts

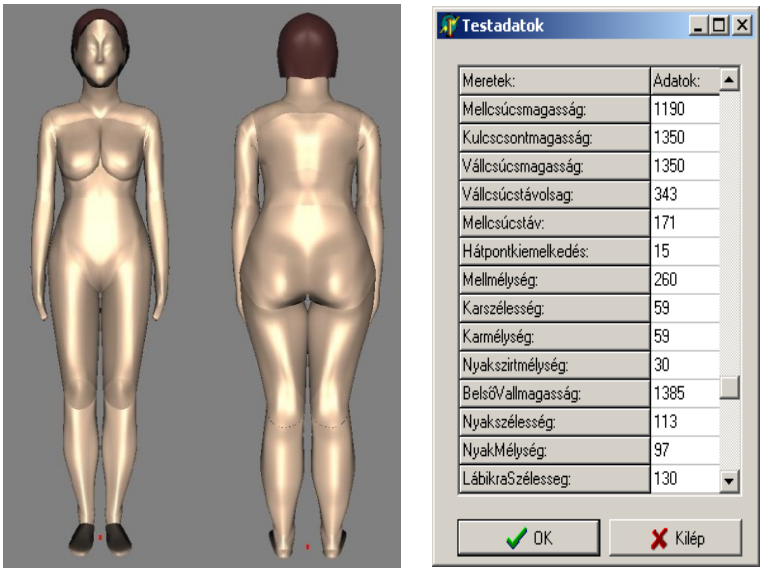


Figure 6: Body figures with different parameters

To provide these parameters with adequate accuracy is crucial to work out a measurement method that eliminates subjectivity and the uncertainty of manual measurement. First, a special measurement method was developed with photographs for determining the main anthropometric dimensions of the human body (Fig. 8). By an iterative solution, the program refines the parameters of the body model until the front and side view contours of the model and the measured person fit as well as possible (Fig. 9-10).

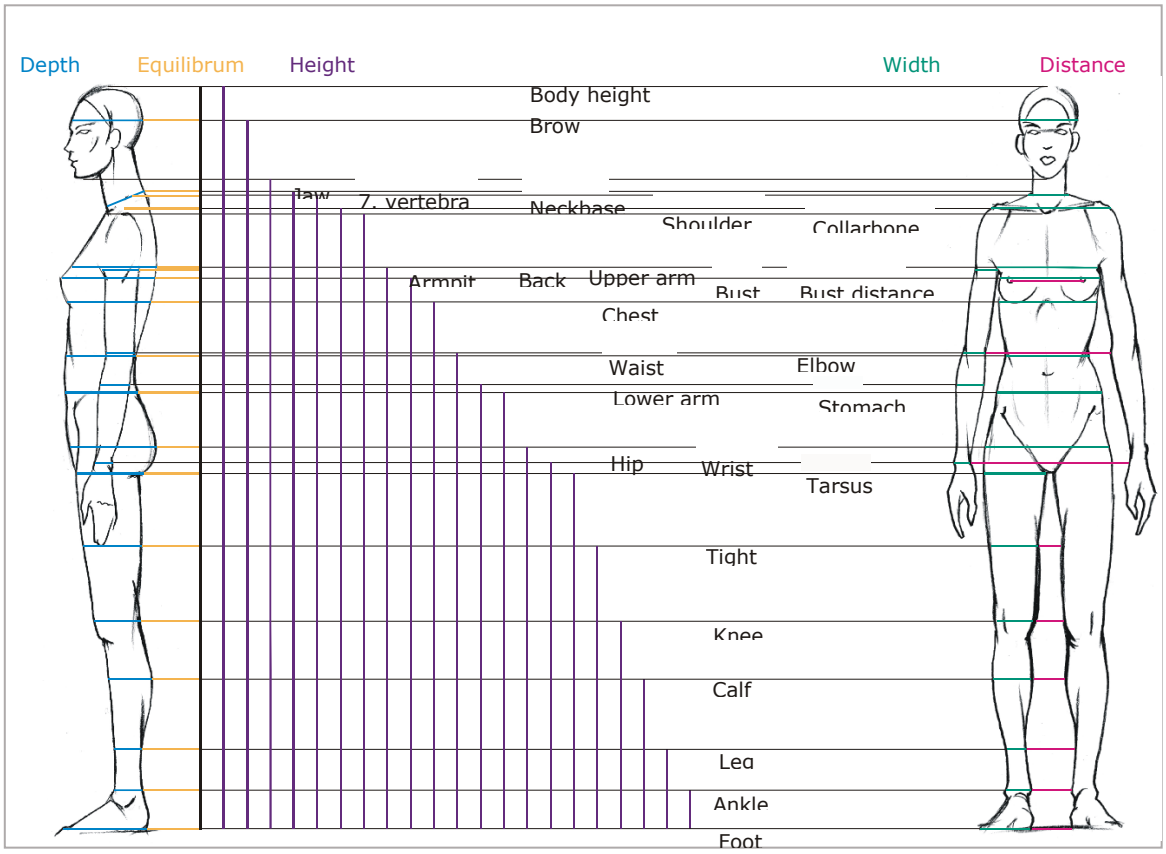


Figure 7: Anthropometric dimensions

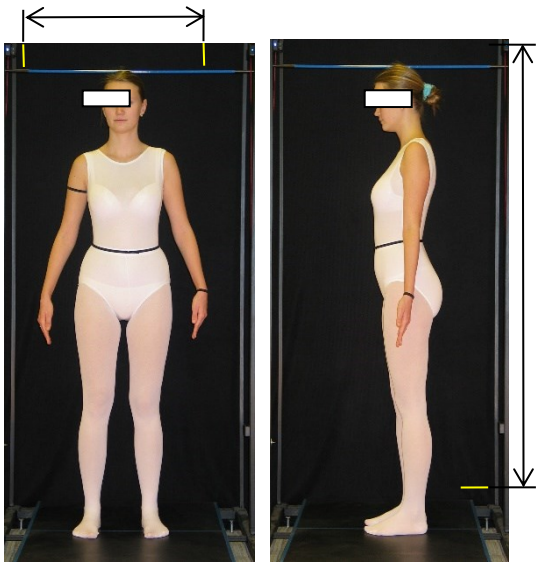


Figure 8: Measurement booth and the model in two views

Figure 9: Contour points and contour lines based on the photographs

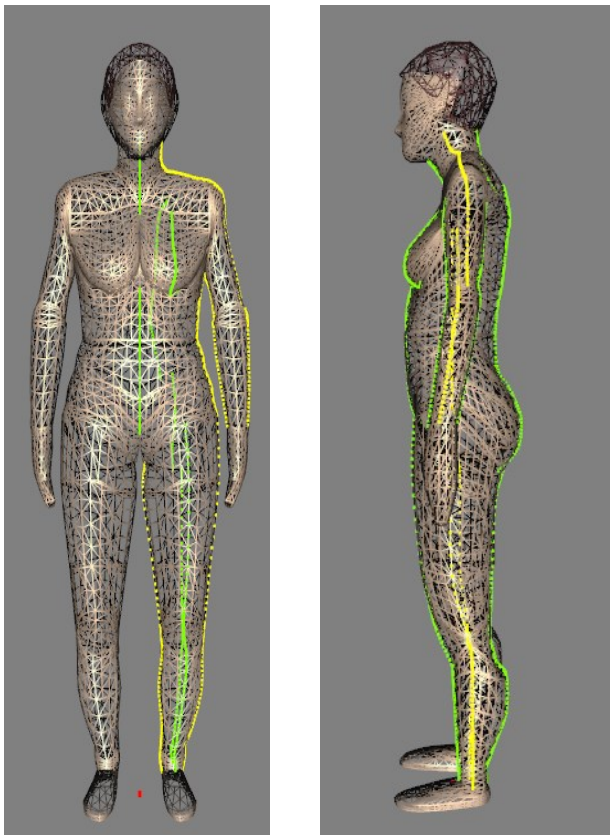


Figure 10: Profile curves on the body model

2.4 Modelling the mechanical behaviour of textile materials

The lifelike rendering of 3D model design requires the simulation of the garment's textile mechanical behaviour, especially how it drapes and hangs under its own weight. The simulation requires the parameters of the applied material model [1, 3, 20-29].

We developed a novel, simple, fast, and direct method based on drape testing to determine the material parameters for draping simulation. So, we built a computer-controlled drape tester, which is essentially a small 3D scanner named Sylvie 3D Drape Tester (Fig. 11). During testing, the four line-laser on the frame project a horizontal cross-section curve on the fabric sample. The pictures of the curve are recorded by four cameras located on the frame above the lasers. The photos are uploaded to the computer after each shot. The height of the frame is changed with preprogrammed steps, and hence, the surface of the draping textile is scanned. After that, the software reconstructs the scanned surface based on the photos (Fig. 12).

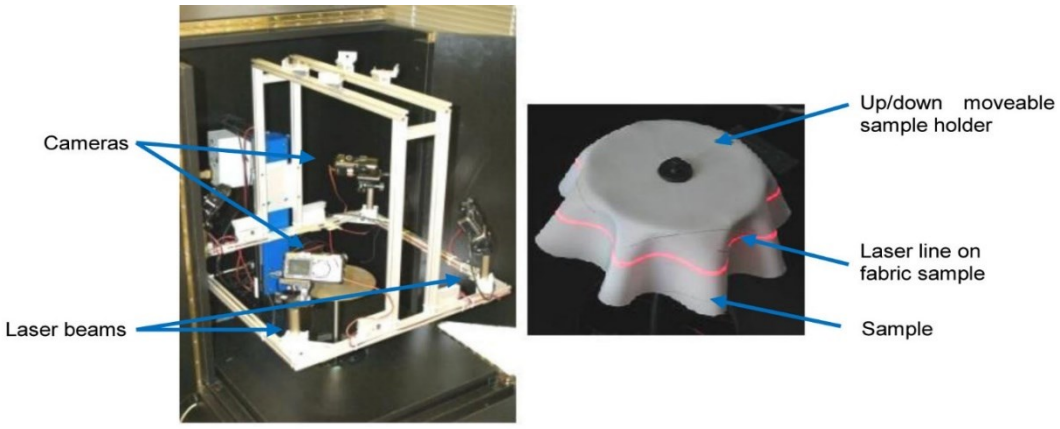


Figure 11: Sylvie 3D Drape Tester

At the same time, the software made the simulation of the drape test. It is based on a model of a network of mass points and combined coupling elements (springs and dampers connected in parallel) joining them (Fig. 13).

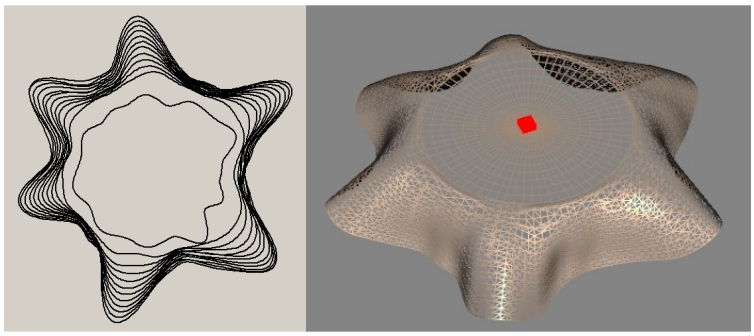


Figure 12: The geometry of the scanned draping textile with the laser contour lines (left) and the surface reconstructed based on the photos (right).

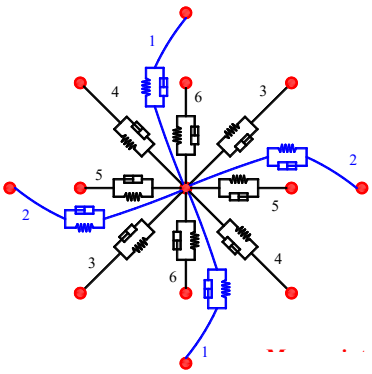


Figure 13: The mechanical model of the simulation

The mathematical model of the mechanical vibration system can be described with the Lagrange equation. Instead of measuring the necessary material parameters individually, we use a numerical iteration method. The parameters of the simulated textile are modified and tuned until the simulated surface is as close to the scanned surface as possible. This way, the material parameters necessary for the simulation of the textile are obtained.

We have developed the rendering 3D model designs in virtual reality with this simulation model and the material parameter defined by the drape tester (Fig. 14).

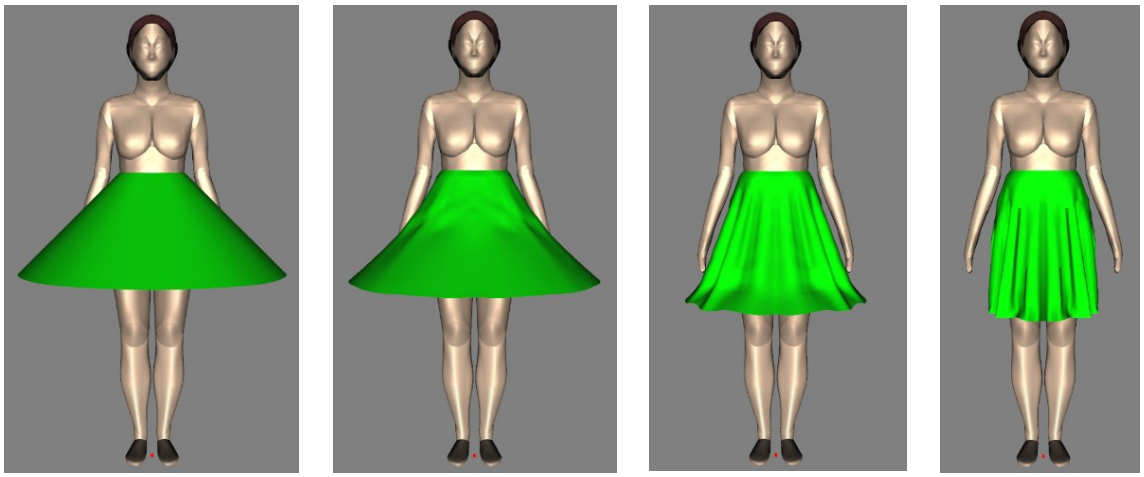


Figure 14: Virtual representation of the formation process of draping a skirt on the body model

2.5 Sylvie 3D Body Scanner

Around the turn of the millennium, we began to deal with producing patterns to individual sizes. For this, an automatic system of body measurements became necessary. We built a body scanner named Sylvie 3D Body Scanner, which works with projected laser lines, like the Sylvie 3D Drape Tester [1, 3, 30-37]. The point cloud determined by scanning must first be separated into body parts so that it can be compared with the parametric body model (Fig. 15-17).

Figure 15: The scanned point cloud

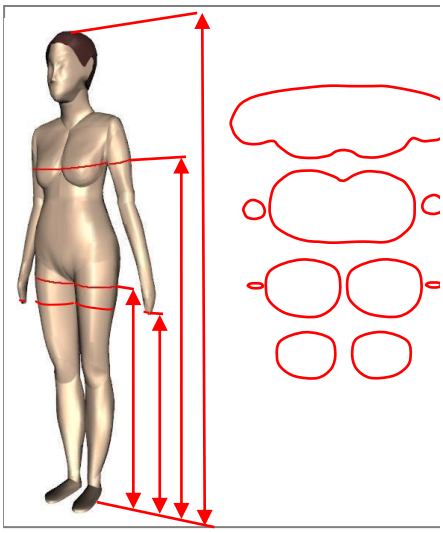


Figure 16: Base dimensions of the body

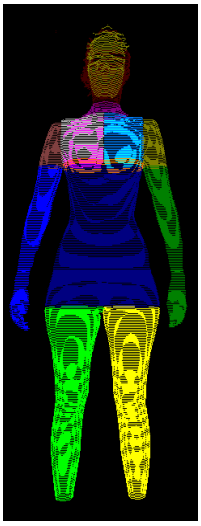


Figure 17: Surface points according to body parts

The related software modified the parametric 3D body model to the examined person's body based on the scanned data and determined the individual body measurements required for cloth design (Fig. 18).

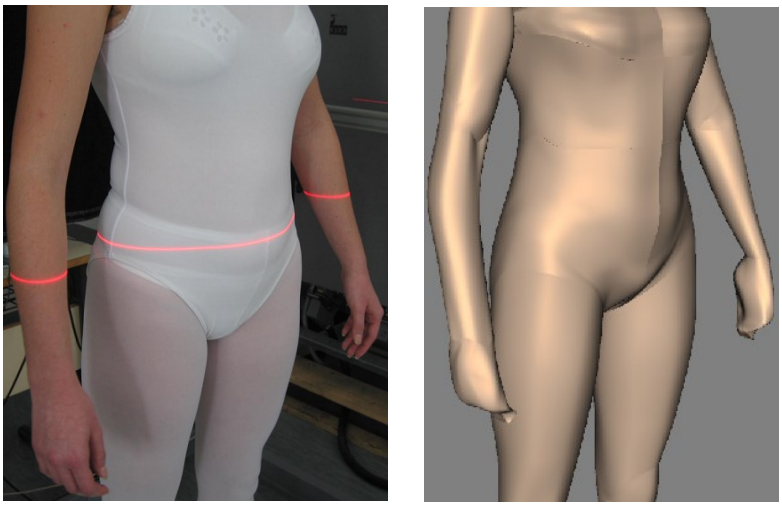


Figure 18: Measured and modeled body surface

2.6 Tailor making in 3D - patterns to individual sizes

As the final part of our system, we have developed a design solution for the made-to-measure garments that gives a digital connection between the 3D design of the garment and the 2D tailoring patterns. The starting point of garment design is the body model corresponding to the measured personal body data [1, 3, 16, 18-19, 33-34, 38].

Like the body model, the spatial surface model of the basic garment pieces – customized, hence fitting the individual dimensions of the body – can be created.

First, the program develops the enclosing covering of the surface of the body model (Fig. 19). After that, it is possible to make the style modification of the 3D surface of the basic garment pieces (Fig. 20). If the 3D surface of the garment pieces is decomposed into parts based on apparel industrial construction rules (Fig. 21) and the parts are laid into the plane (Fig. 22), the patterns of the tailored garment pieces are obtained (Fig. 23).

By projecting the 3D garment surface created on the 3D body model to the plane, we have developed a completely new method for making patterns to individual sizes.

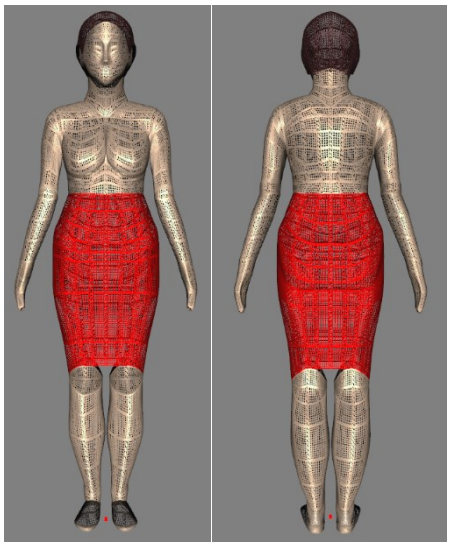


Figure 19: Skirt envelop

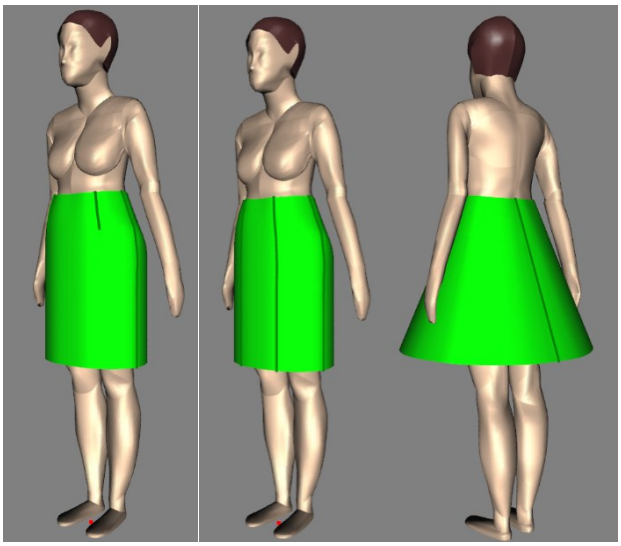


Figure 20: Basic skirt models

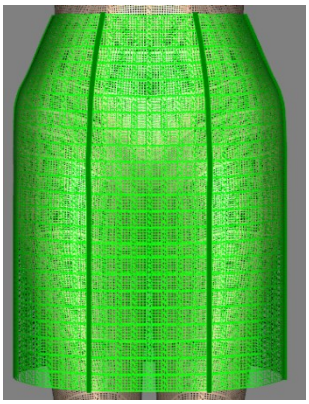


Figure 21: Design of skirt on the body model

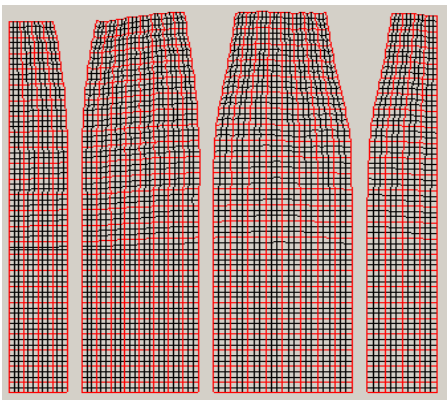


Figure 22: Projected parts of the skirt to the plane

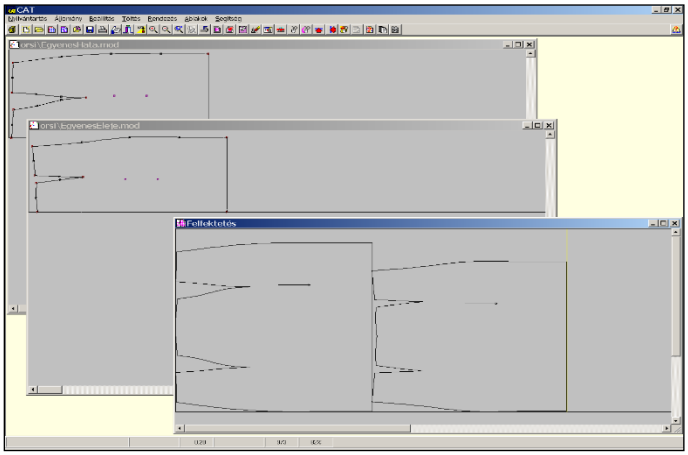


Figure 23: The patterns of the skirt based on the parts laid into the plane

3. CONCLUSIONS

As a summary, the structure of our design system is illustrated in the following scheme (Fig. 24):

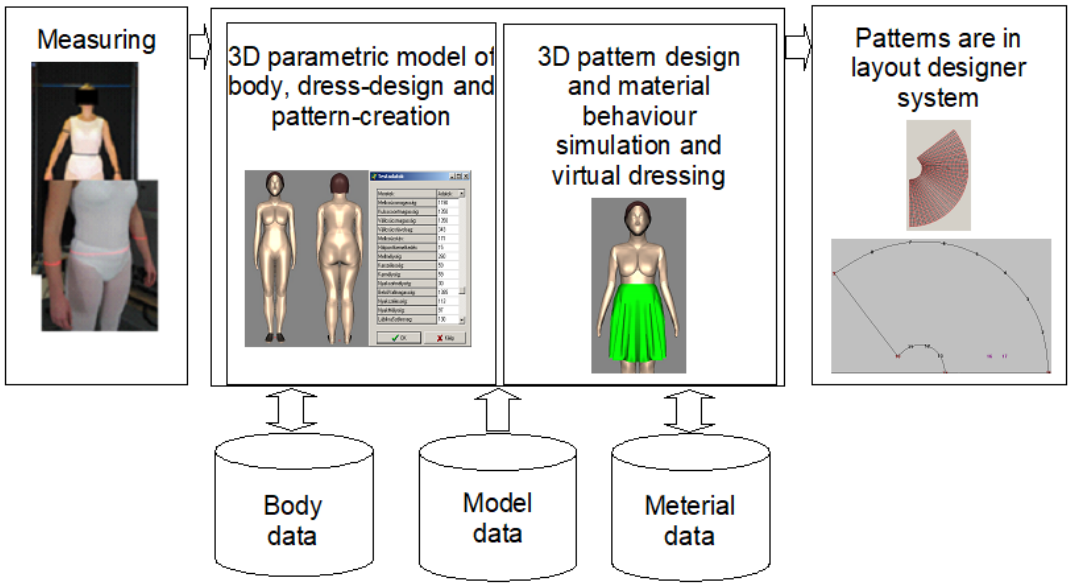


Figure 24: Structure of Sylvie 3D System

REFERENCES

Geršak, J.; Halász, M.; Tamás, P. & Kokas-Palicska, L.: *COMPLEX FABRIC DEFORMATIONS AND CLOTHING MODELLING IN 3D*, LAMBERT ACADEMIC PUBLISHING, SAARBRÜCKEN, (2013)

Halász, M.: *A SZÁMÍTÓGÉPPEL SEGÍTETT KONFEKCIÓIPARI SZÉRIÁZÁS ELMÉLETI ALAPJAI (THE THEORETICAL FOUNDATIONS OF COMPUTER-AIDED PATTERN GRADATION IN THE CLOTHING INDUSTRY)*, PhD thesis, BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS, BUDAPEST, (1996)

Tamás P.: *3D-S RUHATERVEZÉS (3D DRESS DESIGN),* PhD thesis, BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS, BUDAPEST, (2008)

Halász, M. et al.: EINIGE ERGEBNISSE DER ENTWICKLUNG DES RECHNERGESTÜTZTEN GRADIER- UND SCHNITTBILDOPTIMIERUNGSSYSTEM AN DER TU BUDAPEST, *BEKLEIDUNG UND MASCHENWARE*, 27 (1988), PP.103-108

Tamás, P.; Kiss, Z.; Halász, M. & Tóth, B.: CAT FOR WINDOWS - KONFEKCIÓIPARI GYÁRTÁSTERVEZŐ RENDSZER A KÖZÉPISKOLÁK SZÁMÁRA. *MAGYAR TEXTILTECHNIKA* (1947-2005), 48 (1995), PP. 36-38

Adami, K. et al.: CIM SYSTEM IN GARMENT TRADE. *PROCEEDINGS OF CAMP '91 INTERNATIONAL CONFERENCE*, BUDAPEST, HUNGARY, 25-27.09.1991. PP. 180-187 (1991)

Halász, M.; Tamás, P.; Kiss, Z. & Tóth, B.: CIM A KONFEKCIÓIPARBAN, INGGYÁRTÁS EGYÉNI MÉRETRE. *MAGYAR TEXTILTECHNIKA* (1947-2005), **47** (1994), PP. 146-147

Halász, M.; Tamás, P.; Kiss, Z. & Tóth, B.: SZÁMÍTÓGÉPES TERVEZŐ RENDSZEREK A RUHAIPAR SZÁMÁRA: CAT FOR WINDOWS AND CIM FOR TAILOR-MAKING. *MAGYAR TEXTILTECHNIKA* (1947-2005), LI (1998), PP. 36-42

Halász, M.; Tamás, P.; Kiss, Z. & Tóth, B.: COMPUTER AIDED PROCESS PLANNING SYSTEMS FOR APPAREL INDUSTRY: CAT FOR WINDOWS AND CIM FOR TAILOR-MAKING. *PROCEEDINGS OF GÉPÉSZET '98 INTERNATIONAL CONFERENCE*, BUDAPEST, HUNGARY, 28-29.05.1998. PP. 825-829 (1998)

Halász, M.; Tamás, P.; Kiss, Z. & Tóth, B.: APPLIED COMPUTER METHODS IN APPAREL INDUSTRY. *IN-TECH-ED '98 INTERNATIONAL CONFERENCE,* BUDAPEST, HUNGARY, 21-22.10.1998., *MAGYAR TEXTILTECHNIKA, IN-TEH-ED '98 KÜLÖNSZÁM*, LI (1998), PP. 42-44

Halász, M.; Tamás, P. & Tóth, B.: COMPUTER AIDED PROCESS PLANNING SYSTEMS FOR APPAREL INDUSTRY, CAT FOR WINDOWS AND CÍM FOR TAILOR-MAKING. *PROCEEDINGS OF DAAAM '99 INTERNATIONAL CONFERENCE,* VIENNA, AUSZTRIA, 21-23.10.1999. PP. 183-184 (1999)

Tamás, P.; Halász, M. & Tóth, B.: FEATURE BASED MODELLING OF HUMAN BODY*, PROCEEDINGS OF IN-TECH-ED '02 INTERNATIONAL CONFERENCE*, BUDAPEST, HUNGARY, 25-26.04.2002. PP. 170-174 (2002)

Tamás, P.; Halász, M. & Tóth, B.: 3D BODY MODELLING IN CLOTHING DESIGN*, PROCEEDINGS OF GÉPÉSZET 2002 INTERNATIONAL CONFERENCE,* BUDAPEST, HUNGARY, 30-31.05.2002. PP. 570-573 (2002)

Tamás, P. & Halász, M.: 3D BODY MODELLING IN CLOTHING DESIGN, *PROCEEDINGS OF IMCEP 2003 INTERNATIONAL CONFERENCE,* MARIBOR, SLOVENIA, 09-11.10.2003. PP. 64-68 (2003)

Julean R., Halász M.: VIRTUAL MADE-TO-MEASURE GARMENT DESIGN*, PROCEEDINGS OF GÉPÉSZET 2004 INTERNATIONAL CONFERENCE,* BUDAPEST, HUNGARY, 27-28.05.2004. PP. 448-451 (2004)

Tamás P., Halász M. & Gräff J.: 3D DRESS DESIGN*, PROCEEDINGS OF AUTEX 2005 WORLD TEXTILE CONFERENCE,* PORTOROZ, SLOVENIA, 27-29.06.2005. PP. 436-441 (2005)

Szabó, L.; Halász, M.: AUTOMATIC DETERMINATION OF BODY SURFACE DATA, *PROCEEDINGS OF AUTEX 2005 WORLD TEXTILE CONFERENCE*, PORTOROZ, SLOVENIA, 27-29.06.2005. PP. 715-720 (2005)

Nagy-Szabó, O.; Tamás, P. & Halász, M.: RUHASZERKESZTÉS HÁROMDIMENZIÓS TERVEZŐ RENDSZERBEN, *MAGYAR TEXTILTECHNIKA TEXTILTISZTÍTÁS*, 58 (2005), PP. 92-95

Nagy-Szabó, O.; Tamás, P. & Halász, M.: GARMENT CONSTRUCTION WITH A 3 DIMENSION DESIGNING SYSTEM. *PROCEEDINGS OF IN-TECH-ED'05 INTERNATIONAL CONFERENCE*, BUDAPEST, HUNGARY, 08-09.09.2005. PP. 348-357 (2005)

Szabó L. & Halász M.: LINE-LASER 3D SURFACE SCANNING MACHINE PLANNING FOR THE 3D APPAREL INDUSTRY, *PROCEEDINGS OF GÉPÉSZET 2004 INTERNATIONAL CONFERENCE,* BUDAPEST, HUNGARY, 27-28.05.2004. PP. 490-494 (2004)

Kuzmina, J.; Tamás P.; Halász, M. & Gróf, GY.: IMAGE-BASED CLOTH CAPTURE AND CLOTH SIMULATION USED FOR ESTIMATION CLOTH DRAPING PARAMETERS, *PROCEEDINGS OF IN-TECH-ED'05 INTERNATIONAL CONFERENCE*, BUDAPEST, HUNGARY, 08-09.09.2005. PP. 358-365 (2005)

Kuzmina, J.; Tamás P.; Halász, M. & Gróf, GY.: IMAGE-BASED CLOTH CAPTURE AND CLOTH SIMULATION USED FOR ESTIMATION CLOTH DRAPING PARAMETERS, *PROCEEDINGS OF 5TH AUTEX WORLD TEXTILE CONFERENCE*, PORTOROŽ, SLOVENIA, 27-29.06.2005. PP. 904-909 (2005)

Tamás, P.; Geršak, J. & Halász, M.: SYLVIE 3D DRAPE TESTER – NEW SYSTEM FOR MEASURING FABRIC DRAPE, *TEKSTIL*, 55 (2006), PP. 497-502

Halász, M., Tamás, P. & Szabó, L.: DETERMINATION OF TEXTILE-MECHANICAL PROPERTIES USING IMAGE PROCESSING AND SIMULATION, *PROCEEDINGS OF 3RD*

INTERNATIONAL TECHNICAL TEXTILE CONGRESS, ISZTAMBUL, TURKEY, 01-02.12.2007. PP. 464-471 (2007)

Szabó, L. & Halász M.: EXAMINATION OF DEPENDENCE OF DRAPE COEFFICIENT ON THE SAMPLES SIZE, *TEKSTIL*, 57 (2008), PP. 439-447

Halász, M.; Tamás, P.; Gräff, J. & Szabó, L.: COMPUTER AIDED MEASURING OF TEXTILE-MECHANICAL PARAMETERS, *MATERIALS SCIENCE FORUM*, 589 (2008), PP. 311-316

Tamás, P.; Göktepe, F.; Halász, M. & Al-Gaadi, B.: NEW METHOD FOR DYNAMIC DRAPE MEASUREMENT OF FABRICS, *PROCEEDINGS OF AUTEX 2009 WORLD TEXTILE CONFERENCE*, IZMIR, TURKEY, 26-28.05.2009. PP. 579-584 (2009)

Al-Gaadi, B., Halász, M. & Tamás, P.: TEXTILES DYNAMICALLY INFLUENCED DRAPABILITY, *MATERIALS SCIENCE FORUM*, 659 (2010), PP. 361-366

Al-Gaadi, B.; Göktepe, F. & Halász, M.: A NEW METHOD IN FABRIC DRAPE MEASUREMENT AND ANALYSIS OF THE DRAPE FORMATION PROCESS, *TEXTILE RESEARCH JOURNAL*, 82 (2012), PP. 502-512

Szabó, L. & Halász M.: SYLVIE 3D BODY SCANNER KÉPFELDOLGOZÓ ELJÁRÁSÁNAK FEJLESZTÉSE, *MAGYAR TEXTILTECHNIKA: TEXTILIPAR-RUHAIPAR-TEXTILTISZTÍTÁS* (2006-2008), 59 (2006), PP. 100-103

Szabó, L. & Halász M.: DEVELOPMENT OF THE IMAGE POST PROCESSING OF A 3D HUMAN BODY SCANNER, *PROCEEDINGS OF GÉPÉSZET ITERNATIONAL CONFERENCE*, BUDAPEST, HUNGARY, 25-26.05.2006. PP. 1-6 (2006)

Tamás, P.; Halász M. & Somló J.: 3D MEASURING OF THE HUMAN BODY BY ROBOTS, *PROCEEDINGS OF IMCEP 2007 INTERNATIONAL CONFERENCE*, MORAVSKE TOPLICE, SLOVENIA, 10-12.10.2007. PP. 109-115 (2007)

Tamás, P. & Halász, M.: RELATIONSHIP BETWEEN BASIC BODY SIZES AND BODY SHAPE, *PROCEEDINGS OF 4TH INTERNATIONAL TEXTILE, CLOTHING & DESIGN CONFERENCE*, DUBROVNIK, CROATIA, 05-08.10.2008. PP. 665-670 (2008)

Tamás, P. & Halász, M.: HUMAN BODY MEASURING AND 3D MODELLING. *PROCEEDINGS OF 10TH INTERNATIONAL SYMPOSIUM OF HUNGARIAN RESEARCHERS ON COMPUTATIONAL INTELLIGENCE AND INFORMATICS,* BUDAPEST, HUNGARY, 12-14.11.2009. PP. 523-532 (2009)

Somló, J.; Halász, M. & Tamás, P.: SPECIAL APPLICATION OF 3D HUMAN MODELING BASED. *PROCEEDINGS OF IJCELIT GRAPHIC COMMUNICATIONS TECHNOLOGY WORKSHOP*, BUDAPEST, HUNGARY, 18-19.11.2010. PP. 277-283 (2010)

Halász, M. et. al.: 3D VIRTUAL MEASURING OF HUMAN BODY SIZES. *PROCEEDINGS OF 2ND IJCELIT INTERNATIONAL JOINT CONFERENCE*, BUDAPEST, HUNGARY, 21-22.11.2011. PP. 1-9 (2011)

TAMÁS P. et. al.: HUMAN BODY'S SHAPE AND DATA. *PROCEEDINGS OF AUTEX 2012 INTERNATIONAL CONFERENCE*, ZADAR, CROATIA, 13-15.06.2012. PP. 985-990 (2012)

Halász, M.; Kokas-Palicska L. & Tamás, P.: 3D DRESS DESIGN BY VIRTUAL MANNEQUIN, *PROCEEDINGS OF AGILTEX DESIGN WORKSHOP*, IASI, ROMANIAN, 24-27.06.2006. PP. 121-126 (2006)

CORRESPONDING AUTHOR:

Prof. Dr. Marianna HALÁSZ PhD
Institute of Product Design, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University
Doberdó u. 6, H-1034 Budapest, Hungary
E-mail: halasz.marianna@uni-obuda.hu

CREATIVITY, PRODUCT DESIGN, ENGINEERING AND THE ART OF ORIGAMI

Gabriella OROSZLÁNY[1], László KOLTAI [2]

[1] Institute of Product Design, Sándor Rejtő Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

[2]Institute of Media Technology and Light Industry, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

Abstract

Creativity is one of the most important faculties of human thinking, a fundamental skill that allows us to think outside the box and come up with innovative ideas that can change the world. Creativity is particularly important in product design and engineering, and in all areas where new and unique solutions are constantly needed to solve different problems.

Creativity can be developed. One such development technique that has become increasingly popular in recent years is origami. Origami is the Japanese art of paper folding, which involves folding a single sheet of paper into different patterns and shapes. Origami is not only a fun and relaxing hobby, but also a method to develop creativity. Making origami is a manipulation of materials. This manipulation of materials can help research and development because it can be used to make models, prototypes, and designs. In many areas of industry, it can be an excellent source of inspiration and help to develop new ways of solving problems.

In this article, we show how these four areas - creativity, product design, engineering, and origami - are connected, intertwined, and intersect.

Keywords: *creativity, product design, engineering, origami*

INTRODUCTION

At first glance, these four concepts - creativity, product design, engineering, and paper folding - may seem unrelated. However, a closer look reveals that there are many parallels between creativity, engineering, product design, and paper folding.

Creativity is essential in both engineering and product design, both activities require creativity to solve problems and develop new and innovative solutions.

According to the Word Economic Forum, creativity as a skill will be high on the list of the top 10 skills for 2025. And in the years after 2025, creativity is likely to play an increasingly important role in the world of work. [1, 2, 3]

Figure 1: The 10 Most Important Capabilities in 2025[6]

CREATIVITY

The word creativity is derived from the Latin word "creare", which originally meant "to beget, to give birth to, to create, to create".In Hungarian, the verb kreál probably first appeared, meaning "to create". The word "creativity" may have come from this.

The word creativity can be explained in many different ways, but the definitions all have in common that it means some kind of creative ability (e.g. scientific, artistic, musical... etc.), inventiveness, or ingenuity.

Some say that creativity is a special way of seeing and approaching challenges and tasks uniquely. Those with such a unique perspective or vision can adapt more easily to new challenges or unexpected situations. [1, 2, 3]

Some say that creativity is nothing more than a special creative energy.

Creativity encourages you to try to solve the problem at hand not in the accepted, familiar way, but with curiosity and a unique vision. [2, 3]

[6] Source: https://www.forbes.com/sites/tonygambill/2021/10/04/how-the-best-problem-solvers-overcome-perception-bias/

CHANGES IN CREATIVITY WITH AGE

In the 1960s, NASA approached Dr George Land - a researcher of creative output - and asked him to develop a creativity test to select innovative engineers and scientists. Dr. Land accepted the challenge and developed a creativity survey that worked very well. [4] After the results, Dr Land wondered where creativity comes from. Her research tested the creativity of 1600 children aged between 3 and 5. He tested the same children again at age 10 and again at age 15. He then extended the study to 1 million adults. [4] Dr Land looked at the ability of subjects to examine a problem and come up with new, different, and innovative ideas to solve it.

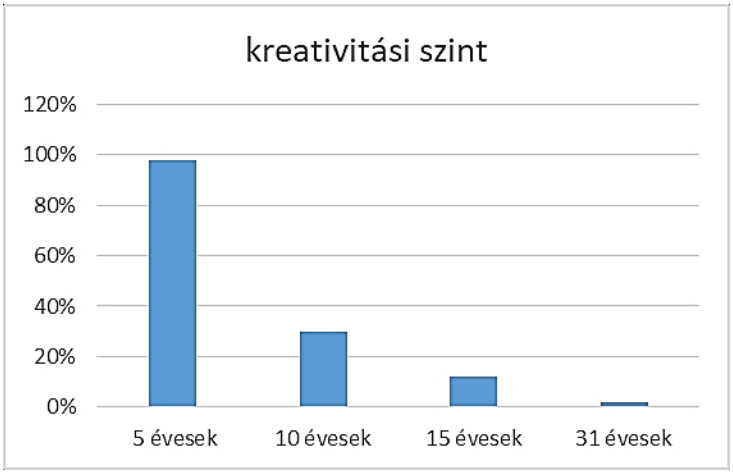


Figure 2: Changes in creativity over time (based on Dr Land's findings)

The results are staggering. We are at our most creative in childhood, and as we grow up we largely lose our creativity. So our creativity levels decline steadily and rapidly with age: what could be the reason? Dr. Land explained in his book "The Breaking Point and Beyond", *"We have concluded that non-creative behavior can be learned."*[7] [4] It follows that if non-creative behavior can be learned, then creativity can be developed. [4]

CREATIVITY AT WORK

Creative thinking always has an outcome, something that is original, novel, significant, or applicable in some way. This could be the result:

- idea,
- proposal,
- a work of art,
- scientific theory.

[7] Dr George Land's book Breakpoint and Beyond: Mastering the Future Today

To maintain and increase their market share, the most innovative organizations and companies often have to solve unique, specific problems and develop solutions that are different from the usual ones. So they need creative, smart people, which is why companies now expect their employees to be creative and innovative. [1, 4]

ENGINEERING AND CREATIVITY

Engineering is often associated with logic, precision, and problem-solving, while creativity is associated with artistic activity. Creativity is a key part of engineering. Engineering is the pinnacle of problem-solving and creative thinking. Engineers find new solutions to problems in our world and often create new technologies that change our lives. But engineering relies not only on logic and calculation but also on creativity. [1, 4] Engineering involves innovative thinking to find solutions to real problems.

The relationship between engineering and creativity is a symbiosis, not a contradiction. While engineering provides the theoretical and technical foundations, creativity fuels innovation, encourages visionary thinking, and facilitates problem-solving beyond traditional boundaries. By combining technical expertise and creative thinking, engineers can push the boundaries of what is possible and trigger transformational change in different industries. One of the most important tools for problem-solving is creative thinking. When an engineer needs to find a new solution to a problem, he or she often has to come up with new ideas, ideas that may not be obvious. Creativity helps engineers see a problem from a different perspective and find new solutions to it. [1, 4] By applying creative principles to engineering challenges, engineers can develop innovative, user-centered solutions that effectively tackle complex problems. [1, 4]

PRODUCT DESIGN AND CREATIVITY

Product design is the process of creating new products to meet the needs of users. Product designers must create products that are both functional and aesthetically pleasing. Creativity is at the heart of product design. Creative product designers can come up with new and innovative ideas that solve problems and improve people's lives. Product designers must also be able to understand the needs of customers and target users and design products that meet those needs. Creativity is used in product design in many different ways. Here are some examples:

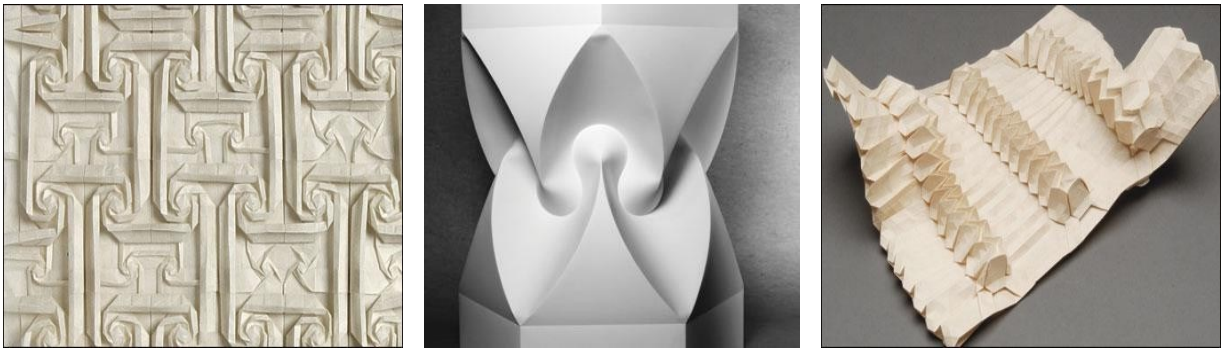
- Generating new ideas: product designers use their creativity to generate new product ideas. This can be done, for example, by brainstorming, sketching, and prototyping.
- Solving problems: product designers use their creativity to solve users' problems. They use their creativity to solve problems. For example, by improving an existing product, adding new features that meet additional user needs.
- Improving the user experience: product designers use their creativity to improve the user experience of products. This can be done by making products easier to use, more efficient, or more enjoyable.

Creativity is essential to product design because it allows designers to create innovative, useful and desirable products.

ORIGAMI IS THE ART OF PAPER FOLDING

Globally, the term "origami" refers to the folding of paper to form objects for fun. Origami is the art of folding paper. [5] In the 1980s, many folders began to systematically study the mathematical properties of folded shapes, leading to a rapid increase in the complexity of origami models. [6] Since the end of the 20th century, there has been a renewed interest, both artistic and scientific, in understanding the behavior of folded material.

The "new origami", which distinguishes it from the old craft practices, has developed rapidly thanks to the contribution of computational mathematics and the development of techniques such as box folding, tessellation and wet folding. Artists such as Robert J. Lang, Erik Demaine, Sipho Mabona, Giang Dinh, Paul Jackson and others are often cited for promoting new applications of the art. The computer aspect and the exchange through social networks, where new techniques and designs are presented, have raised the profile of origami in the 21st century. [7, 8]



a.) b.) c.)

Figure 3: Works by origami artists*: a.) Tomoko Fuse (Japan) origami artist - regarded as one of the world's most outstanding modular origami artists; b.) David Huffman (USA) – electrical engineer and origami artist, specializing in the development of abstract and geometric structures based on curvilinear folds; c.) Eric Gjerde (Norwegian-American) - origami artist, specialising in the development of tessalations*

ORIGAMI STYLES AND TECHNIQUES

There are many different classifications of paper folding. The most common origami styles are, without being exhaustive:

Table 1: Origami styles and techniques

Mathematics origami	Realistic style	Wet origami	Pureland origami
Technical origami	Minimalist style	Crumpled style:	"Pure" origami
Modular origami	Complex style	Kirigami	Ribbon folding
Origami of tessellation	Practical style	Action origami	Tea bag folding

THE LINK BETWEEN CREATIVITY AND EDUCATION

To maximize the benefits of creativity in engineering, educational institutions such as universities should integrate creative thinking and its development into engineering curricula and training programs.

Education has an important role to play in developing creativity. Engineering students need to acquire skills that will help them develop creativity. These skills include, for example, critical thinking, problem-solving, experimentation, research, teamwork, and independent learning.

Some general methods for developing creativity in education:

- Project-based teaching: Project-based teaching involves students solving concrete problems. They are encouraged to think creatively and find new solutions.
    - Encourage experimentation: students should be encouraged to experiment with new ideas and solutions. This will help them learn how to push their limits and find novel solutions to problems.
    - Encourage different approaches: students should be encouraged to try different approaches to solving problems. This will help them learn how to approach a problem from different angles and find new solutions.
    - Encourage individual and group work: students should be motivated to work both individually and in groups. This will help them learn how to work with others and how to share and evaluate ideas.
- Innovation competitions: innovation competitions allow students to share their new ideas and others. This encourages them to think creatively and find new solutions to problems.
- Teaching creative thinking skills: students should learn creative thinking skills such as problem-solving and critical thinking. This will help them to think more creatively in engineering.

HOW ORIGAMI HELPS TO DEVELOP CREATIVITY

Origami is an excellent way to develop creativity using traditional paper folding techniques. It allows you to learn new skills and express your creativity through practice.

1. **Problem-solving:** origami requires following a series of instructions, and folding and manipulating paper to create a specific pattern. This activity requires the individual to critically think and find solutions to achieve the desired result. Encourages problem-solving skills, as you need to figure out the correct sequence of folds to create the desired shape.
2. **Spatial awareness:** origami involves understanding and manipulating spatial relationships. Practitioners need to visualize how a flat piece of paper can be transformed into a three-dimensional object. This process helps to develop spatial thinking skills, which are essential in various creative fields such as architecture, design, and sculpture.
3. **Fine motor skills:** the delicate and precise nature of origami folding improves fine motor skills. Folding operations require careful eye-hand coordination, dexterity and control. This improved motor control can also benefit other creative endeavors such as drawing, painting, or playing an instrument.

4. **Concentration and patience:** origami requires concentration and patience. It teaches the individual to focus attention on the task at hand, to understand complex instructions and to follow them step by step. This practice of persistent attention and patience is valuable in any creative activity, as it allows individuals to fully engage in the creative process and overcome challenges.
5. **Exploration and experimentation:** although origami involves following instructions, there is also room for personal exploration and experimentation. Once individuals have become familiar with basic folding techniques, they can start exploring different variations, creating their designs, or combining origami with other art forms. The freedom to experiment fosters creativity and encourages individuals to think outside the box.
6. **Therapeutic benefits:** origami can have a calming and therapeutic effect on individuals. The repetitive actions of folding can reduce stress, promote relaxation and increase awareness. When the mind is relaxed, it becomes more open to creative ideas and inspiration.
7. **A source of joy:** origami is a fun and relaxing activity that promotes self-expression and creativity.

In summary, origami helps to develop creativity by stimulating problem-solving skills, improving spatial perception, developing fine motor skills, promoting concentration and patience, encouraging exploration and experimentation, and providing therapeutic benefits. It is a versatile and accessible art form that can be enjoyed by people of all ages and backgrounds, making it an excellent tool for developing creative thinking.

Today, engineers, designers and origami artists are working together in several disciplines. Origami is used in many fields, even to solve difficult technological problems. For example, origami helped to develop the folding of a small airbag - a folding process that allowed the airbag to be deployed in a fraction of a second - and the folding technology for solar panels used in space exploration.

CREATIVITY OBJECT-DESIGN CONSIDERATIONS

We aim to provide techniques and opportunities that open the doors of imagination and creativity and help students to dream and realize big ideas. Skills and competencies that can be developed through the planned course:

- developing creativity,
- developing spatial vision,
- developing the ability to associate,
- can help develop geometric thinking,
- can help simplify and transform complex forms, o e.g.: simplifying shapes using geometric shapes, o e.g.: minimizing details, o e.g.: optimizing the contrast effect,
- using the techniques learned, it is possible to create prototypes,
- can help you test new ideas,
- develops the ability to generate ideas,
- helps in model experiments.

OUR EXPERIENCE SO FAR IN INTEGRATING ORIGAMI INTO EDUCATION

On an experimental basis, we used origami in a workshop at the Budapest and the Odorheiu Secuiesc outsourced engineering training. Our experience showed that the students enjoyed and valued the work.

During the training in Odorheiu Secuiesc, students were given individual and group tasks. The individual tasks helped them to learn the basics of folding and encouraged them to complete further tasks. In groups of two, they practiced joint problem-solving, cooperation and division of labor. Groups of two had to build a paper tower from different types of paper in each team, following set rules. The purpose of using different types of paper was to familiarise the students with the different materials and to give them a basic knowledge of materials. The completed towers were compared and ranked according to their height, stability, load-bearing capacity, and aesthetic characteristics.

In Figure 4 you can see the focus, the joint work, and the division of labor and in Figure 5 you can see some of the completed towers.

Figure 4: Origami project at the outsourced training in Odorheiu Secuiesc

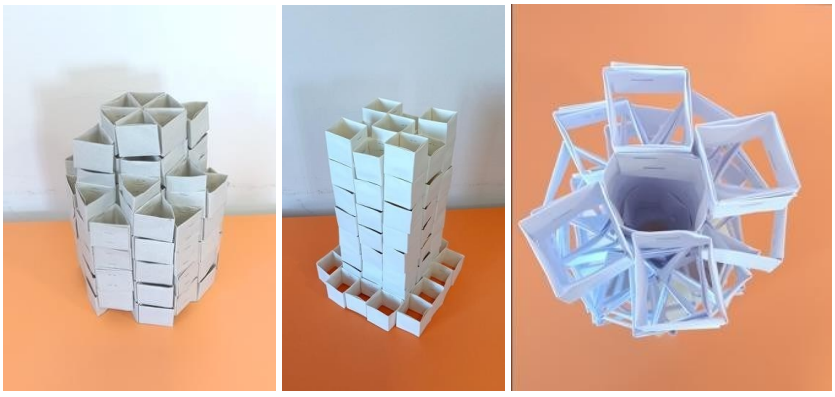


Figure 5: Paper towers at the outsourced training in Odorheiu Secuiesc

In the Budapest training, students were also given individual tasks. The aim of the individual tasks was to learn the basics of folding and to encourage them to complete further tasks. In the second part of the work, the students used pre-designed pattern bases. Using the pattern bases to create simple folds, we created simple basic shapes that are inspiring and versatile. We studied the created geometric shapes,

contrast effects, and movement possibilities (e.g. stretching, compression, twisting, bending and combinations of these) on the pieces we created.

The resulting shapes were transformed into new shapes by moving them around and studying the results again. The individually made basic elements were joined by gluing, creating a modular structure of several identical basic units, which was studied again.

Here too, the students' work was characterized by focus, concentration, accuracy, sequencing of operations, discipline and a willingness to experiment.

Figure 6: Origami project at the Budapest training

SUMMARY

Origami allows children and adults to express their creativity. By creating origami models, children and adults are free to experiment with different folding techniques and shapes.

As a result of our research, and from our practical sessions so far, we have found that origami can have several benefits for developing creativity.

Throughout the projects, we found that origami can help develop spatial thinking. In creating origami models, students had to understand spatial relationships to fold the paper in the right way. This skill can be useful in many areas of mathematics, engineering and art.

Feedback suggests that folding exercises develop problem-solving skills. Origami models are often challenging and require creative thinking to complete successfully.

In addition, it was found that origami-based exercises develop manual dexterity and fine motor skills. When creating origami models, students need fine motor skills to fold the paper accurately.

Origami is a fun and creative activity that can bring many benefits to the education of engineering students.

REFERENCES

[1] SZLAFKAI, É.: ÉLJ KREATÍVAN!, HVG KIADÓ, ISBN 9789633048610, BUDAPEST, (2020)
[2] LAND G., JARMAN B.: BREAKPOINT AND BEYOND: MASTERING THE FUTURE TODAY PAPERBACK, LEADERSHIP 2000 INC, ISBN-10 0962660523, ISBN-13 978-0962660528, (1998)
[3] https://www.forbes.com/sites/tonygambill/2021/10/04/how-the-best-problem-solvers-overcome-perception-bias/
[4] WARDLE D.: CREATIVITY - CAN ANYONE LEARN TO BE CREATIVE? https://www.linkedin.com/pulse/creativity-can-anyone-learn-creative-brandminds/
[5] KOSHIRO, H, HISTORY OF ORIGAMI IN THE EAST AND THE WEST BEFORE INTERFUSION, BY TAYLOR AND FRANCIS GROUP, LLC (2011)
[6] LANG, R.: ORIGAMI DESIGN SECRETS, DOVER PUBLICATIONS, (2003)
[7] MCARTHUR, M.: FOLDING PAPER: THE INFINITE POSSIBILITIES OF ORIGAMI, ISBN 978- 0804843386, TUTTLE PUBLISHING (2012)
[8] MCARTHUR, M.: NEW EXPRESSIONS IN ORIGAMI ART, ISBN 978-0804853453, TUTTLE PUBLISHING (2020)

CORRESPONDING AUTHORS:

Dr. habil László KOLTAI
Faculty of Light Industry and Environmental Engineering, Óbuda University
Doberdó str. 6, 1034 Budapest, Hungary
E-mail: koltai.laszlo@uni-obuda.hu

Dr. Gabriella OROSZLÁNY
Faculty of Light Industry and Environmental Engineering, Óbuda University
Doberdó str. 6, 1034 Budapest, Hungary
E-mail: oroszlany.gabriella@uni-obuda.hu

STUDY OF THE APPLICATION OF ARTIFICIAL INTELLIGENCE TOGETHER WITH CAD PROGRAMS FOR THE DEVELOPMENT OF COLLECTIONS OF CLOTHING MODELS

Imiila RYSBAEVA, Baktygul TURGANBAEVA, Gulida KUDAKEEVA

I. Razzakov Kyrgyz State Technical University (KSTU), Bishkek, KYRGYZSTAN

Abstract

The latest developments in technology have made it possible to increase the level of education of a modern person. Today it is enough to have a smartphone with the Internet and engage in self-education, which allows you to develop your skills and broaden the horizons of a specialist. Currently, curriculum contributes to the creation of in-demand professions, which are further implemented in the educational process, where the application of AI and IT technologies is tasked. As we know, many brands no longer need to update their collections of clothing models every season, as before, for several weeks, so designers have to act very quickly, while maintaining originality and special style. Working with neural networks and artificial intelligence, a fashion designer can use their creative imagination to speed up and simplify their work.

Artificial intelligence empowers and optimizes the fashion industry: it recognizes clothes from photos, accesses virtual fitting sessions, and, without much effort, easily selects the perfect size. The program will automatically design the pattern and technically reproduce the patterns by size, height and fullness. Artificial intelligence will require less creative work from the author, and designers themselves will be able to devote more time to their creativity.

The research paper uses Midjourney AI to make it easier to create new designs for clothing models. An artificial intelligence can be used to create images, solve problems and get new ideas. With the help of this program, it is supposed to create an experimental series of Kyrgyz national costumes, the details of which will be designed in the graphic program of the clothing designer Grafic 12.

Keywords: *Artificial Intelligence, neural networks, design, products, creating, clothing collection, clothing construction*

INTRODUCTION

The latest developments in technology have made it possible to increase the level of education of a modern person. Today it is enough to have a smartphone with the Internet and engage in self-education, which allows you to develop your skills and broaden the horizons of a specialist. Currently, curriculum contributes to the creation of in-demand professions, which are further implemented in the educational process, where the application of AI and IT technologies is tasked.

As we know, many brands no longer need to update their collections of clothing models every season as they used to do in a matter of weeks, so designers have to act very quickly while maintaining

originality and distinctive style. Working with neural networks and artificial intelligence, a fashion designer can use his creative imagination to speed up and simplify his work.

Artificial intelligence empowers and optimizes work in the fashion industry: it recognizes clothes from photos, accesses virtual fitting sessions, and, without much effort, easily selects the perfect size. The program will automatically design the pattern and technically reproduce the patterns by size, height and fullness. It will also require less creative work from the author, and the designers themselves will be able to spend more time on their creativity.

Of course, it is worth remembering that neural networks, like any mathematical tool, are not universal, not a universal panacea, they have a number of limitations and are applicable to a very specific class of problems.

This is not even related to the device or algorithm making the forecast, but to the phenomenon itself. Only when the essential parameters are taken into account, on the basis of which the forecast will be built, will there be some success. These parameters are chosen by experts in a certain field based on their experience and intuition, and have nothing to do with predictive machines. Once such parameters are determined, one can start statistical data processing and build a model of the phenomenon, but this model will only show the dependence of the selected input parameters on the output parameters that took place in the past.

Today there are known scientific studies showing that neural network methods, which have no serious advantages in this respect compared to classical statistical methods of forecasting. The only difference is that classical statistical methods require the calculation of many complex equations, while the neural network approach solves the required equations more naturally, which is related to its design. Thus, neural network methods are essentially a way of solving systems of equations with a large number of unknown coefficients. The algorithm for finding these coefficients is technically faster than similar classical solution methods. From the point of view of computer science and programming development, neural network is a way of solving the problem of efficient parallelism, and if the problem allows parallelization, it is solved by neural network faster and more efficiently than by classical methods.

Digitalization has long penetrated all spheres of life and nowadays we use voice assistants, city security systems recognize faces, and unmanned cars drive on the roads. All this works with the use of neural networks - mathematical models made on the principle of functioning of nerve cell networks of a living organism. In the modern world, artificial intelligent systems that perform creative functions and are traditionally considered the prerogative of humans as called artificial intelligence. If to simplify, artificial intelligence is a system or machine that can imitate human behavior, gradually learn using the collected information.

As for the neural network, it is a mathematical model and is one of the ways to implement artificial intelligence, which after successful training it will be able to return the correct result for missing data in the training sample, or predict the behavior of the system in the near future.

This research paper uses artificial intelligence and graphical programs to design Asian clothing as an example.

EXPERIMENTAL AND RESULTS

Nowadays, despite the saturated assortment of the clothing market, products in national colors people are very interested in. Such products always carry information about the people themselves, their traditions, their morals, way of life. Studying the history of clothing, you can imagine in what conditions lived the people, in what area, living conditions, traditions and analysis of the study shows complete information about the people.

So Kyrgyz national clothing reflects the nomadic way of life. Depending on the region of their residence, clothes differ in trim, patterns and colors. In almost all regions clothes were made of natural fabrics such as: felt, leather, wool (dyed wool) and coarse cotton fabrics. The trim and patterns carried information about the person. The headdress also had its own meaning.

By the headdress, one could determine the status of a person. Women mostly wore: chapan, dress, beldemchi, shөkylө, elechek, ykʏ topu, Figure 1. While women's clothes were distinguished by rich "kurak" trim and color texture, men wore mostly chapan, pants and shirts. Pants were mostly made of leather or suede. As for the cut of clothes, they were not complicated, simple geometric figures, Fig. 2. [4]

In the research work, we used Midjourney AI to make it easier to create new clothing designs. It is an artificial intelligence that can be used to create images, solve problems and get new ideas. Midjourney was used to create a series of Kyrgyz national costumes, the patterns of which were created in the graphic designer program Grafic 12. Subsequently, these models were refined to obtain an accurate cut in the Clo3D program.

Figure 1. Types of clothes worn by Kyrgyz girls and women

Figure 2: Cut of clothes for girls

Exploring the application of artificial intelligence together with computer-aided design and development systems in a computer-aided design (CAD) system to create collections of clothing patterns can yield many interesting results.

- First, AI can be used to analyze fashion trends and predict future trends. Machine learning algorithms can process vast amounts of fashion data, including information about past and current collections, designs, color schemes, and consumer preferences. AI can quickly analyze this data and predict future fashion trends, helping designers create more relevant and in-demand designs.
- Second, AI can be applied to optimize the design process of clothing models. Using machine learning algorithms, AI can analyze and process data on garment designs, sizes, materials and construction to optimize the design and production process. For example, AI can suggest optimal combinations of designs, select appropriate fabrics and details, and recommend optimal sizing to maximize the comfort and fit of garments.
- The third possible application of AI is to create virtual models of products. Using computer vision and generative AI algorithms, virtual models can be created and simulated to be worn on different body types. This can help designers evaluate the visual effect and fit of garments on different body shapes and sizes, which can improve the fit and aesthetics of the models. Exploring and applying AI in collaboration with CAD to develop collections of clothing models can improve the efficiency and accuracy of the design and production process, and increase the relevance and demand for models. This can help fashion designers and clothing manufacturers meet the demands of today's market and increase the competitiveness of their products.

In order to create new sketches of clothing models, generation on Midjourney service was carried out. The algorithm of work on Midjourney is as follows:

1. We can get pictures using exact queries (keywords) that you enter into the Midjourney neural network, it is important how you formulate the thought and how you arrange punctuation marks. Generation is done in real time and takes from 15sec to 1min - four variations will be generated directly in the chat and will be shown. [5]

2. The rules for constructing a query can be divided into three steps:
   - First, you should decide on the main object you want to style. It can be a person, animal, thing, plant, food, country - anything, also objects can be several.
   - Next, the object or objects are augmented with the details you want to see: colors, textures, environment, styling, external analogy, and so on.
   - Then generation parameters are set, which allow you to specify the size of pictures, their randomness, quality and other features.

3. Difficulties arise, understand how to formulate the query correctly, in what order.

4. Positive points noted, surprise how unique, beautiful and modern the neural network works, using only words from the data, also with each query and adding detailed words, the picture was transformed for the better. Figure 3 shows the variants of generating a picture of the sketch of the national Kyrgyz costume. Here we can see that the costume refers more to Chinese sources, as the cut is similar to Chinese costumes.

Figure 3: Primary request [6]

Therefore, several inquiries were made in different variants. In Figure 4 the sketch is already more similar to the national clothes of the Kyrgyz people, which are confirmed by some styles of cut, trims, etc., which is more similar to the national clothes of the Kyrgyz people. What confirms the above mentioned research analysis that it is not quite right to rely completely on AI, so it is necessary to involve a professional in the development of models of products.

Figure 4: Secondary sketch request

Thus, with the use of AI in the research work, sketches of Kyrgyz national clothing as seen by artificial intelligence are obtained. Then in the CAD program Graphis 12 the design of models is developed step-by-step in the introduction of model features to accurately obtain the cut. The design base is worked out, where additions, widths, lengths and some features of the garment design are determined, Figure 5.

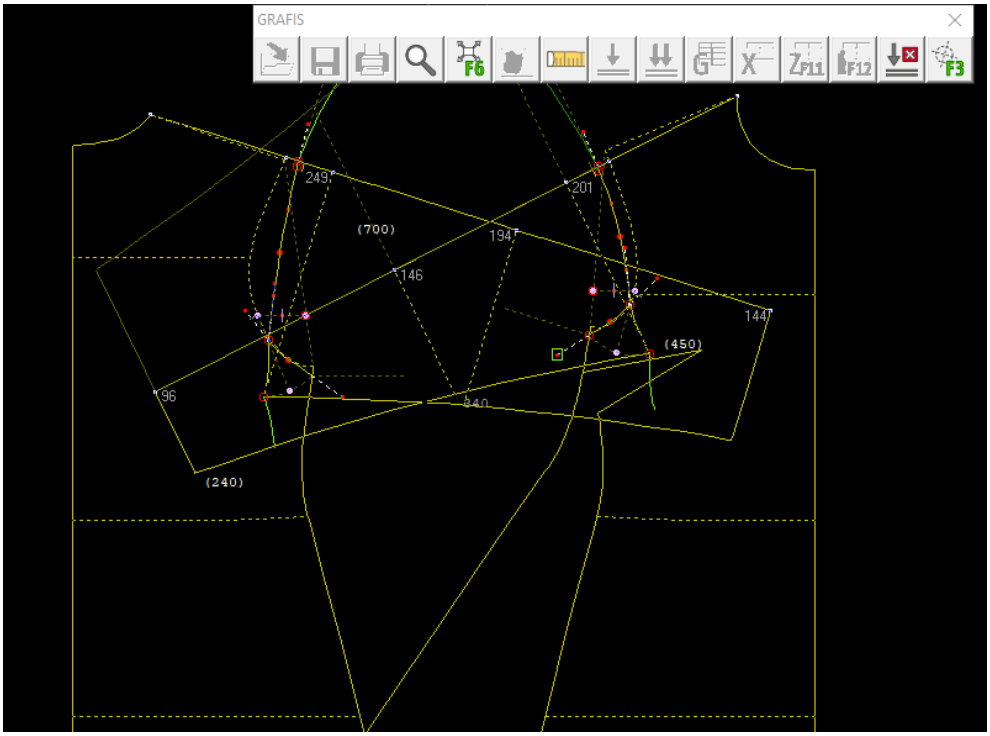


Figure 5: Base of the dress design

A technical sketch of the models is developed for a more accurate vision, here the part membership, sectional treatment, silhouette, etc. are defined. Figure 6.

Figure 6: Technical drawing of the dress

The technical modeling of the design is carried out, the necessary lines are entered according to the model, the shapes are specified, the position of the fittings (if present), the types of clasps, types of collars, etc. are taken into account. All lines are also finalized, as new cutting patterns are made from this model design, Figure 7.

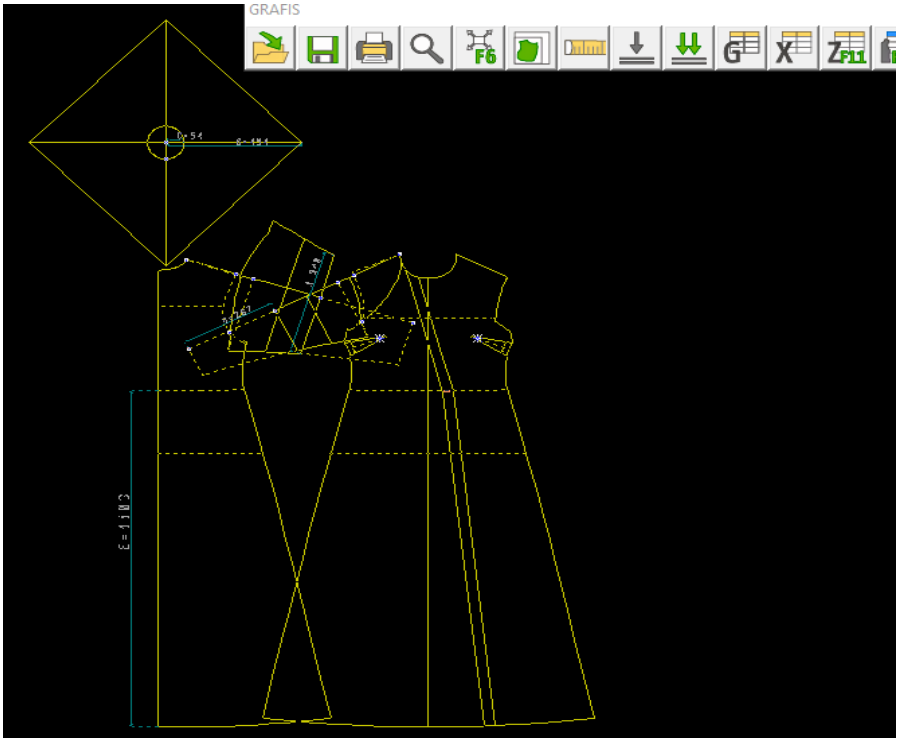


Figure 7: Model design of the dress

At this stage, the pattern is designed: add seam allowances, specify the direction of the warp threads, put marks in the necessary cuts, write the number of the pattern, the quantity in the cut and the name, figure 8.

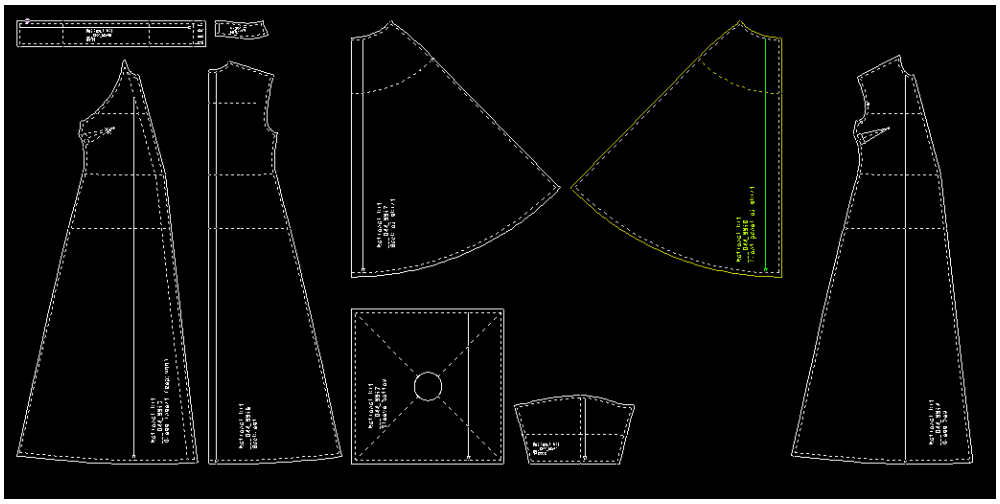


Figure 8: Formalization of dress cut details

To check the cut details, the Clo3D program is used, which allows you to virtually try on clothes. The patterns are downloaded and put on a pre-prepared avatar. This program also has its own sequence of work:

- First, we export the cut details in the Graphis program;
- choosing an avatar and specifying the size of the figure;
- editing cut patterns;
- sewing the cut patterns using the Free saving tool;
- place the patterns around the avatar according to the corresponding points on the figure;
- turn on the simulation function, at this moment the cut patterns are sewn together and the avatar is dressed, Figure 11;
- select the fabric and color;
- finally, the model is viewed through the render function, Figure 9 and 10.

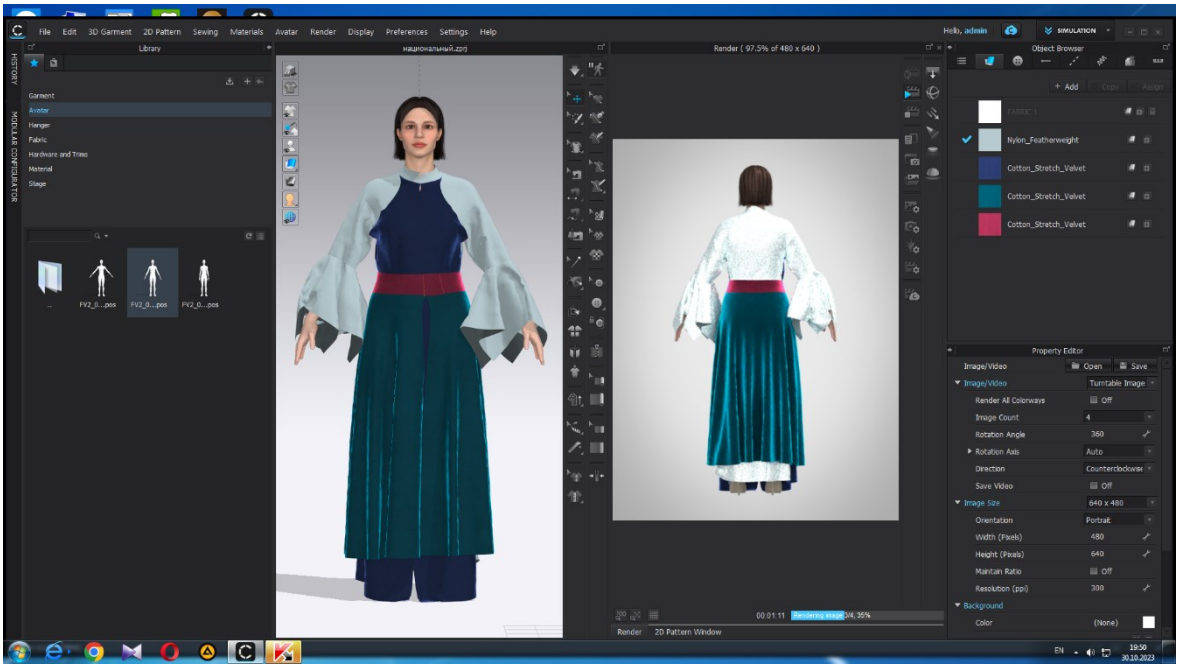


Figure 9. Viewing a dress through the Render function

Figure 10. Viewing a circular dress through the Render function

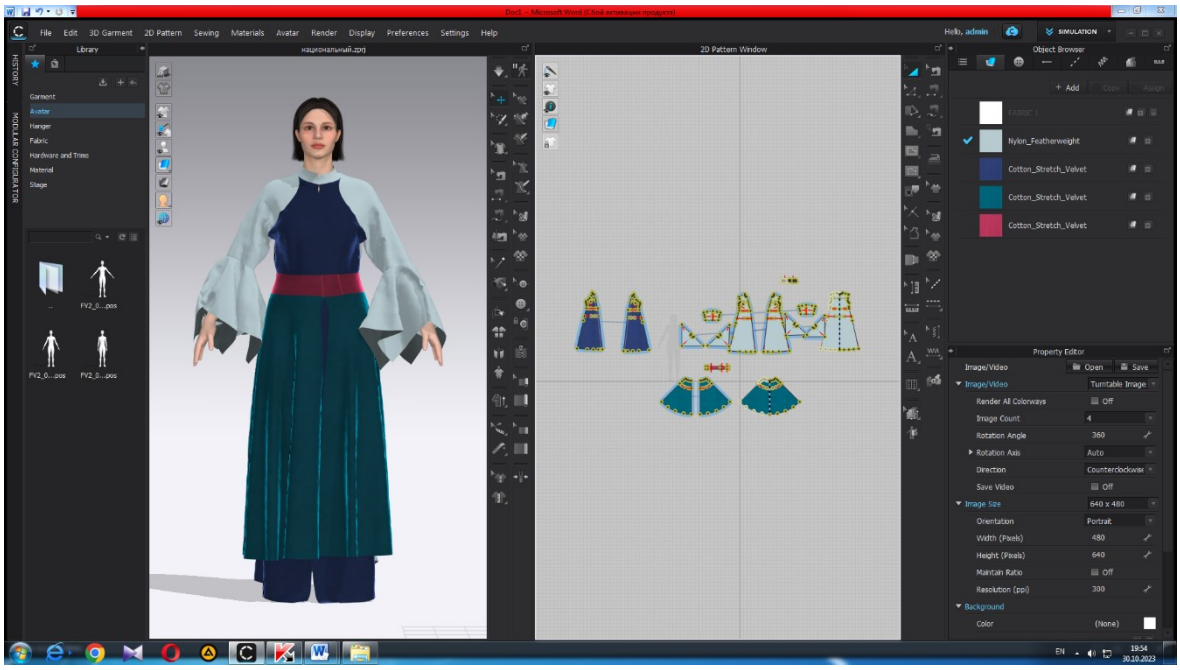


Figure 11. Viewing a dress through the Simulation function

Thus, the time to produce models of new clothes is reduced many times over. In today's world, designers have time to devote more time to creative processes, which allows the generation of more and more original models. In conditions of great competition, this is a big breakthrough, and an opportunity to make yourself known.

DISCUSSION

The use of neural networks is a rapidly and successfully developing direction, which is already showing positive results, and possible shortcomings of the method in design can lead to the creation of models with "zest".

Not unimportant is the fact that from an ecological point of view the use of neural networks and graphical programs is very beneficial, as it eliminates the moment of experimental sewing of the product. This in turn reduces the cost of fabric, accessories and time for its manufacture. The moment of outputting waste of various materials, fittings, etc. is eliminated, thus costs and waste can be reduced.

After some slowdown caused by the Covid-19 pandemic, global demand for clothing continues to grow. In the next few years, this demand will increase the size of the global light industry from $1.5 trillion in 2020 to $2.25 trillion by 2025 [9]. However, this market expansion doesn't mean that manufacturers are ready to easily meet consumer expectations. Like any other industry, the apparel and textile industries must learn to cater to a growing population while keeping in mind the planet's limited resources.

A new study by Grand View Research shows that as a result of increasing demand for apparel in developing countries such as China, India, Mexico and Bangladesh, the global textile markets are expected to grow at a compound annual growth rate of 4.3% through 2027. Already, the development

of new technologies such as AI and the Internet of Things (IoT) are significantly changing the once very labor-intensive textile business [9].

Most textile production facilities now already use programmable machines and mass production of fabrics is now organized much more efficiently than before. AI, on the other hand, can access and collect historical and operational data for manufacturers in real time. If those have a clear view of their operations, it will be much easier for them to modify processes to improve human productivity.

AI can at least partially already be applied at every stage of product creation, whether it is product costing, textile manufacturing, quality control, just-in-time production, data collection, or computerized manufacturing. Typically, integrated AI applications include defect detection, pattern checking and color matching for textile manufacturing. The use of AI has also enabled better options for creating "smart clothes" that utilize IoT and electronic sensors. Through the use of these technologies, such clothing can become more enjoyable and healthier.

The whole process of creating fashion collections begins two or even three years before the finished product is released on the market. It starts with determining the materials and colors for those models that will be in demand by consumers after such a significant period of time. Since fashion trends today are changing rapidly, forecasting is not only difficult in itself, but also time-consuming. Until now, analysts had to determine the next trend by manually poring over photos from shows, studying previously popular styles, social media trends and customer preferences. Professionals can "hit the bull's-eye" or they can miss. AI trained to work with Big Data analyzes previous fashion data, assesses customer demands and preferences, evaluates competitors' movements and identifies market trends much more accurately and quickly. Within minutes of data processing, it is ready to provide accurate information about upcoming fashions. By tracking the latest fashion trends, AI allows brands and manufacturers to go to the top in a matter of days or months.

CONCLUSION

There is now a heated discussion about whether AI can completely replace designers. At this stage, no, AI still learns from models already developed before it, but AI applications can be analyzed, and the photos uploaded to them can be studied, and therefore, at some point, a completely new fashion may emerge from this. Thus, the world's first AI Fashion Week took place in April 2023, with over 300 designers applying [9]. So far, the collections presented there still looked like recognizable imitations of famous brands, only in a higher quality sketch, but after AI design applications were launched, numerous e-comm titans are already taking serious steps to implement this technology at the assortment development stage. For example, a group of professionals from Amazon has developed an artificial intelligence tool that can analyze photos and independently create a brand new clothing design. Another application of this company quickly reads the selected image and gives stylistic advice on the "fashionability" of this or that bow (this also works in relation to products presented on the marketplace by third-party sellers). Not only Amazon, but hundreds of other digital giants have already started their experiments with artificial intelligence and fully optimized the design process. In collaboration with the Tommy Hilfiger brand and New York's Fashion Institute of Technology (FIT), IBM is using artificial intelligence to optimize the design process [9].

Thus, quality trend forecasts and developed models companies proceed to order fabrics that they will later use to make clothes. Here it is a good time to see where AI can be (or is already being) applied in the textile industry.

The research has shown that, already now using all possibilities of neural networks, as a powerful means of increase of effective work of designers and graphic programs together on much facilitates work of the designer, and also it was only on an example of one direction, and if to take such scale, the given made work shows that application of AI and graphic programs gives big advantages.

REFERENCES

1. Artamoshina M.N. Information technologies in sewing production: textbook for students of secondary vocational education / textbook for students of secondary vocational education. production: textbook for students of secondary vocational education / M.N. Artamoshina. M.N. Artamoshina, - M.: Publishing Center "Academy", 2010, - 176s.
2. Bulatova E.B. Evseeva M.N. Constructive modeling of clothes: Textbook for students of higher educational institutions - M.: Publishing Center "Academy", 2004, - 176 p. Center "Academy", 2004.-272s.
3. Designing clothes with elements of CAD: Textbook for universities /E.B. Koblyakova, G.S. Ivleva, V.E. Romanov et al. -4th ed., revision. Supplement; Edited by E.B. Koblyakova. Koblyakova. - Moscow: KDU, 2007.-464 pp.
4. Internet sources: https://goo.su/kv8F
5. Internet sources: https://goo.su/REMGoo
6. Internet sources: https://goo.su/STJ2ZV
7. Internet sources: https://lifehacker.ru/kak-polzovatsya-midjourney/
8. Internet sources: https://goo.su/MvUWmN
9. Internet sources: https://lp-magazine.ru
10. Software: Neural network Midjourney; САПР Графис 12; Clo3D

CORRESPONDING AUTHORS:

Akimjanovna Imiila RYSBAEVA
E-mail: imiyla@kstu.kg,
Taalaybekovna Baktygul TURGANBAEVA
E-mail: turganbaeva.b@inbox.ru
Department of Technology of Light Industry Products, Institute of Technology, I.Razzakov Kyrgyz State Technical University (KSTU)

Madanbekovna Gulida KUDAKEEVA
E-mail: kgm@kstu.kg
Department of Automation and control, Institute of Information Technologies, I Razzakov Kyrgyz State Technical University (KSTU)
66, Ch. Aitmatov Avenue, Bishkek 720044, Kyrgyzstan

TYPES OF INTERLININGS USED MANUFACTURING MEN JACKET

Ineta NEMEŠA, Marija PEŠIĆ, Nadiia BUKHONKA, Valentina BOZOKI

Technical faculty "Mihajlo Pupin", University of Novi Sad, Zrenjanin, Serbia

Abstract

Interlining is a layer of woven, non-woven or knitted fabric inserted between the outer fabric and the lining of a jacket to give a suitable 3D shape and stability to its parts. Different kind of canvas and fusible interlinings are used manufacturing a men suit. Fusible interlining can be created from different origin and qualities base material and adhesive substances applied to it. Special fusing presses are used to fix fusible interlining to separate parts of a jacket. The woven canvas interlinings are machine stitched to outer fabric of a jacket. There is great variety of canvas interlinings which differ in material, qualities, weights and degrees of stiffness. Blindstitch padding machines are used to fix them on the outer material components of a jacket. The machine stitching allows canvas interlining to move/"float" a little in between the outer fabric and the lining. The fusible interlining is glued to outer fabric and cannot move. Both kinds of interlinings have their advantages and disadvantages manufacturing and wearing classical men jacket.

Keywords: *men jacket, fusible interlining, canvas interlining, fusing presses, blindstitch padding machines*

1. INTRODUCTION

Today's men suits significantly differ from their ancestors worn by men in previous centuries. However they still keep the most important features - high quality, perfect fit, neat and elegant look which was obtained by hands of skilful and experienced tailors (see Fig.1). With time garment industry has developed different kind of new materials and machinery to replaces manual sewing techniques and ensure much higher work productivity acceptable for industrial manufacturing conditions [1, 2].

Figure 1: Men jacket and its front interlining

The good shape and fit of a jacket is created by help of its three material layers: face/shell fabric, interlining and lining. Interlining is a layer of woven, non-woven or knitted fabric inserted in between the face fabric and a lining of a jacket to form desired 3D shape and stability to its parts [3]. It use to be called as the inner secret, structure or a skeleton of a suit jacket. The interlining helps the jacket to fit and hang better on a man's body, and with it, to achieve the aim of its design - to create the shape of the masculine physique.

Different kind of canvas and fusible interlinings are used manufacturing a men suit. The woven canvas interlinings are machine stitched to the face fabric of a jacket. There is great variety of canvas interlinings which differ in material, qualities, weights and degrees of stiffness. Blindstitch padding machines are used to fix them on the face material components of a jacket. Fusible interlinings can be created from different origin and qualities base material and adhesive substances applied to it. Special fusing presses are used to fix fusible interlinings to the separate parts of a jacket.

The main interlinings used in a men jacket can be divided in three groups depending of their placement and application (see Fig...), [4]:

- body/front interlining - serves as the foundation of the entire interlining structure, its weight, firmness, and stiffness depends on qualities of a face fabric (see part 5 in Fig.2);
- chest interlining - provides reinforcement for the chest area, it has a stronger stiffness compared to the body interlining. There are several layers of canvas interlining used in combination to create a chest component (see part 3 in Fig.2);
- shoulder interlining - reinforces the shoulder area and is added on top of the body interlining and chest interlining. It has even greater stiffness than the chest interlining. It is used to mould and maintain the shape and lines of the sleeve (see part 2 in Fig.2).

The chest piece is probably the most important part of the suit jacket. This is also known as the forepart. Commonly it is made from two pieces of canvas to produce a naturally curved shape for the chest and shoulder, usually also accompanied by a layer of felt which is attached to soften the chest piece and create a greater comfort for the wearer. There are numerous other parts of a jacket which have to be fixed with interlining: lapels, a collar, sleeve heads, hem lines, vents, pocket flaps, others (see Fig.2), [5].

Figure 2: Different interlinings of a jacket: collar (1), shoulder (2), chest (3), sleeve head (4), body (5), lapel (6) and pocket (7)

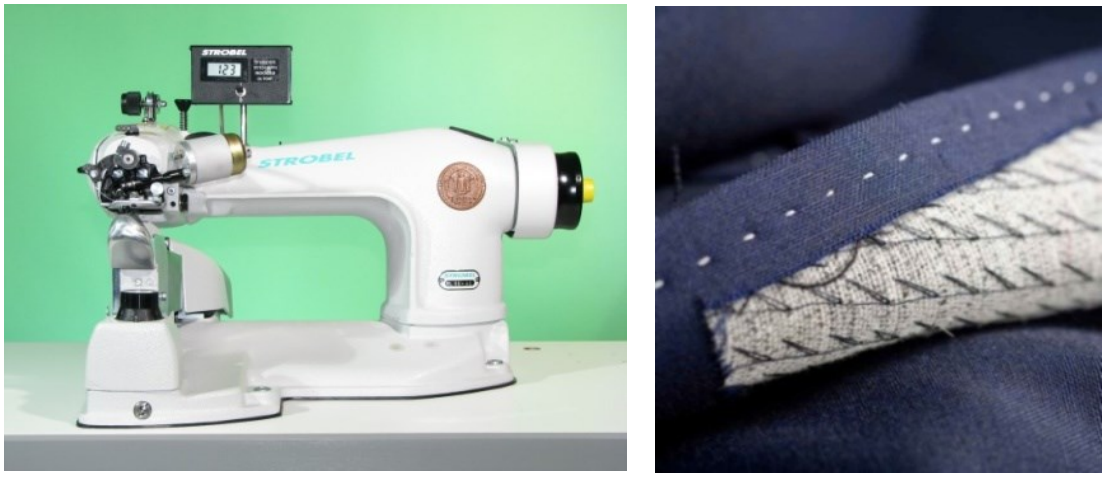
2. CANVAS INTERLININGS

Canvas interlining (also called hymo) is woven textile material which is a blend of natural or synthetic fibres (wool, cotton, linen, polyester, viscose, nylon) and animal hair (horse, camel or goat hair) [6,7]. It is traditional kind of interlining used in tailored men suits. The most often the animal hear is 30% and the cotton is 30% of the material, while other components, such us wool, viscose, polyester are used in smaller amounts [8,9]. There are available also so called Vegan canvas interlinings, in which the animal hair is replaced with synthetic or hemp fibers of similar to animal hair qualities. Vegan canvas are created to follow the sustainable development trend [10].

All materials used for canvas interlining are highly mouldable (by help of humidity, pressure, and heat) to create desired 3D shape of a jacket. Canvas interlinings are able to keep created shape long time passing numerous dry cleaning and wear cycles. Even more, the longer jacket with canvas interlining is worn, the better it conforms to the shape of the human body [11, 12, 13].

2.1 Machinery to fix canvas interlining to a jacket

The special padding sewing machines are used to fix canvas interlinings to the face fabric of a jacket (see Fig.3a), [14]. These machines can perform different operations: flat padding (for front component and its interlinings), roll-padding (for lapels, collars and flaps), and felling (for facings, breaktapes, edge tapes). These padding machines create stitch type 103 to make seams invisible on the top side of a face fabric (see Fig.3b). Roll padding machines are used to create 3D shape of lapels and a collar. They are equipped with a curved work surface called a roll horn (see Fig.3a). By help of it the processed part of a jacket can be slightly curved during a padding operation.



a b

Figure 3. Padding machine Strobel 58-4D (a) and padding with stitch type 103 (b)

Automated roll padding on both right and left lapels can be performed by 2-head roll padding machines (see Fig. 4), [14].

Figure 4: Automated roll padding machine Strobel KA-ED

The layers of canvas is stitched to shell material with loose single thread stitches. This allows the interlining to move a little and "float" in between a face fabric and a lining of a jacket [11, 15]. The canvas interlining sewn in such way is flexible in wear process. When its wearer moves, it moves too.

2.2 Application of canvas interlining in a men jacket

A men jacket is typically made with two types of canvas constructions: a full canvas – covering the whole front panel and a half canvas – running from shoulders to the waistline (see Fig. 5), [11, 12, 13, 15, 16, 17].

Figure 5: Jacket with half canvas and full canvas interlinings

Half canvas interlining

The half canvas construction extends from the shoulders to halfway down the jacket body, it finishes around the top button (see Fig.5). The half canvas creates well-shaped shoulder part and supports a front of a jacket towards the waist. The lower half of the jacket is fixed with fusible interlining. Because less canvas material is used and down part of a jacket is fixed with much lower priced fusible interlining, as

well as, less work is required to prepare and stitch the canvas interlining to a jacket, a half canvas suits are cheaper than full canvas suits. The half canvassed jacket is also lighter and less structured than the fully canvassed suit. The half canvas jackets are good option for warmer weather [11,12,13,15,16,17].

Full canvas jacket

The full canvas interlining goes from top to bottom of the jacket front (see Fig.5). It gives additional structure and allow the jacket to mould more accurately to a shape of a human body. Canvas also improves the durability of a jacket by distributing tension from stress points (such as the elbows and shoulders). The highest quality and price bespoke jackets have full canvas interlining. A full canvas jacket is heavier and more structured, it is preferable for winter suits. Due to more material and work used to create full canvas interlining, a jacket with it will cost more than one with half canvas [11,12,13,15,16,17].

3. FUSIBLE INTERLININGS

The parts of a jacket which are not fixed with canvas use to be fused with fusible interlinings. They have different origin and structure base material and adhesive substances applied to it. The most often interlinings with woven base fabric and weight 30-40g/m2 are used for large front component fusing. Non-woven interlinings with weight 20-35g/m2 are fixed on small components of a jacket [18]. Polyamide and low-density polyethylene are used as a adhesive substances of fusible interlinings.

Fusible interlinings can be manufactured in easier way and from much cheaper raw materials than canvas interlinings. Therefore they are lower priced and widely used in the garment industry to manufacture different kind of garments. However, the parts of a jacket which are fixed with fusible interlinings have little flexibility and they are less breathable than canvas interlinings. They are also less durable to dry cleaning process. The fusible interlinings can ensure acceptable quality reinforcing small components, such as, pocket openings, edges, hemlines, break lines. Used as a front interlining in half canvas jackets, the fusible interlinings reduce significantly manufacturing time and price of a jacket [12,15,16,17].

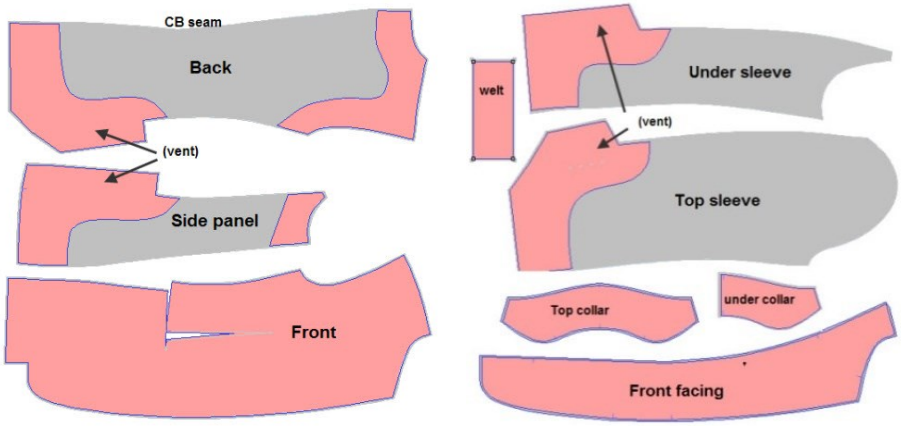


Figure 6: Fused parts of a men jacket

3.1 Machinery to fix fusible interlining to a jacket

The fusing of face fabric and its interlining components is carried out by discontinuous (flat) or continuous work process fusing presses (see Fig.7). The fusing process is performed by help of raised temperature, pressure and humidity. Temperature is the most important and the most critical factor for qualitative fusing. It has to be enough high to obtain high quality fused composite and in the same time enough low not to damage the interlining and the face fabric of a jacket. By help of pressure the melted adhesive gets into the structure of the face fabric. Humidity helps to melt the adhesive substance in lower temperature and more gently [19].

During the last decade the clothing industry can use new generations fusing presses which ensure qualitative fusing process avoiding face fabric shrinkage. Advanced continuous work process fusing presses have a long heating chamber and very sensitive automated heating system. The heating chamber of a press consists of several - up to five, seven, even nine, twelve individually controlled separate heating zones (see Fig.7b). Every heating zone has different temperature and can heat up components step by step in longer heating time. Besides, temperatures for the upper heating zones, which heat the interlining and the lower heating zones, which heat the face fabric, can be adjusted separately taking into account qualities of the materials [18, 19].

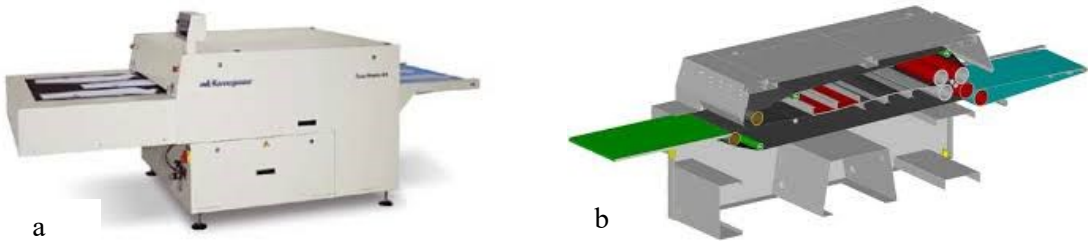


Figure 7: Fusible press (a) with several heating chambers (b)

Different productivity fussing presses are available. They can be equipped with feeding conveyors with several loading belts to place the face material and interlining components on the work surface of a press. Semiautomatic or fully automated collection stackers are used to stack fused components and the end of a fusing process.

4. CONCLUSIONS

Both kinds of interlining - canvas and fusible - are very important materials manufacturing a men suit jacket. Canvas is traditional kind of interlining used by tailors creating highest quality men suits. It gives the best shape to the jacket which is able to adjust fully to the individual human body in its wear process. It ensures also highest comfort level for its wearer being breathable and slightly movable in a jacket. However, production of canvas interlinings and their fixing in a jacket are complicated and time consuming processes. The use of canvas interlinings in a men jacket significantly raises its prise. In mass manufacturing of men suits the half canvas jackets are mostly produced using lower priced canvas materials.

Fusible interlinings are widely used in garment industry. Comparing with canvas, they are lower priced and mach easier fixable to jacket components. However, they create less flexible structure and are less suitable for 3D shaping of a jacket. Manufacturing men suits fusible interlinings can ensure good quality fixing small components. To reduce price of ready goods the fusible interlinings are used for front /body component fixing in the half canvas jackets.

REFERENCES

[1] Cabrera R., Antoine D. CLASSIC TAILORING TECHNIQUES FOR MENSWEAR, ISBN; 9781628921724, BLOOMBURY, 2015
[2] Nemeša I. BLINDSTITCH MACHINES FOR MEN SUIT MANUFACTURING. PART 1, *TEKSTILNA INDUSTRIJA*, (2021), VOL.69/2, PP.34-40
[3] Vilumsone-Nemes I, *INDUSTRIAL CUTTING OF TEXTILE MATERIALS, 2ND EDITION*, WOODHEAD PUBLISHING, ELSEVIER, ISBN-9780857091345, CAMBRIDGE, (2018).
[4]Yamamoto Y. ESSENTIAL ATTACHMENTS FOR JACKETS - INTRODUCTING THE INPORTANT FUNSCTIONS, TYPES, AND MANUFACTURING PROCESS OF INTERLINING, *AVAILABLE FROM:* https://www.tailors-world.com/en/news-en/interlining-canvas-2/
[5] KNIT FUSIBLE INTERLININGS, Available from: https://www.nonwovensindia.com/knitted-fusible-interlinings.html
[6] SEWING FREQUENTLY ASJED QUESTIONS, Available from: https://www.biasbespoke.com/sewingfaqs.html
[7] ROVANGATI PRODUCTS, Available from: http://www.rovagnativincenzo.it/en/products/
[8] CANVASSING, Available from: https://hallmadden.com/canvas
[9] HORSE HAIR CANVAS, Available from: https://www.dsk.co.th/canvas-interlining
[10] CANVAS – THE SECRET OF TAILORING SUIT, Available from: https://thesages.vn/canvas-the-secret-of-tailoring-suit/
[11] FULL CANVAS VS HALF CANVAS: CUSTOM SUIT INTERLINING OPTIONS, Available from: https://harttermanly.com/blog/full-canvas-vs-half-canvas/
[12]FULL CANVAS - HALF CANVAS - UNLINED - FUSED, Available from: https://www.deoost.com/blog/tag/Half+Canvas
[13]CONSTRUCTION/WORKMANSHIP, Available: https://www.universaltailor.com/constructionworkmanship/
[14 Nemeša I. BLINDSTITCH MACHINES FOR MEN SUIT MANUFACTURING. PART 2, *TEKSTILNA INDUSTRIJA*, (2021), VOL.69/3, PP.41-46
[15]WHAT IS FLOATING CANVAS, Available from: https://daraford.com/floating-canvas/
[16] FULL CANVAS VS HALF CANVAS - WHICH SUIT JACKET CONSTRUCTION IS RIGHT FOR YOU? Available from: https://www.oliverwicks.com/article/half-vs-full-canvas#half-canvas-construction
[17]SUIT JACKET CONSTRUCTION, Available from: https://www.beckettrobb.com/pages/suit-jacket-construction
[18]Vilumsone-Nemes I, INDUSTRIAL CUTTING OF TEXTILE MATERIALS, 2ND EDITION, WOODHEAD PUBLISHING, ELSEVIER, ISBN-9780857091345, CAMBRIDGE, (2018),
[19]Nemeša I., FABRIC SHRINKAGE FUSING MATERIAL AS THE REASON OF RAISED MATERIAL CONSUMPTION, CONTEMPORY TRENDS AND INNOVATIONS IN THE TEXTULE INDUSTRY, BEOGRAD, 02.05.2016, PROCEEDINGS, PP. 135-140
Additional source: https://hariomstailor.com/the-different-type-of-suit-interlining-and-why-it-matters/

CORRESPONDING AUTHOR:

Ineta NEMEŠA
Department of Basic and Applied Sciences, Technical faculty "Mihajlo Pupin", University of Novi Sad
Đure Đakovića bb, 23101, Zrenjanin, Serbia
E-mail: inetavil@gmail.com

EVALUATING OF THE EFFECTIVENESS OF DIGITAL CLOTHING IN ONLINE CUSTOMIZATION SYSTEMS

Mykola RIABCHYKOV[1], Viktoriia MYTSA[2]

[1] Lutsk National Technical University

[2] Khmelnytskyi National University

Abstract

Internet customization of clothes involves the active participation of the consumer in the creation of individual clothes for the purpose of their manufacture and use. Existing models of customization do not fully satisfy consumers in the case of production of ready-made products without fitting. The paper proves the feasibility and effectiveness of implementing blocks of digital clothing in the model of customization systems. The developed model resolves the contradiction between the modern possibilities of digital clothing and the difficulties of its implementation by means of digitization of the image, real display online or in virtual fitting rooms. The model of with application of virtual fitting rooms is proposed. An analysis of the conformity of the real product to its three-dimensional image and individual image in the virtual fitting room was made. A survey of potential customers of customization using digital clothing systems and interviews with manufacturers and organizers of online clothing stores were conducted. A comparison of the consumer and material efficiency of online digital clothing and digital clothing in virtual fitting rooms demonstrates the feasibility of implementing processes related to digital clothing into online customization systems.

Keywords: *Digital clothing, customization, fitting room, feedback loop*

1. INTRODUCTION

Internet trade is developing rapidly all over the world. For items of clothing, the processes are complicated by two main factors. The first factor consists in the fact that each customer wants to have personalized clothes that correspond to his preferences and, if possible, are individual. The second factor determines the difficulty in determining the actual appearance of the ordered clothes on a person.

The solution of these problems in a number of cases is associated with Internet customization systems [1]. These systems use a number of modern inventions, such as virtual reality devices and artificial intelligence programs. Blockchain technologies are adopted by many fashion brands [2].

The implementation of such systems requires the use of modern means of creating digital clothing and virtual prototyping technologies [3]. At the same time, one of the problems remains the lack of trust in the virtual matching of clothes.

The general problem consists in the construction of such a model, in which the wishes of the consumer were satisfied to the greatest extent without his real presence, but with the obligatory consideration of feedback.

2. STUDY OF THE STATE OF THE QUESTION, SELECTION OF UNSETTLED PARTS OF THE PROBLEM

The significant growth of online trade is determined by modern challenges and opportunities of the Internet. Research [4] proves the need for as deep knowledge as possible about the clothing sector when organizing online trade. Aspects identified as important by clients. The proposed system only partially solves the problem of customer feedback. Article [5] defines the main factors of consumers' attitude towards the online trade of clothes. The continuation of this trend is observed in the study [6], where it is determined that one of the important factors is the agreement of the actual product with the expectation. Article [7] proves the importance of individual design, reliability of manufacturing according to requirements.

Based on these publications, it is possible to draw a conclusion about the shortcomings of modern Internet trading systems related to a number of factors. One of the most important issues is data security threats. This fact can include theft of users' personal information, data leaks, and attacks on e-commerce sites that can compromise customers' confidential data. Online shopping runs the risk of not providing the buyer with a realistic picture of the quality of the goods. Photos and descriptions may be misleading, and the reality may be different from expectations. This applies not only to the quality of the goods but also to delivery. Returning or exchanging an item can be a complicated process due to poor-quality goods, erroneous orders, or customer dissatisfaction. Delays in delivery, flaws in tracking systems, or unforeseen circumstances such as natural disasters can lead to missed delivery deadlines and customer dissatisfaction.

Digital clothing solves many of the problems associated with the quality of information about the appearance of clothing and its fit on the individual consumer's figure. Despite the increasing development of digital clothing systems, they are not used enough in practical activities. The introduction of digital clothing has the potential to reshape the fashion industry radically. One key factor is trying on clothes virtually before buying them.

The technology that brought digital clothing to life is based on various approaches. One of the most common methods is 3D modeling, where virtual garments are created that can then be worn in augmented or virtual reality. Using special algorithms and simulations, these digital clothing are realistically animated to mimic the way fabric moves and behaves. Advanced image recognition technologies also make it possible to combine digital clothing with real images or videos, offering huge potential for e-commerce. Shoppers can try on different clothes and styles in a virtual environment for a personalized and interactive shopping experience. This fact gives retailers new opportunities to showcase their products and influence customers' purchasing decisions.

The authors [8] describe the possibilities of individual selection of clothes according to individual taste, but determine the need for a certain qualification of the consumer. Research [9] proves the possibility of building a structure based on three-dimensional measurements, which best corresponds to the individual physique.

Based on the analysis of literary sources, it is possible to note the main contradictions of the existing models of Internet customization (Figure 1).

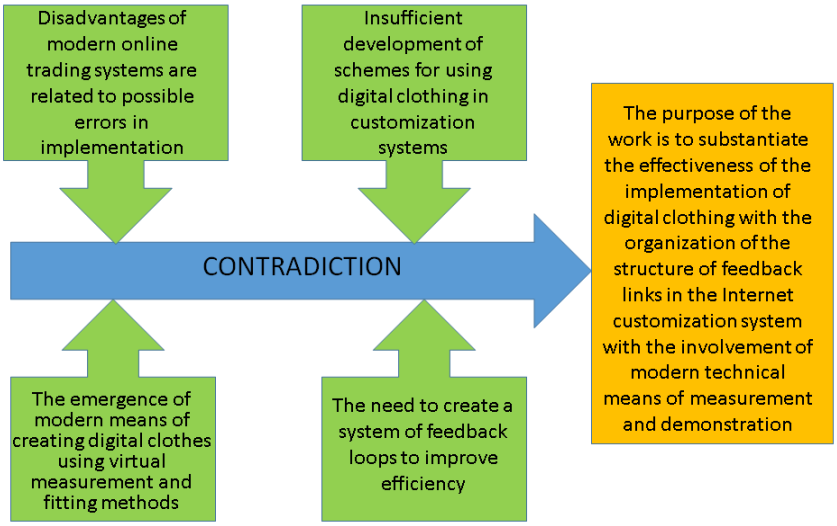


Figure 1: Contradictions of existing customization models

The purpose of the work is to substantiate the model of Internet customization with a network of service centers for the creation of avatars and virtual fitting rooms.

3. THEORETICAL RESULTS. IMPROVEMENT OF THE INTERNET CUSTOMIZATION MODEL USING DIGITAL CLOTHING SYSTEMS

The traditional model of an online customization system (Figure 2) includes the possibility of online communication with the consumer to satisfy their wishes. The general problem consists in the construction of such a model, in which the wishes of the consumer were satisfied to the greatest extent without his real presence, but with mandatory consideration of feedback.

Research proves the feasibility and effectiveness of implementing blocks of digital clothing in the model of customization systems. The developed model resolves the contradiction between the modern possibilities of digital clothing and the difficulties of its implementation employing digitization of the image, real display online, or in virtual fitting rooms.

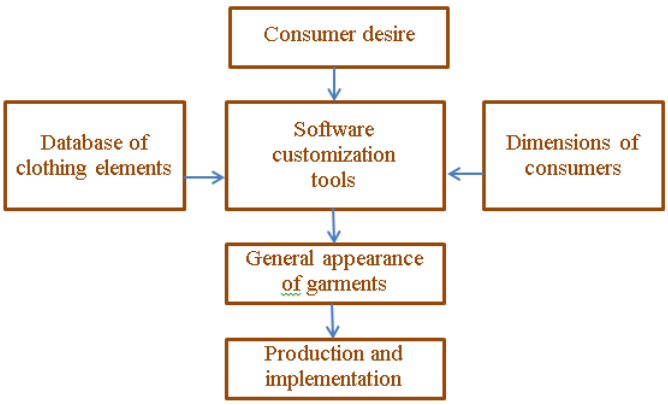


Figure 2: Existing customization scheme

The proposed model (Figure 3) uses several modern inventions, such as virtual reality devices and artificial intelligence programs. Blockchain technologies can be adopted by many fashion brands. Providing a feedback system increases trust and, accordingly, the effectiveness of customization.

The proposed model takes into account the latest achievements in the field of digital clothing and digital technologies and also provides for the creation of several feedback loops.

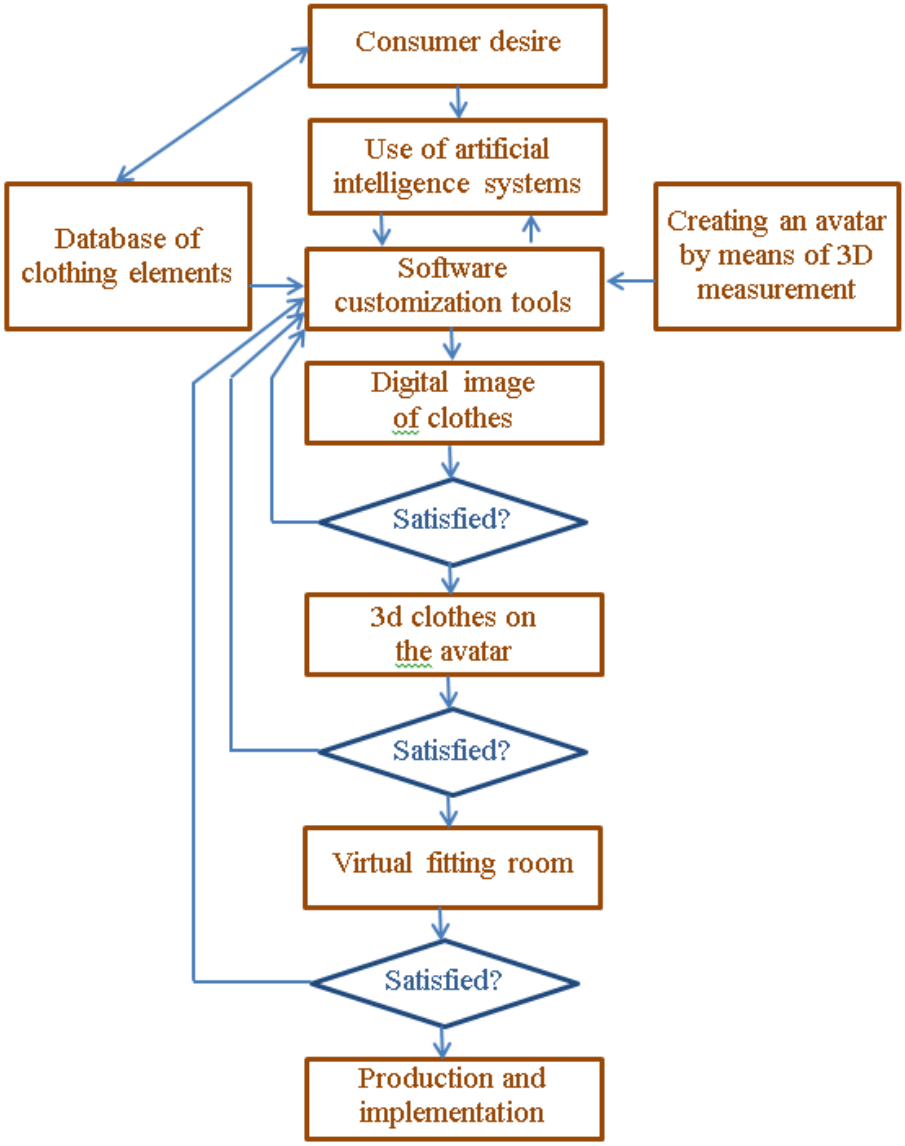


Figure 3: Customization scheme with the use of digital clothing

In particular, new blocks are proposed that take into account the use of artificial intelligence systems, software customization tools, digital images of clothes, 3D clothes on the avatar, use of virtual fitting rooms. These blocks are combined into one algorithm. The feedback system ensures constant contact with the individual consumer and increases the overall efficiency of clothing customization systems.

New business models based on this algorithm are customer-centric, which completely determines their structure: from the value proposition aimed at satisfying the customer's needs, timely delivery and to revenue streams.

2. EXPERIMENT. RECOGNITION OF THE EFFECTIVENESS OF THE PROPOSED MODEL

Interviews and surveys of possible consumers were organized. Consumers were divided into two age groups. Predictably, the younger age group showed a much greater willingness to use digital technologies in the process of designing, manufacturing, and selling clothes. The survey data are shown in Table 1.

Table 1: Questionnaire of potential consumers

Online customization options	Consumers aged 18-30	Consumers aged 31-60
Readiness to perceive the creation of clothes by methods of artificial intelligence	Middle level	Low level
Readiness to create and use 3D avatars	High level	Very low level
Readiness to use virtual fitting rooms	Very high level	Middle level
Willingness to participate in the customization process within existing limits	Middle level	Low level
Willingness to participate in the customization process in the conditions of using digital clothing	Very high level	Middle level

A very high level of readiness to use virtual fitting rooms, as well as willingness to participate in the customization process in the conditions of using digital clothing, was demonstrated. A high level is demonstrated in the field of readiness to create and use 3D avatars.

Representatives of the older age group demonstrated a rather low level of readiness to create and use 3D avatars, which is in contradiction with the survey of representatives of the younger age group. Meanwhile, general trends demonstrate very real prospects, the possibility, and expediency of implementing the proposed scheme with the introduction of digital clothing systems, 3D avatars, and virtual fitting rooms.

Cronbach's Alpha coefficient was calculated to assess the reliability of the survey and to select the most complete set of criteria for the effectiveness of the adjustment. The weighting coefficients of possible directions for the introduction of digital clothing were determined (Table 2). The level of significance was determined on a five-point scale. All the proposed blocks have a fairly high level of significance.

Table 2: Significance of customization model based on the use of digital clothing

Parameter	Relevance	Cronbach's alpha
Digital image	4.14	0.8742
3D clothes	3.55	0.8432
Virtual fitting room	3.67	0.8163
Artificial intelligence	3.72	0.7885
Software customization	4.19	0.9214

High levels of values Cronbach's alpha indicators demonstrate sufficient completeness of the proposed model and the absence of the need to exclude the main blocks, elements, and feedback.

3. DISCUSSION

Digital clothing allows complete freedom of expression for both consumers and designers. The advantage of digital clothing is that there is no need to purchase real clothing online with the risk of not getting what you want. For these purposes, you can create a digital thing. The most real-life application of this technology is digital prototyping. With such images, you can see how the item will fit on different body types, and, based on the results, decide on launching a clothing line or purchasing it.

The transformation of traditional fashion into its correspondence with the so-called meta-fashion is happening very actively, supporting general changes in the world. Consumers become avatars for themselves not only in social networks but also in digital production systems, digital fashion, and online commerce.

The transition of digital clothing into the real sphere requires, on the one hand, certain financial and intellectual investments, and on the other hand, it can potentially significantly increase the efficiency of the online fashion trade. Research shows that potential consumers, especially in the younger age segment, are ready for the practical implementation of digital means in their diversity.

CONCLUSIONS

The model of Internet customization using digital clothing systems and artificial intelligence is proposed. Directions for using 3D measurements, 3D avatars, and virtual fitting rooms are shown.

The conducted surveys confirmed the readiness of the modern consumer to participate in the use of digital clothing, sufficient completeness of the proposed model, and a potential increase in the effectiveness of online clothing customization systems.

REFERENCES

Srivathsan, K. et al. CUSTOMIZATION OF USER EXPERIENCE IN FASHION TECHNOLOGY, *3RD INTERNATIONAL CONFERENCE ON INNOVATIVE PRACTICES IN TECHNOLOGY AND MANAGEMENT (ICIPTM),* UTTAR PRADESH, INDIA, (2023), PP. 1-6. HTTPS://DOI.ORG/10.1109/ICIPTM57143.2023.10117970

Riabchykov, M., Mytsa, V. PROVISION OF NEW MODELS OF ORGANIZATION IN THE FASHION INDUSTRY WITH THE USE OF ELECTRONIC LABELS, *CREATIVITATE. TEHNOLOGIE. MARKETING. CTM 2023*: AL V-LEA SIMPOZION INTERNATIONAL, 31 MARTIE. – CHIȘINĂU: TEHNICA-UTM, (2023), PP. 215-220. HTTPS://FD.UTM.MD/WP-CONTENT/UPLOADS/SITES/37/2023/11/SIMPOZION-CTM-2023.PDF

Papachristou, E., Kalaitzi, D. & Kaseris, M. AN INNOVATIVE PLATFORM FOR DESIGNING AND RAPID VIRTUAL PROTOTYPING OF GARMENTS: THE CASE OF I-MANNEQUIN, IN: *SILVA, F.J.G., PEREIRA, A.B., CAMPILHO, R.D.S.G. (EDS) FLEXIBLE AUTOMATION AND INTELLIGENT MANUFACTURING: ESTABLISHING BRIDGES FOR MORE SUSTAINABLE MANUFACTURING SYSTEMS*, FAIM (2023), LECTURE NOTES IN MECHANICAL ENGINEERING. SPRINGER, CHAM. HTTPS://DOI.ORG/10.1007/978-3-031-38241-3_40

Sharma, H. USING TOPIC MODELING FOR EXTRACTING CUSTOMERS' EXPECTATIONS: A CASE OF WOMEN APPAREL, *BUSINESS PERSPECTIVES AND RESEARCH, 0(0)*, (2023). HTTPS://DOI.ORG/10.1177/22785337221150831

Shi, K. et al. E-SHOPPING ATTITUDES MEDIATE THE EFFECT OF THE BUILT ENVIRONMENT ON ONLINE SHOPPING FREQUENCY OF E-SHOPPERS? *INTERNATIONAL JOURNAL OF SUSTAINABLE TRANSPORTATION*, 17(1), (2021), PP. 41–51. HTTPS://DOI.ORG/10.1080/15568318.2021.1983676

Stoian Bobalca, C. et al. ANALYSING THE PREDICTORS OF THE YOUNG BUYERS' SATISFACTION IN THE E-RETAILING APPAREL SECTOR, *INTERNATIONAL JOURNAL OF RETAIL & DISTRIBUTION MANAGEMENT*, VOL. 49, (2021), NO. 12, PP. 1597-1620. HTTPS://DOI.ORG/10.1108/IJRDM-08-2020-0302

Goyal, N. et al. A STUDY ON ONLINE SHOPPING BEHAVIOUR FOR APPAREL, *2021 3RD INTERNATIONAL CONFERENCE ON ADVANCES IN COMPUTING, COMMUNICATION CONTROL AND NETWORKING (ICAC3N)*, GREATER NOIDA, INDIA, (2021), PP. 1986-1991. HTTPS://DOI.ORG/10.1109/ICAC3N53548.2021.9725504

Yang, C., Tian, W. & Zhang, L. AN IMPROVED TARGET DETECTION ALGORITHM MODEL FOR GARMENT IMAGE DETECTION, *2022 21ST INTERNATIONAL SYMPOSIUM ON DISTRIBUTED COMPUTING AND APPLICATIONS FOR BUSINESS ENGINEERING AND SCIENCE (DCABES)*, CHIZHOU, CHINA, (2022), PP. 99-102. HTTPS://DOI.ORG/10.1109/DCABES57229.2022.00014

Riabchykov, M. et al. FORMATION OF COMPLEX 3D SURFACES SCANS FOR GARMENT CAD, *FIBRES AND TEXTILES*, 30(3), (2023), PP. 13-18 HTTPS://DOI.ORG/10.15240/TUL/008/2023-3-002

CORRESPONDING AUTHOR:

Viktoriia MYTSA
Department of Garment Technology and Design, Khmelnytskyi National University
29016, 11, Instytuts'ka str., Khmelnytskyi, Ukraine
E-mail: mitsa_vv@ukr.net

CORRELATIONS BETWEEN ECONOMIC GROWTH AND CARBON-DIOXIDE EMISSION IN SELECTED COUNTRIES BETWEEN 1990 AND 2021

Sándor J. ZSARNÓCZAI

Institute of Environmental Engineering and Natural Sciences, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

Abstract

Recently because of the global warming resulted by mostly carbon-dioxide gas emission based on the human activity, therefore the mitigating gas emission became important by global cooperation of countries. In the period of 1990 and 2021 the study analyses the volume of carbon-dioxide emissions and its corelations with economic features of selected economies, which have significant role in field of gas emissions and mitigating gas emissions. Economic features of United States, United Kingdom, Japan, Russia, Germany, France, Italy, China, India, Iran, Saudi Arabia, Sweden, Hungary, Poland, Austria, Turkey, Brazil and Egypt are included in the analyse. The research method is based on the statistical program for social sciences (SPSS). China has share by 32.9% in global carbon-dioxide emissions, while the United States has share by 12.6% and the EU-27 has share by 7.3% and India has share by 7.0% in the same time 2021. The study proofs that the total investment in 2021 has strong correlations with CO2 emissions Mt CO2/year, in 2021 and CO2 emissions per capita ton CO2/cap/year, in 2021. The solution for the mitigating carbon-dioxide emissions is to develop advanced green environment friendly technology for using renewable energy resources.

Keywords: *Economic variables, global warming, green technology, investment, renewable energy*

1. INTRODUCTION

The global economic growth in the world economy sharply resulted increase of the carbon-dioxide gas emissions for latest decades. Therefore, the global common force is needed based on wide-side international cooperation for decreasing gas emission from sides of highly developed and developing countries. In all over the world the fossil carbon-dioxide gas emission has increased by 67% since 1990 by the end of 2021, while the number of populations of the world increased by 48%. Aim of study is to show that by the end of 2021 the carbon-dioxide gas emissions increased more than the increasing growth of populations of the world, which was mostly resulted by intensive increase of carbon-dioxide gas emissions in the developing countries. Also, the study emphasizes participation of the selected countries in all of carbon-dioxide emissions. China has share by 32.9% in global in this gas emission, while the United States (US) has share by 12.6% and the EU-27 has share by 7.3% and India has share by 7.0% in the same time 2021 (IMF 2023). China has only alone created carbon-dioxides gas emissions more than one of all together US and EU-27 by the end of 2021. Also, dominate role of China in field of the carbon-dioxide fossil gas emissions is proofed by 8.727 of China in fields of CO2 emissions per capita ton CO2/cap/year, in 2021, while data of the world in this field was only 4.811 and in case of EU-27 was by 6.254.

The study analyses between 1990 and 2021 based on the data base (Table 1) correlations among the economic growth and its influences on the carbon-dioxide gas emission either in field of all this carbon dioxide gas emission of some countries or in field of per capita gas emission in cases of some selected significant economies in four continents. These economies, which are follows as the United States, the United Kingdom, Japan, Russia, Germany, France, Italy, China, India, Iran, Saudi Arabia, Sweden, Hungary, Poland, Austria, Turkey, Brazil, Egypt. These countries with their economic power capacity could globally play important role for decreasing carbon-dioxide gas emissions having greenhouse gas affecting therefore, in order to mitigate global worming resulted by the human activity.

Hypotheses of the study, which are as follows:

The study emphasizes that CO2 emissions growth rate Mt CO2/year, for period of 1990-2021 (EmissMt8) has correlations with CO2 emissions growth rate per capita ton CO2/cap/year for period of 1990-2021 (EmissCapit9) and growth rate of populations for the period of 2021 and 1990 (PopuGrow11).

Study provides proof that how much total investment in percent of GDP in 2021 (TotInvest216) has correlations with CO2 emissions growth rate Mt CO2/year for period of 1990-2021 (EmissMt8) and CO2 emissions growth rate per capita ton CO2/cap/year for period of 1990-2021 (EmissCapit9).

Study proofs important correlation between GDP consequently growth rate at constant price, either in 1990 or 2021 (GDPgrow901 and GDPgrow212).

From importance of the study the correlation can be considerable between CO2 emissions growth rate per unit of GDP PPP ton CO2/k USD/year (EmiPeUn10) and the population growth rate for period of 1990-2021 (PopuGrow11).

The study analyses that the total investment in percent of GDP in 1990 and 2021 (TotInvest905 and TotInvest216) have any possible correlations with unemployment rate, in percent of total labour force in 1990 and 2021 (Unempl903 and Unempl214) and general government gross debt in percent of GDP in 2021 (GenGovDeb7).

The study used many sides actual statistical sources, which mostly came for the UN International Monetary Fund and some National Statistics Offices concerning the selected countries.

The important international initiative was the *Paris Agreement is a legally binding international treaty on climate change*. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in *Paris, France, on 12 December 2015.* In the Agreement partners declared that its overarching goal is to hold “the increase in the global average temperature to well below 2°C above pre-industrial levels” and pursue efforts “to limit the temperature increase to 1.5°C above pre-industrial levels.” Also partners of the Agreement emphasized the climate finance is needed for mitigation, because large-scale investments are significantly required to reduce gas emissions. *By 2030, zero-carbon solutions* could be competitive in sectors representing *over 70% of global emissions* (UN Climate Change, 2023).

By the end of 2021 the EU-27 was the third largest carbon-dioxide emissions (EC, JRC 2022), because its 7.3% share was in global after China by 32.9% and US by 12.6% and then other significant countries

were Inda by its share 7.0%, Russia by its share 5.1% and Japan by its share 2.9%. Emissions of China in 2021 were more than five times larger than in 1990, which accounted for 10.7% of global carbon-dioxide emissions in 1990. In China in 2021 sectors the most contributing to fossil CO2 emissions were power generation by 44% and other industrial combustion by 27%. Also, in China CO2 emissions per GDP PPP (Purchase power parity) amounted to 0.501ton CO2/k US dollar, as highest CO2 intensity of top emitting economies (EC, JRC 2022).

The EU has exceeded the target to reduce its greenhouse gas emissions by 2020 comparably to gas emission in 1990. This target was by 20% for decreasing CO2 equivalent gas emissions by the end of 2020, but EU-27 decreased by 30% (EP 2023, European Parliament). The EU-27 realised 27% decrease in field of CO2 emissions growth Mt CO2/year, 31% decrease in field of CO2 emissions growth per capita ton CO2/cap/year, and 55% decrease in field of CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year, while the population growth increased only by 6% for period of 1990-2021.

These results were positive and better than in case of the world, because globally in the world 67% increase in field of CO2 emissions growth Mt CO2/year, 13% increase in field of CO2 emissions growth per capita ton CO2/cap/year, and 36% decrease in field of CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year, while the population growth considerably increased by 48% for period of 1990-2021. *The difficulty at global level is that even the CO2 emissions growth per capita increased in this period* and not decreased based on the considerable population increase. The global results in these fields could be dangerous for target of green policy given by UN and Paris Agreement.

In US transportation sector generated the largest share of greenhouse gas emissions, as 28% in 2021. Globally the greenhouse gas emissions from transportation primarily come from burning fossil fuel for our cars, trucks, ships, trains, and planes. Over 94% of the fuel used for transportation is petroleum based, which includes primarily gasoline and diesel (IPCC 2022 and more detailed in IPCC 2014, Intergovernmental Panel for Climate Change).

The above-mentioned strategy concerning mitigating CO2 emissions needs for considerable green investment providing more jobs to increasing employment level accompanying with less CO2 emissions. Naturally the mitigation for gas emissions should be based on the support of highly developed economies for developing economies in field of the green technological transfer in order that these developing countries could implement targets of UN to decrease burden of human activity and consumption on the natural environment.

2. MATERIAL AND METHODS

Objectives of the study concerning the analysing methods, as statistical program for social sciences (SPSS), which was prepared in detailed by Salcedo – McCormick (2017). The analysing method is based on SPSS including *main economic variables* concerning economic features of selected countries. These economic variables are as GDP constant price in 1990 (GDPgrow901), GDP constant price in 2021 (GDPgrow212), Unemployment rate, in percent of total labour force in 1990 (Unempl903), Unemployment rate, in percent of total labour force in 2021 (Unempl214), Total investment, in percent of GDP in 1990 (TotInvest905), Total investment, in percent of GDP in 2021 (TotInvest216), General

government gross debt in percent of GDP in 2021 (GenGovDeb7), CO2 emissions growth rate Mt CO2/year (EmissMt8), CO2 emissions growth rate per capita ton CO2/cap/year (EmissCapit9), CO2 emissions growth rate per unit of GDP PPP ton CO2/k USD/year (EmiPeUn10), Population growth rate in percent (PopuGrow11) for period of 1990-2021.

This analyse-method can clearly overview correlations among economic variables as features of researched selected countries based on the original statistical data base in Table 1 (IMF October 2023) for the given period by owned calculation. The up-half-part of the Table 2 provides overview for values of correlations among economic variables. If values of correlations are over 0.800 (80%) these correlations are very strong among the variables, but if these values between 0.500 and 0.800 (50%-80%) correlations are *strong*. If values are under the level of 0.500 (50%) correlations are not important for this analysing. Naturally if the values are closed to the level of 0.500 from downside, the analyse can be accepted. Table 3: Rotated Component Matrix selects eleven variables as economic features of the selected countries in the study *into four components*, of which correlations are demonstrated in towards Figure 1

Table 1: Selected countries in fields of GDP growth rate, unemployment rate, total investment, general government gross debt, CO2 emissions growth Mt CO2/year, CO2 emissions growth per capita ton CO2/cap/year, CO2 emissions growth per unit of GDP PPP ton CO2/k USD /year and population, in percent in Million between 1990-2021, 1990 = 100

Lines	**X**			**Y**							
Countries	**9**	**6**	**8**	**10**	**11**	**4**	**3**	**1**	**2**	**7**	**5**
United States	*-29*	*21*	*9*	*-45*	*32*	*5*	*6*	*2*	*6*	*126*	*22*
United Kingdom	*-52*	*18*	*-43*	*-67*	*18*	*5*	*7*	*1*	*8*	*105*	*23*
Japan	*-9*	*26*	*-7*	*-27*	*1.3*	*3*	*2*	*5*	*2*	*255*	*36*
Germany	-37	23	-35	-57	4	4	6	6	3	70	27
France	-32	25	-22	-50	16	9	8	3	6	113	24
Italy	-28	21	-26	-38	3	10	9	2	7	150	23
Sweden	-44	26	-33	-75	-16	9	2	1	6	30	27
Russia	*-17*	*23*	*-19*	*-37*	*-3*	*5*	*5*	*-9*	*6*	*16*	*-10*
Hungary	*-24*	*31*	*-30*	*-57*	*-8*	*4*	*2*	*-3*	*7*	*76*	*27*
Poland	-14	22	-14	-71	-0.1	3	6	-7	7	54	25
Austria	-8	28	5	-37	14	6	3	28	28	83	27
China	*322*	*43*	*414*	*-67*	*22*	*5*	*5*	*4*	*9*	*72*	*34*
India	175	31	341	-25	61	7	6	6	9	84	26
Iran	131	41	247	40	50	9	14	14	5	42	33
Saudi Arabia	57	25	240	43	116	7	4	15	4	29	16
Turkey	91	32	200	-23	57	12	8	9	12	42	24
Brazil	49	20	114	8	44	13	6	-4	5	90	19
Egypt	56	15	185	-23	82	7	8	2	3	90	27
Average	*32.6*	*26.2*	*84.8*	*-33.8*	*27.4*	*6.8*	*6*	*4.2*	*7.4*	*84.8*	*23.9*
Countries	**9**	**6**	**8**	**10**	**11**	**4**	**3**	**1**	**2**	**7**	**5**

Source: International Monetary Fund, World Economic Outlook Database, October 2023, National Statistics Office.
Note: Ordering List of economic variables concerning the Figures 1,2,3

In 1991 in Saudi Arabia the general government gross debt in % of GDP was 40%.

GDPgrow901 = GDP constant price, in 1990, growth rate in percent change, in national Currency

GDPgrow212 = GDP constant price, in 2021, growth rate in percent change, in national currency

Unempl903 = Unemployment rate, in percent of total labour force in 1990

Unempl214 = Unemployment rate, in percent of total labour force in 2021

TotInvest905 = Total investment, in percent of GDP in 1990

TotInvest216 = Total investment, in percent of GDP in 2021

GenGovDeb7 = General government gross debt in percent of GDP in 2021

EmissMt8 = CO2 emissions growth Mt CO2/year, in percent by the end of 2021, for period of 1990-2021, 1990= 100

EmissCapit9 = CO2 emissions growth per capita ton CO2/cap/year, in percent by the end of 2021, for period of 1990-2021,1990= 100

EmiPeUn10 = CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year, in percent by the end of 2021, for period of 1990-2021, 1990 = 100

PopuGrow11 = Population Million, growth in percent by the end of 2021, for period of 1990-2021, 1990 = 100

Table 2: Correlation Matrix

		GDPgrow901	**GDPgrow212**	**Unempl903**	**Unempl214**	**TotInvest905**	**TotInvest216**	**GenGovDeb7**	**EmissMt8**	**EmissCapit9**	**EmiPeUn10**	**PopuGrow11**
Correlation	GDPgrow901	1.000	**.606**	.070	.117	.377	.357	-.007	.286	.200	.408	.378
	GDPgrow212		1.000	-.170	.053	.055	.222	-.145	.003	.060	-.141	-.102
	Unempl903			1.000	**.429**	.067	.128	-.134	.277	.223	.391	.320
	Unempl214				1.000	-.058	.037	-.205	.242	.146	**.433**	.339
	TotInvest905					1.000	.373	**.420**	.228	.282	-.087	-.007
	TotInvest216						1.000	-.225	**.596**	**.715**	.156	.013
	GenGovDeb7							1.000	-.261	-.199	-.115	-.217
	EmissMt8								1.000	**.949**	.461	**.681**
	EmissCapit9									1.000	.264	.435
	EmiPeUn10										1.000	**.744**
	PopuGrow11											1.000

Source: International Monetary Fund, World Economic Outlook Database, October 2023, National Statistics Office, by owned calculation

Table3: Rotated Component Matrix[a]

	Component			
	1	2	3	4
EmissCapit9	.940			
TotInvest216	.852			
EmissMt8	.852			
EmiPeUn10		.873		
PopuGrow11		.829		
Unempl214		.653		
Unempl903		.615		
GDPgrow212			.909	
GDPgrow901			.845	
GenGovDeb7				.849
TotInvest905				.804

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

Source: International Monetary Fund, World Economic Outlook Database, October 2023,

National Statistics Office, by owned calculation

3. RESULTS AND DISCUSSION

The study overviews main correlations among economic variables during the researched period of 1990-2021, in cases of the 18 selected countries, of which have important economic role and influences on the changing trend of the global economic prosperity. From this point of view their economic feature as

variables can have such kind of correlations, which means how each economic variable can make influence on the other one. Correlations of their economic variables can also show mutual influences of selected countries on each-others.

According the *Table 2* showing correlations among different economic variables, in cases of values of correlations are more than 0.800 (80%) the correlations are ***very strong***, namely CO2 emissions growth

Mt CO2/year, (EmissMt8) has very strong correlation with CO2 emissions growth per capita ton CO2/cap/year (EmissCapit9) for period of 1990-2021. This means that when carbon-dioxide emissions growth generally increases, also, the carbon-dioxide emissions growth per capita increases.

In cases of developed economies CO2 emissions Mt (EmissMt8) has decreased by the end of 2021 for period of 1990-2021, but the US was except, where by the end of 2021 carbon-dioxide emissions growth little has *increased* by 9%, while the carbon-dioxide emissions growth per capita sharply decreased by 29% for the same period. Also, in Austria carbon-dioxide emissions growth little has *increased* by 5%, while the carbon-dioxide emissions growth per capita little decreased by 8% for period of 1990-2021.

China has increased the top level in fields of carbon-dioxide emissions growth by 414% and per capita by 322% for the researched period in spite that population growth increased less by 22% in the same time, and the carbon-dioxide emissions growth per unit of GDP PPP (power purchase parity) ton CO2/k USD/year (EmiPeUn10) considerably decreased by 67%. This last one is a favourable result in international compare, because only Sweden had more than his level by decreasing 75% and United Kingdom (UK) was at the same level. But the carbon-dioxide emissions growth still remained at highly level in China.

*The correlations among variables are **strong*** between 0.500 and 0.800, which are follows:

The CO2 *emissions growth* Mt CO2/year (EmissMt8) has strong correlation by 0.681 (68%) with population growth (PopuGrow11) for period of 1990-2021.

The *total investment*, in percent of GDP in 2021 (TotInvest216) has strong correlations by 0.596 (59%) with CO2 emissions growth Mt CO2/year (EmissMt8).

The *total investment*, in percent of GDP in 2021 (TotInvest216) has strong correlations by 0.715 (71%) with CO2 emissions growth per capita ton CO2/cap/year (EmissCapit9) for period of 1990-2021, because investment increased even in percent of GDP, naturally the carbon-dioxide emissions also increased and in average increasing rates of two variables are closed to each-other (Table 1; IMF 2023).

GDP *growth rate* in 1990 (GDPgrow901) has strong correlation by 0.606 (60%) with GDP growth rate (GDPgrow212) in 2021.

The CO2 *emissions growth* per unit of GDP PPP ton CO2/k USD/year (EmiPeUn10) has strong correlation by 0.744 (74%) with population growth (PopuGrow11) in percent for period of 1990-2021.

The total investment in percent of GDP in 1990 and 2021 (TotInvest905 and TotInvest216) do not have any important correlations with unemployment rate, in percent of total labour force in 1990 and 2021 (Unempl903 and Unempl214) and general government gross debt in percent of GDP in 2021 (GenGovDeb7). Because total investment in both of years did not have considerable influences on increasing or decreasing of unemployment. Sometimes investment even can decrease employment level because of using modern technology resulting increase of unemployment rate either in developed economies or developing one. Naturally sometimes the new investment provides new jobs to extend employment.

In the *Figure 1*, variables are the CO2 emissions growth per capita ton CO2/cap/year, for period of 1990-2021 (EmissCapit9) and the total investment, in percent of GDP in 2021 (TotInvest216) and CO2 emissions growth Mt CO2/year, for period of 1990-2021 (EmissMt8) at horizontal line "X" of coordinate system. While the CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year, for period of 1990-2021 (EmiPeUn10), population growth in percent for period of 1990-2021 (PopuGrow11), the unemployment rate, in percent of total labour force in 2021 (Unempl214) and the unemployment rate, in percent of total labour force in 1990 (Unempl903) are at vertical line "Y" in this coordinate system.

In this Figure 1 it can be seen that in China trends of CO2 *emissions growth* per capita has increased by 322% for period of 1990-2021 (EmissCapit9) and the CO2 emissions growth Mt CO2/year (EmissMt8) increased by 414% at top level for same period. Also, the *total investment of China in percent of GDP in 2021* (TotInvest216) was at top level by 43% within the selected countries of this research, and then in cases of Iran (41%), Hungary (31%), India (31%) and Turkey (32%) in the same time.

The CO2 emissions growth Mt CO2/year (EmissMt8) has increased in India by 341%, in Iran by 247%, in Saudi-Arabia by 240%, in Turkey by 200% and in Egypt by 185% for period of 1990-2021, when these countries increased CO2 emissions growth per capita ton (EmissCapit9) in India by 175%, in Iran by 131%, in Turkey by 91%, in Saudi Arabia by 57%, in Egypt by 56% and in Brazil by 49% for the same period. Also, their total investment, in percent of GDP in 2021 (TotInvest216) was considerable, but total investment was not so much higher than in cases of highly developed economies.

In China the population growth has less increased by 22% for the researched period comparably with other developing countries, where this was so much higher in Saudi Arabia by 116%, in Egypt by 82%, in India by 61%, in Turkey by 57% and in Iran by 50%, in Brazil by 44%. But in case of China, when the population growth moderately increased comparably with other developing economies, this resulted the highly level of CO2 emissions growth per capita. In other countries because of the population growth has increased for the same period more like in Saudi Arabia by 116%, in Egypt by 82%, in India by 61% and in Turkey by 57% therefore, gas emission could be less than in case of China. Finally, the demand is to decrease all of the CO2 emissions growth. In highly developed economies and newly developed economies CO2 emissions growth Mt CO2/year (EmissMt8) *has mostly been decreasing* for same period, as in United Kingdom by 43%, in Germany by 35%, in Sweden by 33%, in Hungary by 30% and also in Italy, France, Russia, Poland, Japan. In selected countries only United State increased very moderately the whole CO2 emissions by 9% and Austria by 5%. Therefore, all of the developed economies have decreased CO2 emissions growth per capita (EmissCapit9) by between 8%-52% - in Austria – United Kingdom - for the same period. The CO2 emissions growth could decrease in spite that the total investment in percent of GDP in 2021 (TotInvest216) considerably increased, for example in *Hungary by 31% as at top level of developed economies*, in Austria by 28%, in Japan and Sweden by 26%, also in US by 21%, which the last one is very considerable concerning the economic measure of US.

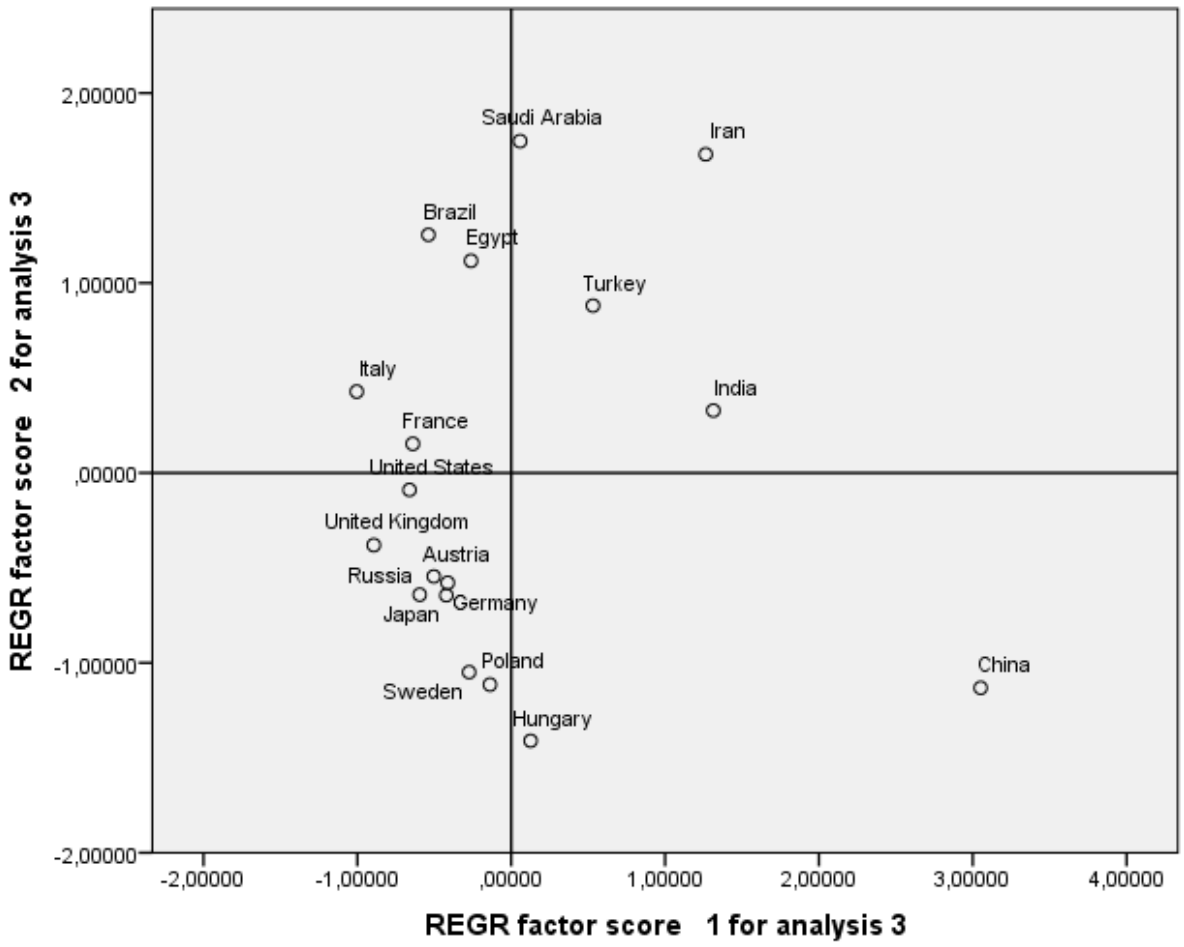


Figure 1: REGR factor score concerning the economic variables EmissCapit9, TotInvest216, EmissMt8 at horizontal line "X" and EmiPeUn10, PopuGrow11, Unempl214 and Unempl903 at vertical line "Y"

Source: International Monetary Fund, World Economic Outlook Database, October 2023, National Statistics Office, by owned calculation.

The population growth in percent for period of 1990-2021 (PopuGrow11) has been moderately increasing in the highly developed economies, as in US by 32%, in United Kingdom by 18%, in France by 16%, in Austria by 14% and in EU-27 by 6%. But in some developed economies the population decreased like in Sweden by 16%, in Hungary by 8% and in Poland by 0.1%. In Japan population increased only by1.3%, as at stagnating level. In spite of this population moderately increasing trend, the CO2 emissions growth per capita ton CO2/cap/year (EmiPeUn10) sharply decreased in developed economies for this period.

Also, the CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year has decreased for period of 1990-2021 (EmiPeUn10) in these highly developed, which shows that the developing trend of modern advanced technology could be efficient to decrease of the cost of gas emissions. This also considerably

decreased in China by 67%, moderately decreased in India by 25%, in Turkey and in Egypt by 23%, but in cases of other countries, this increased in Saudi Arabia by 43%, Iran by 40% and in Brazil by 8%.

This condition shows the importance of the advanced green technology transfer for interest of developing countries based on the wider global international cooperation.

The *Figure 1* shows positions of selected 18 countries in coordinate system, where the *first session* up-right is positive section. The variables are the CO2 emissions growth per capita ton CO2/cap/year, for period of 1990-2021 (EmissCapit9) and the total investment, in percent of GDP in 2021 (TotInvest216) and CO2 emissions growth Mt CO2/year, for period of 1990-2021 (EmissMt8) at horizontal line "X" and also CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year, for period of 1990-2021 (EmiPeUn10), population growth in percent for period of 1990-2021 (PopuGrow11), the unemployment rate, in percent of total labour force in 2021 (Unempl214) and the unemployment rate, in percent of total labour force in 1990 (Unempl903) are at vertical line "Y", which increase or little decrease in countries of this session namely India, Iran, Turkey, Saudi Arabia.

In countries of the *second session* up-left side, namely in Egypt, Brazil, France, Italy the variables, namely CO2 emissions growth per capita ton CO2/cap/year, for period of 1990-2021 (EmissCapit9) and the total investment, in percent of GDP in 2021 (TotInvest216) and CO2 emissions growth Mt CO2/year, for period of 1990-2021 (EmissMt8) at line "X" generally decreases or little increase. But in these countries CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year, for period of 1990-2021 (EmiPeUn10), population growth in percent for period of 1990-2021 (PopuGrow11), the unemployment rate, in percent of total labour force in 2021 (Unempl214) and the unemployment rate, in percent of total labour force in 1990 (Unempl903) at line "Y" remained in increasing or little decreasing growing rate.

In countries of the *third session* down right-side, namely in China, Hungary, variables, namely CO2 emissions growth per capita ton CO2/cap/year, for period of 1990-2021 (EmissCapit9) and the total investment, in percent of GDP in 2021 (TotInvest216) and CO2 emissions growth Mt CO2/year, for period of 1990-2021 (EmissMt8) at line "X" generally increase or little decrease. But in these countries CO2 emissions growth per unit of GDP PPP ton CO2/k USD/year, for period of 1990-2021 (EmiPeUn10), population growth in percent for period of 1990-2021 (PopuGrow11), the unemployment rate, in percent of total labour force in 2021 (Unempl214) and the unemployment rate, in percent of total labour force in 1990 (Unempl903) at line "Y" remained in decreasing or little increasing growing rate.

In countries of the *fourth session* down left-side, as negative session, namely in United States, United Kingdom, Austria, Russia, Germany, Japan, Poland, Sweden, variables, namely CO2 emissions growth per capita ton CO2/cap/year, for period of 1990-2021 (EmissCapit9) and the total investment, in percent of GDP in 2021 (TotInvest216) and CO2 emissions growth Mt CO2/year, for period of 1990-2021 (EmissMt8) at line "X" generally and also EmiPeUn10, PopuGrow11, Unempl214 and Unempl903 at line "Y" decrease or little increase.

China and Hungary are selected into the third session down right-side under line "X", because *in China* the CO2 emissions growth Mt and CO2 emissions growth per capita ton increases, but CO2 emissions growth per unit of GDP PPP ton considerably decreased and unemployment rate in 1990 and 2021 also were at little lower level.

In Hungary CO2 emissions growth Mt and CO2 emissions growth per capita ton little decreased and the total investment, in percent of GDP in 2021 considerably increased at line "X", but at line "Y" the CO2 emissions growth per unit of GDP PPP ton considerably decreased, number of populations little decreased, while unemployment rate in 1990 and 2021 were as little positive values, not decreased. (Table 1; IMF October 2023; National Statistics Office).

The question can emerge that how competition generally is between United States and China in field of CO2 emissions growth and its economic background. As the data-base of Table 1 show that United States has little increased CO2 emissions growth by 9% and decreased CO2 emissions growth per capita ton by 29% for the researched period 1990-2021. While China has considerably increased CO2 emissions growth by 414% and increased CO2 emissions growth per capita ton by 322% for the same period 1990-2021.

In order that differences of both of them can be understood, it is important to think and know that how the top advanced developed technology of China is produced, for how long-time length and how this top technology as same is produced based on fossil or green, as renewable energy resources. Naturally this top technology to be produced probably can be longer time period in China than in case of US. Also, any top technology in China, when this will be adapted in whole economic sectors of China for longer time, because in China 1.5 billion inhabitants mostly 5 times more than population of US. Also, the basic question that how measure of the atom-energy peacefully using in both of countries.

In order that China can arrival the economic developed level of US, it should be important for China to extend development trend in whole China including regional and rural development even based on the One belt and One road. Because of this project is very costly within the country, therefore, this project should be extended as cross border project and international one including some main countries of two continents, as Asia and Europe. Naturally the regional and rural development of China should be accompanying with developing infrastructure including transport, even train, foreign trade increasing, connecting important international seaports, heavy industry and machinery industry, centralising heavy industry into main large metropolises in China and probably in some neighbour countries. When China develops the infrastructure within One belt and One road at present as the US developed infrastructure in American continent mostly one or two centuries before, China should develop this infrastructure probably shorter time length with its population more than US by 5 times.

From side of US since the beginning of 1970, the general developing trend started in every five-year period to introduce the highly level top advanced technology into the whole economy of US. This means that *the top technology should be introduced into whole economic and social development of US in order to remain the international competitiveness of US.* Also, this means that the US should change top technology in every five-year period to realise the continuous international competitiveness of the country. Every after five-year period the country and its large companies, transnational and multi-national corporations under American leadership should sell the earlier top technologies for other less companies or other countries of world economy.

The competition between two large countries US and China is not easy, because this is based on the work efficiency. China has a good position to obtain wide-side economic influences on the world economy.

4. CONCLUSIONS AND SUGGESTIONS

International cooperation is needed at global level mostly among countries, which are highly developed economies accompanying with low level of carbon-dioxide gas emission with developing and renewal industrial countries accompanying with highly level of carbon-dioxide emissions. International cooperation with China is significant in order to extend new green advanced technology to mitigate gas emission, because China has been the first biggest carbon-dioxide emission in the world economy for the recent period.

The *One Belt and One Road* project is very considerable green project provided by China, because most of this large international wide-side investment is based on the *green investment* to use renewable energy resource as *electric energy* use. Within this project the electric train line is cross whole China and cross borders including many countries of Asia and Europe, which can represent for using green energy. Also, this project can ensure emerge of rural areas of Chine with regional development by connecting main towns, central industrial regions, seaports and other large cities of China based on the *extending electrical network.* In order that China can be a real one of the largest industrial and highly developed economies, China should extend electric energy use, as *green energy* and *rural development* within regional development process. This building electric network can ensure *both of main strategic aims.* The United States of American would not have realised its economic prosperity for the latest centuries if US had not developed the whole country-side train network. In that time the train line worked by using fossil energy, but in actual century the green energy should be used in order that China successfully faces large environmental conservation challenge.

One Belt and One Road project of China can make countries be more closed to each-others in order to extend their economic cooperation and foreign trade by closing their different regions, cities, villages, rural areas, strategic towns and seaports, even international airports. The electric green energy in China is a base for all different kinds of economic sectors. Also, the main resource of the green electric energy can be the solar energy by setting up network of solar panels even in main train railway stations closed to main cities or possible consuming local markets, where green-houses can be built to ensure fruits and vegetables for local populations. In this case the network of solar panels can locally ensure the green energy resource for the operating train network and green-houses of food for local populations.

Since the beginning of 1970s *China has sent many students for BSC-MCS-PhD study programs* into most of highly developed economies and many of developing countries based on the scholarship scheme financed by Government of China. Naturally many of students from China could follow their works after their study in those countries in order to stimulate economic cooperation among China and those countries.

Finally, the mankind can win by the green energy and can successfully face challenges of the difficulties of environmental conservation based on the wide-side international cooperation in field of highly developed technological transfer in order to create *green globe* on our Earth.

REFERENCES

[1] EC JRC (European Commission, Joint Research Centre 2022): Gas emissions of all world countries. *JRC/IEA/PBL 2022 Report.Authors:* Crippa M., Guizzardi D., Banja M., Solazzo E., Muntean M., Schaaf E., Pagani F., Monforti-Ferrario F., Olivier, J.G.J., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Grassi, G., Rossi, S., Oom, D., Branco, A., San-Miguel, J., Vignati, E. Joint Research Centre Luxembourg: Publications Office of the European Union, 2022, p 261 PDF ISBN 978-92-76-55802-6 ISSN 1831-9424 doi:10.2760/07904 KJ-NA-31-182-EN-N EU Science Hub, *Available at* https://joint-research-centre.ec.europa.eu and https://edgar.jrc.ec.europa.eu/report_2022#emissions_table

[2] EP (European Parliament, 28-03-2023): EU progress towards its 2020 climate change goals. Available at: https://www.europarl.europa.eu/news/en/headlines/society/20180706STO07407/eu-progress-towards-2020-climate-change-goals-infographic

[3] IMF (International Monetary Fund, 2023): *WORLD ECONOMIC OUTLOOK DATABASE*, October 2023, National Statistics Office. *Available at:* https://www.imf.org/en/Publications/WEO/weo-database/2023/October/weoreport?c=132,134,136,158,112,111,&s=NGDP_RPCH,NGDPDPC,LUR,LE,LP,GGXWDG_NGDP,&sy=1990&ey=2021&ssm=0&scsm=1&scc=0&ssd=1&ssc=0&sic=0&sort=country&ds=.&br=1

[4] IPCC (Intergovernmental Panel on Climate Change 2014): Climate Change 2014: Synthesis Report. *CONTRIBUTION OF WORKING GROUPS* I, II and III to the Fifth Assessment Report of the IPC [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[5] IPCC (2022): Climate Change 2022: Mitigation of Climate Change. *CONTRIBUTION OF WORKING GROUP III TO THE SIXTH ASSESSMENT REPORT* of the Intergovernmental Panel on Climate Change [Shukla P.R., Skea J., Slade R., Al-Khourdajie A., Diemen R. van, McCollum D., Pathak M., Some S., Vyas P., Fradera R., Belkacemi M., Hasija A., Lisboa G., Luz S., Malley J., (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. DOI: 10.1017/9781009157926, Available at: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#overview

[6] UN (United Nations, 2023): *CLIMATE CHANGE*. Available at: https://unfccc.int/process-and-meetings/the-paris-agreement

[7] Salcedo, J.; McCormick, K. (with Peck J., Wheeler A., 2017): SPSS Statistics for Data Analysis and Visualization. Publisher: Wiley, first edition, ISBN 978-1119-003-557, p. 489.

CORRESPONDING AUTHOR:

Sándor J. Zsarnóczai, Associate professor Dr., CSc, Habil
Institute of Environmental Engineering, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University
Doberdó u. 6, H-1034 Budapest, Hungary
Email: zsarnoczaisandorjozsef@gmail.com

QUALITY SERVICE - THE HEART OF QUALITOLOGY

Tamás CSISZÉR

Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University, Budapest, Hungary

Abstract

Traditional Quality Science and Engineering, also known as Qualitology, focuses on the ability of organizations, processes, and products to meet stakeholder requirements. Many tools and techniques have been developed, helping professionals mainly in their quality development programs. Related skills and knowledge have been built into the general competence set of employees, and quality focus has become an important aspect of strategic-level decisions. Meanwhile, an essential part of quality science seems to be vanishing: the service orientation, the aim to help each other improve on individual and organizational levels, too. This paper summarizes the essential elements of the so-called Quality Service approach, including a comparison with Quality Checking, Controlling, Assurance, and Management, and combining it with a network-based quality engineering perspective.

Keywords: *quality science and engineering, network science, service orientation*

1. INTRODUCTION

This paper introduces Quality Service (QS), the heart of Qualitology, also known as Quality Science [1]. In the first part of our work, the most widely known approaches of Qualitology are defined. They are Quality Checking, Quality Control, Quality Assurance, and Quality Management. Then, some related challenges are discussed. Finally, the most relevant pillars of quality service are introduced as a potential solution to the problems mentioned above, and some of the unique tools and techniques of Quality Service, such as Network of Connected and Independent Activities, Network-based Process Risk Assessment, and Network-based Knowledge Value Assessment, are presented.

2. APPROACHES OF QUALITOLOGY

The four main approaches of Qualitology are Quality Checking, Quality Control, Quality Assurance, and Quality Management [2]. 0 shows where these methods are mainly applied, what they want to detect, how they do that, with what kind of tools, by whom, why, i.e., for what, and when, i.e., in what sort of production. They can be defined in the following way:

- **Quality checking** is the detection and correction of product failures by quality controllers with sampling and qualification techniques to stop wrong products in individual or serial production.

- **Quality control** is the detection and correction of the out-of-control status of individual processes by the process team with statistical methods to avoid wrong production in mass production.

- **Quality assurance** is the prevention, detection, and correction of nonconformity of process system by the whole organization with regulation to build trust in standardized production.

- **Quality management** is the prevention, detection, and correction of target loss of the system of processes and organization by the whole organization with goal statements and development programs to achieve goals in optimized production.

Table 1: The four main approaches of Qualitology. The table shows where these methods are mainly applied, what they want to detect, how they do that, with what kind of tools, by whom, why, i.e., for what, and when, i.e., in what sort of production



	Q. Checking	Q. Control	Q. Assurance	Q. Management
Where?	Products	Individual processes	Process system	System of processes and organization
What?	Failure	Out-of-control status	Nonconformity	Target loss
How?	Detection, correction	Detection, correction	Prevention, detection, correction	Prevention, detection, correction
With?	Sampling, qualification	Statistics	Regulations	Goals, development
By?	Q. controller	Process team	Organization	Organization
Why?	Stop wrong product	Avoid wrong production	Build trust	Achieving goals
When?	Serial production	Mass production	Standardized production	Optimized production

These classifications and the connected definition are generalizations. Actual quality-related activities are more complex and cover more expansive fields of operation. Still, it can help present why Quality Service is, on the one hand, a part of all of them and, on the other hand, how it differs from them. The key to the comparison is the challenges of quality management activities.

3. CHALLENGES OF QUALITY MANAGEMENT ACTIVITIES

Some people think that quality management methods are not valuable for operation management. Challenges of quality management expressed by them can be classified as follows:

- Theoretical challenges: Although principles and fundamental laws are easy to understand, the language of related standards is complex, the requirements are too general, and the professional works do not help enough for outsiders to implement appropriate actions. It encumbers the adaption of the quality management approach.
- Practical challenges: Most of the tools and techniques are simple enough to learn, but their application needs a deep understanding of their interdependencies, experience in handling issues in execution, and professional knowledge of the field they would be used in. In addition, it seems that the use of these tools is autotelic in many cases.
- Organization challenges: Some say quality management has nothing new and valuable ideas that have not already been used. Others say it cannot help in operation development effectively

since quality improvement actions are time-consuming and resource-intensive. Due to these – and other – critics, people often resist implementing quality management methods.

- Technical challenges: Special and expensive software such as process modeling, documentation management, and statistical analysis applications must be learned to conduct quality management activities properly. It means that companies need quality specialists who can run relevant processes, causing extra costs in operation.

These are only some criticisms frequently articulated in connection with quality management [3]. To give them an appropriate answer, we must clarify its real positive effects.

4. QUALITY SERVICE (QS) APPROACH

The QS approach can be one of the ways of summarizing the positive effects of quality management and addressing relevant problems. The definition of Quality Service is based on the following fundamental postulate:

1. Production is a network of activities and their outputs;
2. Every output, even a product, is a service or a set of services when handed over or provided;
3. A service is qualified by the quality of its attributes;
4. Attribute quality is based on quality-related services provided by others (predecessors, leaders, successors) that can affect it;
5. Quality Service is the output of activities aiming to help others in ...

- … managing hurdles & effects;
- … ensuring support & motivation;
- … maintaining commitment & flexibility;
- … harmonized production regarding their activities.

It means that the QS approach supports and motivates people to manage hurdles and effects regarding the services of activities and maintain the commitment and flexibility of the whole organization to provide quality service in harmonized production. [0]

Quality Service - the fifth approach of Qualitology

	Q. Checking	Q. Control	Q. Assurance	Q. Management	Q. Service
Where?	Products	Individual processes	Process system	System of processes and organization	**Services of activities**
What?	Failure	Out-of-control status	Nonconformity	Target loss	**Hurdles & Effects**
How?	Detection, correction	Detection, correction	Prevention, detection, correction	Prevention, detection, correction	**Support & Motivation**
With?	Sampling, qualification	Statistics	Regulations	Goals, development	**Commitment & Flexibility**
By?	Q. controller	Process team	Organization	Organization	**Organization**
Why?	Stop wrong product	Avoid wrong production	Build trust	Achieving goals	**Quality Service Provision**
When?	Serial production	Mass production	Standardized production	Optimized production	**Harmonized production**

The QS has four pillars: 1) Harmonized production; 2) Commitment and Flexibility; 3) Support and Motivation; 4) Hurdles and Effects. [0]

To maximize the service quality, we need harmonized production, where activities are aligned in a service network with capacity synchronization, efficient energy consumption and material usage, and pragmatic operation. In addition, we need committed and flexible staff with open minds for improvement opportunities who can cooperate and make consensus while initiating and accepting positive changes. We must provide them with a supporting and motivating environment by ensuring competencies and functions in production, by regulating with easy-to-understand and easy-to-handle Service Oriented Documentation, a combination of SOP and SLA, and by assessing performance based on the quality of activity services. Finally, yet importantly, we must focus on serving and helping our successors and linked partners to maximize the positive and minimize negative impacts of our operation.

Figure 1: The four pillars of Quality Service: Harmonized production, Commitment and flexibility, Support and motivation, Hurdles, and effects.

5. TOOLS AND TECHNIQUES

In the QS method, there are many traditional and new tools and techniques that can be applied in the same or different ways. Three of them are introduced in the next chapters.

5.1 Network of Connected and Independent Activities

People usually think that processes run as a flowchart can map them. The fact is that processes, which are sets of activities, can be modeled rather by a complex network, where nodes represent tasks and edges represent services among them. Every time someone asks somebody for something, a service is called and then provided. The arrow comes from the server and ends in the caller, or vice versa. This is the accurate model of operation. [0]

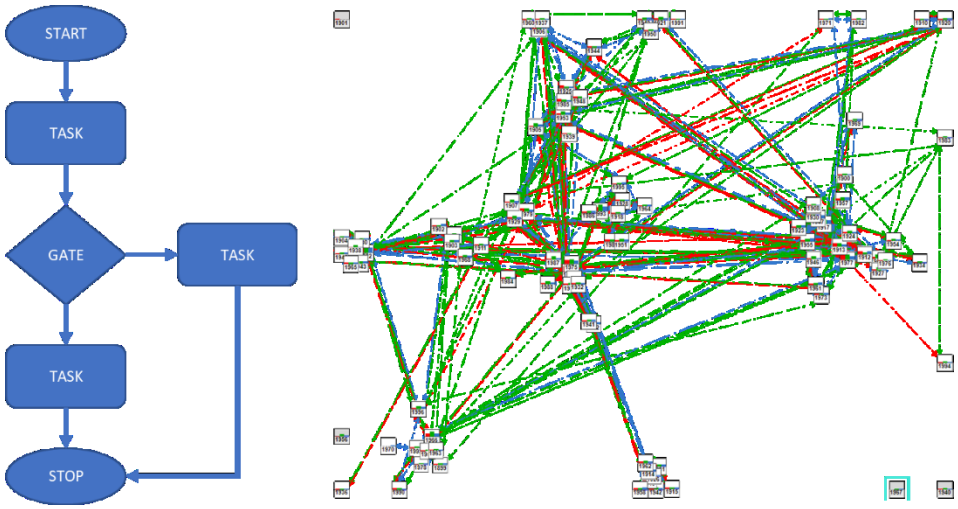


Figure 2: Network of Connected and Independent Activities.

This network can be mapped and analyzed from different perspectives. If we are interested in all connections, we can draw the whole structure. If we want to identify only the strong connections, the network can be cut by the strength of the edges. Similarly, we can present and assess interactivity waiting times or interactivity movements, and many more [4]. The point is that if we can identify and monitor service chains, process anomalies can be assessed in networks like the ones in [0].

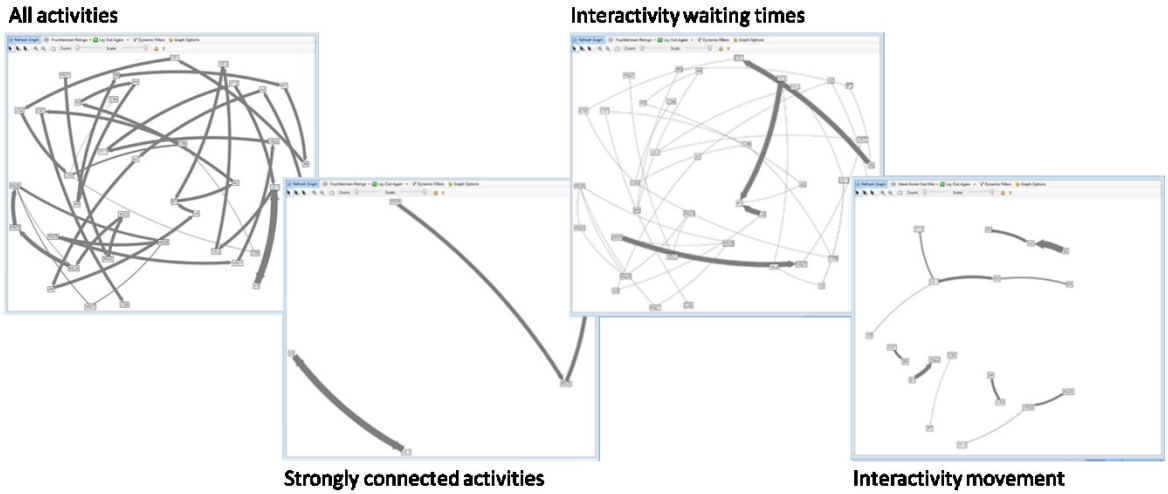


Figure 3: Different View – Different Activity Set.

5.2 Network-based Process Risk Assessment

Every process has operational risks. Their connections can be modeled and analyzed by networks as well, where nodes are risks, while edges represent the number of common occurrences and the time spent between the occurrences of adjacent events. The severity of risk connections, denoted by S, can be calculated with these variables. The bigger the S, the higher the probability that an event will be followed by its successors in the particular risk chain [5]. [0]

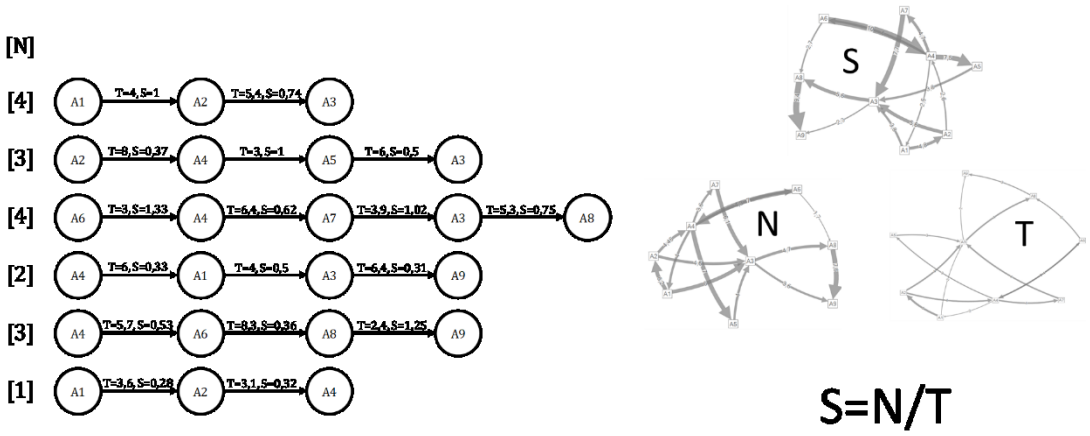


Figure 4: NPRA – Network-based Process Risk Assessment. S – severity, N - common occurrence, T - time between occurrences

5.3 Network-based Knowledge Value Assessment

As the last example for QS tools, we need to mention the Network-based Knowledge Value Assessment, which allows us to calculate the risk of missing competence based on the demand and ownership values of links among competencies, activities, and resources. The bigger the demand for skill and the lower the number of people who own it, the higher the risk of missing it [6]. [0]

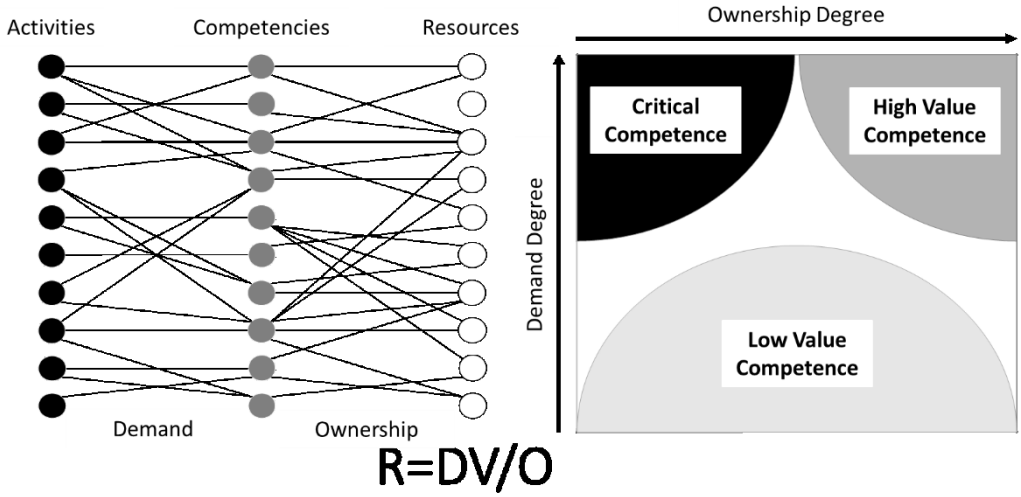


Figure 5: NKVA – Network-based Knowledge Value Assessment: processes cannot be adequately run without resources. This method helps group activities and connect them to the best ones to do them. R - risk of missing competence [-], D - number of activities that need for competence [No], V - rate of value added activities that need for competence [-], O - number of resources that own competence [No].

CONCLUSIONS

Implementing quality management is a challenging mission. We must define, optimize, and regulate processes, create a robust monitoring, measurement, and improvement system, convince management and other people to use them and to follow the associated rules, etc. To be successful, we need to focus on the positive effects, and we need to select and apply only those tools and techniques that can provide real value. The quality Service method, which is the heart of Qualitology, can help us clarify that the most important purpose of our profession is to ensure that internal and external customers receive the best input for their activities. If everybody understands his or her role in the service network and wants to maximize the quality of their services by applying relevant tools and techniques, the whole community, including the 'server,' will maximize the quality of operation.

REFERENCES

[1] Majchrzak, J.: Qualitology: the issue of quality and its assessment, *European Research Studies Journal*, 24(s5) (2021), pp 288-298.

[2] Kövesi, J. et al.: *A minőségmenedzsment alapjai*. Typotex, 978 963 279 700 7, Budapest. (2008)

[3] Beckford, J.: *Quality – A Critical Introduction*. Routledge, 9781315644028, London. (2016)

[4] Csiszér, T.: *A hálózatszemlélet alkalmazási lehetőségei a minőségügyben.* GlobeEdit, 9783330807235, London. (2017)

[5] Csiszér, T.: Assessment of quality-related risks by the use of complex networks, Acta Silvatica et Lignaria Hungarica, (1786-691X 1787-064X) (2023): pp 161-169.

[6] Csiszér, T.: A tudásérték meghatározása minőségügyi szempontból, hálózatelemzési módszerekkel, *Vezetéstudomány*, (0133-0179) (2012): pp 55-62.

CORRESPONDING AUTHOR:

Dr. habil Tamás CSISZÉR
Institute of Media Technology and Light Industry, Rejtő Sándor Faculty of Light Industry and Environmental Engineering, Óbuda University
96/B Bécsi út, 1034 Budapest, Hungary
E-mail: csiszer.tamas@uni-obuda.hu

MULTI-CRITERIA DECISION-MAKING METHODS AS A TOOL FOR IMPROVING THE WASTE MANAGEMENT SYSTEM IN DEVELOPING COUNTRIES – A SHORT REVIEW

Una MARCETA[1], Bogdana VUJIĆ[1], Višnja MIHAJLOVIĆ[1], Jelena VUKOVIĆ[2], Jovana CUGALJ[1]

1 University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia

2 University of East Sarajevo and Faculty of Technology Zvornik, Republic of Srpska, Bosnia and Herzegovina

Abstract

The waste management system in developing countries, as well as in all low-income countries, is undeveloped, includes collection and depositing of waste, which causes negative environmental impact. This practice has led to the existence of many unsanitary landfills, and the implementation of measures leading to remediation and rehabilitation requires high financial investments, and developing countries are not able to solve all problems at once, but it is necessary to establish a list of priorities. On the other hand, when designing new landfills, it is of high importance to identify the most optimal location so that negative impacts on the environment and the population are reduced. In this paper, the research was done through a preliminary review of the literature in which the application of multi-criteria decision-making methods (MCDM) in the field of waste management was analyzed. The models and methods of application of MCDM methods analyzed in previous research confirm the possibility of their application in order to improve the waste management system in developing countries.

Keywords: *waste management, landfill, MCDM methods*

1. INTRODUCTION

Waste management system in developing countries

The world is facing rapid urbanization, which is most dominant in developing countries. The negative consequences of such trend is reflected in the deterioration of the quality of the environment and people's health [1].

The impact of urbanization has negative impact to waste management, in terms of generation of large amounts of waste which characterizes both developed and developing countries, where the rate of growth of waste production per inhabitant is increasing rapidly [2]. Underdeveloped countries and countries in transition are particularly affected by problems resulting from an inadequate waste management system due to legislative, political and economic obstacles [3] [4].

Proper municipal solid waste management is important in order to prevent the negative impact of waste on the environment and involves a series of complex processes related to the minimization of waste generation, collection, sorting and treatment of waste, as well as its storage and final disposal [5].

It is estimated that by 2025, the amount of generated waste at the global level will be doubled compared to half of the 1990s and will amount to 2.2 billion tons per year [6]. Half of the total amount of waste is generated in developed countries, but it is predicted that by 2035, the increase in the number of inhabitants in underdeveloped countries will lead to twice the rate of waste generation in Asian and African countries, while in the United States of America (USA), Canada, Japan, Australia, New Zealand and Western Europe predicts a reduction in waste production [7] . Therefore, countries around the world are focusing their efforts towards defining the goals for reducing the amount of generated waste, the disposal of which is one of the emerging problems of today.

Considering the economic benefits, landfilling is still the most dominant method of solid waste management globally [8] .Developing countries are most often faced with problems of environmental degradation as a result of waste disposal at unsanitary landfills, therefore assessment of potential risks is of great importance when designing such facilities [9] [4].

Multi-criteria decision-making methods

Decision-making has been a part of everyday life since the beginning of mankind, and in the last few decades a special scientific discipline has developed that deals with this problem and is called decision-making theory. With the development of decision-making theory, decision-making becomes a process based on scientific facts and methods, which positively affects efficiency, objectivity, reliability and transparency [10]. Decision-making theory is a young science, but its development has led to the fact that today there are a large number of methods and models whose purpose is to support decision-making. When making decisions, it is very important to use the appropriate method depending on the type of problem being solved, the availability of information relevant to the decision-making process, the knowledge of the decision-maker [11].

Multi-criteria decision-making (MCDM) methods are a decision-making tool, developed for complex multi-criteria problems that contain qualitative and/or quantitative aspects of the problem in the decision-making process. They belong to the field of decision-making theory where they meet: economics, mathematics, statistics, psychology, sociology, organizational theory, philosophy, information technology and other sciences. Solving a multi-criteria problem involves choosing the "best" alternative from a set of available alternatives, where "best" can be interpreted by the decision maker as "most desirable". MCDM methods can be used to identify: optimal alternatives, to rank alternatives, to obtain a certain number of alternatives or to distinguish acceptable from unacceptable alternatives [12]. The main purpose of the MCDM method is to overcome the problems in a consistent way that a person as a decision maker encounters when working with a large amount of complex information. In general, MCDM follows six steps that include: problem formulation, requirements identification, goal setting, identification of various alternatives, criteria development, and identification and application of appropriate decision-making techniques [13].

2. LITERATURE REVIEW

Risk assessment in the area of environmental protection aims to characterize the potential negative consequences of the population's exposure to polluted environmental media, and decision-making in

this area is an extremely complex process that must be based on scientific facts. For this reason, MCDM methods are increasingly used in research in the field of environmental protection. The main goal of this paper is to determine the possibility of application through a preliminary review of the literature MCDM methods as a tool for improving the waste management system in developing countries.

The waste management system in developing countries is far from advanced treatment techniques and mostly involves the collection and disposal of waste in uncontrolled and controlled city landfills, which do not meet basic technical and technological standards. Therefore, the research is directed towards the analysis of the possibility of applying MCDM methods as a tool for assessing the potential risks of existing landfills, in order to identify priority activities in their rehabilitation, as well as in the design of new landfills, in order to minimize their negative impact on the quality of the environment. The application of MCDM methods has experienced a great expansion during the last few decades. Their role in various fields has grown significantly, which is particularly reflected in the development of new methods and the improvement of existing ones [14].

Karunathilake et al. (2020) have identified MCDM methods that are most suitable for prioritization and risk assessment purposes. The authors classified the most frequently applied methods into different groups based on the principle by which they approach the problem (Fugure 1.).

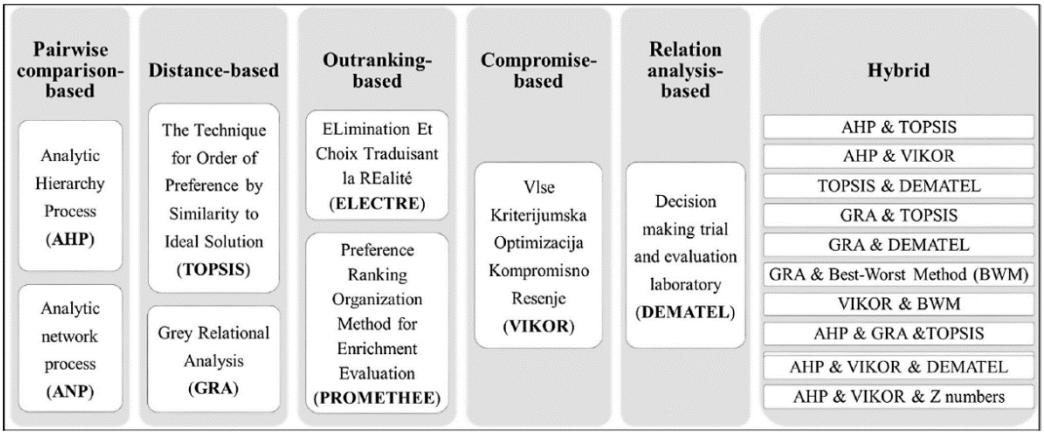


Figure 1: MCDM methods that are most suitable for prioritization and risk assessment purposes

In the 1990s, MCDM was applied in a very few scientific works in the field of environmental protection engineering, while today the number of publications is measured in the thousands. Cegan et al. (2017) identified over 3,000 published papers related to specific applications in the environmental field (water, air, energy, natural resources and waste management). The results of the study show a linear increase in the share of MCDM works in environmental science in all fields of application [15].

Huang et al. (2011) considered the application of MCDM in environmental engineering through 312 articles published in the period from 1990 to 2010. The research subject of the reviewed articles are environmental problems that include the application of MCDM to the management/quality of waste, water, air, energy or natural resources. Out of the total number of articles included in the analysis, 30 articles refer to the problem of waste management, whereby the percentage distribution of MCDA

methods per application area highlights the analytical hierarchical process as the most widely represented method. (AHP) [16].

Regarding the application of MCDM methods with the aim of evaluating the risk of landfills, studies are predominantly oriented towards choosing the optimal location for the construction of a landfill, in order to minimize harmful effects on the environment and the health of the exposed population. Ersoy & Bulut (2009) showed MCDM based methodology for landfill site selection in growing urban regions. Based on developed methodology the suitability of the studied area (Trabzon, Turkey) was successfully evaluated in order to optimally select a landfill site [17]. Gemitzi et al. (2007) presented a methodology for siting municipal solid waste landfills, coupling geographic information systems (GIS), fuzzy logic, and multicriteria evaluation techniques. The method has been applied to Evros prefecture (Greece), an area of approximately 4,000 km2 and the siting methodology results in the composite suitability map for landfill siting [17]. El Alfy et al. (2010) carry out the evaluation of a hazardous waste disposal site using an integration of the GIS and MCDM method. In this study, the most suitable candidate sites for locating landfill in Mansoura city (Egypt) was identified [19]. Chabuk et al. (2019) proposed model for landfill sites selection using MCDM and comparing method of change detection for Babylon Governorate, Iraq. Based on the presented model, the most optimal locations were determined which are suitable to accommodate the cumulative solid waste for the years 2020–2030. [20].

On the other hand, these methods can be a very useful tool for prioritizing and ranking existing landfills as pollutants, in order to take the necessary control and remedial measures. Ubavin et al. (2018) presented a model that enables the determination of priorities for the closure and remediation of unsanitary solid municipal waste landfills, according to the risk they pose to groundwater and the environment. Although with research of this type, the challenge is the lack of data (characteristic for developing countries), the model was successfully applied and validated by a case study that included 128 landfills on the territory of the Republic of Serbia [21].

Marceta et al. (2021) established a model for a landfill prioritization according to the methane risk assessment in developing countries like Serbia. The ranking of landfills according to the risk of emission and atmospheric dispersion of methane was carried out by application MCDM methods. The proposed model was successfully tested and applied to eight landfills in South Backa District in the Republic of Serbia [22].

CONCLUSION

In recent decades, significant research has been carried out in the field of multi-criteria decision-making methods, which has made available practical methods for application in decision-making in multi-criteria problems. Decision-making in the field of waste management, as well as in all problems related to environmental protection, is usually a very complex and complicated process in which it is necessary to find a compromise between socio-political, ecological and economic factors. Due to complexity of environmental protection, MCDM methods are increasingly used in scientific publications whose subject of research is related to the field of environmental protection, including research aimed at determining priorities when implementing measures to improve the waste management system. Government bodies could more effectively set guidelines and regulations, and evaluate prevailing strategies for handling and disposal of waste. In most low-income countries, the dominant practice is to

dispose of waste in uncontrolled landfills, while the concept of a sanitary landfill, which implies an appropriate location, design, and landfill maintenance system with the aim of reducing negative impacts, MCDM is a rarely applied method. In order to establish new practice, significant financial resources are needed, which highlights the risk assessment and determination of priority activities through the MCDM method as a very suitable tool for improving the waste management system in developing countries. Besides, government bodies could more effectively set guidelines and regulations, and evaluate prevailing strategies for handling and disposal of waste at landfills.

REFERENCES

[1] Uttara, S., Bhuvandas, N., Aggarwal, V.: *Impacts of urbanization on environment*. International Journal of Research in Engineering and Applied Sciences 2, 1637-1645, (2012)
[2] Ghiani, G., Laganà, D., Manni, E., Triki, C.: *Capacitated location of collection sites in an urban waste management system*. Waste management 32, 1291-1296. (2012)
[3] Vujic, G., Stanisavljevic, N., Batinic, B., Jurakic, Z., Ubavin, D.: Barriers for implementation of "waste to energy" in developing and transition countries: a case study of Serbia. *Journal of Material Cycles and Waste Management* 19, 55-69. (2017)
[4] Ferronato, N., Torretta, V.: Waste Mismanagement in Developing Countries: A Review of Global Issues. *International Journal of Environmental Research and Public Health* 16, 1060. (2019)
[5] Minelgaitė, A., Liobikienė, G.: *Waste problem in European Union and its influence on waste management behaviours*. Science of the Total Environment 667, 86-93. (2019)
[6] Vaverková, M. D.: *Landfill impacts on the environment*. Geosciences 9, 431. (2019)
[7] Wilson, D.C., Velis, C.A.: *Waste management–still a global challenge in the 21st century: An evidence-based call for action*. SAGE Publications Sage UK: London, England, 1049-1051. (2015)
[8] Modak, P., Wilson, D.C., Velis, C.: *Waste management: Global status*. In: Wilson, DC, (ed.) Global Waste Management Outlook. UNEP, 51-88. (2015)
[9] Cointreau, S.: *Occupational and environmental health issues of solid waste management*: special emphasis on middle-and lower-income countries. UP 2, World Bank, Washington, DC, USA (2006)
[10] Hansson, S.O. (1991) An overview of decision theory. National Board for Spent Nuclear Fuel, SKN 41 Report. Department of Philosophy Pppsala Pniversity.
[11] Nikolić, M.,: *Decision-Making Methods*. University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia. (2012)
[12] Bernardini, A., Turcksin, L., Macharis, C,: CLEVER *Clean Vehicle Researc Report Multi Criteria analysis: method, analysis and results.* (2007)
[13] Karunathilake, H., Bakhtavar, E., Chhipi-Shrestha, G., Mian, H.R., Hewage, K., Sadiq, R.*,: Decision making for risk management: a multi-criteria perspective.* Methods in chemical process safety 4, 239-287. (2020)
[14] Velasquez, M., Hester, P.T. *An analysis of multi-criteria decision making methods*. International journal of operations research 10, 56-66. (2013)
[15] Cegan, J.C., Filion, A.M., Keisler, J.M., Linkov, I.,: *Trends and applications of multi-criteria decision analysis in environmen-tal sciences*: literature review. Environ Syst Decisions 37, 123–133. (2017)
[16] Huang, I. B., Keisler, J., Linkov, I.,: *Multicriteria decision analysis in environmental sciences: Ten years of applications and trends.* Science of the Total Environment, 409(19), 3578–3594. (2011)

[17] Ersoy, H., Bulut, F.: *Spatial and multi-criteria decision analysis-based methodology for landfill site selection in growing urban regions.* Waste Management & Research 27, 489-500. (2009)
[18] Gemitzi, A., Tsihrintzis, V.A., Voudrias, E., Petalas, C., Stravodimos, G.: *Combining geographic information system, multicriteria evaluation techniques and fuzzy logic in siting MSW landfills.* Environmental Geology 51, 797-811. (2007)
[19] El Alfy, Z., Elhadary, R., Elashry, A.: Integrating GIS and MCDM to deal with landfill site selection. *International Journal of Engineering & Technology* 10, 32-42. (2010)
[20] Chabuk, A., Al-Ansari, N., Hussain, H.M., Laue, J., Hazim, A., Knutsson, S., Pusch, R.: *Landfill sites selection using MCDM and comparing method of change detection for Babylon Governorate,* Iraq. Environmental Science and Pollution Research 26, 35325-35339. (2019)
[21] Ubavin, D., Agarski, B., Maodus, N., Stanisavljevic, N., Budak, I.: *A model for prioritizing landfills for remediation and closure: a case study in Serbia*. Integrated Environmental Assessment and Management 14, 105-119. (2018)
[22] Marceta, U., Vujic, B., Srdjevic, Z., Mihajlovic, V., Radosav, D.: *Multi-Criteria Decision-Making Model to Support Landfill Prioritization: Methane Risk Assessment.* Polish Journal of Environmental Studies, 30(2), 1297-1306. (2021)

CORRESPONDING AUTHOR:

Una MARCETA
Technical Faculty “Mihajlo Pupin”, University of Novi Sad
23000, Zrenjanin, Serbia
E-mail: una.tasovac@tfzr.rs

THE INFLUENCE OF SIGN-CHANGING TEMPERATURES DURING OPERATION ON THE PHYSICAL AND MECHANICAL PROPERTIES OF NATURAL LEATHER

Oksana MYKHAILOVSKA, Tetiana NADOPTA

Khmelnytskyi National University, Kyiv, Ukraine

Abstract

A methodology for researching the cyclic effect of "freezing-thawing" on natural leather was proposed, which included a sign-changing temperature treatment of leather samples, followed by a study of their physical and mechanical properties under uniaxial stretching, and resistance to multiple bending. For the research 200 samples were cut from the central part of the heifer of the chrome tanning method with a face coating. As a result, a decrease in the physical and mechanical properties of natural leather (the heifer of the chrome tanning method), which has previously endured the cyclic effect of "freezing-thaw" action, was established, depending on the number of exposure cycles. Therefore, when designing and developing a technology for the production of special footwear for military personnel, it is necessary to take into account the operating conditions and the influence of sign-changing temperatures on the properties of the material.

Keywords: *temperature treatment, freezing-thawing, repeated bending, physico-mechanical properties*

INTRODUCTION

As it is well known, natural leather is utilized in the production of high-quality and ergonomic footwear. Due to its hygienic, aesthetic, technological properties, and reliability, natural leather stands out as one of the most frequently employed materials in the footwear industry. Nevertheless, changes in the operating temperatures of footwear typically have a significant impact on the properties of leather, particularly its elasticity and wear resistance. Therefore, it is crucial to consider these properties in the development of footwear for different climatic zones and purposes [1].

Specialized footwear for military personnel demands specific requirements for quality and functionality [2]. The development of footwear for the autumn-winter-spring season is particularly important, where extreme temperatures can pose a significant challenge for materials, including natural leather. Temperature variations can affect the appearance and structure of leather, determining the durability and preservation of the aesthetic appearance of products. The loss of flexibility and elasticity in natural leather can lead to a decrease in comfort and protection for military personnel, which is unacceptable in situations where reliability and comfort play a decisive role.

Temperature changes induce reactions in the molecular structure of the skin. At low temperatures, moisture in the pores of the skin freezes, leading to increased brittleness. Conversely, at high temperatures, deformation of the molecular structure can result in a loss of elasticity. Understanding these interactions is key to the development of technologies and constructions of footwear that ensure optimal leather properties under various operating temperature conditions.

Hence, it is essential to investigate the properties of natural leathers related to changes in their physical and mechanical characteristics at variable temperatures. Considering the impact of temperatures on the physical and mechanical properties of natural leather allows for the optimization of production, ensuring the quality and ergonomics of footwear products regardless of climatic conditions [3].

EXPERIMENTAL

The nature of changes in the properties of natural leathers with varying degrees of moisture at low temperatures and under the cyclic influence of "freezing-thawing" has been insufficiently studied. Considering the above, a methodology for investigating the cyclic impact of "freezing-thawing" on natural leather is proposed. This methodology involves alternating temperature treatment of leather samples, followed by the examination of their physico-mechanical properties under uniaxial stretching on a tensile machine, as well as resistance to repeated bending.

The study of the properties of natural leathers in the "freezing-thawing" cycle and the influence of this process on their physico-mechanical properties is crucial for understanding the changes in leather properties under low-temperature conditions. This approach consists of several stages that allow assessing the material's resistance to the cyclic impact of temperature changes.

Stage 1 – Selection and preparation of samples: Standard samples of natural leather are determined at the initial stage. The samples should be of the same type of leather, homogeneous in thickness and length. It is recommended to use leather from the same batch to avoid significant variations in initial properties.

Stage 2 – Freezing: Leather samples are placed in a special freezing chamber providing uniform freezing. The temperature is lowered to values typical for extreme low temperatures. Frozen samples are maintained in this state for a certain period.

Stage 3 – Thawing: After freezing, the samples are gradually heated to room temperature, simulating the thawing process. This stage is essential for evaluating how the material returns to normal conditions and how temperature changes affect its structure and properties.

Stage 4 – Investigation of physico-mechanical properties: After the "freezing-thawing" process, an examination of physico-mechanical properties is conducted. In particular, the investigation is carried out on a tensile machine, where the sample is stretched until the moment of rupture. The tensile strength is determined as the maximum stress the material withstands before rupture. This provides information about the material's resistance to stretching under the influence of cyclic temperature changes.

Stage 5 – Resistance to repeated bending: This stage evaluates how changes in physico-mechanical properties affect the material's ability to withstand repeated bending, which is most characteristic of footwear materials during use.

This methodology allows for a comprehensive understanding of how natural leathers respond to cyclic temperature variations, providing insights into optimizing production for quality and ergonomics of footwear materials regardless of climatic conditions.

Such a research methodology provides a comprehensive assessment of the impact of alternating temperatures on the physico-mechanical properties of natural leather, enabling the development of specialized footwear designs for military personnel with enhanced quality and ergonomics in variable temperature conditions [4].

For the research, 200 samples were cut (100 for determining tensile strength and 100 for investigating in repeated bending) from the butt part of the chrome-tanned half skins with a frontal coating: 100 samples along the backbone line and 100 samples perpendicular to the backbone line. For each of the five cycles, 10 longitudinal and 10 transverse samples were used. The specimens for investigating the tensile strength and relative elongation had the form of a bilateral blade with standard dimensions, ensuring consistent conditions for each study.

The alternating temperature treatment of leather samples, packed in polyethylene bags, was carried out using a freezing chamber with the ability to adjust the research temperature from 0 to -20°C. The research regimen included:

- Freezing at -10°C for 10 minutes.
- Thawing at +20°C for 10 minutes.

Thus, one research cycle had a duration of 20 minutes. Leather samples underwent sequentially 10, 20, 40, 50, and 100 cycles of freezing-thawing.

For a more in-depth study of structural changes in the leather occurring during repeated "freezing-thawing," research methods for physico-mechanical properties of materials were utilized. Leather samples underwent uniaxial stretching on a tensile machine. The research process continued until reaching the moment of rupture to obtain tensile strength and relative elongation at rupture parameters. The tensile strength during stretching was determined as the maximum stress before rupture. The relative elongation at rupture was evaluated as the percentage increase in sample length at the moment of rupture.

The resistance of leather to repeated bending was determined for an objective investigation of the leather's strength for upper footwear during repeated bending. The bending speed was 100 cycles/minute, and the bending angle was 30°. Samples sized 45x80 mm were prepared from chrome-tanned half skins with a frontal coating for the studies, which were previously subjected to the effects of alternating temperatures

RESULTS

The obtained data were statistically processed to determine the mean values, standard deviations, and other indicators that allowed assessing the stability and changes in the physico-mechanical properties of the leather after the repeated "freezing-thawing" process.

The results of investigations into chrome-tanned leather indicate a dependence of physico-mechanical properties on temperature and humidity during the studies. As known [5], the most significant changes are observed for leather with a humidity of 60% (the most characteristic percentage of humidity for natural leather), which was the condition for this research.

As a result of the conducted research, it was established that after the repeated "freezing-thawing" process, there is a significant decrease in tensile strength. This indicates a loss of material stability to mechanical stresses. Freezing and thawing can lead to ruptures in the internal bonds of the leather structure, also potentially reducing flexibility and elasticity of the material. (Freezing the leather leads to the formation of ice crystals, which, during bending tests with leather samples, cause mechanical damage to the fibers).

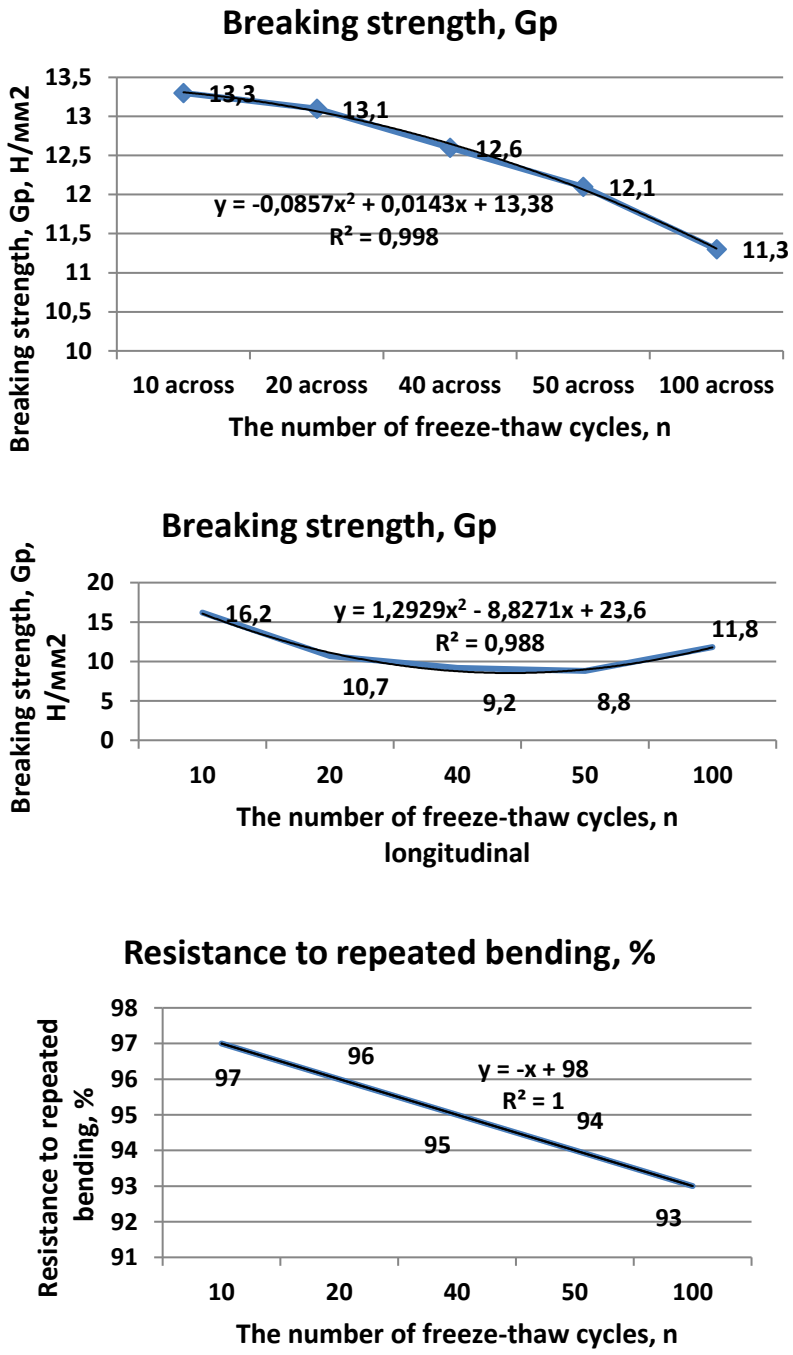


Figure 1: Physico-Mechanical Research of Natural Leather during the "Freezing-Thawing" Process

As a result of the "freezing-thawing" process, an increase in the relative elongation at break is observed. This indicates changes in the deformation characteristics of the material. Such changes are likely attributable to freezing, as it increases the brittleness of the material, enhancing the ability of the leather to deform before rupture.

Additionally, freezing and thawing induce the formation of a more rigid and less elastic structure in the leather due to the disruption of intermolecular bonds and moisture freezing, as evident from the repeated bending tests.

DISCUSSION

The multiple bending cycles during the operation of footwear under temperature variations lead to a significant deterioration in the stability of the material, particularly in the flexibility and elasticity of natural leather. This is especially crucial in the development of footwear for military personnel intended for use in fluctuating temperature conditions. Therefore, it is necessary to consider the pronounced deterioration in resistance to repeated bending, reduction in tensile strength, relative elongation, and increased stiffness.

Another direction to ensure the physical and mechanical properties of natural leather for footwear in the autumn-winter-spring seasons involves the use of tanning technologies that enhance flexibility and material elasticity, especially fatliquoring. Additionally, combining new modern materials with natural leather is employed to increase resistance to bending and moisture absorption (membrane details).

CONCLUSION

In the development of footwear for military personnel intended for the autumn-winter-spring season, it is crucial to consider not only the hygienic properties of materials but also their behavior under the influence of variable temperatures.

Research on the physico-mechanical properties of natural leather under the process of "freezing-thawing" provides essential information about the changes that the material may undergo in low-temperature conditions. The obtained results allow an understanding of how cyclical temperature changes impact the physico-mechanical characteristics of the leather.

Utilizing the obtained results in the design process will enable the development of footwear that, taking into account extreme operating conditions, is reliable and durable under any weather conditions.

Considering the obtained results, it is important to explore the optimization of footwear constructions, especially for military conditions, aiming to ensure maximum stability and efficiency of the material under variable temperatures. Additionally, the application of special tanning technologies and the combination of new materials should be considered to enhance the properties of leather in extreme temperature conditions.

REFERENCES

[1] Basaran, Bahri & Bitlisli, Behzat & Ocak, Bugra & Onem, Ersin. EFFECT OF DIFFERENT ATMOSPHERIC CONDITIONS ON SOME PHYSICAL PROPERTIES OF LEATHER. *TEKSTIL VE KONFEKSIYON*. 21.(2011) 194-198.
[2] Mykhailovska, O, Nadopta, T. QUALITY INDICATORS FOR SPECIAL MILITARY SHOES, *HERALD OF KHMELNYTSKYI NATIONAL UNIVERSITY*, ISSN 2307-5732, ISSUE 3, 2023 (321.
[3] Li, Pui-Ling & Yick, Kit-Lun & Yip, Joanne & Ng, Zerance. (2022). INFLUENCE OF UPPER FOOTWEAR MATERIAL PROPERTIES ON FOOT SKIN TEMPERATURE, HUMIDITY AND PERCEIVED COMFORT OF OLDER INDIVIDUALS. *International Journal of Environmental Research and Public Health*. 19. 10861. 10.3390/ijerph191710861.
[4] Mykhailovska, O, Nadopta, T., Oliynyk, A. DETERMINATION OF THE INFLUENCE OF PREVIOUS DEFORMATIONS ON THE RESISTANCE OF SPECIAL SHOES TO MULTIPLE BENDING, *HERALD OF KHMELNYTSKYI NATIONAL UNIVERSITY*, ISSN 2307-5732, PART 1, ISSUE 5, 2023 (325).
[5] SHOES ARE SPECIAL. NOMENCLATURE OF QUALITY INDICATORS: DSTU 3242–95. – [EFFECTIVE FROM 1996–07–01]. K.: STATE COMMITTEE FOR STANDARDIZATION, METROLOGY AND CERTIFICATION OF UKRAINE, 1995. - 22 P. – NATIONAL STANDARD OF UKRAINE.

CORRESPONDING AUTHORS:

Oksana Mykhailovska Ph.D.
Department of fashion industry in light industry, Faculty of Technology and Design, Khmelnytskyi National University
11, Instytuts'ka str., 29016, Khmelnytskyi, Ukraine
E-mail: mykhailovskao@khmnu.edu.ua

Tetiana Nadopta Ph.D.
Department of fashion industry in light industry, Faculty of Technology and Design, Khmelnytskyi National University
11, Instytuts'ka str., 29016, Khmelnytskyi, Ukraine
E-mail: nadoptate@khmnu.edu.ua