

University of Zagreb Faculty of Textile Technology



BOOK OF ABSTRACTS

**14th Scientific – Professional Symposium
TEXTILE SCIENCE & ECONOMY**

University of Zagreb Faculty of Textile Technology

TEXTILE SCIENCE AND ECONOMY

BOOK OF ABSTRACTS

14th International Scientific – Professional Symposium

TRANSFER OF INNOVATIONS TO THE ECONOMY



26th January 2022, Zagreb, Croatia



ISSN (On - line): 2787-4885

Organized by:

**UNIVERSITY OF ZAGREB
FACULTY OF TEXTILE TECHNOLOGY**



Partners:

UNION OF CROATIAN INNOVATORS



ZAGREB INVENTORS ASSOCIATION



Patrons:



Ministry of Science and Education



Ministry of Economy, Entrepreneurship and Crafts



University of Zagreb



Croatian Employer's Association



Croatian Academy of Engineering



Chamber of Economy



Croatian Chamber of Trades and Crafts



Croatian Association of Textile Engineers



Croatian Leather and Footwear Society

Publisher:

University of Zagreb Faculty of Textile Technology

Editors:

Prof. Ana Sutlović, Ph.D.
Prof. Snježana Firšt Rogale, Ph.D.

Technical editors:

Anja Ludaš, mag. ing. techn, text.
Assoc. prof. Renata Hrženjak, Ph.D.

TZG Logo:

Prof. Martinia Ira Glogar, Ph.D.

Contact address:

University of Zagreb
Faculty of Textile Technology
Prilaz baruna Filipovića 28a
CRO-10000 Zagreb
☎: +(385) (1) 3712500
✉: tzg2020@tff.unizg.hr
<http://tzg.tff.unizg.hr/?lang=en>
<http://tzg.tff.unizg.hr/>

Note:

All the papers presented in this publication have been reviewed. However the editors and the organizers are not responsible for the contents presented within the papers. All the rights belong to the authors, meaning further publication conditions should be agreed upon with the authors. Upon the Book of the Proceedings publication the authors, so as the other persons or institutions wishing to publish reference or in some other manner use the papers from this publication are kindly requested to explicitly identify prior publication in the Book of the Proceedings 2022.

Scientific Programme Committee:

President:

Prof. **Snježana Firšt Rogale**, Ph.D., University of Zagreb Faculty of Textile Technology

Prof. **Sandra Bischof**, Ph.D., University of Zagreb Faculty of Textile Technology

Prof. **Dragan Đorđević**, Ph.D., University of Niš Faculty of Technology Leskovac

Prof. **Martinia Ira Glogar**, Ph.D., University of Zagreb Faculty of Textile Technology

Prof. **Marija Gorjanc**, Ph.D., University of Ljubljana Faculty of Science and Technology

Prof. **Atif Hodžić**, Ph.D., University of Bihać Technical Faculty of Bihać

Prof. **Anica Hursa Šajatović**, Ph.D. University of Zagreb Faculty of Textile Technology

Prof. **Igor Jordanov**, Ph.D., Ss. Cyril and Methodius University Faculty of Technology and Metallurgy

Assoc. prof. art. **Koraljka Kovač Dugandžić**, University of Zagreb Faculty of Textile Technology

Prof. **Stana Kovačević**, Ph.D., University of Zagreb Faculty of Textile Technology

Prof. **Tanja Pušić**, Ph.D., University of Zagreb Faculty of Textile Technology

Prof. **Dubravko Rogale**, Ph.D., University of Zagreb Faculty of Textile Technology

Prof. **Zenun Skenderi**, Ph.D., University of Zagreb Faculty of Textile Technology

Prof. **Miljenko Šimpraga**, Ph.D., University of Zagreb

Prof. **Darko Ujević**, Ph.D., University of Zagreb Faculty of Textile Technology

Organizing Committee:

President:

Prof. **Ana Sutlović**, Ph.D.

Assoc. prof. **Tihana Dekanić**, Ph.D.

Assoc. prof. **Renata Hrženjak**, Ph.D.

Assist. prof. **Lea Botteri**, Ph.D.

Assist. prof. **Snježana Brnada**, Ph.D.

Assist. prof. art. **Ivana Mrčela**

Assist. prof. art. **Marin Sovar**

Assist. prof. **Ivana Špelić**, Ph.D.

Ivan Beritić, mag. ing. techn. text.

Anja Ludaš, mag. ing. techn. text.

Željka Pavlović, mag. ing. techn. text.

Srđan Cvetanović

Reviewers:

Dragana Grujić; Snježana Firšt Rogale; Budimir Mijović; Igor Sutlović; Branka Vojnović; Marija Gorjanc; Tomislav Rolich; Siniša Fajt; Željko Knezić; Dragan Đorđević; Zlatko Vrljičak; Martinia Ira Glogar; Igor Jordanov; Tanja Pušić; Livio Racane; Slavenka Petrak; Blaženka Brlobašić Šajatović; Ana Sutlović; Anita Tarbuk; Alica Grilec; Vesna Marija Potočić Matković; Krešimir Košutić; Mirjana Čurlin; Anka Gardašević; Zenun Skenderi; Alenka Pavko-Čuden; Sonja Šterman; Irena Šabarić; Julija Volmajer Valh; Antoneta Tomljenović; Renata Hrženjak; Andreja Rudolf; Jasminka Končić; Jelena Đukanović; Ivana Salopek Čubrić; Agata Vinčić; Sandra Bischof; Goran Majstorović; Goran Čubrić; Slavica Bogović; Joamin Gonzalez-Gutierrez; Željko Penava; Dubravko Rogale; Miljenko Krhen; Ivana Bakal; Suzana Kutnjak Mravlinčić; Stana Kovačević; Sanja Ercegović Ražić; Ivan Kosalec; Bosiljka Šaravanja

Editor's word

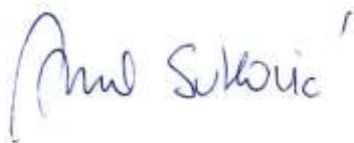
The 14th International Scientific-Professional Symposium "Textile science and economy" - TZG 2022, was organised by the University of Zagreb, Faculty of Textile Technology on January 26, 2022 with the theme "The transfer of innovations to the economy". The TZG 2022 symposium was realised in partnership with the Union of Croatian Innovators and the Zagreb Inventors Association with patrons Ministry of Science and Education, Ministry of Economy and Sustainable Development, University of Zagreb, Croatian Employers Association, Croatian Academy of Engineering, Chamber of Economy, Croatian Chamber of Trades and Crafts, Croatian Association of Textile Engineers and Croatian Leather and Footwear Society. The current topic of TZG 2022, as a basis for sustainable development and increasing the competitiveness of the economy, opened the possibility to submit papers on the latest scientific, artistic and technological achievements with an emphasis on innovation, sustainability, circular economy, advanced processes and technologies, digitalization, ecology in the following thematic areas: textile fibers and advanced materials, textile design, textile refinement and care, dyeing and textile printing, clothing technology, analysis, testing and quality control, design and marketing of textiles and clothing, sustainable textile products and processes, footwear technology, energy, applied fundamental natural and technical sciences and modern educational methods of learning and teaching. At the TZG symposium, 138 participants from the national and international academic community, the economic sector, government institutions, and the field of professional education presented 39 papers in the form of posters and oral presentations. 500 participants followed the meeting online via the official TZG 2022 website and You Tube channel. The international visibility of the TZG 2022 symposium is provided by collaboration and publication of the papers in journals published by MDPI, while a part of the papers will be published in the national journal Textile. Other full papers are available in digital form in the TZG 2022 Book of Proceedings. All papers presented at the TZG 2022 symposium are available in digital form in the TZG 2022 Book of Abstracts. In addition, the proceedings of the symposium "Textile Science and Economy" available in the collection of the German National Library of Science and Technology (TIB), a central comprehensive database for publications in the field of engineering sciences, with the aim of their permanent availability to the scientific community. During the symposium, five plenary lectures were given by distinguished speakers. The head of the Office for Technology Transfer and acting head of the Center for Research, Development and Technology Transfer of the University of Zagreb, Ms. Vlatka Petrović, gave a presentation on "Managing innovation for successful industry-academia collaboration". Linda Kasalo Malić, head of the Project Evaluation and Contracting Sector at HAMAG-BICRO, held a lecture "Possibilities for transformation of the economy through innovation and technology transfer using EU funds". This was followed by Mr. Neven Marković, secretary of the Association of Innovators Zagreb with the presentation "Commercialization of Innovations" and Mr. Matija Žugec from the Association of Croatian Innovators with the topic "Protection of Intellectual Property". The plenary lectures were concluded with a presentation by Prof. Dubravko Rogale Ph.D. "Development and importance of innovations at the Faculty of

Textile Technology". There were also six invited presentations: Prof. Ante Jukić Ph.D., dean of the University of Zagreb, Faculty of Chemical Engineering and Technology "Academic entrepreneurship and transfer of innovations to industry at the Faculty of Chemical Engineering and Technology"; Boris Ćosić, representative of the Centre for Technology Transfer Ltd. of the University of Zagreb, Faculty of Mechanical Engineering and Shipbuilding "The strategic importance of technology transfer for universities / faculties dedicated to the commercialization of academic knowledge - an example of the Center for Technology Transfer at the Faculty of Mechanical Engineering and shipbuilding"; Prof. Nedjeljko Perić Ph.D., from the Nikola Tesla Innovation Centre of the University of Zagreb, Faculty of Electrical Engineering and Computing "Key assumptions and factors for the development of innovations and their transfer to the economy"; representative of the company Čateks dd Nino Kerman "Presentation of the IRI2 project: Development of multifunctional non-combustible fabric for dual purpose"; Tomislav Pokrajčić from the company Jel-Tom doo "Jel-Tom's innovative solutions for the Protection of the marine environment through "Wave Breakers" and "Box Barriers" and others (Croatian patents)"; assoc. prof. Angel Terziev Ph.D., from the Technical University of Sofia "Presentation of the Erasmus + Knowledge Alliance project - ICI-TEX courses- new opportunities for e-learning digital skills for the textile and clothing industry".

Additionally, as part of the consultation, the TTF Gallery organized the exhibition "Three Threads" by assoc. prof. art. Koraljka Kovač, prof. art. Andrea Pavetić and assist. prof. art. Marin Sovar and virtual exhibitions: prof. Snjezana Firšt Rogale Ph.D. "TTF innovations"; assoc. prof. art. Koraljka Kovač Dugandžić and assist. art. Lea Popinjač "Cooperation of the University of Zagreb, Faculty of Textile Technology and Regeneration" and assoc. prof. art. Koraljka Kovač Dugandžić "Textile Design 02 - Cooperation of the University of Zagreb Faculty of Textile Technology, Prostorija and Galleries of the Academy of Fine Arts".

TZG 2022 has once again shown that the Faculty of Textile Technology and the Croatian textile and clothing industry together synergistically create new knowledge and thus advance the development of Croatia.

Proceedings editors:



Prof. **Ana Sutlović** Ph. D.
President of the Organizing Committee



Prof. **Snjezana Firšt Rogale** Ph. D.
President of the Scientific Committee



CONTENTS

Goran MAJSTOROVIĆ Measurement of thermal insulation of a pilot jacket.....	1
Alka MIHELIC-BOGDANIĆ & IVANA ŠPELIĆ Energy efficiency optimization in polyisoprene footwear production.....	2
Iva REZIĆ, Mislav MAJDAK, Petra KIRIN, Marko VINCEKOVIĆ, Slaven JURIĆ, Katarina SOPKO STRACENSKI, Kristina VLAHOVIČEK-KAHLINA & Maja SOMOGYI ŠKOC Functionalized microcapsules with silver for medical textiles.....	3
Juro ŽIVIČNJAK & Dubravko ROGALE Applicable measurement systems for determining the amount of electrostatic charge generated on textile materials.....	4
Igor SUTLOVIĆ, Veljko FILIPAN & Karlo FILIPAN Current situation on energy market and its impact on textile industry.....	5
Željko PENAVAL & Petar PERUŠKO Influence of weft density on the elasticity limit and yield point of fabrics under the tensile load	6
Dragan ĐORDJEVIĆ, Marija KODRIĆ, Radica KRSTIĆ & Nenad ĆIRKOVIĆ Modelling of polyester fabric dyeing after its treatment with eutectic solvent.....	7
Marija KODRIĆ; Suzana ĐORĐEVIĆ; Anita TARBUK; Ivana ČORAK & Dragan ĐORĐEVIĆ Sorption properties during dyeing of enzyme-treated polyester fibers.....	8
Irma RADOVAN & Renata HRŽENJAK Development of corset collection inspired by the influence of waist shape in the 20th century.....	9
Anja LUDAŠ; Martinia Ira GLOGAR & Sanja ERCEGOVIĆ RAŽIĆ Aspects of metamerism in textile dyeing	10
Robert MATAŠIĆ, Patricija DUVNJAK, Ivana SALOPEK ČUBRIĆ & Željka PAVLOVIĆ Comparative analysis of cotton production among leading producers on the international market	11
Petra FRANJKOVIĆ; Ana SUTLOVIĆ; Branka VOJNOVIĆ & Mario CETINA Influence of initial pH value on the adsorption of Reactive Black 5 dye on powdered activated carbon: kinetics, mechanisms and thermodynamics.....	12
Jelena ĐUKANOVIĆ Be smart. Be like Will. Wear wool. Soft sculpture Dress Will - innovation in tradition.....	13
Ines KATIĆ KRIŽMANČIĆ; Ivana SALOPEK ČUBRIĆ & Anita TARBUK Moisture management of sportswear materials.....	14
Goran ČUBRIĆ; Ivana SALOPEK ČUBRIĆ & Antonija PETROV Infrared thermography as a useful tool for improving the performance of athletes	15
Belma KAPIĆ, Kristina VINČAR & Dejlja RAMIĆ The curious case of women's pockets	16
Martinia Ira GLOGAR; Anita TARBUK; Tihana DEKANIĆ; Ivana ČORAK & Petra LABAZAN Influence of cotton cationization on pigment layer characteristics in digital printing	17
Jana JURAN, Maja SOMOGYI ŠKOC, Jelena MACAN & Iva REZIĆ Determination of the influence of sterilization on the properties of compresses	18

Ana ŠARAVANJA; Tanja PUŠIĆ & Tihana DEKANIĆ Release of microplastics into wastewater by washing polyester fabrics.....	19
Blaženka BRLOBAŠIĆ ŠAJATOVIĆ, Diana BILUŠIĆ, Irena ŠABARIĆ & Franka KARIN Diane Frances Spencer as inspiration for own interpretation of the fashion collection	20
Darija BREŠKI, Irena ŠABARIĆ, Franka KARIN & Daniel DOMOVIĆ Synergy of fashion and murals - a display of merging the incompatible in a contemporary clothing collection	21
Antoneta TOMLJENOVIĆ, Juro ŽIVIČNJAK & Ivan MIHALJEVIĆ The wear resistance of socks made of differently spun modal yarns.....	22
Anja MILJKOVIĆ; Lea BOTTERI & Ana SUTLOVIĆ Influence of cotton pretreatment on dyeing with onion peel and pomegranate peel extracts	23
Ivana ČORAK; Iva BRLEK; Ana SUTLOVIĆ & Anita TARBUK Ecological dyeing of modified cotton fabric with natural cochineal dye	24
Tea KAURIN; Tanja PUŠIĆ; Tihana DEKANIĆ & Sandra FLINČEC GRGAC Impact of sinner cycle washing parameters on thermal characteristics and appearance of Proban® - flame retardant material	25
Barbara BILIĆ; Snježana FIRŠT ROGALE; Željko KNEZIĆ; Dubravko ROGALE; Marijan BATINA; Daniel PANTALER & Ivan VINCELJ Production of car seat covers.....	26
Suzana KUTNJAK-MRAVLINČIĆ; Tea KRIŠKOVIĆ; Ana SUTLOVIĆ & Damir GODEC Application of 3D printing from acrylonitrile/butadiene/styrene in the realization of prototypes of heels of women's shoes.....	27
Martinia Ira GLOGAR; Tanja PUŠIĆ; Veronika LOVREŠKOV & Tea KAURIN Textile printing and wash fastness of inherent flame retardant fabrics for dual use	28
Ernestina MARKOVIĆ, Katarina KRSTOVIĆ & Vesna Marija POTOČIĆ MATKOVIĆ The "Novi Dvori" complex as inspiration for the development of a new design	29
Hasan TAHIR; Benny MALENGIER; Carla HERTLEER; Lieva Van LANGENHOVE Self-powered smart insole for the detection of walking pattern anomalies and energy harvesting application.....	30
Frederick FUNG, Zenun SKENDERI & Lubos HES Alternative method of determination of evaporative resistance of socks measured on dry thermal foot model	31
Željko KNEZIĆ; Ivanka HRGAREK; Siniša FAJT; Dubravko ROGALE; Željko PENAVALA & Snježana FIRŠT ROGALE The change of the electrical characteristics of the electrically conductive thread due to the action of force	32
Belma KAPIĆ & Dejlja RAMIĆ Creative consideration of the upcycling method in fashion design.....	33
Maryam ADAVOUDI, Zenun SKENDERI & Dragana KOPITAR Application and finishing the nonwoven layer for automotive air filters media	34

Tomislav IVANKOVIĆ; Antonija RAJIĆ; Sanja ERCEGOVIĆ RAŽIĆ; Sabine Rolland DU ROSCOAT & Zenun SKENDERI Antibacterial properties of non-modified wool.....	35
Anica HURSA ŠAJATOVIĆ; Sandra FLINČEC GRGAC & Daniela ZAVEC Investigation of flammability of protective clothing system for firefighters	36
Sandra FLINČEC GRGAC; Tea TESLA; Ivana ČORAK & Franka ŽUVELA BOŠNJAK Hydrothermal synthesis of chitosan and tea tree oil on cotton fabrics in plain and satin weave.....	37
Snježana KIRIN; Anica HURSA ŠAJATOVIĆ & Snježana FIRŠT ROGALE Determination of working method and time norm of technological sewing operation using MTM, RAV and ZAK method	38
Tea JOVANOVIĆ, Željko PENAVALA & Zlatko VRLJIČAK Deformation of elastic knitted fabrics under cyclic loading.....	39

MEASUREMENT OF THERMAL INSULATION OF A PILOT JACKET

Goran MAJSTOROVIĆ

Faculty of Technical Sciences University of Kragujevac, Čačak, Serbia; goran.majstorovic@ftn.kg.ac.rs

* Corresponding author: goran.majstorovic@ftn.kg.ac.rs

Abstract: Accurate measurements in the field of thermal insulation of clothing began in the 1940s when the US military developed the first thermal mannequin, and more intensively in the 1980s when international research on cold protective clothing, clothing physiology and clothing thermal functions. Thermal insulation is nowadays expressed in SI units by m^2KW^{-1} . In 1941, Gagge et al. published scientific paper in which a warm business suit provides thermal insulation of approximately $0.155 \text{ m}^2\text{KW}^{-1}$ for the entire body, which was originally equal to 1 Clo unit, and refers to a person who is thermally comfortable in a ventilated room where the ambient temperature is 21°C , air flow is 0.1 ms^{-1} , and relative humidity is less than 50%. The Clo, defined in J.R. Mather's "Climatology: Fundamentals and Applications" as units measuring the thermal insulation value of clothing, also. To achieve a simpler perception of these units, it should be pointed out that the naked human body has an insulation value of 0.0 Clo, and a value of 1.0 Clo refers to a person wearing a typical business suit. The Clo unit is easier to understand and is more widely used in clothing engineering. In this paper, a test of the thermal insulation of the so-called pilot jackets was performed. For the needs of the research, the basic of construction was made and two jackets of different basic and lining materials were made. All materials used were laboratory tested for properties textile parameters. The thermal insulation of the pilot jacket was measured on a thermal mannequin, that determines the thermal properties of clothing at rest and the simulation of walking. These tests show that the thermal transfer insulation depends on the materials used, on the basis of which all factors relevant to the technical design of a new garment with precisely specified thermal properties can be determined during the technical design of a garment with the required thermal protection. For the production of a pilot jacket, two outer materials and two lining fabrics were tested and the measurement results and their technical properties were compared, one of which has a waterproof coating. The main purpose of polyurethane coating is to make the waterproof and airtight material. When testing the properties of this fabric in an authorized laboratory, it was found that the mentioned OM-1 material has a much lower vapour permeability than the other OM-2 sample. The ratio of the obtained values for vapour permeability is 2000: $3742 \text{ g m}^{-2} 24 \text{ h}^{-1}$. The value for air permeability reached almost zero for both materials. For sample PJ-1 made of coated material, thermal insulation of 1.32 Clo was obtained, and for sample PJ-2 made of standard material, thermal insulation of 1.11 Clo was measured. A statistical t- test was performed for these two samples to determine if there was a significant difference in the values of the results between these two measured samples. The test confirmed that adding a coating to the material increases the thermal insulation compared to the standard material. From a professional point of view, it can be concluded that in windy and rainy conditions, a jacket with OM-1 coating provides better protection, as it protects the user from moisture and wind penetration, which is not possible with conventional OM-2 material incorporated in the PJ-2 model.

Keywords: *thermal insulation, pilot jacket, thermal mannequin, waterproof and airtight fabric*

ENERGY EFFICIENCY OPTIMIZATION IN POLYISOPRENE FOOTWEAR PRODUCTION

Alka Mihelić-Bogdanić¹; Ivana ŠPELIĆ^{1*}

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: ivana.spelic@ttf.unizg.hr

Abstract: One of the most well-known natural polymers is polyisoprene. Polyisoprene is polymer found in nature as natural polymer derived from rubber trees but can also exist as man-made fibre. The evaluation of energy efficiency improvements in polyisoprene footwear production is shown. The flue gases heat recovery allows significant efficiency improvements and simultaneous decrease of the waste heat rejected to the surrounding. To reduce expensive fuel consumption and furnace stack emissions, heat of flue gases produced by fuel combustion is preferable for air preheating. The air preheater's primary objective is to extract the waste heat from the flue gases leaving the boiler. The paper discusses the possibility of decreasing the natural gas consumption using flue gases heat recovery for feed water preheating applying an air preheater. To improve process plant efficiency, the exhaust flue gases could be used to preheat air, which is required for fuel combustion. The flue gases with the temperature $t_{FG,AP1}=204^{\circ}\text{C}$ (477.15 K) in amount of $V_{m}=12.984\text{ m}^3_{FG}/\text{m}^3_F$ enter the heat exchanger, i. e. an air preheater with efficiency $\eta_{AP}=90\%$, Figure 2. The ambient air enters the air preheater with the temperature $t_{a,m}=24^{\circ}\text{C}$ (297.15 K). The excess air coefficient is $\alpha=25\%$ and the actual volume of air becomes $V_{a,a}=11.807\text{ m}^3_a/\text{m}^3_F$. The specific heat of flue gases is $c_{p,FG}=1.3864\text{ kJ}/\text{m}^3_{FG}\text{grad}$ and for air $c_{p,a}=1.29\text{ kJ}/\text{m}^3_a\text{grad}$. The air preheater (AP) acts as a heat exchanger preheating the combustion air before entering the boiler. The high flue gases outlet temperature exhaust gases from the boiler to the surroundings. However, flue gases temperature can be lowered using air preheater system simultaneously resulting in smaller fuel consumption, thus solving a problem of clean energy generation. By installing air preheater, combustion air natural gas consumption is reduced by 7%. Simultaneously, the boiler outlet flue gases temperature is decreased from 204°C (477.15 K) to 66.93°C (340.08 K) providing sound basis for both economical savings, energy efficiency improvements as well as ecological benefits to the environment. The volume of the flue gases is lowered from $V_{FG,p}=1.7969\text{ m}^3_{FG}/\text{kg}_p$ to $V_{FG,AP,p}=1.671\text{ m}^3_{FG}/\text{kg}_p$ or by 7.01%.

Keywords: polyisoprene; footwear production; energy efficiency improvements; flue gases heat recovery, air preheater

FUNCTIONALIZED MICROCAPSULES WITH SILVER FOR MEDICINE TEXTILES

Iva REZIĆ^{1*}; Mislav MAJDAK¹; Petra KIRIN¹, Marko VINCEKOVIĆ², Slaven JURIĆ², Katarina SOPKO STRACENSKI², Kristina VLAHOVIČEK-KAHLINA², Maja SOMOGYI ŠKOC¹

¹ University of Zagreb, Faculty of Textile Technology, Zagreb, Croatia

² University of Zagreb, Agronomy Faculty, Zagreb, Croatia

* Corresponding author: iva.rezic@ttf.hr

Abstract: World Health Organization has recognized the problem of antimicrobial resistance as one of the most important issues in world health protection. Due to the increasing resistance of harmful bacteria and other microorganisms to conventional drugs, it is necessary to develop new solutions for medical textile materials. The antimicrobial properties of silver ions are intensively investigated in a form of silver ions and silver nanoparticles, so their application on medical textile materials is very important. Therefore, this study aimed to functionalize textile surfaces with antimicrobial microcapsules filled with antimicrobial substances. The characterization tests were performed by ultraviolet and visible spectrometry on samples containing silver in microcapsules in both nanoparticle and ionic forms. Testing of the samples was performed on ready-made microcapsules obtained from sodium alginate, which contained silver in their core. In contrast, the outer shell was made of zinc sulfate 7-hydrate. The encapsulation method using the *Buchi Encapsulator* B-390 encapsulator was used to obtain these microcapsules. For characterization purposes, the test was performed on a two-beam Lambda 20 instrument, manufactured by Perkin Elmer from the United States. The test was performed in the ultraviolet and visible range, in the range of 190 to 900 nm. The test was performed in an aqueous medium in which the microcapsules released silver. The obtained test results will enable the determination of the concentration of silver released over time from microcapsules in an aqueous medium, and based on the obtained results, the antimicrobial properties will be predicted to enable inhibition of growth of certain strains of microorganisms on textile medical materials.

Keywords: *antimicrobial resistance; microcapsule; silver; medicine textile; coatings*

APPLICABLE MEASUREMENT SYSTEMS FOR DETERMINING THE AMOUNT OF ELECTROSTATIC CHARGE GENERATED ON TEXTILE MATERIALS

Juro ŽIVIČNJAK^{1*}; Dubravko ROGALE¹

¹ University of Zagreb, Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: juro.zivicnjak@ttf.unizg.hr

Abstract: Energy balance describes the natural state to which every process, object, and creature tends to, and consists of internal and external processes. Depending on the scientific field, the energy equilibrium state describes differently. *Static electricity* is a phenomenon that describes the instability of an *electric charge* inside or on the surface of an observed object. The phenomenon of electric charge instability occurs after direct contact between two objects or due to the influence of an electric field (ionization). Previously, static electricity was closely related to electrical resistivity, i.e., the electrical conductivity of the observed object. More recently, electrical resistance is no longer sufficient as a reference value, especially with the increasing use of multipurpose materials.

One type of multipurpose materials are *textiles* materials, which in addition to their passive properties such as mass per unit area, breaking strength, elongation, air permeability, resistance to external (mechanical) conditions, water repellency, fire resistance, and so on, contain active elements, that are powered by electricity. Such textiles are called E-, *smart or intelligent* and their functionality time is limited by the capacity of the energy storage unit and proximity to the nearest power source. Therefore, portable energy harvesting devices specially designed for textile materials are introduced. Triboelectric generators (TEG) are the type of generators used in textiles, that convert the generated electrostatic charge to useable electrical energy. Their performance mainly depends on the electrostatic properties of textiles, that are insufficiently analyzed.

The need for further analysis of the electrical properties of textile materials has led to several research papers observing the voltage and capacitance values induced by contact or non-contact electrification of textile materials. From the numerous investigations, a few reference examples were selected in which the electrification of materials was performed by contact or non-contact and with different measurement setups to determine the electrostatic charge.

Keywords: *static electricity, electric charge, textile, voltage, capacity*

PUBLICATION: This paper is to be published as a selection of the conference papers in the journal *Tekstil*.

CURRENT SITUATION ON ENERGY MARKET AND ITS IMPACT ON TEXTILE INDUSTRY

Igor SUTLOVIĆ^{1*}; Veljko FILIPAN¹; Karlo FILIPAN²

¹ University of Zagreb, Faculty of Chemical Engineering and Technology, Zagreb, Croatia

² Catholic University of Croatia, Zagreb, Croatia

* Corresponding author: isutlo@fkit.hr

Abstract: Not so far in past energy prices were predictable and more or less stable, even crude oil prices after oil shocks during seventies of last century followed same pattern. Imposing new energy market concept in the beginning of this century made things much more uncertain in other words we are facing up energy prices growth.

Even, adopted energy and climatic goals tending to low carbon society cannot diminish our dependence on fossil fuels in short and mid-term period. World final energy use in textile industry has doubled in 2004 compared to 1971 from 47EJ/year to 90EJ/year. Electric energy is one of the most used energy types in the textile and clothing plants, used to supply energy for textile machinery, heating and cooling control systems, lighting, and office equipment. Electricity consumption in the total consumed energy participate with share of 93% for spinning, 85% for weaving, 43% for wet processing, and 65% for clothing manufacturing while natural gas and coal serves for rest of energy supply in the textile processing plants.

Emphasis of paper is put on energy prices trends especially those of natural gas, crude oil and electricity. Patterns seen in last few years are now disrupted without warning and could say for irrational reason. Supply lines weren't interrupted, only growing demand in market and political tensions based on strong dependence of EU on natural gas import. It is also seen that growing trend follow all forms of energy and therefore can be concluded that predicting future of prices is impossible especially in light of considering growing demand for energy. As energy is part of our lives, we cannot leave without electricity, natural gas, gasoline etc. it affects our lives from financial point of view. We pay energy in every product we buy, including cloth we wear, and any kind of textile in our every day and professional life. Short analysis showed that processes in textile industry are energy intensive ones so growth of energy prices will cause prices of textile products go up as well.

Keywords: *energy prices; spot market; textile industry*

INFLUENCE OF WEFT DENSITY ON THE ELASTICITY LIMIT AND YIELD POINT OF FABRICS UNDER THE TENSILE LOAD

Željko PENAVAL^{1*}; Petar PERUŠKO¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: zpenava@ttf.hr

Abstract: Woven fabrics is from the physical point of view an anisotropic structure with elastic properties. It is considered neither completely elastic nor completely plastic. Tensile forces cause tearing of the woven fabric or the appearance of elastoplastic or plastic deformations. Plastic deformations are undesirable because undesirable effects and poor quality of the finished product. The good quality of the finished product is achieved if during the use of woven fabric ensure such conditions in which the deformation will be within the elastic or elastoplastic area. By defining the limit of elasticity and yield point of fabrics, one comes to the knowledge of the boundary intensities of the forces to which the fabrics can be subjected, without compromising their quality. Behind yield point, with further increasing force, the yarn begins to deform, and the fabric absorbs permanent (plastic) deformations. In this paper the elasticity limit (elastic region) and the yield point after which the plastic region occurs on the experimentally obtained force-elongation curves, were determined. The impact of weft density changes on values of maximum force, breaking force, force at the yield point and force at the elasticity limit and their corresponding elongations was also analyzed. In the experimental part, tests were carried out on elongation cotton woven fabric specimens in plain weave and twill weave with the same warp density and five different weft densities. From the obtained force-elongation curves ($F-\epsilon$), for all weft densities, when force acts in warp and in weft direction, the elasticity limit and the yield point were determined. The design and modeling of fabrics was carried out using the Blender program in which it was possible to show its three-dimensionality. The first derivation of the function $F'(\epsilon)$ and the second derivation of the function $F''(\epsilon)$ when the force acts in the warp and weft direction are used to determine yield point after which plastic deformation occurs. The first derivative maxima $(F')_{\max}$ represents yield point (ϵ_{yp} , F_{yp}). To determine the elasticity limit (ϵ_e , F_e), the idea was applied to express the tensile force F as a linear elongation function ϵ in elastic region, and in the elastoplastic region the polynomial function will be applied as the simplest solution. The problem was solved with the method of least squares. The relationship between the elongation at break, the elongation at the yield point, and the elasticity limit elongation, for different weft densities for plain weave and twill weave was presented. When the force acts in the weft direction, as the weft density increases, so do the values of the elasticity limit and the yield point. Fabrics in a plain weave with a higher weft density have a greater possibility of elastic and elastoplastic deformation, than fabrics in a twill weave. Fabrics in a plain weave can withstand higher values of maximum force and breaking force than fabrics in a twill weave.

Keywords: *woven fabric; plain weave; twill weave, tensile force, yield point; limit of elasticity*

MODELLING OF POLYESTER FABRIC DYEING AFTER ITS TREATMENT WITH EUTECTIC SOLVENT

Dragan ĐORĐEVIĆ^{1*}; Marija KODRIĆ²; Radica KRSTIĆ¹; Nenad CIRKOVIĆ¹

¹ University of Nis, Faculty of Technology in Leskovac, Leskovac, Serbia

² Innovation center University of Niš, Niš, Serbia

* Corresponding author: Dragan Đorđević, drdrag64@yahoo.com

Abstract: Modelling of dyed fabrics made of 100% polyester fibers with disperse dye, after pre-treatment with the eutectic solvent (ethylene glycol and choline chloride) was studied in this paper. The aim of pre-treatment with eutectic agents is to modify the surface of the polyester fibers in order to improve the adsorption properties as well as the possibility of dyeing in atmospheric conditions and without carriers. Processing polyester in a eutectic mixture changes the surface morphology of the fibers. The surface of the raw PET fabric was clean and smooth, while the treated sample had an altered surface morphology with an eroded surface, stratification resulting in greater surface roughness. It seems that the pre-treatment of polyester goes in the direction of developing the effect of a eutectic solvent, probably due to the enhanced glycolysis reaction caused by ethylene glycol and choline chloride, opening fiber structures, rearranging surface morphology and allowing greater adsorption of dispersed dye. Also, this greater exhaustion of dye can be explained by the possibility that the crystallinity of PES fibers is partially transformed during solvent treatment due to the removal of oligomers from surface layers and the real possibility that such treatment could dislocate parts of macromolecules among microcrystallite regions. In other words, in order for dye molecules to diffuse within the fibers, a free volume must be formed in them. Eutectic solvent treatments appear to help reorganize the free volume within the fiber through thermal changes in the chains of molecules and dye molecules that enter this free space. At the same temperature, the thermal displacement of the molecular chains creates a more permeable and flexible substrate that allows faster dye diffusion, which is partially provided by the treatment with an environmentally friendly solvent. According to the results of the examination of the polyester fabric, it was found that the absorption of the disperse dye is greatly improved after the treatment with a eutectic solvent. As the dyeing time increases, the adsorption capacity increases, while the concentration of dye in the solution decreases over time. As the dyeing process proceeds, the initial concentration of disperse dye decreases proportionally, initially faster and then slower, reaching a minimum at equilibrium time. Less dye remains in the solution and the sorption capacity is higher when the solvent-treated polyester is dyed compared to the raw polyester. Modelling of equilibrium dyeing was done by analyzing three isothermal models, Freundlich, Haslay and Henry. The best result was shown by the Freundlich equilibrium equation, confirming that this model gives a sufficiently accurate and acceptable description of the experimental data and the dyeing process. There is a heterogeneous surface of the substrate with an uneven distribution of heat adsorption on the surface and with the possibility of forming a multilayer adsorption.

Keywords: *polyester; eutectic solvent; dyeing; disperse dye; modelling*

SORPTION PROPERTIES DURING DYEING OF ENZYME-TREATED POLYESTER FIBERS

Marija KODRIĆ^{1*}, Suzana ĐORĐEVIĆ², Anita TARBUK³, Ivana ČORAK³, Dragan ĐORĐEVIĆ⁴

¹ Innovation center University of Niš, Niš, Serbia

² Academy of Vocational Studies in Southern Serbia, Department of Technological and Artistic Studies in Leskovac, Leskovac, Serbia

³ University of Zagreb, Faculty of Textile Technology, Zagreb, Croatia

⁴ University of Nis, Faculty of Technology in Leskovac, Leskovac, Serbia

* Corresponding author: Marija Kodrić, izida50@gmail.com

Abstract: *The process of sorption of disperse dye on pre-treated polyester knitwear is considered in this paper. Pre-treatment of polyester was performed using the enzyme esterase in order to prepare the fibers for easier and simpler dyeing. In the previous processing, the surface morphology of the fibers changes. Unlike the clean appearance of the surface of the raw fibers, the changes on the surface of the treated fibers are very noticeable, defects in the form of surface stratification are observed. The resulting surface deformations make the fibers more permeable to water and dyestuff and change the tactile properties of the knitwear, making it like the touch of natural fiber textiles, as opposed to the characteristic touch of synthetic textiles. The dyeing process of pre-treated polyester knitwear gives better results compared to dyeing raw material. There is the continuity in changes during the increase of initial concentration of dye, i.e., with the increase of concentration the level of exhaustion of dye decreases. With the increase of concentration of dye in solution, in the beginning there is a slightly larger fall of percentage of exhausted dye, in the end of dyeing this fall is lower 8-15 %, for a dyeing period of 10 to 60 min. There is the continuity in changes during time, i.e., the longer time carries the greater level of exhaustion. At lower concentrations, initially, there is a higher percentage of dye exhaustion, at higher initial concentrations the percentage of exhaustion slows down. The linear parts of the curve represent the diffusion in the surface layer, while the parts of the plateau on the curve correspond to the diffusion in the pores. The continuity in changes during the increase of initial concentration and during time, i.e., the greater amount of dye in the solution or longer time of dyeing brings greater amount of adsorbed dye per mass unit of the textile, i.e., at the greatest applied initial concentrations of dye and the longest dyeing the greatest adsorption appears. According to the comparative results for the degree of depletion and sorption capacity of crude polyester and polyester treated enzyme, there is a noticeable difference, the raw sample, in both cases, has a weaker result, i.e., poorer dye exhaustion and poorer sorption capacity. The largest differences in these sorption parameters were observed at the highest initial concentration, 400 mg/dm³.*

Keywords: *sorption, dyeing, polyester, disperse dye, esterase*

DEVELOPMENT OF CORSET COLLECTION INSPIRED BY THE INFLUENCE OF WAIST SHAPE IN THE 20TH CENTURY

Irma RADOVAN¹ & Renata HRŽENJAK^{1*}

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: renata.hrzenjak@ttf.hr

Abstract: The aim of this paper is to create a connection with the contemporary fashion atmosphere through a collection inspired by the influence of waist shapes in the 20th century, and to select and create one model. It presents a historical overview of the development and characteristics of women's corsets, and investigates in more detail and presents the change and application of corsets during the 20th century. The influences of various silhouettes and waist shapes on the construction of corsets are additionally processed, and through the modeling of one's own collection of corsets inspired by the 20th century, the sociological influence of corsets on the body and the use of corsets in body shaping function is presented.

The paper is divided into theoretical and experimental part. The theoretical part is structured into main chapters within which the topic is elaborated. Initially, the human interest in the corset and the aesthetic values of the silhouette are generally discussed and touches on the connection and relationship of the human body to the corset and its influences. The next chapter deals with the basic features of the corset itself and its specifications. In the last part, the paper deals with a detailed presentation of the influence of the pattern on the ruling silhouette, i.e. the shape of the waist through the 20th century, structured in three stages (beginning, middle and end of the century), and explores the sociological significance of corsets.

The experimental part presents a corset collection through sketches, one of which is further elaborated and modeled in a couple of variants and colors. The next part of the experimental consists of the corset construction and modeling according, showing the pattern parts with seam allowances. The last part is structured as a photographic representation of the made corset model according to the author's own measurements.

Keywords: *corset; 20th century; waist shape; clothing construction; clothing production*

ASPECTS OF METAMERISM IN TEXTILE DYEING

Anja LUDAŠ^{1*}; Martinia Ira GLOGAR¹; Sanja ERCEGOVIĆ RAŽIĆ¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: anja.ludas@ttf.unizg.hr

Abstract: In this paper, metamerism was investigated with the aim of determining the difference in the behaviour of pure dyes and mixtures under different light sources. Metamerism is a phenomenon in which two or more observed coloured patterns, of similar hue, look identical under one light source, and by changing the light source, observer, observation field size, or observation geometry, there is a visible difference in colour hue. The quality of new dyes was considered: 1. Yellow Softolon 4R 2. Red Softolon 2B 3. Blue Softolon 4R, compared to old dyes: 1. Tectilon yellow 3R 200% (C.I. Acid Yellow 246) 2. Tectilon red 2B 200% (C.I. Acid Red 361) 3. Tectilon blue 4R-01 200% (C.I. Acid Blue 277:1). The material used is polyamide PA 6.6. The fineness of the samples is 4,4 tex. In previous research, these knitting patterns were dyed with the mentioned acid dyes, and in this work, the samples treated in this way were spectrophotometrically measured. The obtained results are presented graphically in the CIELAB coordinate system a^* / b^* , in the CIELAB remission diagram for pairs of old and new dyes and tabularly through CIE values L^* - brightness, C^* - saturation, h - hue of colour. The considered quality of new dyes in comparison with old dyes from all mentioned researches is equal. Both dyes show no signs of metamerism and are of exceptional quality in the context of colour reproduction and tinting.

Keywords: *Metamerism; dyes (tectilon, softolon); spectrophotometer; different light sources (D65, A, F11).*

COMPARATIVE ANALYSIS OF COTTON PRODUCTION AMONG LEADING PRODUCERS ON THE INTERNATIONAL MARKET

Robert MATAŠIĆ¹; Patricija DUVNJAK¹; Ivana SALOPEK ČUBRIĆ¹ & Željka PAVLOVIĆ^{1*}

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: zeljka.pavlovic@ttf.unizg.hr

Abstract: Cotton is one of the world's leading agricultural cultures and makes up about 2.5% of the world's arable land. According to the available sources, the leading producers of cotton in the world in the last decade are China, India, USA, Brazil and Pakistan. This paper presents a comparative analysis of cotton production for the two leading countries - China (24.76% of total production) and India (19.43% of total production) in terms of geographical predispositions, population, economy, production rate, prices, import and export.

From the data obtained, it can be concluded that China, with all its difficulties over the years, is one of the largest producers of cotton and clothing. Cotton prices fluctuate over the years depending on the world situation, and production also depends on climate change and many other parameters, so there will always be ups and downs in this industry.

Cotton plays a very important role in the Indian economy. It is termed as the most important cash crop of India. It sustains the Indian cotton textile industry, which is the single largest segment of organized industry in the country. It also provides profitable employment to millions of people engaged in harvesting, picking and marketing, cleaning and pressing of cotton. The Indian cotton crop, which occupies about nine million hectares annually, is the largest in the world and accounts for more than one-fourth of the world's cotton area. India is the only country where all four types of cotton are grown.

Keywords: *cotton, international market, production, China, India*

INFLUENCE OF INITIAL pH VALUE ON THE ADSORPTION OF REACTIVE BLACK 5 DYE ON POWDERED ACTIVATED CARBON: KINETICS, MECHANISMS AND THERMODYNAMICS

Petra FRANJKOVIĆ¹; Ana SUTLOVIĆ¹; Branka VOJNOVIĆ¹; Mario CETINA^{1*}

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: mario.cetina@ttf.unizg.hr

Abstract: Textile industry is considered to be one of the major environmental pollutants, primarily due to wastewaters quantity and composition. Wastewaters have a wide range of pH values and temperatures and mainly contain various types of pollutants, most commonly dyes, surfactants, solvents, inorganic salts etc. It is therefore necessary to treat the wastewaters by reducing the amount of harmful substances to legally limited concentrations. One of the most commonly used and effective methods of treating coloured water is adsorption, while one of the most often used adsorbent is activated carbon. In this paper, the effect of initial pH value ($pH_0 = 2.00, 4.00, 8.00$ and 10.00) on the process of isothermal adsorption of Reactive Black 5 (RB5) dye on powdered activated carbon at $45(\pm 1)^\circ\text{C}$ was carried out. Adsorption experiments were performed at different contact times (15, 30, 60, 120 minutes and 16 hours until equilibrium is reached). In order to investigate the mechanism of adsorption kinetic studies have been also performed, using pseudo-first-order and pseudo-second-order kinetic models, as well as intraparticle diffusion model. Additional equilibrium experiments at temperatures of $29(\pm 1), 35(\pm 1)$ and $55(\pm 1)^\circ\text{C}$ at $pH_0 = 4.00$ were also done in a wish to determine thermodynamic parameters of adsorption (standard Gibbs free energy, standard enthalpy and standard entropy changes). Results of this research showed that initial pH value significantly influences the adsorption of RB5 dye onto activated carbon. The highest adsorption capacities and efficiencies of decolouration (E_d) were observed for initial pH values of $pH_0 = 2.00$ and 10.00 ($E_d = 98.4\%$ and 95.6% , respectively), while values for $pH_0 = 4.00$ and 8.00 are much lower. High E_d values at $pH_0 = 2.00$ can be explained by the strong electrostatic interactions between positively charged activated carbon surface and coloured anion of RB5 dye, while at $pH_0 = 10.00$ by attractive $\pi \cdots \pi$ interactions. The experimental data also showed that adsorption at all pH_0 values is kinetically controlled assuming a pseudo-second order process, and that intraparticle diffusion is not the only process that influences on the adsorption rate. Negative values of standard Gibbs free energy change indicated that the adsorption process is spontaneous, and that adsorption of RB5 on activated carbon at the highest temperature is energetically the most favourable. The positive value of standard enthalpy change revealed the endothermic nature of the adsorption process at $pH_0 = 4.00$ and that hydrogen bonds are driving force for RB5 dye adsorption. The positive value of standard entropy change suggests the increased randomness in the dye-adsorbent interaction at the solid/liquid interface.

Keywords: Adsorption; activated carbon; Reactive Black 5; adsorption kinetics; adsorption thermodynamics

BE SMART. BE LIKE WILL. WEAR WOOL. SOFT SCULPTURE DRESS WILL - INNOVATION IN TRADITION

Jelena ĐUKANOVIĆ

University of Donja Gorica, Faculty of Design and Multimedia, Podgorica, Crna Gora

* Corresponding author: sofosofjelena@gmail.com

Abstract: Although fleece is deeply rooted in the cultural heritage of Montenegro, it is rarely processed nowadays, and the market potential of wool is underestimated. Up until a few years ago, wool was a precious raw material in the textile industry; it was bought back and processed by textile mills for their needs or export. However, with the industry being shut down, it is not bought back any more nowadays, and is used sporadically in rural households, mostly for knitting warm winter socks or sweaters.

Wool went from a precious textile material to an ecological challenge because cattlemen usually throw it away after sheep shearing and improperly dispose it in the nature.

Climate changes, green energy sources, preserving resources of drinking water and ocean, environment friendly technology, recycling possibility, maintaining health by taking into consideration more frequent allergic reactions to synthetic fibers and colors, are challenges presented by the modern era, and wool is the common denominator for each of them.

The experimental part of the paper deals with the research of the traditional way of dressing, for example, the use of wool in the production of “*fanjela*” or “*džupa*”. “*Fanjela*” is not a fashion clothing item, it is driven solely by functionality. However, as an anti-fashion item, it presents a creative challenge for producing sculptural or fashion forms.

The creative challenge for creating a soft sculpture – Will dress in traditional wool material is inspired by an educational pictogram which, in addition to educating the public about the positive aspects of wool, raises awareness of the importance of using natural materials and environmental sustainability. By choosing raw and dyed wool yarn, the originality of the material itself was preserved.

Keywords: *fleece; ecological problem; environment friendly technology*

MOISTURE MANAGEMENT OF SPORTSWEAR MATERIALS

Ines KATIĆ KRIŽMANČIĆ^{1*}; Ivana SALOPEK ČUBRIĆ²; Anita TARBUK²

¹ 2K IDEJA, Zagreb, Croatia

² University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: ikatickri@ttf.unizg.hr

Abstract: Materials used in the manufacture of sportswear should be able to maintain heat balance and have adequate moisture management to respond to intense sweating during sport activity. Previous studies have shown that a professional football player sweats 2193 +/- 365 ml during a game. The distribution and absorption of liquid on the textile surface depend on the interaction within the liquid itself and with the fibres. Since the next-to-skin materials used in sportswear are mainly knitted structures, the inter- and intra- yarn porosity play a key role in moisture management. This paper focuses on the study of materials used for professional football sportswear from a moisture management perspective and discusses the influence of porosity.

Keywords: *moisture management, yarn, knitted fabric, materials, sportswear*

PUBLICATION: This paper is to be published as a selection of the conference papers in the journal *Tekstil*.

INFRARED THERMOGRAPHY AS A USEFUL TOOL FOR IMPROVING THE PERFORMANCE OF ATHLETES

Goran ČUBRIĆ^{1*}; Ivana SALOPEK ČUBRIĆ¹; Antonija PETROV¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia,

* Corresponding author: goran.cubric@ttf.unizg.hr

Abstract: Sportswear for active athletes has various functions that perform certain features and help athletes achieve better athletic results. In any sportswear, the physiological aspect is of great importance as it has a great impact on the efficiency and performance of the athletes. In this paper, the interaction between the designed sportswear and the physiological responses of an athlete is described. In addition, it highlights the use of thermography as an important tool for evaluating sportswear and thus improving materials to enhance an athlete's athletic performance. The paper also reviews the research conducted in relation to the use of thermography for the evaluation of sportswear.

Keywords: *thermography; textile; material; evaluation; sport*

THE CURIOUS CASE OF WOMEN'S POCKETS

Belma KAPIĆ^{1*}; Kristina VINČAR¹; Dejlja RAMIĆ¹

¹ Faculty of technical sciences, Bihać, Bosnia and Herzegovina

* Corresponding author: e-mail gutlic.belma@gmail.com

Abstract: *The subject of this paper is researching the issue of inadequate pockets and, in some cases, the lack thereof in women's clothing articles. Going in depth of as to why pockets on women's garments are non-functional and more of an accessory, this paper touches upon subjects of history and technological aspects of the reasons behind this problem and ways of fixing it. While they have been a crucial part of people's everyday lives for centuries, pockets have changed a lot in both shapes and sizes. Fast fashion, and the evolution of clothing industry in general, has affected the average pocket size greatly, with many finding themselves unsatisfied with their garments. The discussion around pockets has been, for the most part, purely one-sided, with women having to bear the burden of inequality. As Charlotte P. Gilman wrote for the New York Times issue in 1905, "Women have from time to time carried bags, sometimes sewn in, sometimes tied on, sometimes brandished in the hand, but a bag is not a pocket". And, as a matter of fact, pockets weren't always a part of ones clothing in the sense that they were tied into it, with poaches and tie-on pockets being the first iterations until the 17th century when men's wear started coming with sewn in pockets. A revolution in garment-making, it still took some time until it became an everyday practice for women's clothing pieces as well. But even so, when pockets were introduced to women's jackets and dresses, they have been much larger than those of today, being able to fit one's belongings, such as money, keys, books, tools, or maybe even for safe-keeping of the husband's belongings. With a deeper dive into history of women's clothing and how pockets were created, this paper goes deeper into why there has been a shrinkage of their size, and why the woman's silhouette plays a crucial part in all of it. While there has been a resurgence of the DiY culture in lieu of the COVID-19 pandemic since the start of the 2020s, one important question regarding clothes and fashion is how much will such a trend last in the modern world and is it capable of changing the well-known standards for garments production in the industry. While ones speculate that this is the next step in modern fashion industry and that a person can and should create clothing that fits them perfectly while also up-cycling garments and items one would consider trash, the fact that fast fashion has never been on a bigger rise world-wide, still very much dictating what and how people dress up in their everyday lives. On the other hand, handbags have been a big part, almost an essential, in women's everyday fashion for over two centuries now. With all of that in mind, where do pockets stand in this turbulent time, and what purpose do they serve? They have had a great impact on society, shifting from being seen as just parts of clothes, most notably pants and jackets, to a symbol of equality and independence for women around the world.*

Keywords: *pockets, poaches, fast fashion, DiY culture*

INFLUENCE OF COTTON CATIONIZATION ON PIGMENT LAYER CHARACTERISTICS IN DIGITAL PRINTING

Martinia GLOGAR^{1*}; Anita TARBUK¹; Tihana DEKANIĆ¹; Ivana ČORAK¹; Petra LABAZAN¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: martinia.glogar@ttf.hr

Abstract: The paper examines the influence of cotton cationization on the print quality in terms of penetration, colour yield and colour depth, which have been analysed in compare to cotton untreated and pretreated with conventional acrylate binder. The purpose of cationic pretreatment of cotton is to improve printability with pigment by introducing positively charged sites on cotton. Due to the pigment in the ink drop being ionized, the ink drops are negatively charged. Therefore, the ink drops could be immobilized on the cationized fabric surface. The print quality in terms of penetration, colour yield and colour depth have been analysed in compare to untreated cotton and cotton pretreated with conventional acrylate binder. The aim of such researches is to find an alternative to conventional binder application in order to achieve optimal colour properties, colour yield and colour fastness but with more satisfactory tactile and physical-mechanical fabric properties. Standard, chemically bleached fabric (WFK Switzerland, type 10A for ISO 2267) of 100% cotton was chosen, in canvas embroidery P1/1 with a flat weight of 170 g/m², the density of the warp and weft 27/27 threads per cm, and with the fineness of the yarn was 295 dtex / 295 dtex. The process of cationization during mercerization was performed with a cationizing agent Rewin DWR (CHT Bezema). Standard (non- cationized) and cationized fabric, with and without additional layering of binder have been printed by digital inkjet pigment printing method. Moisture management testing (MMT) and droplet contact angle measurement with the surface of textile material (Drop Shape Analyzer - DSA25) were performed on standard and cationized fabric, with and without binder, both with and without pigment layer. After printing, the objective values of colour depth (K/S) and colour parameters L*, C* and h° were. The relevant indicators of the cationization effect can be seen by comparing the samples that were not treated with the binder, and for the cationized samples a higher K/S is obtained, which indicates a higher amount of bounded pigment. The samples were analysed also by the method of microscopic imaging using DinoLite microscope. Comparative analysis of microscopic images of samples printed with 50% and 100% pigment content confirmed that the cationized cotton achieves a more uniform pigment layer, higher colour efficiency with less pigment penetration into the textile structure. Printed samples were tested to washing fastness, and the results are presented in terms of total colour difference (dE_{CMC}), according to CMC(l:c) equation, after 1st, 3rd, 5th, 7th and 10th cycle of washing. In the initial printing phase, the K/S values confirmed the obtained higher values of color strength of cationized fabrics. The wash colour fastness phase did not fully confirm the positive effect of cationization on the bonding of the pigment to the cotton fabric, but in the samples with binder, the positive effect of cationization on the stability and bond strength between the polymer layer as a pigment carrier with the cotton fabric was confirmed. This research is part of the extensive work that continues in the field of testing innovative methods of cotton processing in digital pigment printing processes.

Keywords: inkjet printing, cationization, cotton, pigment, wash fastness

DETERMINATION THE INFLUENCE OF STERILIZATION ON THE PROPERTIES OF COMPRESSES

Jana JURAN¹; Maja SOMOGYI ŠKOC^{1*}; Jelena MACAN²; Iva Rezić¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

² University of Zagreb Faculty of Chemical Engineering and Technology, Zagreb, Croatia

* Corresponding author: maja.somogyi@tff.unizg.hr

Abstract: In this paper, the influence of steam sterilization and ethylene oxide sterilization on the physical-mechanical properties of compresses was investigated. The investigation was performed on donated samples of compresses from a reputable manufacturer. Compresses are made of cotton, fiber that is known to date from prehistoric times; one of the widest and most widely used natural fiber in clothing today, but also widely used in medicine.

The resistance of cellulose to various chemical agents primarily determines the behavior of cotton fibers under the action of various chemicals, where for use in the field of medicine (medical textiles) during sterilization there must be no change in physical-mechanical and chemical properties.

In order to determine the effect of two types of sterilization on cotton fiber compresses, according to HRN EN 14079:2008, standardized methods of textile strength in the experimental part of the paper was used. Determination of degree of polymerization with morphological characteristics determined by scanning electron microscope (SEM) was carried out too.

The obtained results of all carried out tests indicate that the performed sterilizations do not significantly affect the physical-mechanical properties of the tested compresses, and they are as such suitable and safe for their purpose. This paper is considering as a scientific contribution in the field of its topic, since at the time of writing; no academic article has been found that would deal with it.

Keywords: *compresses; steam sterilization; ethylene oxide sterilization; medical textiles; testing; SEM*

RELEASE OF MICROPLASTICS INTO WASTEWATER BY WASHING POLYESTER FABRICS

Ana ŠARAVANJA^{1*}; Tanja PUŠIĆ¹; Tihana DEKANIĆ¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: ana.saravanja@ttf.hr

Abstract: Microplastics have become one of the biggest threats to the environment today, a global problem, and should be a cause for concern in the near future. Plastic goes through various degradation processes and breaks down into microscopic particles known as microplastics (MP). Microplastics are generally defined as polymer fragments smaller than 5 mm in size that, when found in the environment, are an inconspicuous but dangerous form of contamination due to their harmful properties. Microplastics are considered as harmful forms of plastic that, due to their toxic properties, impair the health of all living organisms. It is well known that the largest amounts of MP can be found in the oceans and seas. Research shows that each year, about 8 million tons of MPs are released into the oceans. So, it is assumed that by 2050, more plastics will be found in the seas and oceans than fish. Microplastics are ubiquitous and show a great tendency to interact with the ecosystem, endangering biogenic fauna and flora. It can accumulate harmful pollutants that come from the environment and serve as a means of transport. In addition to size, MPs can also vary in color, strength, density, and flexibility. There are two sources of microplastics, the primary and secondary. The primary sources include intentionally produced microplastic particles, for example, microplastics beads and microplastics used in industry (fibers and powders), detergents, cosmetics, hygiene products, etc. This type of microplastics most often enters the environment by discharge of insufficiently treated wastewaters from various industrial plants and municipal wastewater treatment plants. Secondary microplastics are formed in nature by crushing larger pieces of plastic by the action of waves, salt water, UV radiation, and other biotic and abiotic factors. Crushed plastic did not disintegrate or change its chemical structure; it changed only the physical appearance. One of the most important secondary sources of microplastics are synthetic fibres. According to relevant literature, polyethylene makes up about 54.5% of the microplastics floating in the ocean, while polypropylene makes up about 16.5%, and the rest is made up of other polymers, such as polyamides, polyester, polyvinyl chloride, and polystyrene. Nowadays, synthetic fabrics are widely used for clothing, carpets, and various other materials. In general, textiles based on these synthetic materials have the potential to release MPs into the environment during material production or cleaning. Consequently, washing of fabrics or clothing made of synthetic fibers is one of the main sources of microplastics in the environment, since washing machine filters and wastewater treatment plants are not specifically designed to retain microplastics. This review paper identifies the main potential sources and representatives of microplastics pollution in wastewater, as well as alternative methods to reduce the amount of microplastics through washing of polyester fabrics. The concept of microplastics and their intensive release during the washing process of synthetic fabrics will be the subject of research in the field of textile chemistry for a long time.

Keywords: *microplastics; wastewater; textiles; polyester; polyester aging*

DIANE FRANCES SPENCER AS INSPIRATION FOR YOUR OWN INTERPRETATION OF THE FASHION COLLECTION

Blaženka BRLOBAŠIĆ ŠAJATOVIĆ^{1*}; Diana BILUŠIĆ¹; Irena ŠABARIĆ¹, Franka KARIN¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: blazenka.brlobasic@ttf.hr

Abstract: The paper presents an analysis of clothing combinations by Diane Frances Spencer, who served as the inspiration for creating a collection of clothing items. The work of one of the designers whose collections were worn by Diane will be described. In the experimental part, the process of making a certain garment from design, construction, modelling and its realization will be presented. Diana became a confident woman with a strong presence and the ability to indulge in others who had far greater needs than her own.

The material was also selected by a detailed examination of Diana's clothes, in order to find a rich material in appearance and quality. It is a "Chanel tweed" fabric, and the lining is sewn from Viscose. Tweed (fabric) is a material consisting of woollen fibres of linen or diagonal weaving.

That is why this work is a mirror of Diana's fashion awareness, rich blue as the colour of her eyes, complete with the insertion of her own design of cut parts gives a real look of a confident and successful woman like Diana herself was.

Keywords: *Diane Frances Spencer, clothing construction, modelling, design*

SYNERGY OF FASHION AND MURALS - A DISPLAY OF MERGING THE INCOMPATIBLE IN A CONTEMPORARY CLOTHING COLLECTION

Darija BREŠKI¹; Irena ŠABARIĆ¹; Franka KARIN^{1*}; Daniel DOMOVIĆ¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: franka.karin@ttf.unizg.hr

Abstract: Fashion, technology and art have always been closely linked. If we take into account that most clothes, in addition to aesthetics, must also meet functionality in everyday life, it is quite clear that production must be linked to the latest technologies and scientific research in order for the finished product to be representative. Many designers do not think in a conventional way, some of them want to send a strong message to society through fashion. In that case, the inspiration for fashion experiments is often unpredictable and inexhaustible. Designers often use the advantages of modern technologies in their work, which are advancing day by day, thus facilitating the realization of creative ideas in order to better present their vision. By using various computer programs for drawing and pattern making, they only make the process of making a collection easier and faster. The paper briefly describes the work of Alexander McQueen who created fashion ahead of his time and successfully manipulated design and technology in his work, with an emphasis on one collection. Along with it, the work of the versatile artist James Goldcrown is described, who with his murals put Street art in the rank of an artistic direction. In the experimental part of the paper, individual segments of the work of these two, seemingly incompatible designers were selected for inspiration, with the aim of creating a new hybrid collection of clothes based on the work of both artists, but without copying their work. The results show a women's clothing collection based on the work of fashion designer Alexander McQueen and fashion photographer James Goldcrown, who have strengthened the world of fashion with their distinctive work. The collection is shown by computer-generated drawings. One model of the dress was selected and developed and shown in the photos. The results of the work show how to present a collection inspired by seemingly incompatible designers without a literal interpretation, copying the work of the artist, but at the same time using their recognizable elements respecting the work of both artists.

Keywords: *Alexander McQueen, James Goldcrown, fashion, graffiti, murals, technology*

THE WEAR RESISTANCE OF SOCKS MADE OF DIFFERENTLY SPUN MODAL YARNS

Antoneta TOMLJENOVIĆ¹; Juro ŽIVIČNJAK^{1*}; Ivan MIHALJEVIĆ¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: juro.zivicnjak@ttf.unizg.hr

Abstract: The socks are knitted next-to-skin-type garments worn on the feet and often covering the ankle and some part of the calf. They have to fulfil high demands of wear resistance, particularly lower propensity to surface pilling and higher abrasion resistance. As the wear resistance of socks depends on their construction and fibres used, it is very important to select yarns for their production. The casual men's socks are usually made of cotton yarns for softness and comfort, and blended with polyamide and/or Lycra for improved fit, durability and shrink resistance. The applicability of modal fibres, which provide exceptional contact comfort and have better hydrophilicity than cotton, in knitting of socks is insufficiently researched. Socks were usually knitted with spun yarns produced by conventional ringspinning system, but more recently unconventional rotor and air-jet spun yarns have been appeared, resulting in different structure and properties. Therefore, in this paper wear resistance of three groups of men's socks, made in the highest percentage of single ring, rotor and air-jet spun modal yarns of the same linear density in full plating by textured polyamide 6.6 yarns of different linear density were evaluated. Evaluation of socks wear resistance was carried out by investigation of propensity to surface pilling and abrasion resistance of plain knits sampled from leg and the foot parts, both before and after five repeated washing and drying cycles, using Martindale abrasion and pilling tester according to the standardised test methods (EN ISO 12945-2 and EN 13770).

Keywords: socks; modal fibres; yarn type; abrasion resistance; propensity to surface piling; textile testing

INFLUENCE OF COTTON PRETREATMENT ON DYEING WITH ONION PEEL AND POMEGRANATE PEEL EXTRACTS

Anja MILJKOVIĆ¹; Lea BOTTERI^{1*}; Ana SUTLOVIĆ¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: lea.botteri@ttf.hr

Abstract: Cotton materials are the most famous natural material with a wide range of uses. Depending on the further needs of production, cotton fabrics are treated in different ways. Raw cotton materials were scoured in order to remove all impurities from cotton and to achieve better hydrophilicity. Natural pigments from raw cotton were removed by chemical bleaching. Mercerization was also carried out to achieve better adsorption of natural dyes and better luster. All samples were dyed with natural dyes from extracts of onion peel (*Allium cepa* L.) and pomegranate peel (*Punica granatum* L.). Spectrophotometric analysis of the plant extracts was performed on a Cary 50 Solascreen, Varian absorption spectrophotometer in the ultraviolet (250-400 nm) and visible parts of the spectrum (400-700 nm). Spectral characteristics of fabrics were measured using a Spectraflash SF 300 remission spectrophotometer, Datacolor. Whiteness (W_{GIE}) of undyed yarns was performed according to ISO 105-J02:1997 Textiles - Tests for colour fastness - Part J02: Instrumental determination of relative whiteness and of dyed yarns according to ISO 105-J01:1997 Textiles - Colour fastness testing - Part J01: General principles for measuring surface colour.

By using natural dyes, a palette of visually beautiful pastel hues is obtained. Since different cotton pretreatments can affect the properties and structure of the cotton material, the dyeing and spectral characteristics were different, depending on the pretreatment. By processing pre-treated yarns with metal salts of copper, aluminum and ferrum (mordants) the whiteness and yellowness index change, which is to be expected. Mordants in addition to improving the binding of dyes to fiber, also have a major role in changing the whiteness, yellowness index and hue of undyed pre-treated yarns. Samples mercerized at 4% tenacity and dyed with natural onion peel or pomegranate peel dye have higher lightness and luster than samples treated with slack mercerized, but samples treated with slack mercerization have better adsorption of the dye. When cotton yarns are treated with different mordants (metallic salts), different spectral characteristics can be obtained. In cotton yarns dyed with aqueous onion peel extract, the samples treated with aluminum salts have stronger color intensity. Samples dyed with aqueous pomegranate peel extract with added copper salts have the highest color intensity in hue. The darkest colors are obtained by using iron salts with mordant.

Keywords: *cotton yarn; scouring; chemical bleaching; mercerization; natural dyes*

ECOLOGICAL DYEING OF MODIFIED COTTON FABRIC WITH NATURAL COCHINEAL DYE

Ivana ČORAK^{1*}; Iva BRLEK¹; Ana SUTLOVIĆ¹; Anita TARBUK¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: ivana.corak@ttf.unizg.hr

Abstract: The influence of cationization during mercerization and pre-mordanting to the dyeing of cotton fabric with natural dye from *Dactylopius coccus* was researched in this paper. The bleached cotton fabric as well as cationized with Rewin OS were pre-mordanted using iron(II) sulfate heptahydrate (FeSO₄·7H₂O). For the characterization of surface changes after cationization and pre-mordanting, electrokinetic analysis on SurPASS electrokinetic analyzer was performed. Afterwards, fabrics were dyed with natural cochineal dye with and without the addition of an electrolyte, NaCl. For the purpose of determination of dye exhaustion, the analysis of dye solution was performed on the UV/VIS spectrophotometer Cary 50 Solascreen. Spectrophotometric analysis of the samples through phases of modification of cotton fabric was performed using Datacolor 850 spectrophotometer, measuring spectral characteristics from which was determined whiteness degree, color parameters, K/S and color fastness dyed fabric. Comparing cationized and non-cationized cotton fabrics, cationized samples showed better absorption abilities and color fastness. Using electrolyte at untreated cotton fabric improved the process of dye absorption. However, when cationized, usage of electrolyte is not necessary, what makes this process more environmentally friendly. Additionally, high exhaustion of natural dyes also extends the color palette.

Keywords: *cotton fabric; mercerization; cationization; pre-mordanting; dyeing; natural cochineal dye*

IMPACT OF SINNER CYCLE WASHING PARAMETERS ON THERMAL CHARACTERISTICS AND APPEARANCE OF PROBAN[®] - FLAME RETARDANT MATERIAL

Tea KAURIN¹; Tanja PUŠIĆ¹; Tihana DEKANIĆ¹; Sandra FLINČEC GRGAC^{1*}

¹University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

*Corresponding author: sflincec@ttf.unizg.hr

Abstract: The composition and structure of the textile material, the technical characteristics, the degree of pre-treatment, finishing and the external environment conditions (weather, heat, air flow, oxygen concentration) influence their FR (flame retardant) properties. Cotton is preferred material because of its high comfort characteristics, but it is easily flammable and generates burns. Various treatments attempt to quench the flames, reduce the combustible gases and strengthen the generation of non-combustible gaseous degradation products in order to achieve flame retardancy. As most cellulose based materials are non-durable or semi-durable and as such have limited lifetime, design of more durable products is a key strategy to preserve materials properties and reduce the waste amount.

Proban[®] is multiphase treatment of cotton fabrics based on the formation of pre-condensates using a flame retardant (FR) agent based on tetrakis(hydroxymethyl)phosphonium salts (THPx). The assessment of the durability of a product demand the preliminary understanding of how relevant is to extend its lifetime. Changes in surface properties and pore volume are the main causes of the change in material properties. It is therefore important to minimise the risk of agents acting on: (1) protection level, (2) shape and dimensions and (3) additional comfort characteristics.

This research focused on impact of washing conditions on the durability of FR properties and appearance of Proban[®] cotton fabrics was systematically organized through variation in chemistry distribution in Sinner cycle. The chemical share is varied in laboratory conditions as simulation of industrial washing based on component dosing where temperature, time and mechanical agitation were constant. Washing of cotton fabrics was performed through 10 cycles in four baths containing high alkali components, medium alkali components, high alkali reference detergent and water. The limited oxygen index (LOI), calorimetric parameters (Micro Cone Calorimetry), thermal analysis (TGA-FTIR), surface examination (SEM), spectral characteristics and pH of an aqueous extract of fabrics before and after 10 washing cycles were selected for proof of the concept.

Proof of a medium alkali bath as a washing concept for Proban[®] cotton fabric is approved through preservation of FR properties examined through LOI, TGA and MCC parameters and appearance - color and low fibrillation level. Additionally, proposed concept of medium alkali washing can be considered as environmentally friendly and economically viable compared to other washing processes in this research.

Keywords: *cotton; Proban; washing; durability; thermal properties; appearance*

PRODUCTION OF CAR SEAT COVERS

Barbara BILIĆ^{1*}; Snježana FIRŠT ROGALE¹; Željko KNEZIĆ¹; Dubravko ROGALE¹; Marijan BATINA²;
Daniel Pantaler² & Ivan VINCELJ²

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

² Boxmark Leather d.o.o, Trnovec Bartolovečki, Croatia

* Corresponding author: bbilic@ttf.unizg.hr

Abstract: The garment industry not only produces clothing, but also technical textiles, e.g. for car interiors. In principle, the making up of car seat covers is similar to the technological processes of clothing production, but due to the specificity of the leather and the technical textiles used in the production of covers, there are significant differences. The differences are shown in the share of various machines and equipment in the process of cutting and sewing. Car seat cover production processes require different expertise, different types of professional cooperation in the technical preparation of production and technological production processes, the presence of computer technology for the preparation and management of the production process and for the management of the production process. In addition, the size of production batches, the requirements for production accuracy and the investment costs per workplace also vary. Regardless of the percentage differences mentioned above, the basics of ready-made clothing technology are very similar to those of the technological processes in clothing production, so that a clothing technician can very quickly master the basic features of making up covers for car seats. The leading Croatian factory for the production of car seat covers Boxmark Leather d.o.o has its production facilities in Trnovec Bartolovečki near Varaždin and in Zlatar Bistrica. Boxmark Leather d.o.o manufactures car seat covers for Audi, Mercedes, Porsche and other car manufacturers. The first step in the technological process of cutting covers for car seats is leather control, i.e. controlling the leather to mark its damage. Each piece of leather is placed on the device to examine deformations and leather damage. Computer-controlled cutting units with a supersonic jet of water and punches for cutting out leather are used for cutting out parts of the covers. According to the customer's wishes, emblems are made on individual cutting parts using an embroidery machine, a plate with an engraved emblem and an embossing roller. If a part of the cover needs to be completely perforated, an embossing roller is used, and if only an emblem needs to be made, then a decorative embroidery machine or a plate with an engraved emblem is used. The embossing roller and the plate engraved with an emblem stamp the shape of the emblem onto the corresponding part of the leather seat cover under the effect of pressure. In the sewing room, the production lines are organised so that each production line produces a single cover (e.g. front or back seat cover). In a production line, there are about 30 workplaces where technological operations are carried out in a specific chronological order to enable a continuous flow of materials and ensure productivity. Upon completion of the technological process of sewing car seat covers, the final control is carried out. The selection of the sewing needle is very important when sewing leather because, along with the looper, it is an element that is directly involved in forming the sewing stitch. A completely new market has opened up for manufacturers of machine sewing thread for consumers who make up exclusively technical textiles, including car seat covers. This type of market requires threads of exceptional strength and weather resistance, as well as high temperature resistance during sewing and use.

Keywords: *car seat cover; leather; organisation; machine sewing needle*

PUBLICATION: This paper is to be published as a selection of the conference papers in the journal *Tekstil*.

APPLICATION OF 3D PRINTING FROM ACRYLONITRILE/BUTADIENE/STYRENE IN THE REALIZATION OF PROTOTYPES OF HEELS OF WOMEN'S SHOES

Suzana KUTNJAK-MRAVLINČIĆ^{1*}; Tea KRIŠKOVIĆ²; Ana SUTLOVIĆ¹; Damir GODEC³

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

² Shoe factory *Ivančica d.d.*, Ivanec, Croatia

³ University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia

* Corresponding author: skutnjak@ttf.unizg.hr

Abstract: The paper researches the process of applying 3D printing for prototyping women's heels from ABS, using the FDM process on a desktop printer. One of the limitations of FDM-ABS 3D printing on 3D desktop printers is the printing of monochrome or two-color 3D objects (depending on the number of printer nozzles), which makes it difficult to meet the requirements for high-quality reproduction. Therefore, the possibilities of dyeing the printed ABS heels subsequently with disperse dyes by the exhaustion process were investigated. The developed prototypes of ABS heels are in cooperation with the development team of the footwear factory *Ivančica d. d.* Ivanec built into functional and wearable models of women's pumps. The polymer applied for 3D printing of test bodies for all research conducted is ABS made by MakerBot (white, red, orange, green, and purple). White ABS was applied for innovative post-dyeing process with disperse dyes to achieve colored ombre effects. Three primary disperse dyes of different chemical compositions were used during the research: Cibacet Yellow 2GC, Cibacet Red 3B and Foron Blue RD GLF. Based on the geometry and dimensions the original mold of the women's No. 37 shoe, simple CAD heel models, hollow structures and more complex geometric shapes were constructed in the computer program Rhinoceros 5. Heel prototypes were fabricated using the FDM process from ABS on a MakerBot Replicator 2X desktop printer. The parameters of the 3D print were determined based on conducted research of mechanical properties: linear filling L45, layer thickness 0.15 mm, infill density 40 %, and printing temperature 205 °C. Ombre dyeing was performed by capillary movement of the dye solution along the substrate. By rotating the 3D printed ABS specimens, i.e., changing the direction and type of dye, different shaded effects were obtained. The bath ratio was 1:30, pH and it was adjusted with 20 % acetic acid, color concentration (Dc) 1 and 3 and % by weight of the material. The results confirmed the possibility of achieving multicolor effects with the aim of obtaining value-added products in the field of visual effects. The incorporation of the 3D printed heel prototypes from ABS into functional models of women's shoes was combined with the classic production of shoes within the industrial production of footwear with the aim of creating personalized models of wearable shoes or smaller limited series. The emphasis on the prototype of the heel, i.e. the application of new technologies (3D printing) in combination with traditional methods of footwear, is emphasized by the choice of contrasting colors of the upper material in relation to the heel. The upper of the realized prototypes is a model of a classic women's pump, with an ergonomically modelled cut according to the rules and requirements of shoe construction, made of leather which is still one of the most valued and high quality materials in footwear.

Keywords: fused deposition modelling; 3D printing, acrylonitrile/butadiene/styrene; dyeing; footwear design; heel prototype

PUBLICATION: This paper is to be published as a selection of the conference papers in the journal *Tekstil*.

TEXTILE PRINTING AND WASH FASTNESS OF INHERENT FLAME RETARDANT FABRICS FOR DUAL USE

Martinia GLOGAR^{1*}; Tanja PUŠIĆ¹; Veronika LOVREŠKOV¹; Tea KAURIN¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: martinia.glogar@ttf.unizg.hr

Abstract: Regarding printing on inherently non-combustible fabrics, a review of the literature revealed a significant research gap and a relatively small number of publications. In this paper, the printability of non-combustible blended fabrics with reactive dyes fabrics were analysed through evaluation of their spectral and FR characteristics before and after washing process. The tests were performed on non-commercial, inherent FR fabrics of the targeted composition. It should also be emphasized that the tests were performed on fabrics developed at the University of Zagreb, Faculty of Textile Technology as part of the project activities. Research was performed on five fabrics varied in composition and weave. Two fabrics were in twill 2/2, two in twill 3/1 and one in rips. The warp thread of these fabrics are the same, blend of meta-aramid (95%) and para-aramid (5%), while the weft threads are different in composition. The flame resistance of the pristine fabrics was tested by LOI - Limited Oxygen Index. Printing with reactive dyes was performed by hand screen procedure. After drying and fixing of the prints, wash fastness was tested. The results of LOI indicate on high resistance to burning, so all samples meet the criteria specified for the inherently flame resistant fabrics that LOI > 26%. Comparison of LOI values does not show significant differences within variations in weft and weave. The values of pH measurement indicated acidity of the surface, which may be caused by yarn preparations, so samples were before printing washed in a mild detergent composed from anionic and non-ionic surfactants. Microscopic images of printed fabrics show that the binding of dyes in the process of printing and fixing, occurs exclusively on the viscose components of the yarn. This is also a reason of achieving relatively low values of colour strength K/S. The ratio of lightness (L*) and chroma (C*) showed the accordance with the K/S values. Based on the performed analysis, it can be confirmed that it is possible to achieve a certain level of colouration in fabrics that contain a high proportion of aramid fibres, if a certain ratio of cellulose component is contained. In samples used in this part of the research, the weft yarn contained a component of viscose that has the ability to bind reactive dye, and colouration was achieved even in samples that had a certain basic colour, ie were not completely uncoloured (Fabrics 1, 2 and 4). Also, the results confirmed the optimal wash fastness in the process of five washing cycles. This research is part of the comprehensive research of the characteristics of FR fabrics and the possibility of their finishing in the processes of dyeing and printing.

Keywords: *FR fabric, printing, wash fastness, spectrophotometry*

THE "NOVI DVORI" COMPLEX AS INSPIRATION FOR THE DEVELOPMENT OF A NEW DESIGN

Ernestina MARKOVIĆ¹; Katarina KRSTOVIĆ²; Vesna Marija POTOČIĆ MATKOVIĆ^{3*}

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: marija.potocic@ttf.unizg.hr

Abstract: This paper presents the development of a knitwear design from the idea to the realization of the finished product. The design is inspired by the geometric shapes that adorn the traditional building of Vršilnica in Novi dvori. The openings of the building, with their composition, create a symmetry that is very common both in art and in knitwear design. The harmony and rhythm of the shape were transferred and elaborated for the sock collection. The development of a design collection includes idea development and personal research, exploring technical possibilities, and production. Inspiration can come from a variety of sources and is often a combination of a variety of inspirations and available sources. For example, in this work there is a combination of architecture and geometry. The idea alone is not enough to design an object, knowledge of the market is also important. This paper is about a combination of cultural heritage and tourism of the city of Zaprrešić. Sketches or a visual diary that offers a glimpse into the designer's personal creative journey are important for the proper development of the collection. Designers develop their identity through the way they gather and process research. Interesting results come from investigation and individual approach to the concept or theme. The historical building of Vršilnica, which served as inspiration for this work, is located on the Novi dvori estate, where numerous agricultural buildings have been preserved. Although they are not representative buildings like castles and palaces, but fully functional buildings, they have a special landscape and cultural value. Vršilnica is a circular building 18 meters in diameter with a high, three-storey conical roof covered with shingles. Rooms were built on the north and south sides of the threshing floor to store hay, corn, etc. to protect them from moisture. Since a lot of dust is raised when threshing grain, the threshing floor was usually located outdoors. Therefore, this threshing floor in Novi dvori is one of the few preserved examples of the economic architecture of a noble estate from the 18th century.

Vršilnica was completely renovated in 2018 and is now a multimedia center for cultural events and business meetings [2,3,4,5]. Vršilnica Novi dvori is the only example of a completely preserved building of this type, not only in Croatia, but also in the wider cultural area of Central Europe. The first 10 sketches were made by hand, then 8 of them were selected for implementation and edited in Photoshop, where they were adapted to the shape of the sock. Then the pattern were drawn on graph paper and prepared for transfer to the program Photon, where the design of the sock is realized. Eight socks were developed with a jacquard pattern and knitted on the Lonati sock machine using the CAD- CAM Diagraph program.

Keywords: *design, knitting, socks, symmetry, Vršilnica, Novi dvori*

SELF-POWERED SMART INSOLE FOR THE DETECTION OF WALKING PATTERN ANOMALIES

Hasan TAHIR^{1*}; Benny MALENGIER¹; Carla HERTLEER¹; Lieva VAN LANGENHOVE¹

¹ Centre for Textile Science and Engineering, Ghent University, Gent, Belgium

* Corresponding author: hasan.tahir@ugent.be

Abstract: Several diseases are characterized by complications with the walking pattern, including Parkinson's disease (PD) causes irregular and asymmetrical walking patterns due to unequal intensity of the neurological signals, which is a disabling pathology affecting millions of people globally. To detect the irregular and asymmetrical in walking patterns, a smart self-powered shoe insole sensor is developed using a flexible triboelectric knitted braid inside a flexible silicon tube. The triboelectric braid was made with PTFE (Polytetrafluoroethylene), Nylon and HC-12 Madeira conductive yarns. PTFE (Polytetrafluoroethylene) is highly negative, and Nylon is highly positive triboelectric yarns. Madeira HC12 Conductive Thread with resistance $< 100\Omega/m$ was used to collect the signals. A device (walking simulator) with systemic and non-symmetric walking patterns with variable pressure application was used to characterize signals from the smart self-powered shoe insole sensor. The walking simulator motion could be precisely controlled to characterize the signals from the mounted insole. An XY system driven by stepper motors performs a movement in the horizontal direction. A pneumatic cylinder performs vertical movement. G-Code controls the whole system of walking patterns. This is a protocol for CNC machines, offering the possibility to control the system through a serial connection from a PC. The results revealed that using a self-powered shoe insole sensor to detect the walking pattern anomalies is promising. It could have the ability to detect the change in walking pressure and walking patterns.

Keywords: *walking pattern ; asymmetrical walking; walking simulator; knitted braid*

ALTERNATIVE METHOD OF DETERMINATION OF EVAPORATIVE RESISTANCE OF SOCKS MEASURED ON DRY THERMAL FOOT MODEL

Frederick FUNG^{1*}; Zenun SKENDERI²; Lubos HES¹

¹Technical University of Liberec, Liberec, Czechia

²University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: tassfashion@gmail.com

Abstract: This paper introduces an alternative method to test the evaporative resistance (Ret) of clothing using a dry thermal foot model. In a regular regime, when testing Ret of clothing, a sweating thermal foot model would be used; however, the expensive cost, high maintenance and malfunction of sweating holes cause many problems. A different method of Ret measure is recommended. Experiments were according to the ISO 11092 standard¹⁻² when the environmental climate is in a steady-state to measure the Ret of samples. In the experiment, a wet (but not dripping wet) 100% cotton sock was put onto the thermal foot model as the base of the "sweating layer." Tailor-made socks from testing materials were put on the thermal foot model until steady-state, then measurement started. The tailor-made sock³ was introduced to create a closely fitted sock to wear on top of the sweating layer for the experiment. In the Result section, the dry measurements - thermal resistance (Rct) - were also taken for comparison and discussion to the wet measurements - evaporative resistance (Ret).

Keywords: *thermal resistance; evaporative resistance; alternative method; thermal foot model; tailor-made*

THE CHANGE OF THE ELECTRICAL CHARACTERISTICS OF THE ELECTRICALLY CONDUCTIVE THREAD DUE TO THE ACTION OF FORCE

Željko KNEZIĆ^{1*}; Ivanka HRGAREK²; Siniša FAJT³; Dubravko ROGALE¹; Željko PENAVAL¹ & Snježana FIRŠT ROGALE¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

² Finesa Consora d.o.o., Donje Ladanje, Croatia

³ University of Zagreb Faculty of Electrical Engineering and Computing, Zagreb, Croatia

* Corresponding author: zeljko.knezic@ttf.unizg.hr

Abstract: This paper deals with the influence of force on the values of electrical resistance of electrically conductive threads and their elongation. The measurements were conducted using a measurement system developed at the Faculty of Textile Technology. The changes in the electrical resistance of electrically conductive thread subjected to loading forces during elongation were examined. The examinations were carried out on a single thread and threadlike yarn with the same raw composition, different structures, different number of monofilaments and different fineness. Experimentally, values were obtained indicating that the electrical resistance of the electrically conductive thread changes as a function of the number of monofilaments, the structure of the thread, the fineness, and the magnitude of the force that tensions the yarn.

Electrical conductors can be embedded into textile fibres or electrically conductive metal foils can be embedded into textile flat products. The conductive fibres and foils may be used in the form of receiving and transmitting antennas in clothing. Conductors in textile fibres can also be used to implement very light, thin and invisible electrical and electronic collections for powering all installed devices and for transmitting data between these devices and for transferring data between them.

Electrically conductive fibres and foils can also be used as electrical heaters embedded directly into the fabric or knitted fabric threads. Due to the flow of electricity, conductive fibres and foils can generate heat due to their ohmic resistance, which can be regulated by adjusting the voltage values, helping to maintain body temperature in colder environmental conditions.

An innovative measurement system was constructed to measure the electrical resistance and thread elongation at a load determined BY FORCE, as part of the HRZZ project IP-2018-01-6363.

The measuring system consists of a mechanical device for obtaining the tension of an electrically conductive thread with a digital dynamometer, a digital instrument for measuring the elongation of an electrically conductive thread due to the action of a certain force, a digital laboratory metre ESCORT ELC-3133A for measuring the value of the electric resistance of the electrically conductive threads gripped in electrically insulated dynamometer clamps, and a computer for storing and processing the measured data and computer support in working with the camera.

The electrically conductive thread used in the experimental part of this paper bear the designation *statex* SHIELDDEX® Yarn. They were purchased from Shieldex Trading Inc. The electrically conductive threads are products coated with silver, which has antibacterial properties and they are thermally and electrically conductive. Three different electrically conductive thread are used in the experimental part of the paper (codes 117/17Z, 117/17x2 and 235/36x2). All three electrically conductive thread are made of high strength polyamides (PA 6.6) and are coated with 99% pure silver. The X thread is single and has 17 monofilaments, its fineness after coating with silver is 142 dtex. The Y thread is double and has 2 times 17 monofilaments each, a total of 34 monofilaments, its fineness after coating with silver is 295 dtex. The Z thread is double and has 2x36 monofilaments, its fineness after coating with silver is 604 dtex. From the results shown, it can be seen that the action of a force on electrically conductive thread changes the value of electrical resistance. For the same difference in the magnitude of the force (from 1N to 5N), a greater change in electrical resistance (about 100 ohms) is observed in a structurally simpler sample (sample 1 - code 117/17Z) and the smallest change in electrical resistance (about 2 to 3 ohms) for the same change in the acting force (from 1N to 5N) is observed in the last sample of electrically conductive thread - sample 3, code 235/36x2.

Keywords: *change of tension, conductive yarn, electrical conductivity, elongation*

PUBLICATION: This paper is to be published as a selection of the conference papers in the journal *Tekstil*.

CREATIVE CONSIDERATION OF THE UPCYCLING METHOD IN FASHION DESIGN

Belma KAPIC^{1*} & Dejla RAMIĆ¹

¹ Faculty of Technical Engineering, Bihać, Bosnia and Herzegovina

* Corresponding author: gutlic.belma@gmail.com

Abstract: Due to the alarming level of greenhouse gases in the environment, the rapid depletion of natural resources and the increasing level of industrial waste, each individual production activity has come under sustainable control. In recent years, with the improvement of environmental concepts, sustainable fashion has achieved better development in related industries. From spinning, weaving, dyeing, finishing to fashion design, clothing production, retail, use and disposal, effective actions can be taken to reduce the consumption of natural resources and reduce environmental pollution. This research is focused on the upcycling method. With this method, by reconstructing and redefining textile waste, this paper aims to promote the principles of sustainable fashion. The method is defined through the process of creating a new and functional garment, women's jacket, with the remaining textile waste materials from furniture upholstery production, procured from a local company, and unusable garments that might otherwise be dumped in landfills. The ecological, economic, and sociocultural advantages of applying the upcycling method in clothing design are listed, as well as the various disadvantages and obstacles of this process in different contextual situations.

Keywords: *sustainable fashion; upcycling method; fashion design; fashion waste*

APPLICATION AND FINISHING THE NONWOVEN LAYER FOR AUTOMOTIVE AIR FILTERS MEDIA

Maryam ADAVOUDI^{1*}; Zenun SKENDERI¹; Dragana KOPITAR¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: maryam.adavoodi@gmail.com

Abstract: Most of the filter media used in fuel and oil filtration are manufactured by wet-laid processes using cellulosic fibres. Recent technological advances in extrusion-based nonwovens manufacturing have led to increased demand for spunbond or meltblown media in high-end fuel and oil applications. Filter media manufacturers have developed unique fibre and processing combinations to improve automotive oil and fuel filtration efficiency. In this research for producing the filter media, the nonwoven needle punching layer is produced and coated by resin for increasing moulding characteristics that adapts more easily to different shapes of final filter media. The release of collected particle cakes in a fabric filter will be aided if the original fabrics are singed. These finishing process provide good abrasion resistance and enhanced dimensional stability for final filter media.

Keywords: *nonwoven; air filter; polyester; layer*

ANTIBACTERIAL PROPERTIES OF NON-MODIFIED WOOL

Tomislav IVANKOVIĆ^{1*}, Antonija RAJIĆ¹, Sanja ERCEGOVIĆ RAŽIĆ², Sabine ROLLAND du ROSCOAT³
and Zenun SKENDERI²

¹ University of Zagreb, Faculty of Science, Zagreb, Croatia

² University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

³ Université Grenoble Alpes, CNRS, Grenoble INP**, 3SR, UMR 5521, Grenoble, France

*Corresponding author: tomislav.ivankovic@biol.pmf.hr

Abstract: Wool is considered to possibly exhibit antibacterial properties due to the ability of wool clothing to reduce the build up of odor, which arises from microbial activity of skin microflora. Indeed when tested with standard method of agar diffusion plate, the untreated wool can be classified to show certain antibacterial effect due to the lack of growth under the specimen. Therefore, we analyzed in detail what happens to bacterial cells in contact with untreated wool placed on inoculated agar plates by counting viable cells attached to the specimens after 1 and 24 h of contact. We also analyzed untreated cotton samples for comparison. All wool and several cotton samples showed no growth under the specimen but it was shown without a doubt that neither textile material kills bacteria or inhibits cell multiplication. A reasonable explanation is that bacterial cells firmly attach to wool fibers forming a biofilm during multiplication. When the specimen was lifted of nutrient agar surface, the cells in the form of biofilm remained attached to wool fibers removing the biomass and resulting in clear, no growth zone under. By imaging the textile specimens with X-ray microtomography we concluded that the amount of attached cells could be dependent on surface topography. The results indicate that certain textiles, in this case wool, could exhibit antibacterial properties by removing excess bacteria that grew on the textile/skin interface when taken off the body.

Keywords: wool fabric; antibacterial properties; standard agar diffusion plate test; method of analysis

INVESTIGATION OF FLAMMEABILITY OF PROTECTIVE CLOTHING SYSTEM FOR FIREFIGHTERS

Anica HURSA ŠAJATOVIĆ^{1*}; Sandra FLINČEC GRGAC^{1*}; Daniela ZAVEC²

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

² TITERA innovative technologies, Šentilj, Slovenia

* Corresponding authors: anica.hursa@ttf.unizg.hr, sflincec@ttf.unizg.hr

Abstract: The main characteristic of clothing for protection against heat and flame is the protection of users from external influences and dangers in the conditions of elevated temperatures and exposure to flame, fire, smoke and water. The paper presents research on the clothing system for protection against heat and flame using a fire mannequin, and systematically analyses the damage caused after testing. As part of the damage analysis, the existence of microdamages and impurities on the clothing system was determined using a USB Dinolite microscope. In addition, the intensities and composition of gaseous decomposition products during thermogravimetric analysis of samples were investigated. The results of the research using a fire mannequin show that the user of the examined clothing system would not have sustained injuries dangerous to health and life, which confirmed the protective properties. The results of TG-FTIR indicate that the decomposition of the fabric sample of the modacrylic-cotton fiber mixture takes place in three stages, and the identified gaseous degradation products are H₂O, CO₂ and CO.

Keywords: *protective clothing for firefighters; flame mannequin; flammability of materials; thermal decomposition*

HYDROTHERMAL SYNTHESIS OF CHITOSAN AND TEA TREE OIL ON COTTON FABRICS IN PLAIN AND SATIN WEAVE

Sandra FLINČEC GRGAC^{1*}; Tea TESLA¹; Ivana ČORAK¹; Franka ŽUVELA BOŠNJAK¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: sflincec@ttf.unizg.hr

Abstract: Chitosan, the second most used natural polymer, is characterized by its biodegradability, biocompatibility and, antimicrobial efficiency, and today it is applied on various types of textiles by conventional and advanced technological processes to achieve a stable treatment. The paper aimed to enhance the antimicrobial activity of chitosan by using tea trees. The influence of crosslinkers and catalysts on the possibility of obtaining stable bonds using hydrothermal in situ synthesis between cellulosic material and chitosan with and without tea tree essential oil was investigated in detail. The surface morphology of the samples was investigated using Field Emission Scanning Electron Microscopy and the distribution of chitosan particles on the surface of the material is visible with the appearance of agglomerates and thin film which cover the surface of the fibers. A larger amount of chitosan particles is visible on the sample in the plain weave. After the maintenance cycle, the reduction of chitosan particles on the surface of the material is clearly visible in all samples, but all samples were covered with a thin film. Samples in the plain weave have stronger coverage with chitosan particles than those in satin. In the case of samples, a larger amount of bound particles was retained in the plain weave, and the reason is found in the interweaving of the fabric. In the plain weave connection, each weft is intertwined with each warp. This creates a large number of "channels" in which chitosan particles could remain. In satin weave, the warp thread connects every fifth thread of the weft. There is a larger flat surface between the threads and the finish is easier to remove from the surface since there are no indentations as in fabrics in plain weave. Spectral bands obtained by Fourier transform of infrared spectrum in Attenuated Total Reflection measurement technique analysis indicate that all tested samples had physicochemical changes in the structure, which were largely retained on the samples treated with both bath (Bath I and II) and after the maintenance cycle. In the samples treated with Bath I, a change in the spectral band at wave number 899.37 is visible, which indicates asymmetric stretching of the ring in the region of C1-O-C4 β -glycosidic bonds with possible signal amplification due to the presence of terpinen-4-ol from tea tree essential oil. Analysis of the samples on the goniometer proved the hydrophilicity of the tissues, despite the film forming on the surface of the treated samples. This property is desirable for materials used as a wound dressing. The results of antimicrobial efficacy determined according to AATCC TM 147-2016 showed resistance of chitosan-treated materials to bacteria and fungi in most cases, but only samples treated with chitosan and tea tree oil developed a zone of inhibition according to the fungus *Candida Albicans*.

Keywords: cotton; chitosan; tea tree oil; in situ hydrothermal synthesis; hydrophilicity; antimicrobial effect

DETERMINATION OF WORKING METHOD AND TIME NORM OF TECHNOLOGICAL SEWING OPERATION USING MTM, RAV AND ZAK METHOD

Snježana KIRIN^{1*}; Anica HURSA ŠAJATOVIĆ²; Snježana FIRŠT ROGALE²

¹ Karlovac University of Applied Sciences, Karlovac, Croatia

² University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: snjezana.kirin@vuka.hr

Abstract: The paper presents the process of determining the working method and time norms for the technological process of sewing the back sleeve seam on a men's jacket. The designed workplace on a universal sewing machine is presented, the optimum working method is determined and the time norm of the technological operation is determined using the MTM (Method Time Measurement), RAV (determination of sewing time for straight seams) and ZAK (determination of sewing time for curved seams) methods. The results obtained indicate that the technical equipment of the sewing machine and the working method influence the structure of the technological sewing process. By developing an optimal working method, the optimal number of auxiliary hand technological suboperations is achieved, the workload and fatigue of the workers is reduced and the optimal time for performing the technological operation is achieved.

Keywords: *technological sewing operation; work method; time norms; MTM method; RAV method; ZAK method*

DEFORMATION OF ELASTIC KNITTED FABRICS UNDER CYCLIC LOADING

Tea JOVANOVIĆ¹*; Željko PENAVAL¹; Zlatko VRLJIČAK¹

¹ University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

* Corresponding author: teajovanovic81@gmail.com

Abstract: The article describes the application of elastic knitted fabrics in fine women's nylon stockings, sports and recreational clothes, swimsuits and various flat ribbons used in clothes production. The elongation of elastic weft knitted fabrics is usually two to four times larger in the course direction (transversely) than in the wale direction (longitudinally). Depending on the purpose, longitudinal elongation is often larger in warp knitted fabrics while the knitted fabrics used in the production of swim trunks and swimsuits have nearly the same elongations. Elongation at break in such knitted fabrics is from 100 % to even 600 % and many of them are classified as hyper-stretchable and hyperelastic materials. Due to such a large elongation, a force/elongation diagram was described for uniaxial tensile load. Four points on the diagram which are important for studying tensile properties of knitted fabrics were described. The first point is located at the end of the first linear part of the diagram and it approximates the end of elastic deformation. The second point is at the vertex of force/elongation curve. The third point represents the beginning of the second linear part of the force/elongation curve, which is assumed to be the start of permanent or plastic deformation of knitted fabric. The largest force at break of knitted fabric was registered at the fourth point. In all the analysed samples, the amount of knitted fabric elongation was determined for the points, in both course and wale directions. Cyclic loadings were conducted according to the standardized method at the elongation speed 350 mm/min. For each sample and direction, the knitted fabric was stretched to the amount of the set points. In all the measurements, three parameters were analysed after five consecutive cyclic loadings: drop in force, residual deformation and hysteresis index. A special emphasis was placed on the analysis of the hysteresis curve index, which ranged from 0.000 to 0.920 in the conducted measurements. The index was the lowest in very porous unused knitted fabrics of a fine women's stocking lying on the leg under the crotch: usually 0.000 to 0.100. Unused knitted fabrics intended for recreational clothes had the hysteresis index 0.3 to 0.7, while the used swimsuit knitted fabrics had a lower hysteresis index: 0.3 to 0.5. Elastic ribbons used in clothes production had the highest hysteresis index: 0.8 to 0.92. The analysis of the obtained hysteresis indices in certain elongation areas indicates it would be useful to direct future research towards elastic areas that depend on knitted fabric structure and elongation size. The measurements showed that knitted fabrics with a smaller hysteresis index follow their own law of elasticity, while knitted fabrics with a bigger hysteresis follow a significantly different law of elasticity. In very porous structures, knitted fabrics stretch up to even 200 % at a force smaller than 1 % of the knitted fabric breaking force. Tensile properties, particularly the hysteresis index, significantly change after use and multiple washes of elastic knitted fabrics.

Keywords: *elastic knitted fabrics, recreational and sports clothes, hysteresis curve, hysteresis index*

Donors:



HRVATSKA OBRTNIČKA KOMORA

GALKO

GALKO d.o.o.



TVORNICA TEKSTILA TRGOVIŠĆE d.o.o.



ODJEĆA d.o.o.



ČATEKS d.d.



MIRTA – KONTROL d.o.o.



IVANČICA d.d.

Jamnica

JAMNICA d.o.o.