VLÁKNA a TEXTIL

FIBRES AND TEXTILES

1

Volume 28.
March
2021

STU FCHPT

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Textile Engineering

Trenčianska univerzita Alexandra Dubčeka v Trenčíne
Fakulta priemyselných technológií v Púchove

VÚCHV

VÚTCH CHEMITEX

Spoločnosť priemyselnej chémie

CHEMOSVIT FIBROCHEM

Indexed in:
SCOPUS
Chemical Abstracts
World Textiles

ISSN 1335-0617
print version

ISSN 2585-8890
online version

Fibres and Textiles
Vlákna a textil

Published by

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology
- Technical University of Liberec, Faculty of Textile Engineering
- Alexander Dubček University of Trenčín, Faculty of Industrial Technologies
- Slovak Society of Industrial Chemistry, Bratislava
- Research Institute of Man-Made Fibres, JSC, Svit
- VÚTCH – CHEMITEX, Ltd., Žilina
- Chemosvit Fibrochem, JSC, Svit

Vydáva

- Slovenská technická univerzita v Bratislave, Fakulta chemickej a potravinárskej technológie
- Technická univerzita v Liberci, Fakulta textilní
- Trenčianska univerzita Alexandra Dubčeka v Trenčíne, Fakulta priemyselných technológií
- Slovenská spoločnosť priemyselnej chémie, Bratislava
- Výskumný ústav chemických vlákien, a.s. Svit
- VÚTCH – CHEMITEX, spol. s r.o., Žilina
- Chemosvit Fibrochem, a.s., Svit

Editorial office and distribution of the journal
(Redakcia a distribúcia časopisu)

Ústav prírodných a syntetických polymérov
Fakulta chemickej a potravinárskej technológie
Slovenská technická univerzita v Bratislave
Radlinského 9, 812 37 Bratislava, SK
Tel: 00 421 2 59 325 575
e-mail: marcela.hricova@stuba.sk

Order and advertisement of the journal
(Objednávka a inzercia časopisu)

Slovenská spoločnosť priemyselnej chémie,
člen Zväzu vedecko-technických spoločností
Radlinského 9, 812 37 Bratislava, SK
Tel: 00 421 2 59 325 575
e-mail: marcela.hricova@stuba.sk

Order of the journal from abroad – excepting Czech Republic
Objednávka časopisu zo zahraničia – okrem Českej Republiky

SLOVART G.T.G, s.r.o. EXPORT-IMPORT
Krupinská 4, P.O.Box 152, 852 99 Bratislava, SK
Tel: 00421 2 839 471-3, Fax: 00421 2 839 485
e-mail: info@slovart-gtg.sk

Typeset and printing *(Sadzba a tlač)*

FOART, s.r.o., Bratislava

Journal is published 4x per year
Subscription 60 EUR

Časopis vychádza 4x ročne
Ročné predplatné 60 EUR

Evidenčné číslo MKCR SR Bratislava EV 4006/10

IČO vydavateľa 00 397 687

Fibres and Textiles (1) 2021
Vlákna a textil (1) 2021
March 2021

Content

APPLICATION'S BARRIERS OF QUALITY SYSTEMS IN READY-MADE GARMENT FACTORIES IN THE KINGDOM OF SAUDI ARABIA

Noor Abdulhadi Alsubyani and EmadEldin Sayed Gohar

Fashion and Textile Department, Faculty of Human Sciences and Designs, King Abdulaziz University, Jeddah, Saudi Arabia
nalsubyani@kau.edu.sa; egohar@kau.edu.sa

Abstract: *Most types of garment products are produced through a series of sequential processes that vary slightly from one factory to another. Each part of the manufacturing process affects the final quality of clothing. The primary purpose of quality control is to ensure the existence of the product at the lowest possible cost. In practice, this cannot be achieved by controlling production processes and minimizing the occurrence of defective production and beyond the limits of specifications. The research aims to identify the different factors that affect the quality of production of women's abaya in Jeddah, to analyze methods of women's abaya quality control and to develop proposals for methods to raise quality*

Keywords: *quality systems, ready-made garment industry.*

1 INTRODUCTION

The ready-made garment is one of the manufacturing industries that are produced in multiple departments, and it is done by converting raw materials into clothing products. Since it is one of the consumer industries, it includes all types of under and outer wear that people consume at all times, and its manufacture depends on the use of textile products. This is the reason which makes the two sectors closely related to each other, and therefore the establishment of integrated industries is considered necessary to achieve economic exploitation [1].

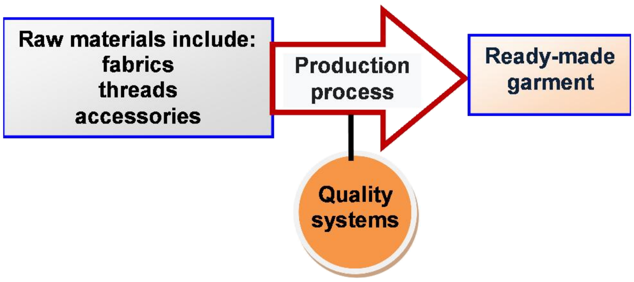


Figure 1 The role of inputs and outputs within the garment factory

Most types of ready-made garment are produced through a series of successive processes that vary slight from one factory to another, and each of these processes consists of a work cycle that contains a series of important stages such as cutting, knitting, finishing and ironing, with the aim of completing a work or completing a unit of production. Every part of the manufacturing process affects the final quality of the garment [2].

The Garment production processes can be illustrated through the following format:

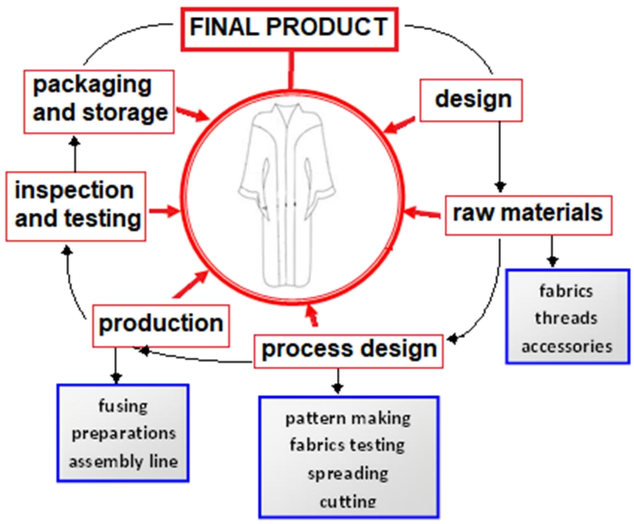


Figure 2 Ready-made garment production processes

1.1 Quality in the ready-made garment industry

<u>*Quality control*</u>

Control requires the presence of requirements and follow-up to achieve these requirements and intervenes to try to correct any deviation from the requirements that occurs during the fulfilment. If we apply the concept of control in the field of quality, then the requirements mean standard levels of quality and control which means an attempt to correct any deviation in quality from its standard level. Accordingly, we can define quality control as all the activities and efforts exerted by all employees of the facility, that combine to achieve the desired standard levels of quality [3].

The primary purpose of quality control is to ensure the quality of the product at the lowest possible cost. In practice, this cannot be achieved by controlling production processes and minimizing the occurrence of defective production and beyond the limits of specifications.

There are four practical steps involved in controlling the quality of industrial products:

1. Determining the required level of quality through market research, product designs and specification.
2. Evaluating the conformity between the product and the specifications, and this is by taking regular samples from the production line and then conducting measurement operations on its characteristics. And compare the results with their counterparts specified in the specifications and determine the values of the difference between them.
3. Evaluating and analyzing the causes leading to these differences and taking corrective and preventive measures.
4. Planning for continuous improvement of quality by reviewing product specifications [4].

Rajkishore Nayak and Rajiv Padhye [5] divide quality in the ready-made garment industry into three steps:

I. Preproduction quality control

During preproduction quality control, all garment's elements is tested before assembling. Other production supplies "interlinings, threads and other design elements" are manufactured to ensure their quality before starting to manufacture. This affects the factory by save time and money in the long term.

II. Quality control during production

Achieving the quality of apparel products depends on every step in the production process, which includes pattern drawing, spreading, cutting, assembling and finishing. Accuracy must be followed in cutting as well as during the assembling of parts. Careless sewing or poor attention to detail leads to unacceptable errors in the final product.

III. Final inspection

The final inspection process is carried out after conducting a quality test of materials and the quality of manufacturing processes. Products are tested according to the requirements for performance, general appearance, size and fit. It's tested by placing garments in manikins or models. In addition to visually inspecting them to ensure that they are free from any errors in the production process. Thus, the stitching quality and the connection of the components of the garment and the accessories are checked [5].

Production process of garments like fabrics, accessories, etc. in the warehouse always starts when all of the necessary items are received, and is done after the material delivered. Usually, manufacturers check the quality in the “Checkpoints” to be sure that the only good quality items will be use.

Table 1 Inspection level

Department	Inspection level
fabric store	random check according to AQL 2.5
accessories & trim	random check according to AQL 2.5
fabric spreading and cutting	marker checking , fabric test report check, fabric spreading, cutting, sorting and bundling
embroidery & printing	check up 100% on embroidery, printing
sewing	in line check at crucial operation, random checking end of line 100%checking
finishing	final inspection (after pressing)

<u>*Quality Checkpoints in Garment Production [6] (onlineclothingstudy.com)*</u>

This approach improves product quality and increases productivity by placing emphasis on product, process design and monitoring.

Advantages of an effective quality system [7]:

- increase customer satisfaction
- low waste rate,
- high motivation for workers,
- for a more efficient and effective organization,
- achieving better positions in the markets,
- make more profits.

Therefore, the focus of this research has been on identifying the various factors that affect the quality of women's abaya production in Jeddah, Kingdom of Saudi Arabia, and strengthening the basic concepts of quality and methods of application, review and evaluation of the technical personnel in ready-made garment factories.

2 EXPERIMENTAL

<u>*Research aims:*</u>

- identify the different factors that affect the quality of production of women's abaya in Jeddah,
- analyze methods of women's abaya quality control,
- develop proposals for methods to raise quality.

<u>*Research importance:*</u>

- contribute to the advancement of the readymade garment industry in the kingdom of Saudi Arabia,

- spreading the culture of applying quality systems by strengthening its basic concepts,
- providing scientific support to technical personnel inside ready-to-wear factories.

Research limits: choosing 5 factories for the production of women's abaya in Jeddah, Saudi Arabia.

Research methodology: descriptive approach follows through analytical study.

Research tools: field visits, a questionnaire, interviews.

The practical study included assessing the quality of 5 factories for women's abaya production in Jeddah through exploratory field visits, linking them to theoretical studies, applying research tools; then identifying quality problems in the stages of producing the women's abaya, and drawing conclusions and discussing them.

3 RESEARCH RESULTS

3.1 The various factors that affect the quality of running the women's abaya

They are divided into four types:

I. Defects related to process materials (raw material)

II. Defects caused by human errors (including) the use of untrained workers, frequent defects due to human errors during assembly operations

III. Defects caused by machines and equipment as a result of temporary or permanent faults in the embroidery and production machines.

IV. Errors due to mixed factors, because it is not possible to specifically limit the cause of the defects.

The following is an explanation of the defects that were detected during the practical study:

I. Defects in operating materials

These materials include: fabrics, threads and accessories.

II. Defects caused by human errors (assembly defects)

Usually the number of workers in this stage is greater than at any other stage, so the occurrence of many errors is very possible, and monitoring this process while it performs is extremely important to complete it correctly the first time.

III. Defects caused by machinery and equipment

Production and quality are affected by several factors that may be due to defects in machines. These faults include:

- The life of the operating machines.
- Absence of periodic maintenance.
- Negligence in the maintenance system (periodic - intermittent).
- The worker's lack of awareness of all the factors surrounding the machine (the method of operation and dealing with machine problems that may occur during production)

IV. Mistakes due to mixed factors

Sometimes the defect cannot be classified precisely as the defects appear due to both human factors and machine faults

3.2 Quality control methods for the production of women's abaya

Before embarking on quality processes, all factors affecting them must be identified and limited to develop quality plans to reduce these defects and eliminate them as much as possible.

The process of describing operating defects includes four stages:

- list all possible defects,
- preparing the defect description form,
- preparing illustrations for each defect,
- follow up the percentage of the appearance of each defect throughout production periods.

The following is a presentation of these points that were observed during the practical study:

1. Determine the operating defects

All possible errors that may occur during the operation period are counted. The most important sources for this inventory are:

- customer reports,
- attention payed to the product and the identification of all production defects
- reports of quality supervisors and supervisors of production lines.

2. Preparing the defect description form

This is an essential step for operating quality control, and operating defects are described in order to be rectified and taken into account.

3. Preparing illustrative models for the production model

During the production process, samples of the correct product shape are described in order to distribute them to each stage of the operation, as well as to the quality control, as well as the initial sample of the model according to the customer's request is placed in a visible and easy place and this sample is used as a model for all production personnel. Illustrations are also prepared in the event of any defect to clarify the causes of this defect and methods of treatment.

4. Observation and evaluation

The process of observation and evaluation takes place through periodic monitoring of the amount the workers' responses to the method adopted for quality and on the base of the determination of the deficiencies in the capabilities of the factory.

4 CONCLUSION

From what has been presented above, we can extract the most important measures to raise the quality of operating the women's abaya:

- putting check points for the fabric while it is straightening in preparation for the cutting process,
- putting quality during and after the cutting process and matching the parts of the resulting piece with the pattern and making a report on that,
- preparing a periodic program for inspection and maintenance of the factory machines in a way that does not hinder production, which increases the efficiency of the machine and reduces the errors resulting from it,
- establish a regular system for changing the machine needles whenever needed by the maintenance worker,
- preparing training programs for workers on a regular basis to raise their efficiency,
- providing an alternative worker and motivating workers to raise their efficiency,
- the periodic interview with the workers to clarify the most important strengths and weaknesses of each worker and motivate them to develop their skills,
- make quality a general behavior for all workers at all levels, including workers and supervisors of production lines, through periodic meetings with them,
- preparing illustrations of the shape of defects that appear in the final and undesirable product, their causes and ways to avoid them,
- at the beginning of production, an initial form for the quality reports is defined and distributed to the quality supervisors,
- evaluating the quality control schedule is one of the most important factors that lead to raising the quality of operation and quickly identifying production problems,
- knowing the causes of defects and classifying them into defects (labor - machines - raw materials - cloth - mixed),
- the necessity of linking the incentive rate to both the quality and the quantity of production.

Recommendations:

- continuous training for technical personnel in the garment industry in Saudi Arabia,
- adding quality courses in specialized colleges to support the labor market with qualified cadres,
- every garment factory should implement different quality management tools.

ACKNOWLEDGEMENTS: *This project was funded by the Deanship of Scientific Research (DSR) at King Abdulaziz University, Jeddah, under grant no. G: 618-253-1441. The authors therefore thank DSR for the technical and financial support.*

5 REFERENCES

1. Nader K.S.M., Hamdan N.I.: The manufacture of ready-made clothes in the Kingdom of Saudi Arabia, 1st ed., Saudi Arabia: King Fahd National Library indexing during publication, 2010 (in Arabic)
2. Musa S.Z., Rizk S., Gohar E., Abbas A.: Planning and Production of the Garment Industry, 1st ed., Cairo: The World of Books, 2003 (in Arabic)
3. GOTEVOT: Quality control, KSA (in Arabic), http://download-engineering-pdf-ebooks.com/4118-free-book
4. Al-Titi K.M.I.: Quality Management and Industry, Jordan, Amman: Al-Hamid Library for Publishing and Distribution, 2010 (in Arabic)
5. Rajkishore N., Rajiv P.: Garment Manufacturing Technology the Textile Institute, 2014
6. Quality Check Points in Garment assembly process – Goldnfiber / Apparel Merchandising Blog, Quality Check Points in Garment assembly process – Goldnfiber | Apparel Merchandising Blog
7. Rizk S.A.-L., Abdel-Karim M.Al-B.: Quality in the Clothing Industry, 1st ed., Cairo: The World of Books, 2003 (in Arabic)

SUSTAINABLE CLOTHING DISPOSAL BEHAVIOR, FACTOR INFLUENCING CONSUMER INTENTION TOWARD CLOTHING DONATION

Rakotoarisoa Maminirina Fenitra[1], Tanti Handriana[1], Idrianawati Usman[1], Nirahariyatie Hartani[2], Gancar Candra Premananto[1] and Sri Hartini[1]

[1]*Department of Management, Faculty of Economics and Business, Universitas Airlangga, Surabaya, Indonesia*
[2]*Universiti Utara Malaysia, School of Government (SOG), Kuala Lumpur, Malaysia*
maminirina.fenitra.r-2018@feb.unair.ac.id; tanti.handriana@feb.unair.ac.id; indrianawati-u@feb.unair.ac.id; nirahartani1@gmail.com; gancar-c-p@feb.unair.ac.id; sri-hartini@feb.unair.ac.id

Abstract: *This study aims to explain the consumer sustainable clothing disposal behavior. We examined the factor that influences clothing donation intention behavior. This empirical study used data from* 109 *respondents in Indonesia. Data were collected through self-reported survey questionnaire using convenience sampling methods. Regression analysis was conducted to statistically amylase the data and tests the hypothesis. The findings show that attitude toward environment and attitude toward clothing donation positively influence clothing donation intention. Environmental attitude has a higher coefficient. Environment concerns have a positive influence clothing donation intention through environmental attitude, besides, environment concern also positively influence clothing donation intention through attitude toward clothing donation. Emotional value has a positive influence environmental attitude whereas it does not influence attitude toward clothing donation. Further, religiosity does not have any influence environment attitude and attitude toward clothing donation. This study contributes to the theory of clothing disposal behavior and has a further implication to related study. Few limitation are acknowledge in this study, finding is limited to clothing donation, although clothing disposal method forms in a different way. We suggested further study to implement our model with a different clothing disposal method such as recycling.*

Keywords: *Clothing disposal behavior, donation, sustainable behavior, environment concern, attitude, knowledge, religiosity, Indonesia.*

1 INTRODUCTION

Clothing industries is one of the fastest-growing markets that significantly contribute to the economy. Although, over the past few decades the growth in clothing industry has brought a significant contribution to the economy, issues occurred when it comes to the disposal stage of the products. Disposal is the final stage of consumption when customers decided not to use a certain product [1]. Disposal of clothing brings about a negative impact on the environment as well as the social [2]. EDGE statistically reported that fashion industry contribute 10% of the global greenhouse gas emission. Common objective website in 2017 reported that 57% of the clothes purchase is dumped in the landfilled and 25% go to incineration and only 10% are recycled and 8% reused. Furthermore, its undeniable developing countries like Indonesia face a severe problem due to the clothing disposal, a survey conducted by New YouGov in regard to quantify the clothing disposal in Indonesia in 2017 reported that 3 out of 10 Indonesian trashed clothes after wearing it just once. Marketing scholars become more concerned about the environment [3-5].

Clothing disposal behavior is needed to be studied, as understanding the consumer consumption pattern in context of clothing would help to tackle these issues in micro and macro-environmental factors in a different way. It would help bringing positive consequences to the society, environment and economy [1].

Firstly, donating clothing would prevent excessive waste flow that goes to the land field. Second, clothing disposal namely clothing donation is a way that helps the society to help others and promote the religious practices, sympathy and altruism [6]. Finally, it will enhance and encourage value creation to promote the circular economy [7, 8, 59] and fashion [9]. It is salient to comprehend the consumer behavior toward clothing disposal for environment and marketing reasons [10].

Prior research on clothing consumption have been focused on product acquisition phase and seem overlooked the post-purchase [11]. The interest on disposal has increased the interest of economist, policymaker, waste management and as well as marketing scholars [12-15]. Research in field of marketing was relatedly concerned with environmental issues and sustainable marketing, although several scholars have attempted to investigate the factor influencing clothing disposal behavior [16, 17, 61, 62]. There is no doubt to mention that there is a lack of attention to investigating the role emotional value, religiosity environmental concern on clothing disposal behavior particularly clothing disposal behavior. Prior study studies suggested that the clothing disposal behavior needed to be studied separately [1].

Several researchers conceptualized their study various way of how consumer dispose clothing namely; keeping the product, a consumer may keep the unwanted or unused product as memories and maybe continue to use it in the future for example, reuse [7, 18, 19], recycle [20, 63]. Permanently dispose of the product, this category is when consumers want to get rid of the product permanently by selling it or throw it away and so on for example, through away, swap and sell, give it to donation, family or friends [5, 17, 21]. Temporarily disposing of the product, consumer disposes the product in a way that not losing in form of loaning the product or renting it to someone else [61, 62]. This present study is focused on clothing donation which refers to giving clothing to those who needed to help them [5, 16, 18, 22, 23].

Few consideration that not been adequately addressed in previous studies. Prior studies mainly conducted in developed countries so conducting this research in developing countries would help to fill this gap. Most of the previous studies focused on a specific gender. Study by Ha-Brookshire [24] and Lee [25] demonstrated the domination of female respondents. Existing inconsistence findings motivates the author to develop an alternative framework related to fill the gap in the literature. Our central goal is determined the factor influencing clothing donation intention behavior. In doing so, we integrated emotional value, religion and environmental concern to our model. We examined and distinguished the most relevant factors between environmental attitude and attitude toward clothing disposal in explaining clothing donation intention based on the theory of planned behavior [26]. Our findings are expected to answer the question on which factor influences clothing donation intention behaviour. Does attitude (toward environmental and clothing donation) mediate the relationship between these factors and clothing donation intention? This study is to investigate the consumer behavior toward clothing donation in Indonesia.

2 LITERATURE REVIEW

2.1 Clothing disposal behavior

Disposal is the process of the phase when consumers decide to stop using an unwanted or still usable product [1]. It refers to the stage when consumer decided to get over and stop using and wearing the clothing either its still-usable or not usable. What consumer do or how consumer dispose their clothing after using it has become a challenge for the marketing, policymaker as it have a negative impact on for the society and environment. Due to the mass production at a low price, fast fashion industry, and the flow of natural resources cause an excessive waste generation. Cruz-Cárdenas [27] revealed that younger consumers are more likely to dispose of their clothing in a more un-environmental friendly way. Besides, studies found that consumers tend to dispose of their clothing when they want to purchase new fashion clothing [21], free space for their wardrobe or they got bored with the clothing [28].

Clothing disposal behavior has become a separate topic for marketing research specifically in post-consumption behavior. This field has gained much intention from marketing scholars and academics since the first exploration by Jacoby [29] in the new knowledge on disposal in “What about disposition?”. This topic has grown attention and expanded through the past few decades. Scholars conceptualized the clothing disposal behavior as reuse [7, 18, 19], recycle [20, 63], a donation [5], give away to family and friends [22], through away, swap and sell [21]. In this study, we centralized our focus on clothing disposal behavior in terms of donating [16, 23]. Bianchi and Birtwistle [5] referred donating apparel as offering unwanted clothing to family and friends, or to one’s who need. Clothing donation behavior has been linked with social responsibility consumption, consumers ‘environment concern [22, 16]. Further, clothing donation is tied with individual characteristics and beliefs [1]. An individual have higher concerned about the environment are more likely to donate their clothing. However, Bubna and Norum [30] argued in their study on male disposal apparel that apparel donation is more self-oriented and utilitarian function. We proposed that several factors positively influence the clothing donation intention namely, environmental concern, personal religiosity, emotional value, attitude.

2.2 Clothing disposal intention behavior

This study conceptualized based on the theory of planned behavior [26]. The theory suggested that behavior is explained by intention to perform a certain behavior which is called intention behavior. Behavior intention is define by Ajzen [26] to an individual tendency to act in certain way. This theory fundamentally implemented to understand the link among an individual’s beliefs, motives such as attitude, intentions and behavior. Environmental attitudes influence the clothing disposal behavior [27]. In contrast, Stephenson [31] emphasized that there is a weak positive link between attitude toward donation and intention to donate.

Similarly to Lee [25] suggested that religions have no relationship to donation intention behavior. Higher attitude toward (environmental and clothing disposal) leads to higher intention toward clothing disposal. Therefore, this study suggested that the higher the positive attitude toward clothing donation, the higher their intention toward clothing donation. Higher the environmental attitude fosters clothing donation intention.

H1: Attitude toward environment positively influence the intention toward clothing donation

H2: Attitude toward clothing donation positively influence the intention toward clothing donation

2.3 Clothing donation behavior and environmental concern

Environmental concern is defined as the level of which individual is being concerned about environmental issues. Environmental concern is one psychological factor that influences the disposal behavior and the decision-making process [1]. Fraj [32] stated that when an individual is concerned in certain issues they must process motivation, skills and little knowledge which might push them to take some action. Thus suggested that the more individual concerned about the environment the more their attitude toward clothing donation and also the more their positive attitude toward environment. This study suggested that when individuals the degree of environmental concern of individuals increase the more positive attitude they reflect toward environment and clothing donation.

H3: Environmental concern positively influence the attitude toward clothing donation

H4: Environmental concern positively influence the attitude toward environment

2.4 *Religiosity*

Religiosity defined by Egbert [33] as "society based beliefs and practices relating to God or a higher power commonly associated with a church or organized group". Dube and Wingfield [34] argued that religiosity is degree of an individual's devotion and faith to their beliefs, doctrines and practice toward their religion. It characterized and classified by Schneiders [35] the way "understanding and living in the presence of the numinous". Religiosity correlated with consumer psychology and behavior in several aspects of life [36] and considered by Chapman [37] as a factor related to donation.

<u>*Religiosity and environmental attitude*</u>

There are few studies investigated the link between religiosity and environmental: Wardekker [38] found that there is a slight link between religiosity and environmental concern. Pepper [39] revealed a positive relationship among religiosity and environmental friendly. Dilmaghani [40] explored the important relationship among religiosity and environmental concern and found a positive relationship among religiosity and environmental concern. In line with Arli [41], investigated the impact of religion and green marketing and found that environment behavior is positively influenced by intrinsic religiosity. The findings highlighted the link between religiosity and environment behavior specifically environmental attitude [41]. Therefore, this suggested that when the degree of religiosity of an individual increases, the environmental attitude of individual incline.

H5: Religiosity positively influence the attitude toward environment

<u>*Religiosity and donation attitude*</u>

Prior studies have established the influence of religiosity on consumer behavior. Previous empirical findings showed that attitude to donate are directly influenced by religiosity [42] and intention to donate [43]. Diop [44] investigated the effects of religiosity and social capital on civic engagement in Muslim consumer in Qatar. His study found that religiosity plays a major role in donation behavior. Dogan [45] emphasized that donation intention behavior is determined by the individuals' relative degree of religiosity. These evidences are supported by recent study of Kasri [46], they demonstrated that donation intention behavior is determined by the individuals' relative degree of religiosity. A significant positive influence of religiosity on attitude toward donation was mentioned. On the other hand, Stephenson [31] asserted that religiosity does not determine the willingness to donate. These two variables are not associated with one another. Therefore, we argued that the higher the degree of religiosity of individuals the higher the positive attitude toward clothing donation.

H6: Religiosity positively influence the attitude toward clothing donation

2.5 Emotional value

Emotional value is among the factors considered to be associated with consumer behavior. Danish [47] refers to emotional value as "the ability to arouse feelings and affective states by alternative product capacity" which recognized as the combination of feelings and emotions with the consumption of products [48]. For example, Bubna and Norum [30] described that there is an emotional link between a person and the object, the strength of the emotional tied between consumer and product which might determine the way how they dispose of the product. Prior study found that emotional value has a significantly positive effect on consumer behavior [49]. Wei [60] examined the effect of perceived value (emotional, functional, functional value) on intention behavior toward sustainable fashion products and the empirical result indicated that emotional value explains the intention behavior. These findings are supported by the recent study of Yu [49].

H7: Emotional value positively influence the attitude toward environment

H8: Emotional value positively influence the attitude toward clothing donation

3 METHODOLOGY

3.1 Materials and procedures

This study was conducted in Indonesia to provide an empirical understanding of clothing disposal behavior. Convenience sampling method was used when collecting the data to ensure the accuracy of the information. Data were collected from individual though a self-reported survey questionnaires. The questionnaire consisted from a several multi-items constructed measurements, using 5-Likert scale. All scale items were assed with five Likert scale range from 1 to 5: 1 - strongly disagree, 2 - disagree, 3 - neutral, 4 - agree, 5 - strongly agree.

3.2 Variable measurement

This measure was adopted to allow us to quantitatively evaluate the respondent responses and assess the respondent behavior, and to analyze the data in statistical methods [50]. The items used in the questionnaires were adapted from the synthesis of previous from [5, 7, 22, 23, 28, 36, 44, 47, 49, 51]. Emotional value operated with four items adapted from [47, 49]: 1) “Donating unwanted clothing would feel like making a good personal contribution to something better”, 2) “Donating clothing would feel like the morally right thing”, 3) ”Donating clothing would make me feel like a better person” and 4) “Donating clothing would give me pleasure”. Religiosity operated with four items adapted from [36, 44]: 1) “I make financial contributions to my religious organizations”, 2) “I pray every time I am supposed to”, 3) “It is important for me to spend periods in private religious thought and prayer” and 4) “I always do most of the ritual practices in my religion”. Environment concerns operated with four items adapted from [7, 51]: 1) “I am concerned about wasting the resources of our planet”, 2) “Human beings must maintain the balance with nature to survive”, 3) “Human beings are severely abusing the environment” and 4) “I would describe myself as environmentally responsible, potential environmental impact of my actions when making many of my decisions.” Attitude toward environment operated with three items adapted from [28]: 1) “Everyone is responsible for protecting the environment in their everyday life”, 2) “Preserving and protecting the environment should be one of our priorities” and 3) “If all of us, individually, made an environmentally responsible decision; it would have a significant effect”. Attitude toward clothing donation operated with two items adopted from [5, 23]: 1) “Donate clothes to charity to do my part in decreasing the environmental problem”, and 2) “It makes me feel good to donate unwanted clothing”. To determine the consumer intention toward clothing donation, three items were adapted from [28, 44]: 1) “I will donate my unwanted clothing in the future”, 2) “I intend to make a donation soon” and 3) “I will probably donate my unwanted clothing in the future”.

3.3 Participants

Data from 109 individuals collected through survey questionnaires were used in this study. Table 1 described the characteristics of the respondents of this study, among the 109 individuals, 68.8% of the sample were female and 31.2% male. The sample aged ranged from 18-25 years old represent 50%, 26-35 represent the 35.8% of the sample, 36-45 represent the 13.8%. The sample education background; 41.3% of the sample have a bachelor's degree, 33.0% have a master, 14.7% have a diploma and 11.0% finished secondary school.

Table 1 Sample characteristics

Characteristic of respondents	n	%	% Cum
Gender			
Female	75	68.8	68
Male	34	31.2	100
Age (years)			
18-25	55	50.5	50.5
26-35	39	35.8	86.2
36-45	15	13.8	100.0
Education			
Secondary	12	11.0	11.0
Diploma	16	14.7	25.7
Bachelor	45	41.3	67.0
Master	36	33.0	100.0
Status			
Single	76	69.71	69.7
In relationship	33	30.3	100
Occupation			
Government	16	14.7	65.1
Self-employed	13	11.9	94.5
Private sector	19	17.4	82.6
Student	55	50.5	50.5
Other	6	5.5	100
Religion			
Other	6	5.5	5.5
Buddhism	7	6.4	11.9
Islam	67	61.5	73.4
Christian	29	26.6	100.0
Total	109	100	

3.4 Validity and reliability

In this study, CFA was conducted to assess validity and reliability of the indicator, and items measurements consist of 19 items from 5 variables. KMO and Bartlett’s test was conducted, the KMO score 0.846 with a significant level of 0.000. Moreover, Chronbach’s Alpha score is 0.909 with a number of items 19 which indicated the consistency of the measure used in this study.

Thus, the measurement was reliable as the Chronbach's Alpha is above 0.7 [50]. Furthermore, confirmatory factory test shows that the factor loading of the 19 items is ranged from 0.420 to 0.798; it shows that the 19 items used in this study are accurate [52] which is factor loading meets above 0.40.

Table 2 KMO and Bartlett's test

KMO of sampling adequacy.		0.846
Bartlett's test of sphericity	**Approx. chi-square**	1282.083
	df	171
	Sig.	0.000

3.5 Assumption classic test

We assessed Breusch-Godfrey serial correlation LM test to identify the autocorrelation. The probability chi-square value is 0.315 which is greater than 0.05, thus we concluded that there is no autocorrelation found.

Table 3 Autocorrelation test: Breusch-Godfrey serial correlation LM

F-statistic	1.092165	**Prob. F(2.101)**	0.3394
Obs*R-squared	2.307442	**Prob. chi-square(2)**	0.3155

Variance Inflation Factors (VIF) was conducted to detect the multicollinearity, the VIF test shows attitude toward clothing donation = 2.136, attitude toward environment = 1.702, religiosity = 1.272, emotional value= 1.973, environment concern = 1.778. Table 4 shows that VIF of the variables are smaller than 10 and greater than 0.1 indicated that there is no multicollinearity problem.

Table 4 Variance inflation factors

Variable	Tolerance	VIF
C		NA
Attitude toward clothing donation	0.468	2.136
Environmental attitude	0.588	1.702
Religiosity	0.786	1.272
Emotional value	0.507	1.973
Environmental concern	0.562	1.778

Heteroscedasticity test ARCH was conducted to identify the variance differences from residual in observation with other observations. The probability chi-square 0.1 which is greater than statistical significant level of 0.05 indicated that there is no heteroscedasticity.

Table 5 Heteroscedasticity test: Breusch-Pagan-Godfrey

F-statistic	1.906	**Prob. F(1.211)**	0.099
Obs*R-squared	9.235	**Prob. chi-square(1)**	0.100

4 RESULTS AND DISCUSSION

The hypothesis testing is based on the probability level <0.001, <0.01 and <0.05 [52]. The intention behavior can be explained by the dependent variable with R-square = 0.561 F = 67.77. The 56% of the variance in intention behavior is explained by dependent variables.

The H1 tested the relationship between environmental attitude and intention toward clothing donation. Particularly, it examined the positive influence of environmental attitude on intention behavior toward clothing donation. The result showed that attitude has a positive influence on intention behavior toward clothing donation with (β: 0.352, S.E: 0.082; t-statistic: 4.277), and p-value 0.000 which is < 0.001 significant level. This explains statistically that environmental attitude positively influences the intention behavior toward clothing disposal behavior. Thus, the result accepted H1, this is in the same line with Park [53]. The respondents of this study are considered to have a positive attitude toward the environment. Their tendency to donate clothing was strengthen by their perception on toward the environmental protection and preservation in their daily life. However, this finding was in contradictory to Stephenson [31] and Lee [25].

The second hypothesis tested the link between attitude toward clothing donation and intention toward clothing donation. Particularly, we determined the positive influence of attitude toward clothing donation on intention toward clothing donation. Table 6 indicated a positive association between attitude toward clothing donation and intention toward clothing donation with (β: 0.554, S.E: 0.060; t-statistic: 8.900) and p-level of 0.000 which is < 0.001. Thus, the result supported the H2. This finding supported the proposition of Ha-Brookshire [24].

Table 6 Regression analysis

	Variable	Coef. β	S.E	t	p
H1	Environmental attitude → Clothing donation intention	0.352	0.082	4.277	0.000***
H2	Attitude toward clothing donation → Clothing donation intention	0.554	0.062	8.909	0.000***
H3	Environment concern → Attitude toward clothing donation	0.225	0.090	2.484	0.014*
H4	Environment concern → Environmental attitude	0.524	0.073	7.162	0.000***
H5	Religiosity → Environmental attitude	0.099	0.056	1.761	0.081
H6	Religiosity → Attitude toward clothing donation	-0.029	0.069	-0.418	0.676
H7	Emotional value → Environmental attitude	0.108	0.063	1.705	0.091
H8	Emotional value → Attitude toward clothing donation	0.640	0.078	8.109	0.000***

Note: significant level *<0.05, **<0.01, ***<0.001

Based on the data clothing donation behavior is determined by consumer attitude toward clothing donation. The more they are favorable and feel positive about clothing donation the more likely there are intend to donate their clothing. This is due to the fact that their act would contribution to reduce the environmental issue. Although, this finding suggested that environmental attitude and attitude toward clothing disposal are best predict behavior intention toward clothing donation. Attitude toward clothing donation highly predicts of intention toward clothing donation. This means that Indonesian consumers have a positive attitude toward clothing donation rather than environmental attitude. The present result supported the finding by Cruz-Cárdenas [27] demonstrated environmental attitude influence the clothing disposal behavior

The third hypothesis examines the relationship between environmental concern and attitude toward clothing donation. Particularly, this study examined the positive influence of environmental concern on intention toward clothing donation. The results show that environmental concern has a positive influence on attitude toward clothing donation with (β: 0.225, S.E: 0.090; t-statistic: 2.484) and p-level of 0.014 which is <0.005. Thus, the result supported the H3. This finding supported the findings from the previous study in clothing disposal. Consumers are concern about the impact of their activity on the environment which gives a positive attitude toward donation behavior. This study supported by Joung and Park-Poaps [54] indicated that clothing donation behavior is related to environment concern.

H4 examines the link between environmental concern and environment attitude. Particularly, this study examined the positive influence of environment concern and attitude toward environment. The result statically shows (β: 0.524, S.E: 0.073; t-statistic: 7.162) and p-level of 0.000 which is <0.05. Thus, the result supported H4. This finding is in line with Sung [55]. It can be explained that when consumers acknowledge of environment concerns tends to have a positive attitude toward environment than might leads them to act in a more sustainable way of disposing of their clothes. This supported the previous study by Pan [56] asserted that environment attitude highly associated with disposal method.

The H5 examines the relationship between religiosity and attitude toward environment. Particularly, this study examined the positive influence of religiosity on attitude toward environment. The result statically shows that religiosity positively influences the attitude toward environment with (β: 0.099, S.E: 0.056; t-statistic: 1.761) and p-value of 0.080 which is >0.05. Thus, our result rejected the H5, hence religiosity does not influence attitude toward environment. Based on the statistic result, the finding did not support the finding of prior studies [39-41]. This inconsistency of findings might be since the respondents did not associate environment issues with religiosity.

Hypothesis 6 examines the relationship between religiosity and attitude toward clothing donation. Particularly, this study examined the positive influence of religiosity on attitude toward clothing donation. The result statically shows that religiosity positively influences the attitude toward clothing donation with (β: -0.029, S.E: 0.0699; t-statistic: -0.418) and p-value of 0.676 which is >0.05. Thus, the result is not supported H5. By means that religiosity does not have an influence attitude toward clothing donation. This present study revealed that religiosity does not influence individual attitude to donate clothing. However, this result did not support the finding of Kasri [46] stated that religiosity has positive influence on donation attitude. Previous study hypotheses that our intended action might shaped by our religiosity level or the reverse [45].

Hypothesis 7 examines the relationship between emotional values on attitude toward environment. Specifically, we determined to identify a positive influence of emotional value on attitude toward environment. The result statically shows (β: 0.010, S.E: 0.0.063; t-statistic: 1.705) and p-value of 0.091 which is >0.005 indicated that the H6 is not supported. Emotional value refers "as an ability to arouse feelings and affective states by alternative product capacity" [47]. However, this study found that emotional value does not influence attitude toward environment. However, a previous study indicated a positive influence between emotional value and consumer behavior [49]. The finding did not predict a significant relationship between emotional value and attitude toward environment.

H8 examines the relationship between emotional value and attitude toward clothing donation. Particularly, this study examined the positive influence of emotional value on attitude toward clothing donation. The result statically shows that emotional value positively influences the attitude toward clothing donation with (β: 0.640, S.E: 0.078; t-statistic: 8.109) and p-value of 0.000 which is <0.05. Thus, the result supported H8. This study suggested that emotional value positively influence that attitude toward clothing donation. The result shows that there is a significant positive influence of emotional value on clothing disposal behavior [49].

5 CONCLUSION

This study has a theoretical and practical contribution, notwithstanding a few limitations are acknowledged. The first consideration is the sample, female respondents were dominated. In terms of age, 86.3% of the sample is young generation 18-35 years. This represents that our finding might be limited to the younger generation. Cruz-Cardenas [57] emphasized that women are more active and participate in the disposal by gifting and donating. Also, Cruz-Cardenas [57] showed that younger individuals, women are more likely to dispose of clothing in more sustainably manner. Thus, further study recommended broadening the sample to elder people and conducting the study with the male respondents.

Moreover, the majority of the respondents were Muslim which represented 61.5% of the sample. Cleveland [58] distinguished perception and behavior between both Muslims and Christian in the study related to religion, value and globalization. Moreover, this study was conducted in Indonesia, an emerging country in Southeast Asia. Thus, the finding is limited to Indonesian consumers. Therefore, author suggested the future study to extend to comparative cross-cultural studies and culture and religion background. Further, since our study did not considered religion as a determinant of environmental and clothing donation. We would like to encourage and recommend future study to integrate a psychological factor such values, empathy as this current Covid-19 situation has encouraged people to go for cloth donation to help other who are in difficulties.

To conclude, this research aims to provide an additional understanding of the existing literature on clothing disposal behavior. This study contributes to the literature of clothing disposal behavior specifically in clothing donation intention behavior. We identified the factors influencing attitude toward environment as well as an attitude toward clothing donation. The main finding emphasized that attitude toward clothing donation and attitude toward environmental better explain intention behavior toward clothing disposal. Further, attitude toward environment is a higher predictor to explain intention behavior toward clothing donation. The findings contribute an insightful understanding of sustainable clothing disposal behavior. The result suggested that environment concern, emotion positively influence attitude toward environment. Environment concern and emotional values have a positive significant influence on attitude toward clothing donation. While, emotional value did not influence the attitude environment. Moreover, religiosity neither influences attitude toward environment nor attitude toward clothing donation, as a result based on the evidence in Indonesia.

Clothing donation does not relate to religiosity rather than environment concern. A consumer who is concern about the environment is more likely to have a positive attitude toward donation and attitude toward environment that leads to clothing donation behavior. To promote clothing donation, practitioners including marketer, environmental policymaker, charities should take an environmental approach to motivate consumers to be more engaged in sustainable clothing disposal methods such as a donation. Our findings could give assets for shape a strategy to promote sustainable clothing disposal.

6 REFERENCES

1. Cruz-Cárdenas J., Arévalo-Chávez P.: Consumer behavior in the disposal of products: forty years of research, Journal of Promotion Management 24(5), 2017, pp. 617-636, https://doi.org/10.1080/10496491.2018.1405514
2. Norum P.S.: Towards Sustainable clothing disposition: exploring the consumer choice to use trash as a disposal option, Sustainability 9(7), 2017, pp. 1-14, https://doi.org/10.3390/su9071187
3. Doane D.: Taking flight: The rapid growth of ethical consumerism, London, UK, New Economics Foundation, available from: https://neweconomics.org/2001/11/taking-flight
4. Sanne C.: Willing consumers - or locked in? Policies for a sustainable consumption, Ecological Economics 42(1-2), 2002, pp. 273-287, https://doi.org/10.1016/S0921-8009(02)00086-1
5. Bianchi C., Birtwistle G.: Consumer clothing disposal behavior: a comparative study, International Journal of Consumer Studies 36(3), 2011, pp. 335-341, https://doi.org/10.1111/j.1470-6431.2011.01011.x
6. Yuan J., Chen W., Li X., Fang H.: Research and recycling of waste clothing based on corporate social responsibility. Journal of Advanced Oxidation Technologies 21(2), 2018, Article number 201805295
7. Cruz-Cárdenas J., Guadalupe-Lanas J., Velín-Fárezc M.: Consumer value creation through clothing reuse: A mixed methods approach to determining influential factors, Journal of Business Research 101, 2018, pp. 846-853, https://doi.org/10.1016/j.jbusres.2018.11.043
8. Shirvanimoghaddam K., Motamed B., Ramakrishna S., Naebe M.: Death by waste: Fashion and textile circular economy case, Science of The Total Environment 718, 2020, 137317, https://doi.org/10.1016/j.scitotenv.2020.137317
9. Sandvik I.M., Stubbs W.: Circular fashion supply chain through textile-to-textile recycling, Journal of Fashion Marketing and Management 23(3), 2019, pp. 366-381, https://doi.org/10.1108/JFMM-04-2018-0058
10. Farrant L., Olsen S.I., Wangel A.: Environmental benefits from reusing clothes, The International Journal of Life Cycle Assessment 15(7), 2010, pp. 726-736, https://doi.org/10.1007/s11367-010-0197-y
11. Cook S.Ch., Yurchisin J.: Fast fashion environments: consumer's heaven or retailer's nightmare?, International Journal of Retail & Distribution Management 45(2), 2017, pp. 143-157, https://doi.org/10.1108/IJRDM-03-2016-0027
12. Pinheiro E., de Francisco A.C., Piekarski C.M., de Souza J.T.: How to identify opportunities for improvement in the use of reverse logistics in clothing industries? A case study in a Brazilian cluster, Journal of Cleaner Production 210, 2019, pp. 612-619, https://doi.org/10.1016/j.jclepro.2018.11.024

13. Arangdad S.R., Thoney-Barletta K., Joines J., Rothenberg L.: Influence of demographics and motivational factors on US consumer clothing and shoes disposal behaviour, Research Journal of Textile and Apparel 23(3), 2019, pp. 170-188, https://doi.org/10.1108/RJTA-08-2018-0051
14. Dash P.: Review on import/export and recycling of second hand clothes, International Journal of Psychosocial Rehabilitation 23(6), 2019, pp. 535-540, DOI: 10.37200/IJPR/V23I6/PR190805
15. Subramanian K., Chopra S.S., Cakin E., Li X., Lin C.S.K.: Environmental life cycle assessment of textile bio-recycling – valorizing cotton-polyester textile waste to PET fiber and glucose syrup, Resources, Conservation & Recycling 161, 2020, 104989, https://doi.org/10.1016/j.resconrec.2020.104989
16. Joung H.M., Park-Poaps H.: Factors motivating and influencing clothing disposal behaviours, International Journal of Consumer Studies 37(1), 2013, pp. 105-111,https://doi.org/10.1111/j.1470-6431.2011.01048.x
17. Norum P.S.: Trash, charity, and secondhand stores: An empirical analysis of clothing disposition, Family and Consumer Sciences Research Journal. 44(1), 2015, pp. 21-36, https://doi.org/10.1111/fcsr.12118
18. Morgan L.R., Birtwistle G.: An investigation of young fashion consumers' disposal habits, International Journal of Consumer Studies 33(2), 2009, pp. 190-198,https://doi.org/10.1111/j.1470-6431.2009.00756.x
19. Weber S., Lynes J., Young S.B.: Fashion interest as a driver for consumer textile waste management: reuse, recycle or disposal, International Journal of Consumer Studies 41(2), 2016, pp. 207-215, https://doi.org/10.1111/ijcs.12328
20. Domina T., Koch K.: Convenience and frequency of recycling: implications for including textiles in curbside recycling programs, Environment and Behaviour 34(2), 2002, pp. 216-238, https://doi.org/10.1177/0013916502342004
21. Laitala K.: Consumers' clothing disposal behaviour – a synthesis of research results, International Journal of Consumer Studies 38(5), 2014, pp. 444-457, https://doi.org/10.1111/ijcs.12088
22. Bianchi C., Birtwistle G.: Sell, give away, or donate: an exploratory study of fashion clothing disposal behaviour in two countries, The International Review of Retail, Distribution and Consumer Research 20(3), 2010, pp. 353-368, https://doi.org/10.1080/09593969.2010.491213
23. Yee L.W., Hassan S.H., Ramayah T.: Sustainability and philanthropic awareness in clothing disposal behavior among young Malaysian consumers, SAGE Open 6(1), 2016, pp. 1-10, https://doi.org/10.1177/2158244015625327
24. Ha-Brookshire J.E., Hodges N.N.: Socially responsible consumer behavior? Exploring used clothing donation behavior, Clothing and Textiles Research Journal 27(3), 2009, pp. 179-196, https://doi.org/10.1177/0887302X08327199
25. Lee J.Y., Halter H., Johnson K.K.P., Ju H.: Investigating fashion disposition with young consumers, Young Consumers 14(1), 2013, pp. 67-78, https://doi.org/10.1108/17473611311305494
26. Ajzen I.: The theory of planned behaviour, Organizational Behavior and Human Decision Processes *50*(2), 1991, pp. 179-211, https://doi.org/10.1016/0749-5978(91)90020-T
27. Cruz-Cárdenas J., González R., ´ Gascó J.: Clothing disposal system by gifting: characteristics, processes, and interactions, Clothing and Textiles Research Journal 35(1), 2016, pp. 49-63, https://doi.org/10.1177/0887302X16675725
28. Kwon T.A., Choo H.J., Kim Y-K.: Why do we feel bored with our clothing and where does it end up?, International Journal of Consumer Studies 44(1), 2019, https://doi.org/10.1111/ijcs.12540
29. Jacoby J., Berning C.K., Dietvorst T.F.: What about disposition?, Journal of Marketing 41(2), 1977, pp. 22-28 https://doi.org/10.2307/1250630
30. Bubna J.M., Norum P.: Male apparel disposal: case study of consignment versus donation, Journal of Fashion Marketing and Management 21(2), 2017, pp. 235-246, https://doi.org/10.1108/JFMM-11-2016-0105
31. Stephenson M.T., Morgan S.E., Roberts-Perez S.D., Harrison T., Afifi W., Long S.D.: The role of religiosity, religious norms, subjective norms, and bodily integrity in signing an organ donor card, Health Communication 23(5), 2008, pp. 436-447, DOI: 10.1080/10410230802342119
32. Fraj E., Martinez E.: Environmental values and lifestyles as determining factors of ecological consumer behaviour: an empirical analysis, Journal of Consumer Marketing 23(3), 2006, pp. 133-144, https://doi.org/10.1108/07363760610663295
33. Egbert N., Mickley J., Coeling H.: A review and application of social scientific measures of religiosity and spirituality: assessing a missing component in health communication research, Health Communication 161), 2004, pp. 7-27, DOI: 10.1207/S15327027HC1601_2
34. Dube L.F., Wingfield S.S.: Economics, sociology, politics, and religion: success of marketing students, Atlantic Economic Journal 36(4), 2008, pp. 503-504, https://doi.org/10.1007/s11293-008-9145-7
35. Schneiders S.M.: Religion and spirituality: strangers, rivals, or partners?, The Santa Clara Lectures 6, No. 2, 2000
36. Nguyen T.D., Chou S.Y., Blankson Ch., Wilson P.: The invisible identity in a visible world: how religiosity mediates consumer culture and the marketplace, Journal of Product & Brand Management 29(1), 2019, pp. 15-30, https://doi.org/10.1108/JPBM-10-2018-2066
37. Chapman C.M., Louis W.R., Masser B.M.: Identifying (our) donors: Toward a social psychological understanding of charity selection in Australia, Psychology & Marketing 35(12), 2018, pp. 980-989, https://doi.org/10.1002/mar.21150
38. Wardekker J.A., Petersen A.C., van Der Sluijs J.P.: Ethics and public perception of climate change: exploring the Christian voices in the US public debate, Global Environmental Change 19(4), 2009, pp. 512-521, https://doi.org/10.1016/j.gloenvcha.2009.07.008

39. Pepper M., Jackson T., Uzzell D.: An examination of Christianity and socially conscious and frugal consumer behaviors, Environment and Behavior 43(2), 2010, pp. 274-290, https://doi.org/10.1177/0013916510361573
40. Dilmaghani M.: Which is greener: secularity or religiosity? Environmental philanthropy along religiosity spectrum, Environmental Economics and Policy Studies 20, 2018, pp. 477-502, https://doi.org/10.1007/s10018-017-0201-x
41. Arli D., Tjiptono F.: God and green: Investigating the impact of religiousness on green marketing, International Journal of Nonprofit and Voluntary Sector Marketing 22(3), 2017, Article No. 1578, https://doi.org/10.1002/nvsm.1578
42. Shukor S.A., Anwar I.F., Aziz, S.A., Sabri H.: Muslim attitude towards participation in cash *waqf*: antecedents and consequences", International Journal of Business and Society 18(S1), 2017, pp. 193-204
43. Kashif M., Sarifuddin S., Hassan A.: Charity donation: intentions and behaviour, Marketing Intelligence & Planning 33(1), 2015, pp. 90-102, https://doi.org/10.1108/MIP-07-2013-0110
44. Diop A., Johnston T., Le K.T., Li Y.: Donating time or money? The effects of religiosity and social capital on civic engagement in Qatar, Social Indicators Research 138, 2018, pp. 297-315, https://doi.org/10.1007/s11205-017-1646-9
45. Dogan V., Tiltay M.A.: Caring about other people's religiosity levels or not: how relative degree of religiosity and self-construal shape donation intention, Current Psychology 39, 2020, pp. 33-41, https://doi.org/10.1007/s12144-017-9739-9
46. Kasri R.A., Ramli U.H.: Why do Indonesian Muslims donate through mosques?: A theory of planned behaviour approach, International Journal of Islamic and Middle Eastern Finance and Management 12(5), 2019, pp. 663-679, https://doi.org/10.1108/IMEFM-11-2018-0399
47. Danish M., Ali S., Ahmad M.A., Zahid H.: The influencing factors on choice behavior regarding green electronic products: based on the green perceived value model, Economies 7(4), 2019, pp. 1-18, https://doi.org/10.3390/economies7040099
48. Lin P-Ch., Huang Y-H.: The influence factors on choice behavior regarding green products based on the theory of consumption values, Journal of Cleaner Production 22(1), 2012, pp. 11-18, https://doi.org/10.1016/j.jclepro.2011.10.002
49. Yu S., Le J.: The effects of consumers' perceived values on intention to purchase upcycled products, Sustainability 11(4), 2019, pp. 1-20, https://doi.org/10.3390/su11041034
50. Sekaran U., Bougie R.: Research Methods For Business: A Skill-Building Approach, 7th ed., Wiley, 2016, ISBN: 978-1-119-26684-6
51. Asif M., Xuhui W., Nasiri A., Ayyub S.: Determinant factors influencing organic food purchase intention and the moderating role of awareness: a comparative analysis, Food Quality and Preference 63, 2018, pp. 144-150, https://doi.org/10.1016/j.foodqual.2017.08.006
52. Hair J.F., Black W.C., Babin B.J., Anderson R.E.: Multivariate Data Analysis, 7th ed., Harlow: Pearson Education Limited, 2014, 734 p., ISBN: 9781292021904
53. Park M., Cho H., Johnson K.K.P., Yurchisin J.: Use of behavioral reasoning theory to examine the role of social responsibility in attitudes toward apparel donation, International Journal of Consumer Studies 41(3), 2017, pp. 333-339, https://doi.org/10.1111/ijcs.12347
54. Joung H-M., Park-Poaps H.: Factors motivating and influencing clothing disposal behaviours, International Journal of Consumer Studies 37(1), 2011, pp. 105-111,https://doi.org/10.1111/j.1470-6431.2011.01048.x
55. Sung K-W.: The effects of an environmental education with newspaper in education (NIE) on the environmental concern and practice, Journal of Korean Academy of Nursing 38(6), 2008, pp. 891-901, DOI: 10.4040/jkan.2008.38.6.891
56. Pan Y.: Fashion thinking and sustainable HCI, Extended Abstracts on Conference on Human Factors in Computing Systems, Toronto, Canada, April 2014, pp. 355-358, https://doi.org/10.1145/2559206.2559967
57. Cruz-Cárdenas J., González R., del Val Núñez M.T.: Clothing disposal in a collectivist environment: A mixed methods approach, Journal of Business Research 69(5), 2015, pp. 1765-1768, https://doi.org/10.1016/j.jbusres.2015.10.052
58. Cleveland M., Laroche M., Hallab R.: Globalization, culture, religion, and values: Comparing consumption patterns of Lebanese Muslims and Christians, Journal of Business Research 66(8), 2013, pp. 958-967, https://doi.org/10.1016/j.jbusres.2011.12.018
59. Hedegård L., Gustafsson E., Paras M.K.: Management of sustainable fashion retail based on reuse - A struggle with multiple logics, The International Review of Retail, Distribution and Consumer Research 30(3), 2019, pp. 311-330, https://doi.org/10.1080/09593969.2019.1667855
60. Wei X., Jung S.: Understanding Chinese consumers' intention to purchase sustainable fashion products: The moderating role of face-saving orientation, Sustainability 9(9), 2017, pp. 1-15, https://doi.org/10.3390/su9091570
61. Peña-Vinces J., Solakis K., Guillen J.: Environmental knowledge, the collaborative economy and responsible consumption in the context of second-hand perinatal and infant clothes in Spain, Resources, Conservation and Recycling 159(1), 2020, pp. 1-11, https://doi.org/10.1016/j.resconrec.2020.104840
62. Mukendi A., Henninger C.E.: Exploring the spectrum of fashion rental, Journal of Fashion Marketing and Management 24(3), 2020, pp. 455-469, https://doi.org/10.1108/JFMM-08-2019-0178
63. Walter E.E.: Textile recycling attitudes and behaviors among college students (unpublished master's thesis). Eastern Illinois University, USA, 2008

REVIEW OF MEN'S SHIRT PATTERN DEVELOPMENT FOR THE LAST 100 YEARS PART 2: SLEEVE AND CUFF

Frederick Tungshing Fung, Lubos Hes and Vladimir Bajzik

Technical University of Liberec, Faculty of Textile Engineering, Department of Evaluation Studentska 1402/2, 46117 Liberec, Czech Republic
tassfashion@gmail.com, lubos.hes@gmail.com, vladimir.bajzik@tul.cz

Abstract: *This article is Part 2, the continuation from the title of "Review of Men's Shirt Pattern Development for the Last 100 Years, Part 1: The Bodice". A look back on how the shirt sleeve and cuff were developed in the last hundred years. A discussion on the future development of the sleeve and cuff patterns will be in the conclusion.*

Keywords: *sleeves, cuffs, men's shirt, fit, pattern development, history.*

1 INTRODUCTION

A sleeve pattern is part of a completed traditional shirt pattern set, and which is sewn onto the arm sync seam and is covered from the shoulder to the elbow down to the wrist [1]. Sleeves provide us with both functional and aesthetical purposes. As functional elements, sleeves protect our arms from weather changes, give us freedom of movement and comfort, and prevent irritations or stimulations from the environment [2]. As aesthetical elements, sleeves enhance the bodice with different styles, fits and shapes [3]. In a traditional shirt pattern set, a cuff piece is attached to the end of a sleeve (sleeve hem) where a sleeve placket has been installed. A sleeve placket is a narrow piece of fabric sewn onto the back sleeve as an opening that allows the wearer to put on or to remove the clothing easily (Figures 1 and 2).

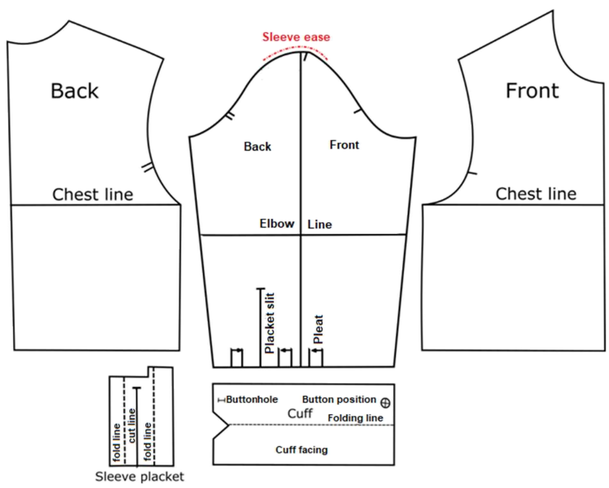


Figure 1 A complete set-in sleeve with cuff and sleeve placket

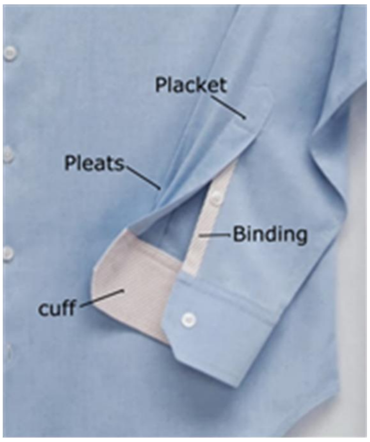


Figure 2 Showing a set-in sleeve with technical terms

Cuffs' original purpose was to protect the lower part of the sleeve from fraying and dirt, and it could be detached and changed easily; considered shirt was a luxury item only for the rich in the old days [4, 5]. Nowadays, cuffs are functioned as the closures for sleeves to keep us warm and a compliment for the sleeve style to give us psychological comfort [6].

In Part 1 (The Bodice) [7] of this study, a completed set of men's shirt patterns and three major patternmaking methods were introduced as the fundamental information. Then, through different significant periods, were analyzed the shapes, function and purposes of the bodice pattern.

In Part 2, major types of sleeves and cuffs were introduced; and through different significant development in the history of time, patterns of sleeves and cuffs were analyzed by the styles, shapes and sizes and their purposes until the modern day time. Finally, we will discuss the future pattern development of sleeves and cuffs that follows the new direction of technologies.

2 ANATOMY OF A SLEEVE

A sleeve contains a sleeve cap, two side seams and a sleeve hem. A sleeve cap is the measurement of the arm sync plus ease. The bigger armhole, shorter sleeve cap height, baggier sleeve style, and more freedom for movement but increases wrinkles gather underarm. On the other hand, smaller armhole, taller cap height, slimmer sleeve style and limited movement, yet fewer wrinkles appeared underarm (Figure 3) [8].

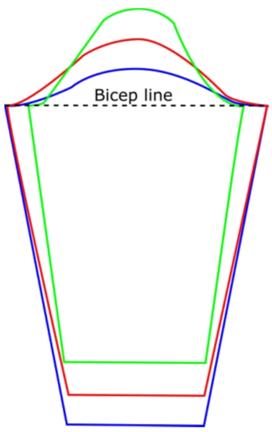


Figure 3 Same sleeve length but higher the sleeve cap height, narrower the bicep line

2.1 Types of sleeves

Sleeves are divided into three major types: set-in sleeve, raglan sleeve and Kimono sleeve [9].

Set-in sleeve

Set-in sleeves are attached to the shoulder point and around the arm sync seam. Most of the set-in sleeves have an extra room (ease allowance) around the sleeve cap to accommodate the contour of the upper arm and to provide movement comfort as presented in Figure 4, and the ease can be converted into gathers, darts, tucks or just ease-in to join the bodice.

Figure 4 Shirt with set-in sleeve and cuff

Sleeve length can be short, mid-length, long or any length in-between for the fashion sack. The width can be fitted, flared, baggy or anything trendy. Sleeve hem can also be finished in a variety of ways with or without a cuff. More, for a very slim-fitted sleeve, a gusset is needed to compensate for the restriction of movements (Figure 5). A sleeve just has the sleeve cap without length is called a cap sleeve and is a design element usually in women's clothing.

Figure 5 A gusset piece is inserted underarm

Raglan sleeve

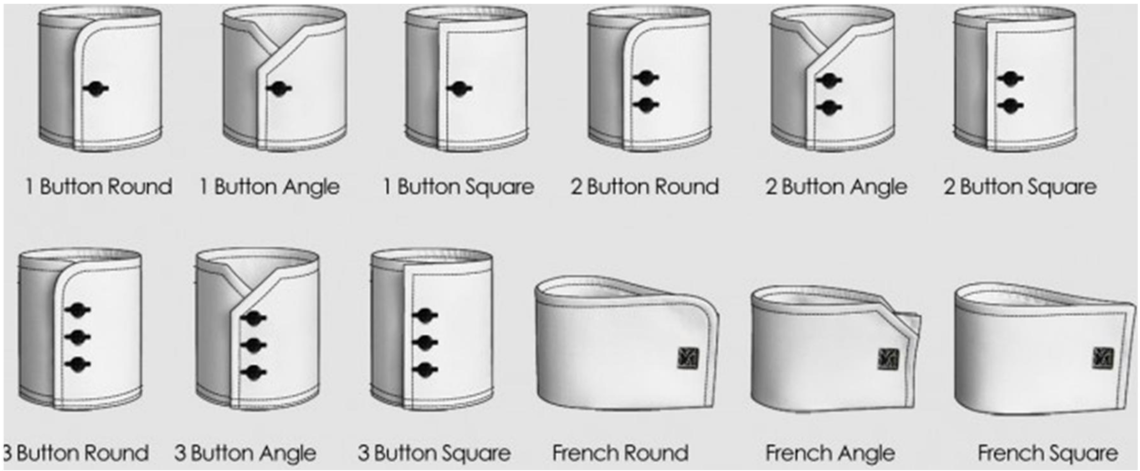
Raglan sleeve pattern [10] is a long pattern piece because part of the bodice, usually the front and back from part of the neckline closes to the shoulder and cuts diagonally to the armhole, is joined to the sleeve. It creates a roomy sleeve for movement, however; it also increases the wrinkles underarm due to the extra fabric used (Figure 6).

Figure 6 A baseball shirt with raglan sleeves

Kimono sleeve

Influenced by the Japanese Kimono [11, 12] of which the sleeves and the bodice are joined in one piece. Arm sync can be deep or shallow but wrinkles are always shown at underarm areas (Figure 7).

Figure 7 A pair of big and loose Kimono sleeves on a shirt



a)

b)

Figure 8 Barrel and French cuffs in styles of combinations of cuff width, cuff corner finish and number of buttons

2.2 Types of cuffs

In tradition, cuffs are only paired up with set-in sleeves to gather the extra fullness from the upper sleeve by pleating and to fit comfortably to the narrower circumference of the wrist. Cuffs come in so many different styles and are roughly divided into four major types: barrel cuff, French single/double cuff, convertible cuff and reversible/turnback cuff.

<u>*Barrel cuff*</u>

This is the most commonly used cuff type for men's shirts. The barrel cuff is a simple piece of rectangular fabric wrapped into a tube-like shape and sewn onto the sleeve hem, then is fastened with a button or a snap (Figure 8a and Figures 9a-c).

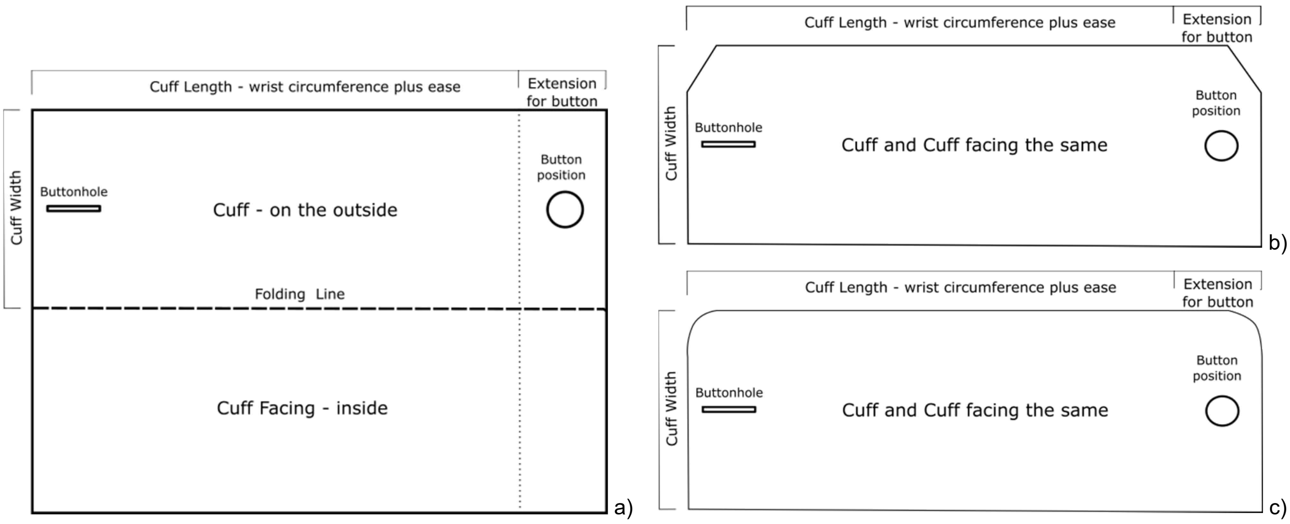


Figure 9 Pattern of a square cuff, no seam allowance (a), pattern of a mitered/angle cuff, no seam allowance (b), pattern of a round cuff, no seam allowance (c)

French cuff – single/double

A traditional French/double cuff is double the width of the barrel cuff so it can turn back on itself and is shaped like a trapeze to be fastened by cufflink through two buttonholes without any button. When the cuff is shaped like a barrel cuff with two buttonholes on either end of the cuff and be fastened by a cufflink is a single cuff (Figure 8b and Figure 10).

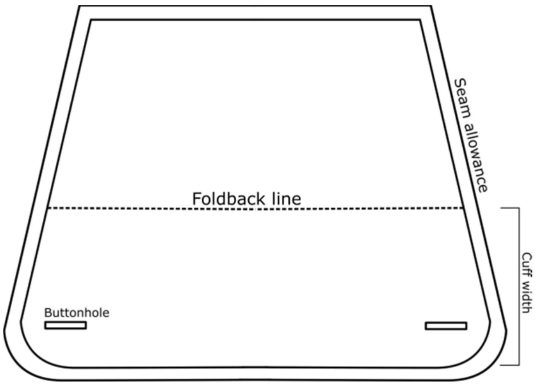


Figure 10 A round corner French cuff (double) with seam allowance

Convertible cuff

It is a barrel cuff with an extra buttonhole on th button side of the cuff so it can be converted to a single French cuff (Figure 11).

Figure 11 A convertible cuff has two buttonholes and one button at the cuff ends and allow you to change from barrel to French cuff (single) style easily

Reversible cuff

Reversible cuffs are also named cocktail, turnback or James Bond cuffs (since it was shown in the movie). Cuff is shaped like barrel cuffs but the width is double so it can be turned back on itself and fastened by a button. Modern reversible cuffs will use a contrast fabric for the cuff facing and will be shown on the outside when it is turned back (Figure 12).

2.3 Styles of cuffs

Cuff styles are the combinations of one, two, three button and square, round, mitered corner. However, French cuffs are only paired with cufflinks and are styled by a different corner without buttons (Figure 8).

Figure 12 A reversible cuff is similar to a barrel cuff but has a contrast facing to give a different look when you turn back the cuff

3 THE TRANSFORMATION OF MEN'S SHIRT SLEEVES AND CUFFS FOR THE LAST 100 YEARS

Even though men's shirt bodice has been changing from pull-over to coat shirt style (front button-down), from baggy fit to very slim fit, to hip-hop baggy then to modern classic fit; shirt sleeves and cuffs even have been changed for a few time, however; the basic shapes are similar since the main purposes of sleeves and cuffs are to give the wearer protection, warmth and comfort in movement; hence psychological comfort becomes minor important. The following are the highlights of sleeves and cuffs from the last 100 years.

The 1900s – 1920s

Inherited from the late Victorian era, the cutting of men's shirts was still big and roomy at the beginning, then it slimmed down through time. Dress shirts and work shirts were similar in size but dress shirts were always starched to set well; and ornated with pleats, tucks or just plain on the chest, tall collar and sewn by felled seams. On the other hand, work shirts had a soft collar. During the Edwardian era, social relationships were strictly defined, and "manners" was important among and between the classes, such that; work shirt also named outing shirt and negligée shirt (not sleepwear) which was cut the same as work shirt with a soft collar but was made with different materials (not heavy twill), and was worn in different occasions.

Sleeves and cuffs during this time were loose and long; upper arm circumference was 48 cm; wrist 25 cm and length was 89 cm including cuff. Dress shirt and work shirt sleeves were faced with sleeve facing or with squared plackets; round and pointy plackets were developed later on (Figure 13), 2-button, 3-button and adjustable button cuffs (Figure 14) appeared on wider cuff width, also detachable cuffs attached on a wristband – a narrow piece of fabric to encase the sleeve hem (Figure 15).

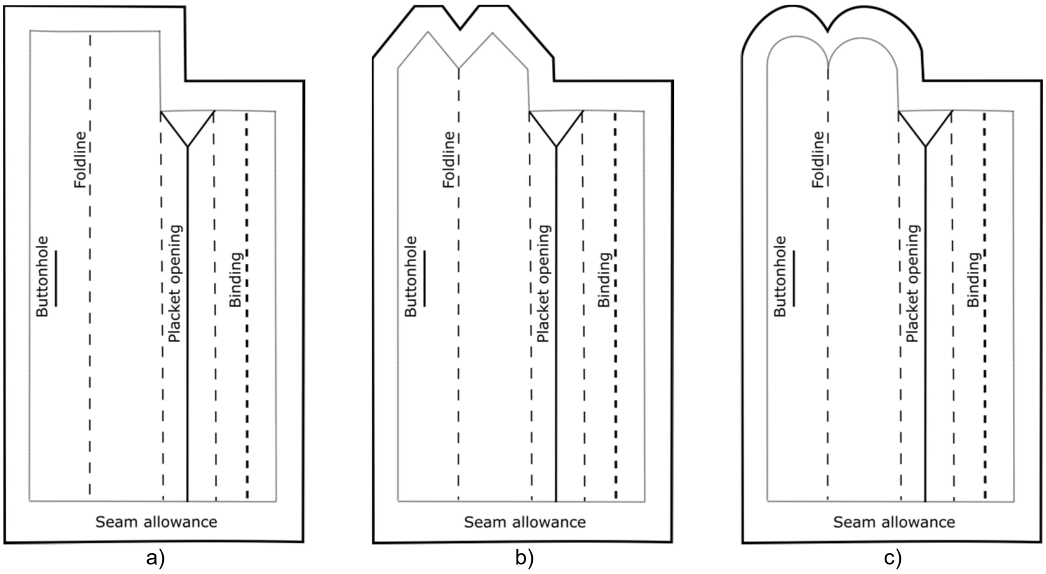


Figure 13 A square placket (a), a pointy placket (b) and a round placket (c)


a)


b)

Figure 14 An extra button to adjust the tightness around the wrist

Figure 15 A pair of starched detachable cuff with loops to hook on the buttons on the waistband

Work shirt emphasized strength, sturdiness and durability, in such that a few details were developed to suit these purposes:

- Elbow patch - double thickness on elbow area (Figure 16)
- Double sleeve - back yoke connected to the backside of the sleeve (Raglan style) and double the thickness on the sleeve back (Figure 17)
- Ventilation arms - air holes were punched along the underarm edges or part of the underarm seams were unsewn (Figure 18)
- Triple seams for durability

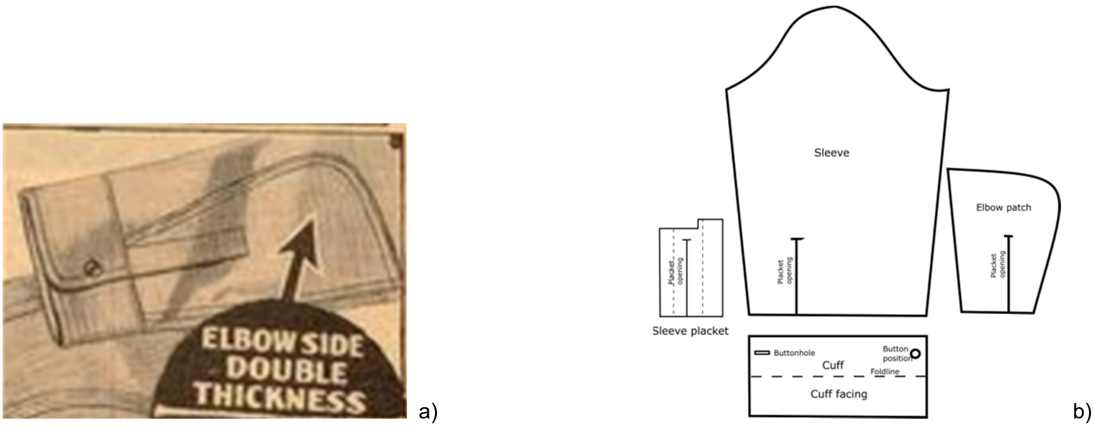


Figure 16 An elbow patch on the back sleeve with a square placket (a) and a set of square placket sleeve with elbow patch patterns (b)

Figure 17 A double sleeve and double back pattern set is the joining of the back yoke and the back sleeve of the raglan style in one continuous piece and is cut twice for better durability, wear and tear

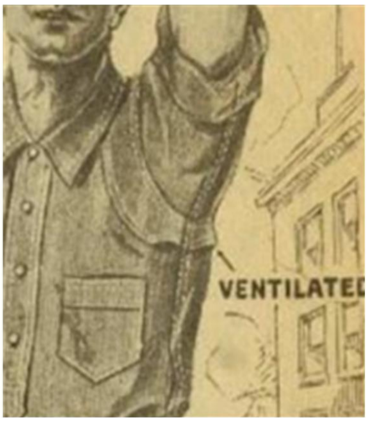


Figure 18 Part of the underarm seams was unsewn for ventilation of moist and heat

Until the early 20s', work shirts for a 38 cm neck size, were slimmed down to chest 114 cm, waist 105 cm, sleeve width 36-38 cm, length to 86 cm (from center back to wrist) including a cuff for work purposes and this marked the model of the modern classic fit for today. Very soon, the dress shirts were quickly adapted. The classic sleeve pattern set is presented in Figure 1.

The 1930s – 1940s

Hawaiian shirts, Cuban collar shirts and Camp shirts were popular during this era, short sleeves everywhere from quarter length to midarm to ¾ length (especially in baseball shirts and knit shirts, Figure 19), full of colors, joy and energy. French cuffs were another trendy fashion symbol since cufflinks were popular as men's jewellery to show off their social statics among them. However, the origin of French cuffs was still debating between the British and French.

The 1950s – 1970s

From the 50s' to 60s', the cutting of men's shirts remained unchanged, French cuffs were still used in formal attire and the classic fit was still popular, yet fabrics had more choices of colors and patterns. Polyester, which was invented in the 1940s, gained momentum and began to flourish in the 1970s. Suddenly everybody was wearing tight, even skinny tight shirts and pants with slim sleeves and wide cuffs fastened by three buttons. Floral prints, psychedelic patterns, bright pinks and greens once awhile adorned the drop-shoulder sleeves on men's clothing on a "Saturday Night Fever" (Figure 20).

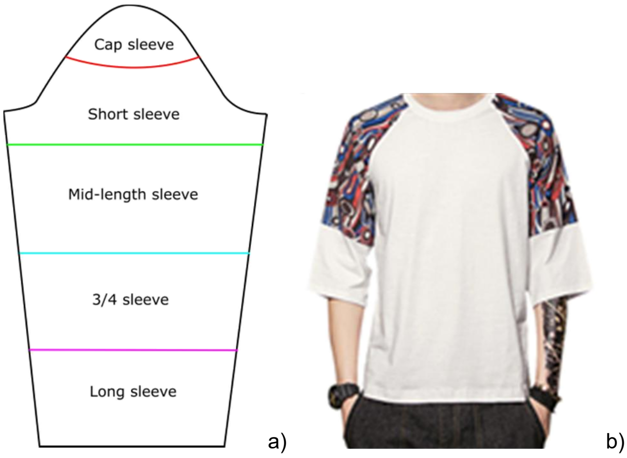


Figure 19 Sleeve length comparison diagram (a) and a three-quarter length T-shirt with raglan sleeves (b)

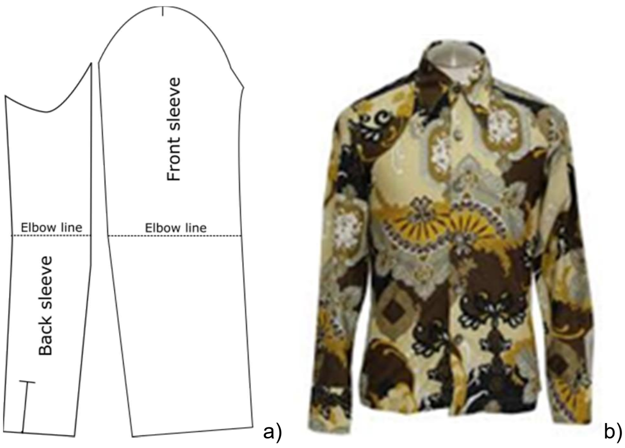


Figure 20 A two pieces tailor sleeve takes out extra fabric to create a slim look (a) and slim fitted polyester shirt with a psychedelic print (b)

The 1980s – 1990s

In contrast to the 70s', super baggy Hip-hop tee, dropped shoulder shirts, power shoulder-padded jackets, oversized armhole, exaggerated sleeve length, soft and draped; and cuffs were replaced by elastic ribbing, all and all were reflecting the freedom and rebellion spirits during this era (Figure 21).

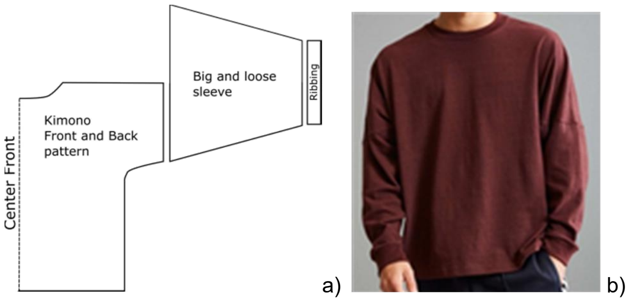


Figure 21 Showing half Kimono front with a full loose sleeve and a ribbing for wrist closure (a) and a Kimono style shirt with loose sleeve and a drop-shoulder effect (b)

The 2000s – 2020

Stepping into the new millennium, fashion branched out into different trends. Big and baggy, clean-cut, retro, rebellious, futuristic and all other styles; yet they all have the common thread that is the silhouette of the clothing is slimmer, even Hip-hop style is not as exaggerated as the 80s'. Instead of the craziness of fashion trends from the 80s and 90s', sensible fitted shirts with good proportions and colors came back to the spotlight (Figure 22).

Figure 22 Ordering tailor shirts or other merchandises online will be the future trend of lifestyle

More and more tailor-made clothing for the individual is available that you can order using online shopping [13] and at an affordable price. Since Michael Aldrich [14-15] started "teleshopping" in 1979, the basic idea of online shopping was set. Forty years later, online shopping has become a lifestyle. "It is growing at exponential rates. The ease of researching, buying, shipping and the huge availability of options from small retailers to large brands is driving more consumers online than ever before", said Larisa Bedgood – vice president of the V12 Data [16].

Size range is covering more diverse groups of body types or you can follow the online instructions to take your measurements for the tailor shop before you order it. For the mass production clothing brands, size ranges are also increased to meet customers' needs; however, the fits of men's shirts are still maintaining in three major groups which are Classic, Regular and Slim fit and they may be named differently like Casual fit, Tall fit, Contemporary fit and so on just to suit the brand's image and their consumers' market. There are also variations of fits derived from the major groups like Relaxed fit, Extra Slim fit and others. These are the fits that developed in-between or a bit more extreme from the three major groups. For examples, the Extra Slim fit is a bit tighter than the Slim fit resembling the 70s' clothing and the Relaxed fit is between the Classic and the Regular fit. The bottom line is that all these complicated scales and names are just to up-selling their products to their customers.

4 DISCUSSION AND CONCLUSIONS

From the beginning of the century, sleeves and cuffs were big and loose for comfy during work, and the triple-stitch seams plus other features like elbow patches, double sleeves, detachable cuffs and so on; to make sure the durability and strength of the clothing can last longer; considered shirts still an expensive item for work or leisure. During the 30s', short-sleeves, French cuffs and the Classic fit were in trend; until the new inventions of the colorful, stretchy polyester provided with all the slim-cut swiped through the 70s' and the baggy, crazy, no-boundary, full of imaginations 80s' - 90s'. Fashion trends nowadays seem to come back to the quiet, sophisticated, details oriented manner with a good proportional cut on clothing.

Since a few decades ago, researchers from clothing science and technologies have been looking for a new method to renew the men's shirt patterns. Chan et al. [17, 18] was comparing four popular traditional methods of shirt drafting, analysed them, and combined them with a 3D body measuring technique to predict the shirt patterns (Figure 23).

Other researches [19-22] were focused on wearing ease, postures and body movement, body heat, sweat and ventilation influenced on shirt patterns. With the improvement of the shirt patterns, sizing or grading systems and the computer-aided cutting systems [23-26] have to implement to offer the completed service (Figures 24-25).

Figure 23 A 3D body scanner

However, all these new inventions and technologies are based on the original basic men's shirt patterns for reference. Moreover; men's shirts are mostly made from woven fabric, even though fabric content may be blended in polyester fibres and added in a small percentage of spandex, elastin or nylon to change the properties of the fabric to improve the abrasion, resiliency, elasticity and so on; however, woven fabric is still dictated by the warp and weft weaving structure which characterized the fabric (like draping, tenacity) and influences the cutting of the pattern, for example cutting on grainline is completely different from cutting on the bias. When looking at recent years of athletic sportswear which are usually made from knit or hi-tech fabrics that are composed of several different structures or materials to create one piece (Figure 26). Different sections or different cut patterns are combined to provide different functions to give the wearer the ultimate comfortable experience.

With the innovative growth in the technology of woven textiles, men's shirt patterns may follow this trend of comfort and functionality first before aesthetic needs and style. The classic sleeve and cuff that people have been using for over a century may completely change into a simplified and fluent one-piece sleeve with cuff joined together; or may even cut into three horizontal sections that fit the upper arm, elbow and forearm in contour format. The possibilities are unknown and this will be the witness of our time.

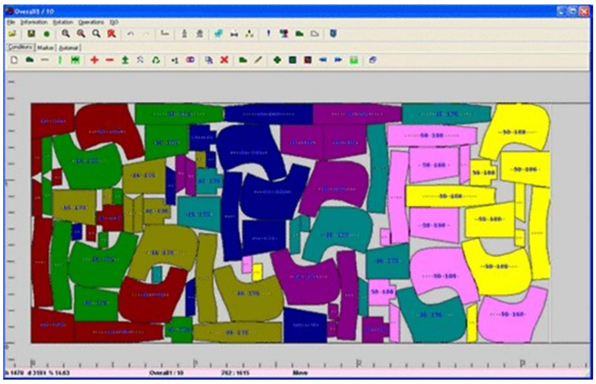


Figure 24 Using CAD system to arrange different sizes of patterns on a printout before fabric cutting

Figure 25 A laser fabric cutting machine

Figure 26 Hi-tech athletic wear with different sections, cut in pattern and functions composed together into one piece

5 REFERENCES

1. Aldrich W.: Metric Pattern Cutting for Menswear, 5th ed., Wiley-Blackwell, 2011, 200 p., ISBN 978-1405182935
2. A Comprehensive Guide to Sleeves MasterClass. https://www.masterclass.com/articles/what-are-the-different-types-of-sleeves-in-fashion
3. dfpbook.pdf, https://www.wildginger.com/pdffiles/dfpbook.pdf
4. Victoria and Albert Museum, Cromwell Road, South Kensington, London SW7 2RL, http://www.vam.ac.uk/content/articles/h/history-of-fashion-1840-1900/
5. Weston Thomas P.: Mid-Late Victorian Fashion and Costume History1860-1901, https://www.fashion-era.com/mid-late_victorian_fashion.htm
6. From Sack Coats to Trucker Hats: 100 Years of Men's Fashion HowStuffWorks https://lifestyle.howstuffworks.com/style/fashion/trends-looks/100-years-of-mens-fashion.htm
7. Fung F.T., Hes L., Bajzik V.: Review of Men's Shirt Pattern Development for the Last 100 Years, Vlákna a textil (Fibres and Textiles) 27(3), 2020, pp. 49-58
8. Christman L.A.: Digital Flat Pattern: The Apparel Designer's Handbook, 2nd ed., Wild Ginger Software, Inc., Auburn, AL, 2016. 369 p.
9. Coffin D.P.: The Shirtmaking Workbook: Pattern, Design, and Construction Resources - More than 100 Pattern Downloads for Collars, Cuffs & Plackets, Quarry Books, 2015, 176 p., ISBN 9781589238268
10. The History of the Raglan https://www.nextlevelapparel.com/history-of-the-raglan-page
11. Green C.: The Surprising History of the Kimono, JSTOR Daily, 2017, https://daily.jstor.org/the-surprising-history-of-the-kimono/
12. Kimono, accessed in Wikipedia: https://en.wikipedia.org/w/index.php?title=Kimono&oldid=990054401
13. Men's Suits, Custom Made To Measure Suits, INDOCHINO, http://www.indochino.com/collection/Suits/
14. Aldrich M.: Online Shopping in the 1980s, IEEE Annals of the History of Computing 33(4), 2011, pp. 57-61, ISSN: 1058-6180
15. The History of Ecommerce: How Did It All Begin?, Miva Blog, 2011 https://www.miva.com/blog/the-history-of-ecommerce-how-did-it-all-begin/
16. Bedgood L.: 25 Stats on Consumer Shopping Trends for 2019, Business 2 Community, 2019, https://www.business2community.com/consumer-marketing/25-stats-on-consumer-shopping-trends-for-2019-02175812
17. Chan A.P., Fan J.T., Yu W.: Men's Shirt Pattern Design Part Ⅰ: An Experimental Evaluation of Shirt Pattern Drafting Methods, Sen'i Gakkaishi 59(8), 2003, pp. 319-327, https://doi.org/10.2115/fiber.59.319
18. Chan A.P., Fan J.T., Yu W.: Men's Shirt Pattern Design Part Ⅱ: Prediction of Pattern Parameters from 3D Body Measurements, Sen'i Gakkaishi 59(8), 2003, pp. 328-333, https://doi.org/10.2115/fiber.59.328
19. Havenith G., Heus R., Lotens W.A.: Clothing ventilation, vapour resistance and permeability index: changes due to posture, movement and wind, Ergonomics 33(8), 1990, pp. 989-1005, https://doi.org/10.1080/00140139008925308
20. Jang S-E.: A study on sizing system and preferable ease in a men`s dress shirt for virtual mass customization system, Journal of the Korean Society of Clothing and Textiles 32(1), 2008, pp. 99-109, DOI: 10.5850/JKSCT.2008.32.1.099
21. Chi L., Kennon R.: Body scanning of dynamic posture, International Journal of Clothing Science and Technology 18(3), 2006, pp. 166-178, https://doi.org/10.1108/09556220610657934
22. Xu J., Zhang W., Xiao P.: A study on impact factors of the distance ease between body and garment, In: 2008 9th International Conference on Computer-Aided Industrial Design and Conceptual Design, Beijing, China, 2008, pp. 201-205, doi: 10.1109/CAIDCD.2008.4730551
23. Liu Z., Harlock S.C.: A computer-aided grading system for both basic block and adapted clothing patterns: Part II: The grading algorithms, Textile Research Journal 65(2), 1995, pp. 95-100, https://doi.org/10.1177/004051759506500205
24. Schofield N.A., LaBat K.L.: Exploring the relationships of grading, sizing, and anthropometric data, Clothing and Textiles Research Journal 23(1), 2005, pp. 13-27, https://doi.org/10.1177/0887302X0502300102
25. Han H.S., Kim J.Y., Kim S.M., Lim H.S., Park C.K.: The development of an automatic pattern-making system for made-to-measure clothing, Fibers and Polymers 15(2), 2014, pp. 422-425, https://doi.org/10.1007/s12221-014-0422-6
26. Petrak S., Rogale R.: Methods of automatic computerised cutting pattern construction, International Journal of Clothing Science and Technology 13(3/4), 2001, pp. 228-239, https://doi.org/10.1108/09556220110396542

6 ILLUSTRATIONS

- Figures 1, 3, 9a-c, 13a-c, 16a, 17, 19a, 20a, 21a: owned figures
- Figures 2, 6, 7, 11, 10, 14b, 15, 19b, 20b, 21b, 22: from Pinterest, pinterest.ca
- Figures 4: The Icon Shirt, Kitsbow, https://www.kitsbow.com/products/the-icon-shirt-1
- Figures 5: Lola. Fitted Sleeve Sloper: part 2 - built-in gusset, 2014, http://overflowingstash.com/2014/07/07/fitted-sleeve-sloper-part-2-built-in-gusset/
- Figure 8: Tailors MB. Cuff Styles, Bespoke Suit, 2015 https://modistobt.wordpress.com/2015/01/28/cuff-styles/
- Figure 12: Touch of Modern, https://www.touchofmodern.com/guides/3-different-shirt-cuff-styles
- Figure 14a: Hugh & Crye, https://www.hughandcrye.com/pages/convertible-cuffs
- Figure 16a, 17, 18: A Brief History of the Work Shirt - 1900-1930 The Rite Stuff, https://the-rite-stuff.com/blogs/news/the-evolution-of-the-work-shirt-the-work-shirt/

- Figure 23: SS20 Size Stream 3D Body Scanner, https://www.tradeindia.com/products/ss20-size-stream-3d-body-scanner-6480953.html
- Figure 24: 9 Key Factors of Marker Making in Clothing Industry, Garments Merchandising, https://garmentsmerchandising.com/key-factors-of-marker-making/

THE 3rd BUCKLING PHASE OF A SEWING NEEDLE INTERACTION WITH THE HEAVY MULTILAYERED FABRICS

Wael A. Hashima and Ibrahim A. Elhawary

Textile Engineering Department, Alexandria University, Egypt
wa_ahm2007@yahoo.com

Abstract: *In the present work the interaction between the lower end of the sewing needle and the sewn multilayer having massive fabrics is studied. The sewing needle lower end just penetrate the top layer of the cloth starts to be surrounded by fabrics and yarns that activate as fixer to the needle end. As the industrial lower end travels downward, the fixation is increased so that the needle became a column fixed-fixed ends. In the present work, it is a summed that the industrial sewing needle has a constant cross-section (CSA with $\bar{\varphi}$ = 1.965 mm). Actually the needle is a bar with variable (CSA) that could be transferred to a column with constant (CSA). By the way this problem is more complicated. The future vision of this work is to build stand in the laboratory to verify the different values of the critical loads.*

Keywords: *sewing needle, penetration phase, column, restrained ends, buckling load, Euler and critical, equivalent length coefficient, elastic stability η.*

1 INTRODUCTION

In the clothing manufacture technology, a sewing process is running via a sewing needle reciprocating motions in the vertical direction through a driving mechanism irrespective of its kinematic chain, the end of the sewing needle penetrates the sewn layers of the fabric, starting from the top layers to underneath the lower layer, causing a looping of the sewn thread to connect or to fix the layers to each other. This will enable people to have ready-made garments or apparel [1, 2].

Figure 1 shows the different phases of the sewing needle lower-end, penetration vertically in the layers of the cloth layers. During penetration from the top layer to the lowest layer, the sewing needle lower end is subjected to different degrees of resistance [1, 2]. The resistance of the fibers, yarns and fabrics is presented by a virtual constrains: start from zero to the third degree level as illustrated in exhibit (Figure 1).

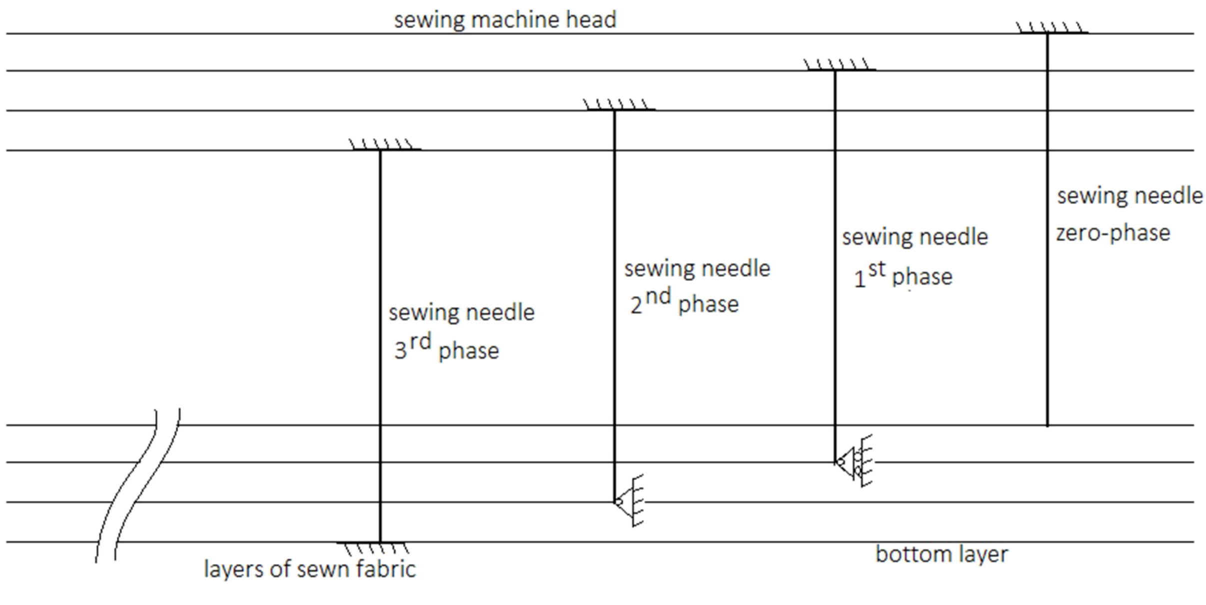


Figure 1 Different phases of a sewing needle penetration in the sewn fabric layers
zero-phase - the sewing needle is fixed-free end column (cantilever); 1st phase - the sewing needle is fixed-hinged (movable) end column-beam; 2nd phase - the sewing needle is fixed-hinged (angular) end column-beam; and 3rd phase – the sewing needle is fixed-fixed end column-beam

In addition, it was done extensive study on a standard commercial needle with two stepped sections with $\overline{\varphi}$ = 1.965 mm, EI = 2.52 N.m^2, length ℓ = 60 mm. It was found that for zero penetration, buckling load P_{cr} = 104 N, while Euler load P_e = 415 N consequently $\gamma = \sqrt{\frac{P_e}{P_{cr}}} = 2$ [1].

Also, the 1st & 2nd phase of sewing needle penetration in the multi-layered sewn fabric were studied. It was found the axial critical compressive force F_{cr} = 848 N, while the Euler load F_e = 415 N & equivalent length $\lambda = 0.699$ [2].

Groz-Beckert has reported and graphed the distribution of the penetrating force during sewing process as shown in Figure 2. At the start of the free need touch the top layer of the fabric (zero penetration) an impact force is generated = 25 N (the highest value). Due to continuity of penetration, the resisting force on the needle drops to 6 N. Finally at the end of penetration when the needle extruding from the lower layer of the sewn fabrics the penetration force drops to zero lower end is outside fabric, but visually the value of force = 10 N due to the increase of needle cross-section. This means that the sewing needle has different phase during its penetration in the sewn fabric [3].

In the work [4] it has been mentioned the use of Pisarenko technique what could be applied for calculating the critical load of the sewing needle with variable CSA (Cross-sectional area). In the work [5], it has been explained the balancing of the multiproduct garment production line using the simulation technique. The study was applied on the production line consists of 12 class 301 single needle sewing machine, eight class 504 overlock-stitch machine and six class 401 chain – stitch machines. This means that the study solved the problem mainly via sewing department [5].

The industrial sewing machine could be divided to four categories as: half-automatic, mechanical class, basic sewing machine and automatic transfer line [6]. Concerning the elastic compressive balancing load of sewing needle (as slender column), the machine detail, the energy method - critical & Euler loads - could be applied [7-10], etc.

Finally, if the needle is not changed regularly, it can cause major quality problems. The needle is subject to the most use of all machine parts as it penetrates the material at speed of 5000-6000 stitches/min for lockstitch and 8000-10000 stitches/min for chain stitch. The friction caused by the penetration between needle and fabric causes an extreme heat with the needle temperature of 250-300°C. When the fabrics are stitched together, the impact of the needle as it penetrates the fabric can cause needle buckling and distortion of the yarns and fibers. A smaller diameter needles reduces the mechanical forces exerted on the yarn. The mechanical strain on the yarns increases if the needle is damaged. The damage can cause the fibers to rupture which reduce the seam strength significantly [11].

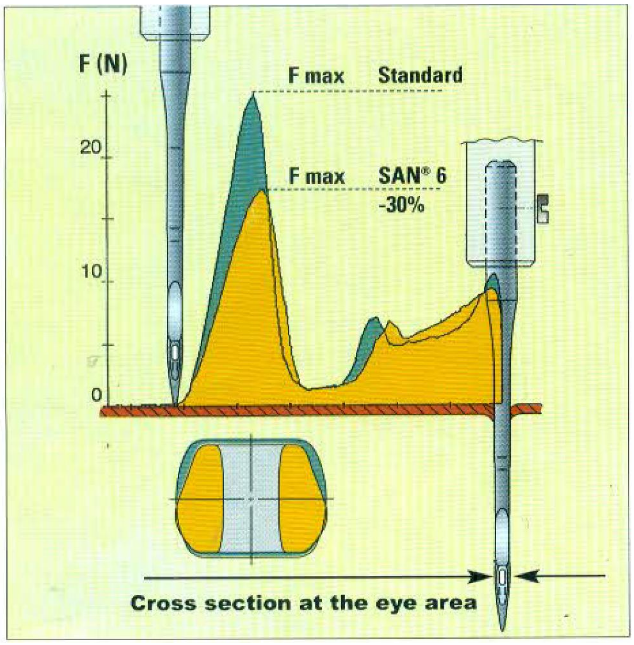


Figure 2 Phases of the sewing needle free end – interaction with the sewn layers of fabric [3]; the blue color refers to the standard needle in the chart; the orange color refers to the SAN 6 needle in the chart, both needle are Groz-Beckert made

2 THEORETICAL APPROACH

Figure 3a shows an industrial sewing needle where it is fixed – fixed ends during its travel form the top layer of multilayer to the bottom layer of sewn fabric (heavy type). The loads on the needle as it buckles are shown in the figure. From Figure 3b it could be seam that the loads balancing requires that:

$$P.X + F.y - M_A = M_0 \qquad (1)$$

As it is well known that the resisting moment M_0 is:

$$M_0 = -EI.X^{\backslash\backslash} \qquad (2)$$

The differential formula for equilibrium (balancing) of the sewing needle can be written as:

$$X^{\backslash\backslash} + \lambda^2.X = -\frac{F}{EI} + \frac{M_A}{EI} \qquad (3)$$

where: $\lambda^2 = -F/EI$.

The solution of the formula (3) has a general solution that consists of a complementary part and a particular part satisfying the entire equation. Thus the general solution of formula (3) is:

$$X = A\sin\lambda y + B\cos\lambda y - {}^{F.y}/_{P} + {}^{M_A}/_{P} \qquad (4)$$

From boundary conditions of the sewing needle:

$$\left.\begin{array}{ll} X(0) = 0 & X^{\backslash}(\ell) = 0 \\ X(\ell) = 0 & X^{\backslash}(\ell) = 0 \end{array}\right\} \qquad (5)$$

Then where *y=0*, we have:

$$B = -{}^{M_A}/_{P};\ A = {}^{F}/_{P\lambda} \quad (6)$$

By substituting of formula (6) in equation (4), we will have:

$$X = {}^{F}/_{P\lambda}\sin\lambda y - {}^{M_A}/_{P}\cos\lambda y - {}^{F.y}/_{P} + {}^{M_A}/_{P} = 0 \quad (7)$$

By introducing $X(\ell) = 0$, we can write:

$${}^{F}/_{P\lambda}\sin\lambda\ell - {}^{M_A}/_{P}\cos\lambda\ell - {}^{F.y}/_{P} + {}^{M_A}/_{P} = 0 \quad (8)$$

When we apply $X^{\backslash}(\ell) = 0$, we can say:

$${}^{F}/_{P}\cos\lambda\ell + {}^{M_A.\lambda}/_{P}\sin\lambda\ell + {}^{F}/_{P} = 0 \quad (9)$$

From formulas (8 & 9) for a nontrivial solution of F & M_A, we must obtain (fundamental critical load formula):

$$\lambda\ell\sin\lambda\ell + 2\cos\lambda\ell - 2 = 0 \quad (10)$$

By introducing the trigonometrical identity $\sin\lambda\ell = 2\sin\lambda\ell/2\ \cos\lambda\ell/2$ and $\cos\lambda\ell = 1 - 2\sin^2\lambda\ell/2$, then equation (10) can be written as:

$$\sin\frac{\lambda\ell}{2}\left[\frac{\lambda\ell}{2} - \sin\frac{\lambda}{2}\right] = 0 \quad (11)$$

The last formula (11) can be satisfied if either the first term $\sin\frac{\lambda\ell}{2}$ or the items in the parenthesis disappear. If the first term disappears, the solution is $\lambda\ell = 2\pi.n$ where $n = 1, 2, 3,$ ....from which the critical axial compressive force P_{cr} is obtained by substituting $n = 1$, this means that:

$$P_{cr} = \frac{\pi^2}{\left({}^{1}/_{2}\right)^2} * \frac{EI^{\backslash}}{\ell^2} = \eta^{\backslash}\frac{EI}{\ell^2} \quad (12)$$

where: $\lambda = \frac{1}{2}$, $\eta^{\backslash} = 4\pi^2$ and $P_{cr} = P_e$ (Euler load).

For the sewing needle (symmetrical) of an industrial sewing machine, the value $\frac{EI^{\backslash}}{\ell^2} = 42$ N [8]. The critical load is:

$$P_{cr} = 1658\ N \quad (13)$$

If the terms in the parenthesis vanish, then the lowest value that gives satisfaction equation $\frac{\lambda\ell}{2}\cos\frac{\lambda\ell}{2} = 0$ or $\tan\frac{\lambda\ell}{2} = \frac{\lambda\ell}{2}$ is $\lambda\ell = 8.987$ from that; the critical axial compressive force P_{cr} (for unsymmetrical) is:

$$P_{cr} = \frac{80.766}{(1)^2} * \frac{EI^{\backslash}}{\ell^2} \quad (14)$$

For the industrial sewing needle $(EI^{\backslash}/\ell^2) = 42\ N$, then:

$$P_{cr} = 3392\ N \quad (15)$$

i.e. for the sewing needle, the critical load when it completely fixed from both ends, specially lower end when it penetrates a heavy multilayer sewn fabrics, the axial critical compressive force P_{cr} is varying from 1658-3392 N.

The symmetric buckling load of the sewing needle is shown in Figure 3c in such more of buckling means that the lower end of the sewing needle just to get started few millimeters in the sewn multilayer fabrics. The continuity of the lower end of the sewing needle – downward motion - gives more resistance to penetration. Therefore the strength of lower end fixation is increased consequently, the buckling made of the needle is getting may be unsymmetrical as shown in Figure 3d. The change from buckling symmetrical mode to the unsymmetrical buckling made will be explained as follow:

This may be related to the strength of support rigidity or stiffness where it is weak we have low critical load i.e. less resistance to buckling, while when the support stiffness is great will lead to great resistance for buckling. Consequently the axial compressive critical load is folded, i.e. is relative high value. The values of equations 14 and 15 correspond to critical load of symmetric (Figure 3c) or unsymmetrical (Figure 3d) buckling modes of the sewing needle, consequently. The critical load of the symmetric buckling mode is lower than that of the unsymmetrical buckling mode.

The needle will buckle in the symmetric mode, unless the mid length of the needle is traced against lateral movement, P_{cr} will follow formula (13) will have little significance to us. The elastic line of the symmetric buckling mode can be obtained by substituting *F*=0 (because of symmetry) and $\lambda = \frac{2\pi}{\ell}$ in equation (7), then:

$$X = \frac{M_A}{P}\left(1 - \cos\frac{2\pi y}{\ell}\right) \quad (16)$$

If we write $\lambda\ell$ as the effective length of the fixed – fixed sewing needle, the equivalent pinned – pinned sewing needle Euler theorem $\lambda\ell$ (Figure 3c) that will with stand the same critical load as fixed – fixed sewing needle that has length ℓ can be obtained by finding a solution for the following formula:

$$\frac{\pi^2 EI}{(\lambda\ell)^2} = \frac{4\pi^2 EI}{\ell^2} \quad (17)$$

That can give $\lambda\ell = \frac{1}{2}\ell$ $i.e.$ $\lambda = \frac{1}{2}$, i.e. the equivalent length of the Euler beam (pinned – pinned column) is half of the fixed – fixed column the inflection points of the fixed – fixed needle are at a distance of $\ell/2$ apart (Figure 3c). The factor λ is called effective length factor of the fixed – fixed sewing needle. To the verification that the inflection points are indeed (as is shown in Figure 3c), we will write the moment expression along the length of the sewing needle and set it equal to zero to calculate distance y that gives the location of the inflection point. By differentiating the formula (16) twice we can write the moment expression as:

$$M = -EI.X^{\backslash\backslash} - EI\ \frac{M_A}{P}.\frac{\pi^2}{\ell^2}.\cos\left(\frac{2\pi y}{\ell}\right) = 0 \quad (18)$$

then $\cos\left(\frac{2\pi y}{\ell}\right) = 0$ or $y = \frac{n\ell}{4}$, $n = 1, 2, 3, \ldots\ldots$

Using $n = 1$ & 3 give $y = {}^{\ell}/_{4}$ & $3\,{}^{\ell}/_{4}$.

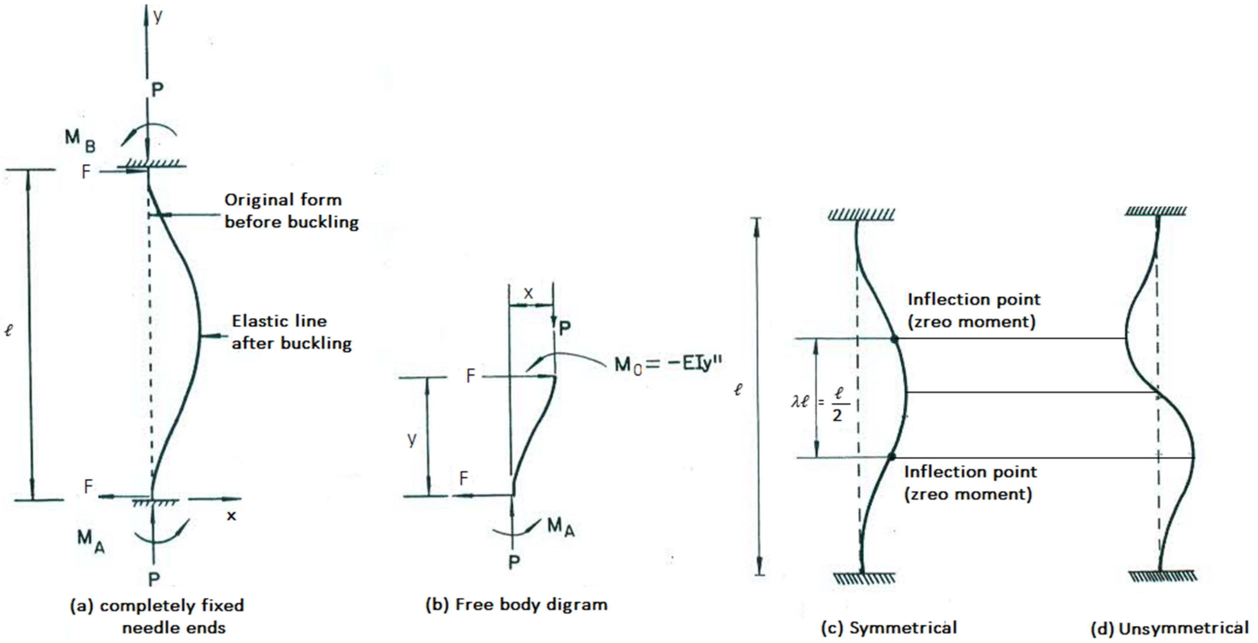


Figure 3 Fixed-fixed industrial sewing needle (a, b); symmetric and unsymmetrical buckling modes of a fixed-fixed industrial sewing needle (c, d)

Hence inflection points are located at $y = {}^{3\ell}/_{4} - {}^{\ell}/_{4} = {}^{\ell}/_{2}$ as shown in Figure 3c.

Generally, for a centrally and fixed – fixed sewing needle, the equivalent (effective) λ can be evaluated directly by the formula:

$$\lambda = \sqrt{\frac{P_e}{P_{cr}}} \tag{19}$$

where: P_{cr} – critical axial compressive force of sewing needle i.e. resisting force during needle penetration in the sewn fabric; P_e – Euler force of the pinned – pinned (minimum value of P_{cr}) sewing needle that have the same length factor similar to that of equations (17 & 19) can be easily derived from the definition of length factor λ as in equation (17).

By application of sewing needle database [8] for equations (12 & 14) we can have $P_{cr} = P_e = \pi^2 \frac{EI}{\ell^2}$ and for fixed – fixed ends column (needle) with symmetrical buckling curve $P_{cr} = 39.9484 \times \frac{EI}{\ell^2}$.

3 CONCLUSIONS & FUTURE VISIONS

From the previous results and discussions the following conclusions & future visions can be drawn out:

1. The industrial sewing needle when just to get starting of penetration in the layers of heavy multilayer sewn fabrics, several cases of ends constrain will be built:

   Case A: The lower end of the sewing needle will be surrounded by textile materials pressing everywhere to accumulate internal pressures. This will grip the needle lower end to make it fixed or completely partially supported:

   a) The needle elastics buckling line is symmetric i.e. has a two symmetric inflection points where bending moments around them is zero. The distance y between them is ${}^{\ell}/_{2}$ and between each point and needle supports is $y = {}^{\ell}/_{4}$ (this is for 3rd phase of penetration).

   b) The critical load (fundamental) in general is $P_{cr} = \eta^{\backslash} \frac{EI}{\ell^2}$

   where: P_{cr} - fundamental critical load, $\eta^{\backslash}$ - elastic stability factor, $\left(\frac{\pi}{\lambda}\right)^2$, EI - needle bending stiffness and ℓ - needle length

   then $P_{cr} = 4\pi^2 \times 42 = 1658\ N$, when $\eta^{\backslash} = 4\pi^2$, $\lambda = \frac{1}{2}$ & $\frac{EI}{\ell^2} = 42\ N$.

   Case B: When the lower end of the sewing needle of the industrial sewing machine – travels downward is increased, consequently:

   a) The buckling elastic line of the sewing needle became unsymmetrical.

   b) The anti-symmetric critical load is $P_{cr} = \frac{8\ 07\ 6\ 6}{(1)^2} \cdot \frac{EI}{\ell^2} = 81 * 42 = 3392\ \ N$

2. The equivalent length factor is $\lambda = \sqrt{\frac{\mathrm{P_e}}{\mathrm{P_{cr.}}}} = 0.3496\ \cong 0.30$

3. Always for the sewing needle under buckling load $\eta^{\backslash} = \frac{\pi^2}{\lambda^2}$, $P_{cr} = \eta^{\backslash} \frac{EI}{\ell^2}$, for traditional sewing needle $\frac{EI}{\ell^2} = 42\ \ N$, λ equivalent length factor.

4. The 3rd phase of the sewing needle interaction with the sewn multilayer fabric is fixed – fixed ends with different shapes of buckling elastic line.
5. Future vision means intensive experimental to verify the theoretical approaches. In addition, the theoretical study must consist of the sewing industrial needle with its variable cross-sections (CSA). In the running study we considered the sewing needle is with constant cross-section (CSA).
6. The data base of the applied needle for calculation is a commercial and industrial type with two – stepped sections, $\ell = 60\,mm$, $\bar{\varphi} = 1.965\,mm$ (constant cross-section), $I = 7.3185\,(E-13)\,m^4$.
7. The equation of the buckled elastic line of the fixed – fixed ends needle (symmetrical) $X = \frac{M_A}{3390}\left(1 - cos\,\frac{2\pi y}{\ell}\right)$.

ACKNOWLEDGMENT: *The authors are willing to introduce thanks giving for prof. Dr. Eng. Sherwet H. Elgolmy for invaluable and scientific help in carrying out the research work.*

4 REFERENCES

1. Hashima W.A., Elhawary I.A.: The interaction between the free end of the sewing needle and top layer of the sewn fabric, Arctic Journal 74(2), 2021, paper ID: fV90f
2. Hashima W.A., Elhawary I.A.: The 1st & 2nd penetration of a buckling load of a sewing needle via reciprocating travelling into a clothing manufacture technology, Alexandria University, AEJ, Egypt, 2021, under publication
3. Groz-Beckert Co., Germany, https://www.groz-beckert.com/en/products/sewing/
4. El Gholmy S.H., Elhawary I.A.: A formula for calculating the critical load of the needles used in the garment and apparels sewing technology: Part1: Pisarenko technique, Nature and Science 11(10), 2013, pp. 88-93, http://www.sciencepub.net/nature
5. Elhawary I.A., El-Gholmy S.H., Momtaz H.M.: Balancing the Multi-product Garment Production Line Using the Simulation Technique, TBIS – Textile Bioengineering and Informatics Symposium Proceedings, 8-11 September 2019, Soochow University, Suzhou, China
6. Mcloughlin J., Mitchel A.: Fabric finishing: Joining fabrics using stitched seams, chapter 16 in: Textile and Fashion, Sinclair R. (Ed.), Woodhead Publishing, 2015, pp. 379-412, ISBN: 978-1-84569-931-4
7. Chen W.F., Lui E.M.: Structural stability - Theory and Implementation, Prentice Hall; 1st ed., 1987, ISBN: 978-0135005392
8. Feodosev V.I.: Strength of Materials, English copy, Mir Publisher, Moscow, 1968, 570 p.
9. Pisarenko G.C., Matveev V.V., Varvak P.M., Yakovlev A.P.: A Reference Book of Strength of Materials, Naukova Press, Kiev, Ukraine, 1975 (in Ukrainian)
10. Panamarev C.D., Buderman V.I., Lukharev K.K., Makyshin V.M., Malinin N.N., Fodoce V.N.: The Basic Modern Methods of the Machine Design, Machine Design Press, Moscow, 1952 (in Russian)
11. Sinclair R. (Ed.): "Textiles and Fashion - Materials, Design and Technology, Woodhead Publishing, 2015, ISBN: 978-1-84569-931-4

A SURVEY AND DESIGN STUDY OF A PROTECTIVE CYCLING TOP WEAR

Sukran Kara[1], Sevil Yeşilpınar[1] and Mert Arslan[2]

[1]Dokuz Eylül University, Engineering Faculty, Textile Engineering Department, Tınaztepe Campus, 35397 Buca Izmir, Turkey
[2]Roteks Tekstil Ihracat San. ve Tic. A.Ş, Izmir Ataturk Organized Industrial Zone, 10002 ST No.26, 35620 Cigli Izmir, Turkey
sukran.kara@deu.edu.tr; sevil.yesilpinar@deu.edu.tr; mertarslan@roteks.com.tr

Abstract: *Cycling is a popular sport which is preferred by all age groups all around the world. As it is an active sport, it requires special types of clothing to provide comfort to the wearer. In spite being a healthy activity, cycling can result with acute or chronic injuries. In this study, an extensive survey was conducted to the cyclists in order to reveal their preferences of cycling clothes, their requirements, their accidental experiences and safety needs. By considering the survey results, optional designs of a more protective and functional cycling top wear were outlined. In order to avoid from acute injuries which were stated to be in the shoulder and arm areas the most, a para-aramid and spacer/silicon foam supported design was proposed. Also, the visibility was enhanced by the implementation of active lightening on the front and back sides of the clothing.*

Keywords: *cycling top wear, survey study, protective clothing, functional clothing, clothing design.*

1 INTRODUCTION

Recently, there has been an increasing interest in sports because of the desire to be healthier, to relieve stress and to create a lifestyle. Cycling is one of the most popular sports as it appeals to all age groups, promotes general good health, does not require high costs and can be made in all seasons. In addition of being a sport, cycling is a means for a cheap, healthy and a green transportation [1].

Cycling sports can serve to both recreational and professional purposes. The cycling types namely, road cycling, cyclo-cross and mountain biking belong to professional cycling pursuits [1]. They can cover various time intervals and different levels of performance. Therefore, cycling may need different clothes with special properties. Some of the selection parameters of cycling clothes are the price, appearance, size, fit, design, availability and quality [2]. Appearance and fit can be the most important selection parameters for recreational cyclists. But, especially for professional cycling, functional properties and comfort properties are of higher importance [2-4]. Some of the functional and comfort properties expected from cycling clothes are moisture absorbency, moisture management, fast drying, breathability, lightness, stretchability, heat preservation, resistance to sunlight, high visibility etc. [2, 5, 6].

By considering various requirements from the cycling clothes, many studies were done in the literature in particular research areas. Some studies searched the fit of cycling clothes. For example; Vuruskan and Ashdown [7] built half scale dress forms for active body positions of cyclists by capturing 3D body positions using body scanners. In the further study, they produced 3D printed active forms which were equipped with pressure sensors to measure the fit of cycling shorts [3]. Liu et al [4] determined the digital clothing pressure for static condition and dynamic cycling condition by using software and optimized the design of a cycling t-shirt. Compressional properties of compressive cycling clothes were also studied in the literature. Leoz-Abaurrea and Aguado-Jimenez [8] investigated the effect of upper body compression garments on the cardiovascular and thermoregulatory strain of cyclists those cycled in hot environment. Brighenti et al [9] compared the performance effect of a new type of whole body compression garment with ordinary summer cycling cloth in hot climate (32°C). Hintzy et al [10] studied the effects of thigh compression shorts on muscle activity and soft tissue vibration during cycling. Another study field on cycling clothes was the visibility as it could provide protection against cycling accidents. Lahrmann et al [11] made an extensive study in which the effect of bright colored cycling wear on the number of cycling accidents was searched. Lee [12] designed a cycling jacket incorporating solar powered LED (light emitting diodes) sensor lights in order to improve visibility. Koo and Huang [13] tested different configurations of flashing LEDs on cycling clothes to the psychological perception of drivers. Kgatuke et al [14] developed a cycling jacket integrated with LEDs. As smart solutions to cycling clothes; Paiva et al [15] designed and produced a smart cycling cloth that was able to measure the heart beats of cyclists by means of different materials such as textile and silicon based electrodes. Qiu and Hu [16] proposed and defined the design of a smart cycling top wear that could measure the heart rate, body temperature and moisture of the cyclist by implementing electronic devices to the clothing.

In addition to these researches, there are rare other studies on cycling clothes. As an example, Oglakcıoglu et al [6] investigated the thermal comfort properties of sewn parts of cycling clothes. Teyeme et al [2] searched the pains/injuries of 94 cyclists, which occurred during or after cycling. Vuruskan [17] conducted a cross-national survey study for cycling clothes in which 25 cyclists from Turkey and 25 cyclists from United States were included. In the survey, customers' perspectives on fit and customization were questioned. Teyeme et al [18] organized some wear trials for 4 kinds of cycling wear in order to determine their comfort properties. Kwon and Kim [19] developed a cycling top wear with the combination of 3 fabrics in order to response different sweating rates and compression needs. Also, there are other studies in the literature; conducted to evaluate the comfort properties of knitted fabrics/garments those could be useful for the design of cycling clothes. For example, Suganthi and Senthilkumar [20] examined the moisture management properties of 7 bilayer knitted fabrics composed of different raw materials. Ozkan and Kaplangiray [21] investigated the thermal comfort of 7 knitted fabrics that could be used for athletes' wear. Abreu et al [22] determined the thermal comfort properties of 3 knitted shirts that were suitable for sportswear. Wong and Yeung [23] organized wear trials for 8 knitted sportswear in order to evaluate their comfort properties.

The aim of this study was to create a design idea of a more functional and protective cycling clothing, by considering the user behaviours, experiences and requirements. For this purpose, firstly, an extensive survey was conducted to 500 cyclists in order to collect required information related to their current cycling clothes. In addition, information was collected about their accidental experiences in order to add protective segments on the clothing.

This study differs from the literature by collecting detailed information on cycling clothes about seam problems, visibility preferences, model preferences, comfort requirements and accidental issues and, as all this information was used to create smart solutions for cyclists.

2 MATERIALS AND METHODS

The survey containing 38 questions/statements were constructed according to an 8-step process [24]. According to this methodology, firstly, it was determined what the new information would be obtained from the survey. Then the most appropriate survey type and sampling method was determined. In the next steps, useful questions were constructed and conducted to cyclists via a plan. Then the data was analyzed and presented as tables, figures and mean values. Both the questions and data were controlled several times to avoid from errors.

The final survey form can be found in the Appendix. In the survey, information about the usage behaviors, model preferences, protection and visibility requirements, seam problems and accident experiences were collected in addition to some demographical information.

The survey was firstly tested on a small cyclist group to get feedbacks about the understandability of the questions. After revisions, the last version of the survey was conducted to cyclists utilizing Google Documents, between the dates of June-December 2019. Convenience sampling method was used as it was the least expensive and time consuming method [25]. According to the literature [26, 27], at least 384 participants should be taken where the target population is higher than 10 million. Therefore, in this study, data collection was completed when the total number of respondents reached 500 cyclists. All of the questions were answered by the respondents. The survey was conducted to cyclists in Turkey, including all geographical regions.

In the survey; Likert scale questions (in matrix form), multiple choice questions, Yes/No type questions and open-ended questions were used. Frequency values, means and plots of responses were compared to evaluate the results.

Table 1 Design methodology of cycling top wear

Requirements	Design properties	Materials and fabrication methods
Protection Functionality Usability Maintenance Wearability	Higher visibility function	LED application, colour selection
	Impact protection	Silicon and spacer paddings
	Protection against fall	High mechanical property raw materials
	Thermal and wet comfort	Use of meshed fabrics
	Form fitting	Use of elastane containing fabric
	Seam properties	Use of gusset to eliminate armpit seam
	Easy maintain	Detachable LEDs

For the clothing design, a user-centered approach was adopted for this work [28, 29]. As the design methodology, first 3 steps of the clothing design and development framework that was employed by Rajamanicham, Park and Jayaraman was utilized [30]. For this purpose, firstly, the requirements of our target group were detected by the aforementioned survey study. Then the design properties were formed. At the next step, suitable materials were selected. Details of the adapted design methodology for cycling wear design are summarized in Table 1. By using these principles, 2D flats were created containing alternatives. The cycling clothes were designed by using Designer 9 (Gerber, Artworks Expert). Patchwork design [31] of 4 kinds of fabrics was performed, including the usage of elastane containing polyester fabric, aramid fabric, meshed fabric and supportive spacer fabric, in order to enhance protection and comfort properties of the final design.

3 RESULTS AND CONCLUSIONS

3.1 Demographics and cycling behaviours

Age and gender information of respondents were taken as demographics. The age range of the respondents was 16-65 years old (mean: 34.5, st. dev.: 11.3) (Figure 1a).

The study covered a broad range of ages from 16 to 65. Therefore, the standard deviation was high. 87% of the respondents were male where 13% of respondents were female (Figure 1b). Also, 53% of respondents were licensed cyclists.

Cycling behaviours of respondents are given in Figure 2. According to Figure 2a, respondents used at least one of the 5 bicycle types. At least 30 respondents were taken from each bicycle types. 40% of respondents had been cycling for 7 years or more (Figure 2b). They trained cycling for different time intervals, weekly (Figure 2c). 71% of respondents cycled 2-4 h, non-stopping (Figure 2d). From all these behavioural information, it can be concluded that, respondents were well experienced on cycling.

3.2 Accidents related to cycling

Cycling injuries can be classified into 3 types, namely; traumatic, bicycle contact and overuse (chronic) injuries [32]. Traumatic injuries can be sourced from crashes with other vehicles or bicycles, from potholes, rocks, dogs, operator errors or by mechanical reasons [33]. In this study, traumatic injuries had been explored to reveal if any protection could be provided by altering cycling clothes' design and materials.

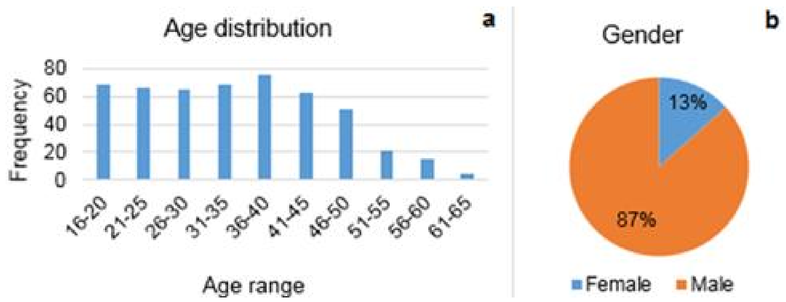


Figure 1 Demographics of respondents

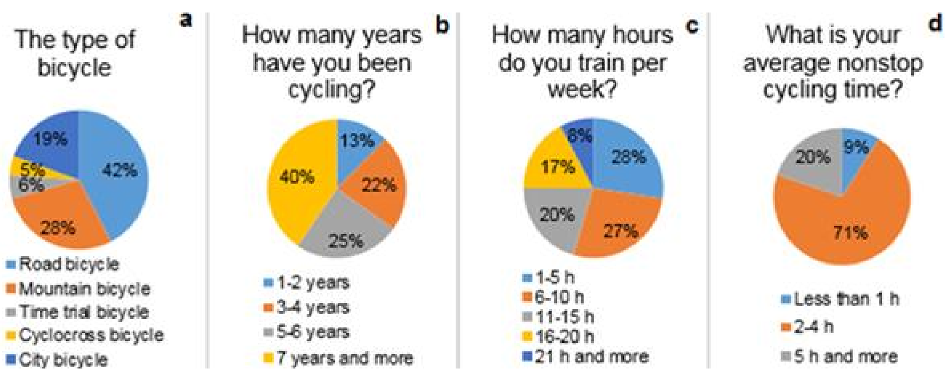


Figure 2 Cycling behaviours of respondents

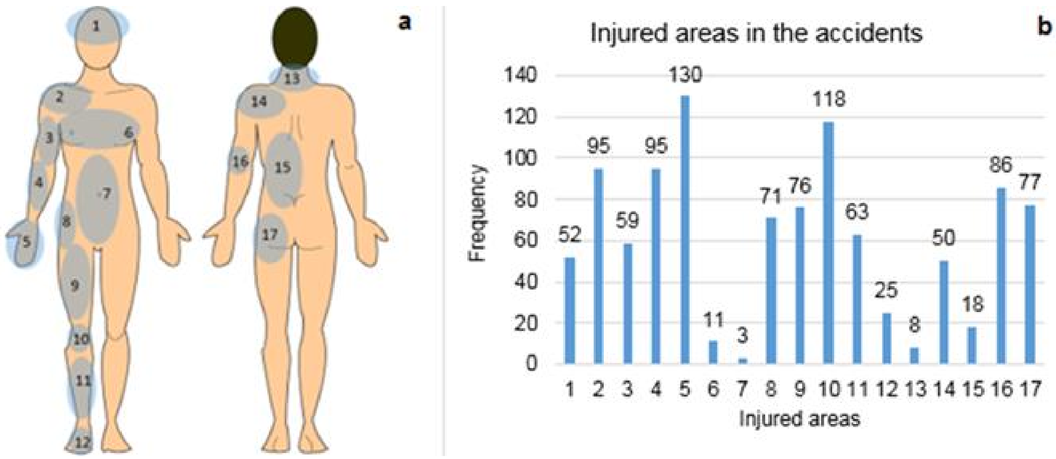


Figure 3 Injury areas of cyclists

According to the results, 59% of respondents stated that they experienced accidents during cycling.

The injured areas of the body were marked in Figure 3a.

The areas such as 2, 3, 4, 5, 15, 16 and 17 also covered "y" axis symmetry of the body. In Figure 3b, frequencies of the injured areas are given. According to results, most injured area was the hands area (26% of respondents) and it was followed by knees area (23.6%). Also almost 20% of the respondents were injured in the shoulders and lower arms area. The total number of upper arm (3), lower arm (4) and elbow (16) injuries was 240. The least injured areas were abdominals, chests and necks.

3.3 *Protection, visuality and comfort related requirements from cycling clothes*

Respondents mostly cycled in the summer season and under intense sunlight (Figure 4a). Nevertheless, 458 of them at least rarely cycled in the dark weather (Likert mean: 3.2). Also, 93% of respondents stated that they needed high visibility in the dark (Figure 4b). 464 cyclists increased their visibility by using bicycle lights and also 457 of them enhanced the visibility by using clothing (Figure 4c). Among the clothing visibility enhancements, using reflective fabrics was the most employed method (Figure 4d). Higher visibility can protect the cyclists from accidents; therefore, the safety of the cyclists can be enhanced [11, 34-36].

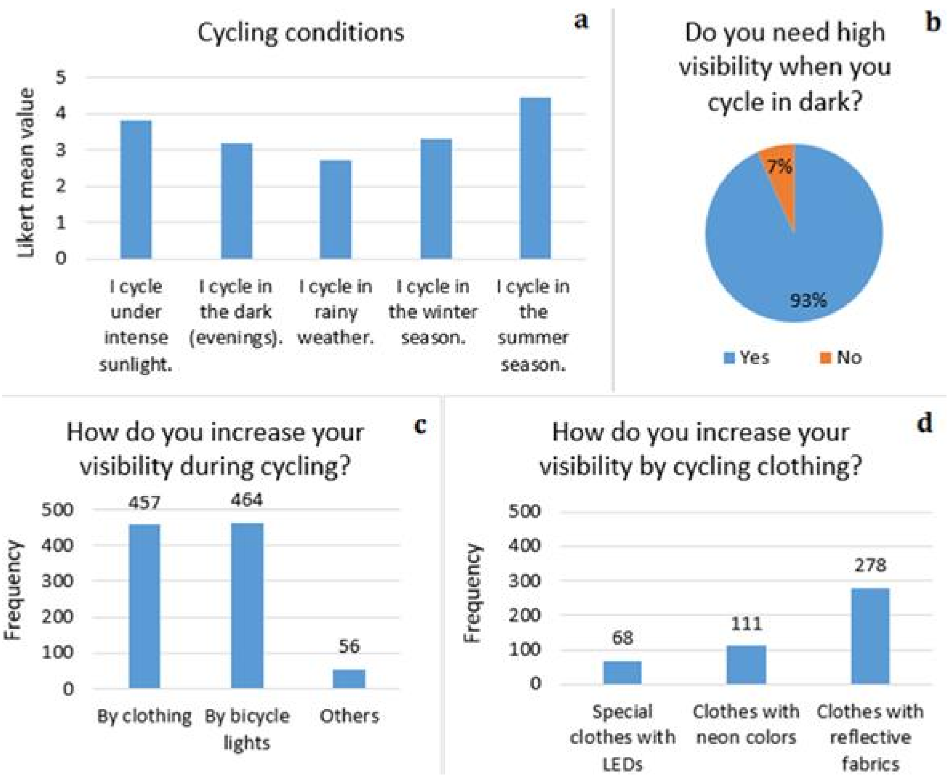


Figure 4 Visuality of cycling clothes

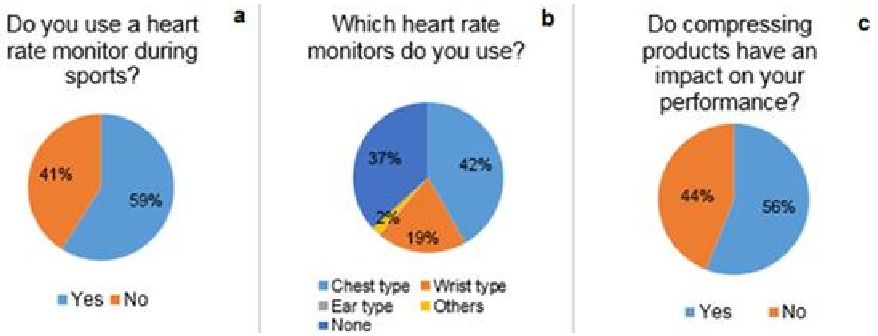


Figure 5 Functional options in cycling

Figure 6 Comfort needs of cyclists

59% of respondents used heart rate sensors during cycling (Figure 5a). Mostly, chest type sensors were used by respondents (Figure 5b). Also, 56% of respondents thought that compressing products could impact their performance (Figure 5c).

Comfort related requirements from cycling clothes were also questioned in the survey and the results are shown in Figure 6. Likert mean values for being thin, lightweight, air permeable, moisture permeable, fast drying and thermal insulator were higher than 4.4. The mostly desired comfort property of cycling clothing was drying fast (Likert mean: 4.8). It was followed by being lightweight, air permeable and moisture permeable at high levels (Likert mean: 4.7). In addition, comfort approaches of female and male cyclists were similar. The literature also supports the needs of moisture/heat transfer properties and lightweight of cycling clothes [37]. In addition, it was determined in a survey based study that the most common discomfort problems of cyclists were related to moisture and thermal discomfort sensation in their current clothes [2].

3.4 Seam problems of cycling clothes

Most of the respondents (75%) stated that they did not have seam problems (Figure 7a). The rest of the respondents experienced marks on their bodies along the seam lines, the most (Likert mean: 2.5). The seam related problems were detected in the armpit area on top wear and in crotch area on bottom wear (Figures 7c, 7d).

3.5 Cycling clothes preferences and maintenance behaviors

Cycling clothes preferences of respondents are given in Figure 8. According to Figure 8a, 59% of respondents wore M or L size clothes. 69% of respondents preferred fitted models instead of regular models (Figure 8b). 87% of respondents preferred cycling clothes with 3 or more pockets (Figure 8c). 73% of respondents preferred raglan armhole and 74% of respondents preferred full length zipper on the top wear (Figures 8d, 8f). Raglan armhole increases the movement range of shoulder and zipper provides easy take off of the clothes [37]. Collar preferences changed according to model (Figure 8e). Collar preferences may be up to the fashion. As the bottom clothes, almost half of the respondents preferred tights with straps while the rest half preferred tights without straps (Figure 8g). In Figure 8h, sleeve length preferences of respondents in both summer and winter time are presented. According to the figure, most of the respondents preferred short sleeve in summer time and long sleeve in winter time, rather than the other sleeve types such as sleeveless, elbow and ¾ sleeve lengths.

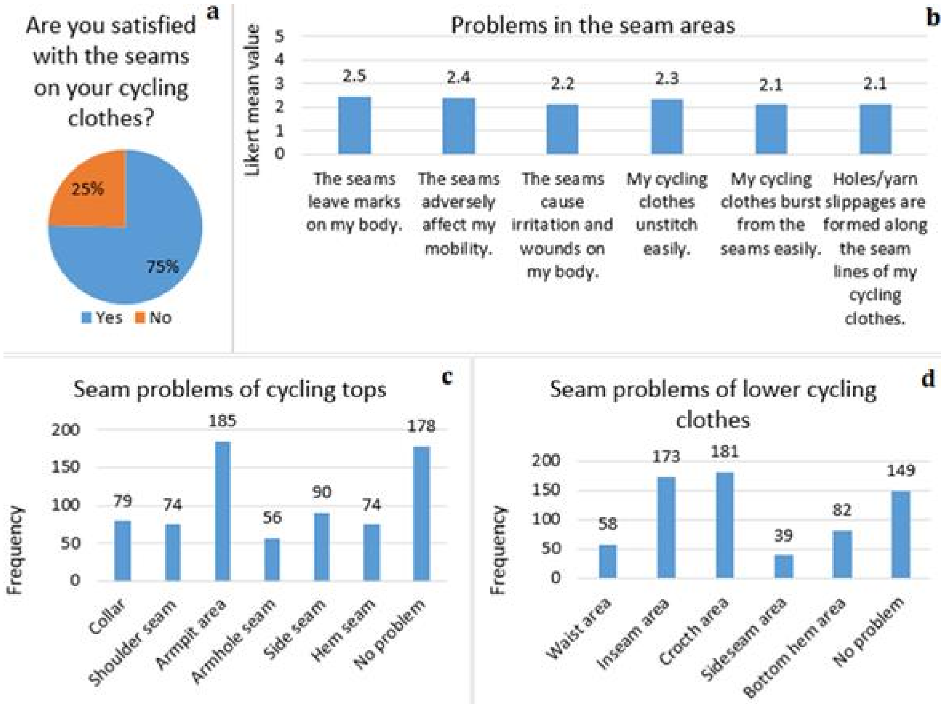


Figure 7 Seam related problems

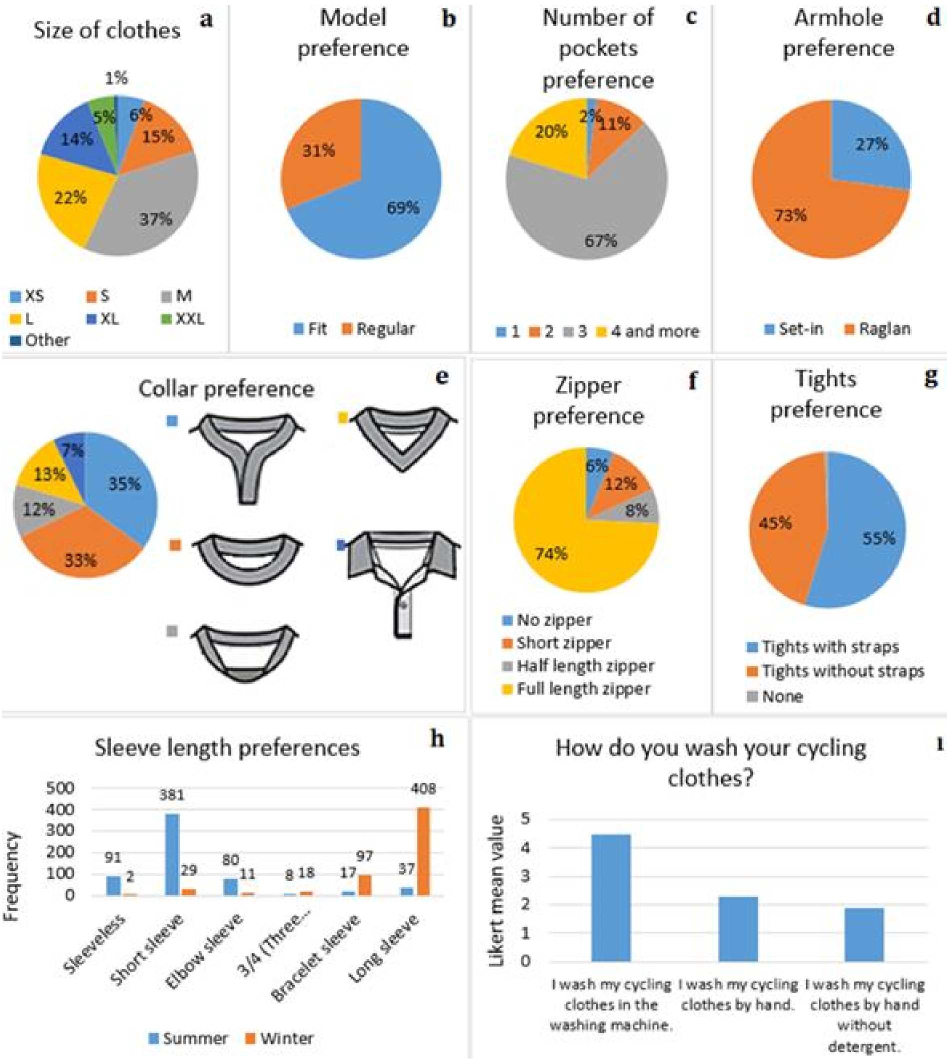


Figure 8 Cycling clothes preferences and maintenance

4 DISCUSSION AND CYCLING GARMENT DESIGN

Images of some commercial cycling top wears are given in Figure 9. By considering both the commercial products and survey results, a basic cycling top wear was designed as given in Figure 10. It is planned to be made of elastane containing knitted fabric. It is designed to be fit cut; it has 3 pockets, raglan armhole and full length zipper, according to clothing preferences of survey participants.

Figure 9 Images of commercial cycling wears. Products of a) Decathlon [41], b) Rapha [42], c) POC [43], d) Pedla [44]

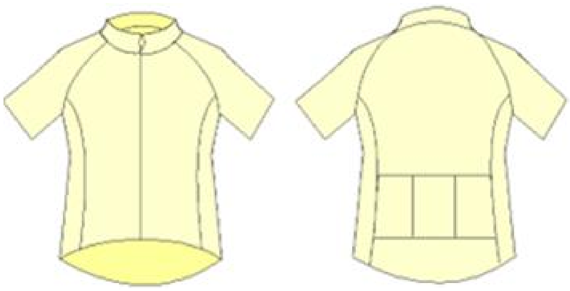


Figure 10 A classical one color cycling top wear (jersey)

Only in Turkey in the year of 2018, 8514 traffic accidents included bicycles and 125 cyclists died according to official statistics [38]. Therefore, in this study, information about both injuries in accidents and visibility preferences were collected to develop a clothing design that would provide extra protection to the wearer.

According to survey results, shoulders, elbows and arm area were the most injured areas that could be protected by the top wear. In order to provide protection to these areas, the outer side of the sleeve was designed to be supported with a spacer fabric and aramid fabric combination. As aramid fabric has high strength [39], it will be durable against cutting when the arm of the cyclist contact with the road in case of fall. So the exposure of the skin to the road will be inhibited and it is expected to prevent wounds. Short sleeve was not preferred because of the aramid support along the arm.

Also, the elbow and shoulder parts of the clothing was planned to be supported with additional knitted spacer pads in order to absorb the impact in case of fall.

For the ideal protection, weft knitted spacer fabrics with different thicknesses can be tested to determine their damping capability of impact [40]. Spacer fabrics can provide protection while maintaining lightweight.

Also, impact absorbing pads may be produced from silicon containing cushions, which have currently use in cycling shorts as given in Figure 11.

Figure 11 Silicone foam containing cycling short pad vs spacer fabric for soft padding: a) silicon sponge [45], b) spacer fabrics [46]

For the sleeve construction, different designs were developed and 5 of them are given in Figure 12.

In these designs, the coverage and patterns of aramid and spacer pads are altered. The designs of a, b and d were eliminated because of the voluminous structure of spacer pads. Those designs could result with reduced mobility and sewing problems in the curvy armhole places. Figure 12e was preferred as the final sleeve design as the spacer pads were placed in the target sides as shoulder and elbow. In addition, it was more advantageous by having less amount of expensive aramid fabric, when compared to design in Figure 12c.

To have an idea about the compatibility of knitted polyester fabric and aramid fabric, a sewing trial was performed. For this purpose, a knitted aramid fabric was sewn with a single-jersey polyester fabric by using 5 yarn overlock stitch as shown in Figure 13.

Two fabrics (aramid and polyester knitted fabrics) were found to be compatible in terms of sewability and stretching, also there were no visual problems along the seamline. Here, polyester was trialed because it is used in commercial cycling clothes, extensively. And the reason to support the polyester fabric with aramid was that the aramid fabrics had high mechanical properties. In the further studies, fabrics with different raw materials can be tested as alternatives. By considering these results and sketches, the final cycling top wear was designed as in Figure 14.

In the design, to eliminate the seam problems in the armpit area, a diamond gusset may be added as shown in top left side of Figure 14. Also, this gusset may be manufactured from meshed fabric in order to enhance the heat and moisture transfer from the armpit. The design can be used for cycling in dry weathers of spring or autumn seasons. Also, it can be used as an inner layer for winter season, too. For the summer season, the sleeve can be made of an elastane containing meshed fabric in order to improve the moisture and air permeability, to maintain both the protection and comfort at the same time (Figure 15).

The visibility of top wear was enhanced by using contrast and vivid neon colors and active LED supports. Most of the respondents stated that they did not use LEDs on their cycling clothes. Literature showed that the usage of flashing LEDS can improve the recognition of cyclist in the dark. Koo and Huang's study [13] suggested to put the flashing LEDs on the lower garment at hip, knee and ankle. But also, the LED configuration on the top wear took good scores. Therefore, for this study, LEDs' configurations were designed as given in Figure 14. An alternative LED configuration can be formed as in Figure 16. A LED array was planned to be placed in the front and back torso as given in figures. Also, a small pocket was added to carry the battery. Kgatuke et al [14] made a design by inserting LEDs in the weaving process. According to our survey results, most of the cyclists wash their clothes in washing machine, so, in this study, detachable LED arrays were proposed in the design to plug off easily before washing. The attachment of LED arrays may be enabled with Velcro or snap fasteners. A variant of this cloth might be designed with integrated gloves.

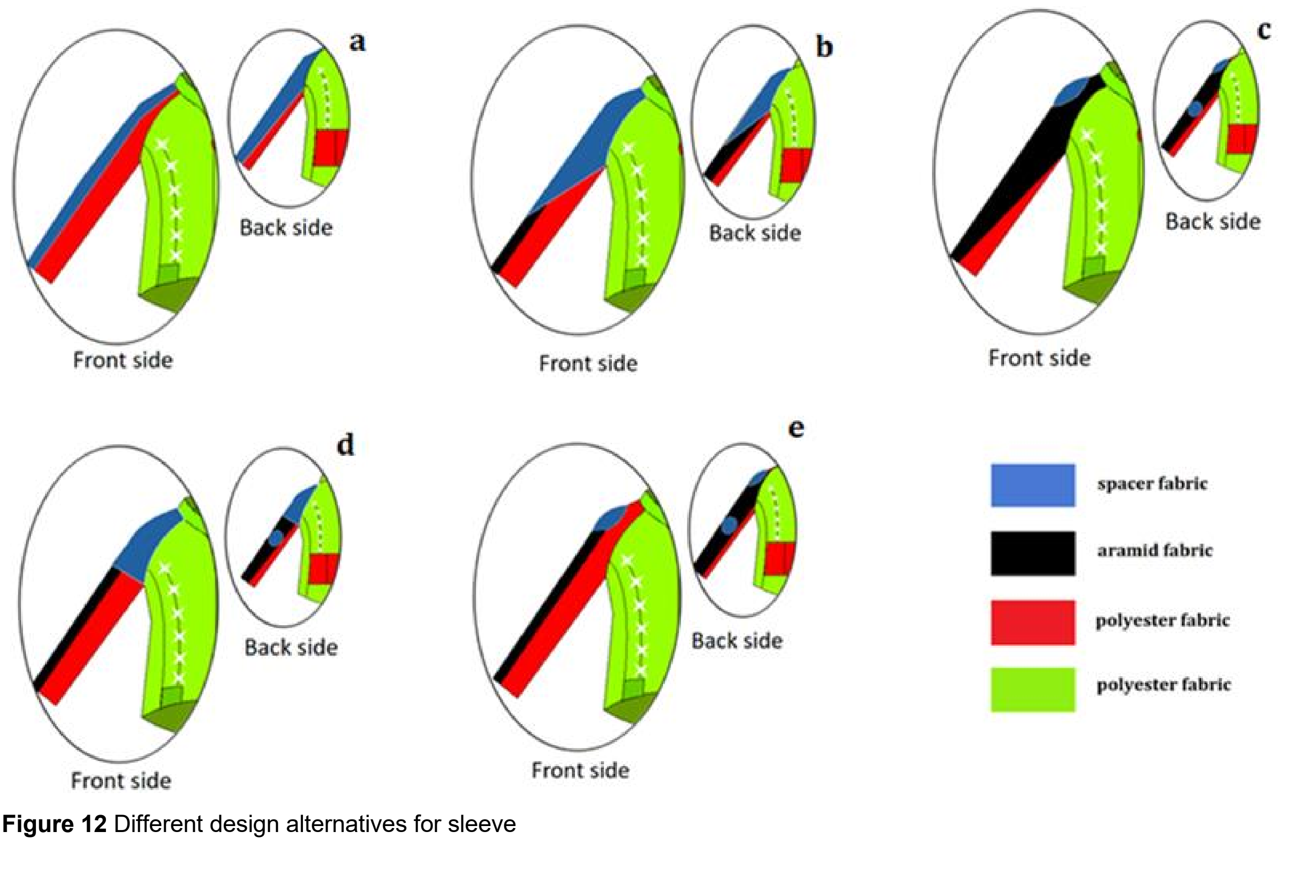


Figure 12 Different design alternatives for sleeve

Figure 13 Sewing trial of aramid fabric with polyester fabric

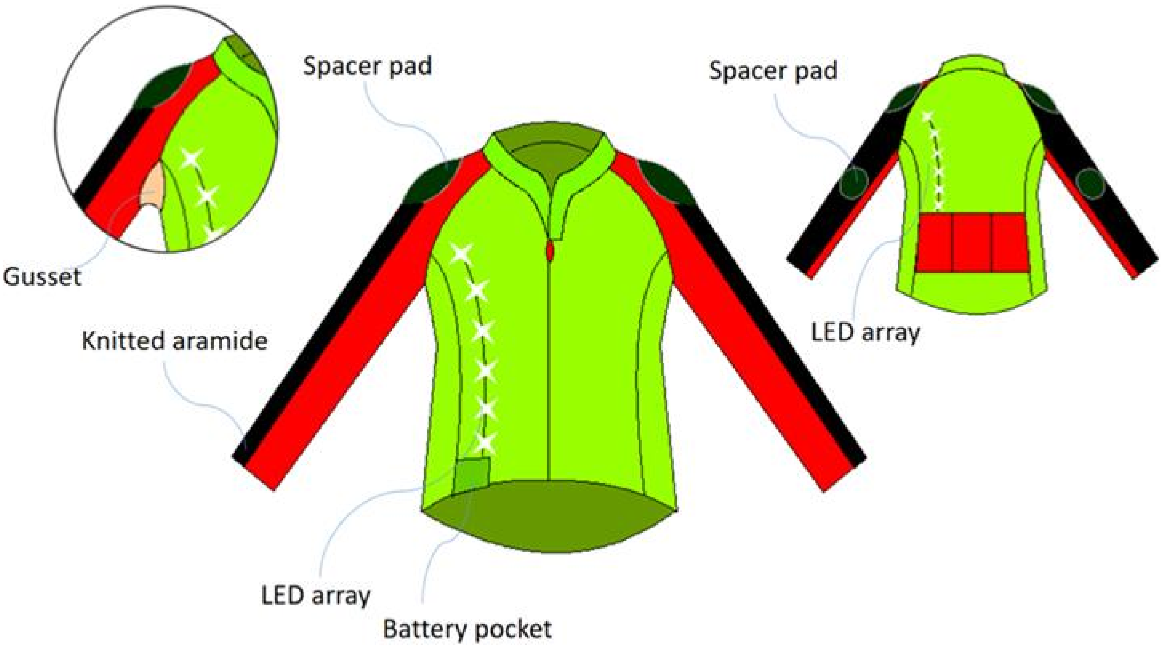


Figure 14 Design of a LED containing cycling jersey supported via aramid fabric and spacer pads

Figure 15 Design of the proposed cycling jersey with mesh sleeves for summer season

Figure 16 Design of the proposed cycling jersey with alternative LED arrangement

Additional important implications of this study can be summarized as below:

- More than half of the cyclists stated that they used heart rate sensors. 42% of the respondents used chest type heart rate sensors that should have high contact with the body. As an alternative, ear type heart rate sensors may be integrated to the cycling top wear as the authors realized for sailing garments in previous studies [47]. It can provide wear comfort and extra mobility to the cyclists.
- Cyclists have high expectations from their clothes in terms of physiological comfort. Moisture management finishing may enhance the comfort properties of cycling jerseys.
- There were no serious problems about the seams of cycling clothes. But some cyclists stated that, their seams left marks on their bodies. It is related to fit cut of cycling clothes those contact with body tightly. This problem can be solved by replacing sewn seams with taped seams. Taped seams provide a flat and smooth hand to the seam [48]. This can be applied along the straight side seams or lowly curved seams as it is harder to apply welding tapes in highly curved areas such as crotch and armpit seams.

5 CONCLUSION

Within the context of this study, an extensive survey research was performed to collect essential information to create the design idea of a more functional and protective cycling cloth. By considering survey results and literature search, 2D flats of protective cycling top wears were created as proposals.

For the design development process, patchwork design approach was found advantageous in obtaining protective clothing that also exhibited high level of comfort. In the designs, 4 types of textile structures, namely elastane containing knitted polyester fabric, knitted aramid fabric, meshed polyester fabric and spacer fabrics, were combined together by considering their general properties. In the further studies, material alternatives are planned to be tested for the selection of the best combinations.

In addition, detachable LED configurations were found suitable for visibility enhancement and easy maintaining.

In the further studies, the cycling cloth designs can be realized and wear trials can be done for long term studies. This study is expected to help the cycling clothes producers by revealing real problems and requirements of cyclists from their clothes. Also, it is expected to sketch a new perspective for the design of protective cycling clothes.

6 REFERENCES

1. Downer E.F., Cassidy T.D.: Cycle clothing from a lifestyle perspective in the UK's contemporary marketplace, International Journal of Fashion Design, Technology and Education 5(1), 2012, pp. 33-43, https://doi.org/10.1080/17543266.2011.597786
2. Teyeme Y.W., Malengier B., Tesfaye T., et al.: An empirical analysis of potential cyclist injuries and cycling outfit comfort, Journal of Textile Science and Fashion Technology 4(1), 2019, pp. 1-10, DOI: 10.33552/JTSFT.2019.04.000578
3. Vuruskan A., Ashdown S.P.: Fit analyses of bicycle clothing in active body poses, Proceedings of International Textile and Apparel Association Annual Conference 73(1), 2016, Iowa State University Digital Press
4. Liu K., Kamalha E., Wang J., Agrawal T.K.: Optimization design of cycling clothes' patterns based on digital clothing pressures, Fibers and Polymers 17(9), 2016, pp. 1522-1529, https://doi.org/10.1007/s12221-016-6402-2

5. Hayes S.G., Venkatraman P. (Eds.): Materials and Technology for Sportswear and Performance Apparel, CRC Press, 2018, 372 p., ISBN: 13: 978-1138748354
6. Oglakcıoglu N., Illeez A.A., Erdogan M.Ç., et al.: Effects of sewing process on thermal comfort properties of cycling clothes, Journal of Textiles and Engineer 20(90), 2013, pp. 32-41, https://doi.org/10.7216/130075992013209004
7. Vuruskan A., Ashdown S.P.: Development of half scale dress forms in active body positions for bicycle clothing design and fit, Proceedings of International Textile and Apparel Association Annual Conference 72(1), 2015, Iowa State University Digital Press
8. Leoz-Abaurrea I., Aguado-Jimenez R.: Upper body compression garment: physiological effects while cycling in a hot environment, Wilderness & Environmental Medicine 28(2), 2017, pp. 94-100, https://doi.org/10.1016/j.wem.2017.02.005
9. Brighenti A., Bortolan L., Savoldelli A., et al.: Effect of new type of compression garments on sub-maximal and maximal cycling performance in the heat (32°C), Sport Sciences for Health 9(3), 2013, pp. 127-131, https://doi.org/10.1007/s11332-013-0158-5
10. Hintzy F., Gregoire N., Samozino P., et al.: Effect of thigh-compression shorts on muscle activity and soft-tissue vibration during cycling, The Journal of Strength and Conditioning Research 33(8), 2019, pp. 2145-2152, DOI: 10.1519/JSC.0000000000002402
11. Lahrmann H., Madsen T.K.O., Olesen A.V., et al.: The effect of a yellow bicycle jacket on cyclist accidents, Safety Science 108, 2018, pp. 209-217, https://doi.org/10.1016/j.ssci.2017.08.001
12. Lee J.K.: Design: Lady Harberton: an interactive cycling outfit incorporating solar powered LED sensor lights, Proceedings of the 2018 ACM International Symposium on Wearable Computers, 2018, pp. 266-271, https://doi.org/10.1145/3267242.3267299
13. Koo H.S., Huang X.: Visibility aid cycling clothing: flashing light-emitting diode (FLED) configurations, International Journal of Clothing Science and Technology 27(3), 2015, 460-471, https://doi.org/10.1108/IJCST-09-2014-0104
14. Kgatuke M., Hardy D., Townsend K., et al.: Exploring the role of textile craft practice in interdisciplinary e-textiles development through the design of an illuminated safety cycling jacket, Proceedings 32(1), 2019, p. 12, https://doi.org/10.3390/proceedings2019032012
15. Paiva A., Vieira D., Cunha J., et al: Design of a smart garment for cycling. Proceedings of International Conference on Innovation, Engineering and Entrepreneurship, HELIX 2018. Lecture Notes in Electrical Engineering 505, 2018, pp. 229-235, https://doi.org/10.1007/978-3-319-91334-6_32
16. Qiu C., Hu Y.: The research on the design of outdoor sports monitoring function cycling jerseys, European Journal of Business and Social Sciences 4(02), 2015, pp. 180-189
17. Vuruskan A.: Customers' perspectives on fit and customization of cycling sportswear: Cross-national comparison, Journal of Textile and Apparel (Tekstil ve Konfeksiyon) 29(2), 2019, pp. 142-151, https://doi.org/10.32710/tekstilvekonfeksiyon.488284
18. Teyeme Y.W., Malengier B., Tesfaye T, et al.: Comfort evaluation of cyclists jerseys using wear trial test, Tekstilec 63(4), 2020, pp. 263-275, https://doi.org/10.14502/Tekstilec2020.64.263-275
19. Kwon Ch.R., Kim D.E.: Development of women's cycle wear top with improved function, Fashion & Textile Research Journal 21(1), 2019, pp. 75-87, https://doi.org/10.5805/sfti.2019.21.1.75
20. Suganthi T., Senthilkumar P.: Moisture-management properties of bi-layer knitted fabrics for sportswear, Journal of Industrial Textiles 47(7), 2018, pp. 1447-1463, https://doi.org/10.1177/1528083717692594
21. Ozkan E.T., Kaplangiray B.: Investigating thermophysiological comfort properties of fabrics used in athlete clothes, Journal of Fashion Technology and Textile Engineering 8(3), 2020
22. Abreu M.J.A., Catarino A.P., Cardoso C., Martin E.: Effects of sportswear design on thermal comfort, Proceedings of AUTEX 2011 Conference, 8-10th June 2011, Mulhouse, France, pp. 50-55
23. Wong A.S.W., Li Y., Yeung K.W.: The influence of thermal comfort perception on consumer's preferences to sportswear, Elsevier Ergonomics Book Series 3, 2005, pp, 321-328, https://doi.org/10.1016/S1572-347X(05)80051-5
24. Bas T.: How to prepare a survey? (Anket Nasıl Hazırlanır?) Publisher: Seçkin Yayıncılık, Turkey, 2008, ISBN-13: 978-9750224362 (in Turkish)
25. Atasagun H.G., Oner E., Boyacı B., Okur A.: Underwear purchasing behavior of Turkish consumers and a quality function deployment application, Journal of Textiles and Engineer (Tekstil ve Mühendis) 26(114), 2019, pp. 168-175, https://doi.org/10.7216/1300759920192611406
26. Coskun R., Altunısık R., Yildirim E.: Research Methods in Social Sciences (Sosyal Bilimlerde Araştirma Yöntemleri), 9th ed., Sakarya Kitabevi, Turkey, 2017, ISBN: 9786054229710 (in Turkish)
27. Malhotra N., Birks D.: Marketing Research: An Applied Approach, 3rd ed., Prentice Hall/Financial Times, England, 2007, 835 p., ISBN: 9780273706892
28. Ariyatum B., Holland R., Harrison D., Kazi T.: The future design direction of smart clothing development, The Journal of The Textile Institute 96(4), 2005, pp. 199-210, https://doi.org/10.1533/joti.2004.0071
29. Chun-yan Q., Hu Y.: The review of smart clothing design research based on the concept of 3F+ 1I, International Journal of Business and Social Science 6(1), 2015, pp. 199-208
30. Rajamanickam R., Park S., Jayaraman S.: A structured methodology for the design and development of textile structures in a concurrent engineering framework, Journal of the Textile Institute 89(3), 1998, pp. 44-62, https://doi.org/10.1080/00405009808658682
31. Shishoo R. (Ed.): Textiles in Sport, 1st ed., Woodhead Publishing, 2005, ISBN: 9781855739222
32. Silberman M.R.: Bicycling injuries, Current Sports Medicine Reports 12(5), 2013, pp. 337-345, https://doi.org/10.1249/JSR.0b013e3182a4bab7
33. Baker A.: Traumatic bicycle injuries in a Masters club, Traumatic Injuries 200, 2003, pp. 1-8

34. Schwellnus M.P., Derman E.W.: Common injuries in cycling: Prevention, diagnosis and management, South African Family Practice 47(7), 2005, pp. 14-19, https://doi.org/10.1080/20786204.2005.10873255
35. Kwan I., Mapstone J.: Visibility aids for pedestrians and cyclists: a systematic review of randomised controlled trials, Accident Analysis and Prevention 36(3), 2004, pp. 305-312, https://doi.org/10.1016/S0001-4575(03)00008-3
36. Hagel B.E., Romanow N.T.R., Morgunov N., et al.: The relationship between visibility aid use and motor vehicle related injuries among bicyclists presenting to emergency departments, Accident Analysis and Prevention 65, 2014, pp. 85-96, https://doi.org/10.1016/j.aap.2013.12.014
37. Kun Z., Yanzhen W.: Research on bicycle riding clothes, Science Research 3(5), 2015, pp. 252-255, doi: 10.11648/j.sr.20150305.13
38. Turkey traffic accidents summary, 2019, https://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Trafik/TrafikKazalariOzeti2018.pdf
39. Mollaei A., Ahmadi M.S.: Effect of structural parameters on the cut resistance of para-aramid and ultra-high molecular weight polyethylene weft knitted fabrics, The Journal of The Textile Institute 111(5), 2020, 639-645, https://doi.org/10.1080/00405000.2019.1656700
40. Liu Y., Hu H., Long H., et al.: Impact compressive behavior of warp-knitted spacer fabrics for protective applications, Textile Research Journal 82(8), 2012, pp. 773-788, https://doi.org/10.1177/0040517511433147
41. Decathlon, access date: 09.10.2020, https://www.decathlon.com.tr/rc100-vib-forma-id_8572626.html
42. Rapha, access date: 09.10.2020, https://www.rapha.cc/eu/en/shop/mens-pro-team-training-jersey/product/PTT02SSCBF
43. Poc Sports, access date: 09.10.2020, https://www.pocsports.com/eu/essential-road-light-jersey/58212.html?dwvar_58212_color=Granite%20Grey%2FZink%20Orange&cgid=cycling-jerseys#slide0
44. Pedla, access date: 09.10.2020, https://thepedla.com/collections/mens-jerseys/products/lana-merino-ls-jersey-black
45. Silicon sponge, access date: 09.10.2020, https://shopee.com.my/Cycling-Shorts-Padded-Pants-Silicone-sponge-breathable-thickening-3D-Bicycle-Riding-Men-Women-Bike-shorts-Berbasikal-Seluar-pendek-i.10967596.391430031
46. Spacer fabrics, access date: 09.10.2020, https://www.vomatex.de/3DSpacerFabrics.html
47. Kara S., Yesilpinar S., Senol Y., et al.: Design of an electronically equipped sailing garment for improved safety, Industria Textila 68(1), 2017, pp. 23-30
48. Jana P.: Assembling technologies for functional garments - An overview, Indian Journal of Fibre and Textile Research 36, 2011, pp. 380-387

7 APPENDIX

Survey Form

DESIGN OF A CYCLING TOPWEAR

Age:
Gender:

What type of bicycle do you use?
- ☐ Road bicycle
- ☐ Mountain bicycle
- ☐ Time trial bicycle
- ☐ Cyclocross bicycle
- ☐ City bicycle

How many years have you been cycling?
- ☐ 1-2 years
- ☐ 3-4 years
- ☐ 5-6 years
- ☐ 7 years and more

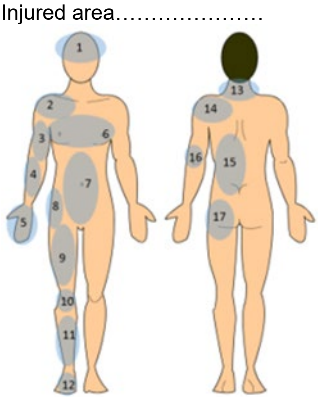
How many hours do you train per week?
- ☐ 1-5 h
- ☐ 6-10 h
- ☐ 11-15 h
- ☐ 16-20 h
- ☐ 21 h and more

What is your average nonstop cycling time?
- ☐ Less than 1 h
- ☐ 2-4 h
- ☐ 5 h and more

Are you a licensed cyclist?
- ☐ Yes
- ☐ No

Did you experience any accidents during cycling?
- ☐ Yes
- ☐ No

Please indicate the injured areas in the accidents?
Injured area…………………



How long do you wear your cycling clothes?
- ☐ 1 year
- ☐ 2-3 years
- ☐ 4 years and more
- ☐ Until it becomes unusable due to accidents, etc.

What is your size of clothing?
- ☐ XS
- ☐ S
- ☐ M
- ☐ L
- ☐ XL
- ☐ XXL
- ☐ Other

What is your model preference for your cycling clothes?
- ☐ Fit
- ☐ Regular

How many pockets do you prefer on your cycling clothes?
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4 and more

Do you need high visibility when you cycle in dark?
- ☐ Yes
- ☐ No

What are the materials you use to increase visibility?
- ☐ Special clothes with LEDs
- ☐ Clothes with neon colors
- ☐ Clothes with reflective fabrics
- ☐ Bicycle lights
- ☐ Others

Do you use a heart rate monitor during sports?
- ☐ Yes
- ☐ No

Which type of heart rate monitor do you use?
- ☐ Chest type
- ☐ Wrist type
- ☐ Ear type
- ☐ Others
- ☐ None

Do you think that compressing products have an impact on your performance?
- ☐ Yes
- ☐ No

Are you satisfied with the stitches on your cycling clothes?
- ☐ Yes
- ☐ No

Please indicate your agreement degree to the statements below.

Properties of cycling clothes	Strongly agree (5)	Agree (4)	Undecided (3)	Disagree (2)	Strongly disagree (1)
My cycling clothes should be thin					
My cycling clothes should be lightweight					
My cycling clothes should dry fast					
The thermal insulation of my cycling clothes should be good					
The air permeability of my cycling clothes should be high					
The moisture permeability of my cycling clothes should be high					

How do you wash your cycling clothes?

Washing behaviour	Always (5)	Often (4)	Sometimes (3)	Rarely (2)	Never (1)
I wash my cycling clothes in the washing machine					
I wash my cycling clothes by hand					
I wash my cycling clothes by hand without detergent					

Please indicate the weather conditions you cycle.

Weather conditions	Always (5)	Often (4)	Sometimes (3)	Rarely (2)	Never (1)
I cycle under intense sunlight.					
I cycle in the dark (evenings).					
I cycle in rainy weather.					
I cycle in the winter season.					
I cycle in the summer season.					

Please indicate the problems you experience with the sewn places of your cycling clothes.

Sewing problems	Always	Often	Sometimes	Rarely	Never
The seams leave marks on my body					
The seams adversely affect my mobility					
The seams cause irritation and wounds on my body					
My cycling clothes unstitch easily					
My cycling clothes burst from the seams easily					
Holes/yarn slippages are formed along the seam lines of my cycling clothes					

Indicate the areas where you have the most seam problems with your cycling top clothes.

- ☐ Collar
- ☐ Shoulder seam
- ☐ Armpit area
- ☐ Armhole seam
- ☐ Side seam
- ☐ Hem seam
- ☐ No problem

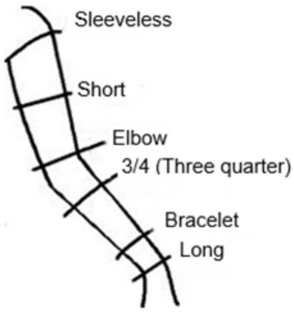
Indicate the areas where we have the most seam problems with your lower cycling clothes.

- ☐ Waist area
- ☐ Inseam area
- ☐ Crotch area
- ☐ Sideseam area
- ☐ Bottom hem area
- ☐ No problem

Which cycling tights do you prefer?

- ☐ Tights with straps

- ☐ Tights without straps



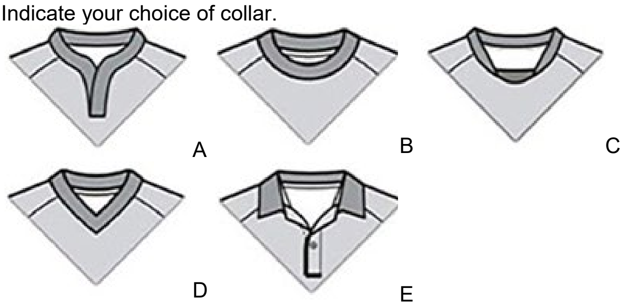
Which sleeve length do you prefer in the SUMMER season?

- ☐ Sleeveless
- ☐ Short sleeve
- ☐ Elbow sleeve
- ☐ 3/4 (Three quarter) sleeve
- ☐ Bracelet sleeve
- ☐ Long sleeve

Which sleeve length do you prefer in the WINTER season?

- ☐ Sleeveless
- ☐ Short sleeve
- ☐ Elbow sleeve
- ☐ 3/4 (Three quarter) sleeve
- ☐ Bracelet sleeve
- ☐ Long sleeve

Indicate your choice of collar.



Indicate your choice of armhole.

- ☐ Set-in
- ☐ Raglan

Indicate your choice of zipper.

- ☐ No zipper
- ☐ Short zipper
- ☐ Half-length zipper
- ☐ Full-length zipper

IMPROVEMENT OF THE METHODOLOGY FOR ASSESSING THE CLOTHING PSYCHOLOGICAL COMFORT USING SEMANTIC DIFFERENTIAL

Svetlana Kuleshova, Oksana Zakharkevich, Julia Koshevko and Galyna Shvets

Khmelnitskyi National University, Department of Technology and Design of Garments
Institytska str. 11, 29016 Khmelnitskyi, Ukraine
kuleshova_lana@ukr.net; zbir_vukladach@ukr.net; juliakoshevko@gmail.com

Abstract: *The aim of the paper is to present the improvements of the methodology for assessing the clothing psychological comfort by using semantic differential. The differential allows one to achieve high quality of garments. It is assured by using the prototype expert system for selection of clothes according to the consumer's wishes on the basis of the methodology of Kansei engineering. The list of characteristics of the ideal clothing model was formed on the basis of theoretical research in the field of psychological comfort of clothing. The performed ranking of characteristics allows calculating of the coefficients of psychological comfort. A questionnaire for assessing the psychological comfort of clothing consists of semantic differential scales for each characteristic. The assessment based on the results of a survey has been performed by using the developed questionnaire. Improved process of the assessment of psychological comfort of sewing products allows one to form a new approach to the modern quality management system. Application of the presented methodology will further improve the process of developing an individual style in clothing.*

Keywords: *psychological comfort, psychographic segmentation, ideal clothing model, semantic differential, fashion dresses, harmonized dress.*

1 INTRODUCTION

Designing of sewing products has a number of specific features that distinguish it from the design of other technical objects. The problem of designing modern clothing is more complicated, because it is directly related to a person. That is why one of the specific features of clothing design is the importance of scientific reflection on the need to take into account the impression of clothing. Visual perception of models, collections, individual products and individual constructive elements by different groups of consumers must be taken into account [1].

The study and forecast of demand for projected models without the use of psychological methods, mainly sociological surveys, leads to unexplored system of consumer perception and, in the end, considerable economic losses in designing [2].

It is known that the first emotions of clothes received by a person during the first time seeing clothes and its elements. This usually happens when you meet a product in the process of testing. After that emotions are tested in the process of wearing clothes. Impressions of clothing may change. The difference in the sensual perception of clothing at the stages "seen - trying" can induce the purchase of clothes or refusal to buy. In this case, the designer affects the result of perceiving the product of its activities at various stages [3]. Thus, the problems of the area of consumer quality of clothing can be formulated as follows:

1) the problems of studying and evaluating various aspects of the perception of clothing by consumers;
2) the problems of deepening the concept of comfort clothing to the level of psychological comfort in the senses.

It becomes apparent that the psychological comfort of a garment can only be achieved if the psychological characteristics of the individual are taken into account. It might be achieved by studying the peculiarities of the impression of clothing in consumer groups. The study will help to determine the overall quality of products for the consumer.

2 ANALYSIS OF PUBLISHED DATA AND STATING THE PROBLEM

The basic requirement of clothing is that it must not cause discomfort for the wearer. Modern consumers are interested in clothing that not only looks good but also feels good. It has been identified, by both natural and synthetic fiber markers, that consumers are increasingly involving more than their visual sense and are allowing touch, smell, intuition and emotion to influence their decisions.

As a result, greater importance being attributed to the shopping and wearing experience interest is growing in better feeling fabrics. Comfort is being reinforced a key parameter in clothing. Good health is a treasure. The textiles are making human life, a natural healthy life and making it comfortable.

Comfort has been identified by major fiber marketers as one of the key attributes for consumer's desirability on apparel products in all markets. Comfort as a pleasant state of physiological, psychological and physical harmony between a human being and the environment. Physiological comfort is related to the human body's ability to maintain life, psychological comfort to the mind's ability to keep it functioning satisfactorily with external help and physical comfort to the effect of the external environment on the body.

Clothing as a near environment of the human body plays a vital role in achieving human comfort and over the past few decades, extensive and systematic investigations of clothing comfort, function, and ergonomics have been conducted, specifically with protective clothing.

A great part of the researchers agrees that comfort is a multidimensional and subjective experience. The author [4] was one of the first ones to acknowledge the clothing comfort as a complex phenomenon, which comprises at least 3 dimensions: the physical, the physiological and the psychological. The mechanisms and underlying principles associated with human physiological needs, comfort attributes of clothing, and their interaction with a variety of environments have been formalized and established. The author does not propose a specific method of assessing psychological comfort. Parameters that should be considered when assessing this measure of comfort were not specified either.

The authors [5, 6] have proposed a clothing comfort concept and a clothing comfort model. According to them, the clothing comfort is "a state of satisfaction indicating physiological, social-psychological and physical balance among a person, his/her clothing, and his/her environment." The theoretical model proposed by [5, 6] is crucial to understanding the importance of the psychological aspect of comfort. However, authors intended that those attributes must be discussed and refined in the future works. Therefore, current work is aimed at becoming the next step in developing the concept of improving the psychological comfort of garments based on the emotional component in the perception of the clothing model. The main idea is to combine such approaches as semantic differential methods and methods of evaluation of the level of harmonization of clothes. The model proposed by [7] contains a list of the attributes associated with the social-psychological dimension that is divided according to the clothing comfort triad (person, clothing, environment). Despite believing that all three components of the triad have a social-psychological dimension, all of these attributes are neither well agreed upon by researchers nor well elucidated in the literature.

The technology [8] opens the possibilities for smart multifunctional clothing systems. This has led researchers to explore various approaches to improving wearing comfort and trying to understand thermo physiological processes. The wearing comfort itself is differentiated in four categories: thermo-physiological comfort, sensorial comfort, ergonomic comfort, psychological comfort as well as aesthetic appeal. The paper [9] describes the evaluation of thermal comfort through measurement of the physiological and psychological responses to changes in the microclimate surrounding the human body. But in the context of clothing, there has been a focus mainly from a physical-mechanical and/or physiological point of view. Little consideration was given for the more subjective aspects such as the aesthetic and emotional ones.

Psychological comfort is a positive evaluation of the product, which is made on the basis of the integration of the comfortable feelings of the various modalities and the individual acceptance of the product by the consumer [5]. In this manner the psychological comfort of clothing is still poorly studied, but it is a very valuable indicator, which in most cases determines the choice of the consumer. Its neglect can lead to significant economic losses in the implementation of clothing models, as the provision of optimal physiological indicators does not always contribute to the rapid implementation of products. The study of the effect obtained in the product allows one to withstand competition, which is especially important for small businesses in a saturated market. A method of determining psychological comfort might be used to study the requirements for clothing along with the results of targeted marketing.

This document presents a continuation of research [10, 11]. They were held with a purpose to develop a method to assess the clothing comfort with taking into account physical parameters such as temperature and humidity space between the fabric of garment and the human body. As a result of the research authors aim to develop the indices to select the garment, which would be advisable to wear in some environmental conditions by certain person, who is described by their psychological preferences and certain body type.

3 THE PURPOSE AND OBJECTIVES OF THE STUDY

The aim of this study is to improve the clothing design process by ensuring the consumer psychological comfort by creating a harmonious image of garment visual perception. In order to achieve this goal it is necessary to solve the following tasks:

- theoretical and analytical research of consumers population segmentation by their relations to clothes;
- study of the emotional component of psychological comfort, the definition of its significant characteristics in the visual perception of the model of clothing;
- improving the methodology for assessing the clothing psychological comfort on the base of visual perception in the process of artistic design using semantic differential (SD) of the impression from outfit.

4 MATERIALS AND METHODS

4.1 Theoretical and analytical research of consumer segmentation by their relation to clothes

Companies make products in order to fulfil the needs and wants of a customer. There is a constant requirement for a customer for buying new products or services, and these wants keep on evolving and changing with age, income etc. This is directly related to the human psychology or psychographics of a customer. Thus, if a company is able to understand the customer's psychology, it can target them better with the products and services. In these cases, psychographic segmentation is extremely critical for a company [12].

Psychographic segmentation complements demographic and socioeconomic segmentation to explain and predict consumer behavior. Insights from psychographic segmentation enable marketers to understand consumers' decision-making processes better and more efficiently target audiences with highly-relevant messaging to influence their responses to marketing, brands, products or services [13, 14].

For urgent response to the needs of the fashion market we summarized consumer's psychographic portraits. The results of the research described in [12-15] were taking into account while summarizing the portraits. The classification is basically segmentation of the total market by attributes of psychology, activities, interests, opinions, personality traits of people, lifestyle, values and attitudes. The proposed classification helps identify consumers based on how they think, focusing on customer psychology (Table 1).

The mathematical description of the connections in groups *A*, *B*, *C* (in the Table 1) is presented by following expression:

$$A \equiv Cl \in \left\{ Cl^{ec}, Cl^{cr}, Cl^{ser} \right\}, \tag{1}$$

where: *Cl* – consumer class, Cl^{ec} – economic class, Cl^{cr} – creative class, Cl^{ser} – serving class.

$$B \equiv Ps^{p} \supseteq Ps_{cl} \cup Pst_{cl} \cup Bv_{cl} \tag{2}$$

where: Ps^p – psychological portrait of a consumer; Ps_{cl} – psychological peculiarities of the personality of a class representative; Pst_{cl} – category of a psychotype of the class representative; Bv_{cl} – basic values of the class.

$$C \equiv Ps^{b} \supseteq L_{cl}^{Sd} \cup L_{cl}^{R} \cup L_{cl}^{F} \cup L_{cl}^{E} \cup L_{cl}^{V} \tag{3}$$

where: Ps^b – psychological peculiarities of the consumer's behaviour; L_{cl}^{Sd} – socio-demographic level of the class; L_{cl}^{R} – rational level of the class; L_{cl}^{F} – functional level of the class; L_{cl}^{E} – emotional level of the class; L_{cl}^{V} – value level of the class.

A set of characteristics of the group A, which describes elements of the groups B and C, is a cortege:

$$Cl = \left\langle n_{c1} n_{cm1} b_{v1} r_1, \ldots, n_{ci} n_{cmj} b_{vn} r_m \right\rangle \tag{4}$$

where: n_{ci} – psychological peculiarities of the person; *i* – the number of descriptive characteristics of the psychological characteristics of the individual; n_{cmj} – category of a psychotype; *j* – number of descriptive characteristics of the categories of a psychotype; b_v – basic values; *n* – number of descriptive characteristics of the basic values; r_m – consumer reaction when choosing a fashion product; *m* – number of descriptive characteristics of the reactions of a consumer.

Table 1 Class stratification of consumer's psychographic portraits

Consumer characteristics groups			
A	***B***		***C***
Class characteristic	***Categories of psychotypes***	***Basic values***	***Behaviour (criteria for choosing a fashion product)***
Economic class: participates in the creation and circulation of capital	Careerists (purposeful pragmatists) Imitators	Material success Social status Career, achievement	Status (limited reach) Aesthetics (stylishness) Prestige(a high quality)
Creative class: creates new ideas, products, technologies, a new creative sense	Independent - Innovators Hedonists	Self-development Interesting job, freedom of choice	Individuality Novelty (originality) Expressiveness (conceptuality)
Serving class: provides support for the creation of economic and creative values	Intellectuals (traditionalists)	Stable work Decent wage Satisfactory vacation	Availability (moderate prices) Familiarity (widespread) Acceptability (adaptability)

On the vertical of the triad model, the process of forming the type of consumer based on psychological characteristics (C^{PS}) describes the cross sections of subsets of characteristic groups:

$$C^{PS} \supset Cl \cap Psp^{p} \cap Ps^{b} \quad (5)$$

The obtained connections provide an opportunity to understand the behavior, attitude and personality of the consumer. Besides, it might provide the means to offer psychological correction with help of elements of the shape and color of the fashion garment.

Information about the psychological characteristics of the consumer is a starting point for solving the problem of achieving the psychological comfort of clothing.

4.2 Study of the emotional component of psychological comfort, the definition of its significant characteristics in the visual perception of the model of clothing

Claims of a consumer to the aesthetic quality of the product are determined by external and internal factors [16]. The external factors (F_{EX}) are basic because they contain all information about consumers and their impressions of clothing. Such factors form criteria of claims for aesthetic quality that is of external origin. They meet the requirements of human psychological comfort (Ps^{cf}):

$$F_{EX} = Ps^{cf} \supset Ev^{pos} \cup Fl^{cf}_{PPH} \cup P_{PPH} \quad (6)$$

where: Ev^{pos} – positive self-estimation in the clothing.

$$Fl^{cf}_{PPH_i} = \left\{ Fl^{cf}_{V\ i}, Fl^{cf}_{T\ i}, Fl^{cf}_{S\ i}, Fl^{cf}_{Sm_i}, Fl^{cf}_{Ts_i} \right\} \quad (7)$$

$St = \{St_i\}$; i=1…3,

where: $Fl^{cf}_{PPH_i}$ – comfortable psychophysiological feelings: visual impression ($Fl^{cf}_{V\ i}$), tactile feelings ($Fl^{cf}_{T\ i}$), sound ($Fl^{cf}_{S\ i}$), smell ($Fl^{cf}_{Sm_i}$), taste ($Fl^{cf}_{Ts\,i}$) in the situation St_1 – first impression, St_2 – fitting, St_3 – wearing clothes.

$$P_{PPH} = \left\{ n^{1}_{PPH}, n^{2}_{PPH}, n^{3}_{PPH}, n^{4}_{PPH}, n^{5}_{PPH} \right\} \quad (8)$$

where P_{PPH} – psychophysiological perception; n^{1}_{PPH} – emotional experiences; n^{2}_{PPH} – emotional reactions; n^{3}_{PPH} – perception of an image according to experience; n^{4}_{PPH} – intuition; n^{5}_{PPH} – mental reflection.

$$P_{PPH} \subset AP_{SB} \quad (9)$$

$$AP_{SB} = \sum A_{SB} + \sum G_{SB} + \sum V_{SB} + \sum N_{SB} + \sum I_{SB} + \sum S_{SB} \quad (10)$$

where: AP_{SB} – subjective attitude of the person to clothes.

In accordance to the psychographic portraits of consumers (see Table 1), the AP_{SB} system includes:

ΣA_{SB} – total index of compliance with age characteristics of a consumer;

ΣG_{SB} – total index of compliance with the gender characteristics of a consumer;

ΣV_{SB}– total index of "value" of clothing in the system of consumer's values;

ΣN_{SB} – total index of clothing compliance with the system of consumer's needs;

ΣI_{SB} – total index of compliance with consumer's settings;

ΣS_{SB} – total index of compliance with socially desirable stereotypes of a consumer.

These dependencies describe characteristics of the emotional components of psychological comfort. Thus, the psychological comfort of the consumer is formed with a positive subjective attitude of the individual to the chosen clothing model. A positive self-assessment of appearance in this product and a comfortable psychophysiological perception are vital for the psychological comfort of the consumer.

4.3 Ranking of characteristics of the ideal clothing model

Improved diagnostics of the psychological comfort of clothing at visual perception is carried out according to such an algorithm:

1. Investigation of the characteristics of an ideal model of clothing by means of questionnaires.
2. Selection of garments photos.
3. Estimation of outfits while locating the images of them on the photo of a particular consumer.
4. Analysis of evaluation data.

Eighteen models of women's dresses were selected from 66 images those comprise a dataset of the expert system described in [17, 18]. The selection was performed by way of the dialogue between a user and the expert system. These models were used for experimental estimation of psychological comfort of the model of clothes.

The list of characteristics of the ideal clothing model for women's dresses was compiled based on the results of the literature review [17-21]. Depending on the specific conditions such as range, purpose, materials, as well as the psychographic characteristics of the consumer, the list of characteristics of the ideal clothing model might be supplemented. Characteristics of the ideal model of the women's dress are given in the Table 2.

Table 2 Characteristics of the ideal clothing model

Code	Characteristic definition
X1	Concordance of colours and consumers appearances
X2	Concordance of colours to the fashion trends
X3	Concordance of colours and usage circumstances
X4	Harmonious colour design of the clothing model
X5	Ratio of the garment parts measurements to the consumer's height
X6	Concordance of the garment size and human body size
X7	Proportional allocation of the construction lines
X8	Proportion and concordance of the parts sizes to the garment size

Experts evaluated each characteristic on the list. The expert groups consisted of experts in the garment industry (20 experts) and consumers (20 experts). Two questionnaires were conducted simultaneously. The degree of coherence of the results of evaluating the characteristics of the ideal style is confirmed by the coefficient of concordation and Pearson's criteria (Table 3).

Table 3 The consolidated results of the evaluation degree of coordination of expert opinions

ω for the expert group			χ^2_p for the expert group		
professionals (20 people)	*consumers (20 people)*	*total*	*professionals*	*consumers*	*total*
0.955	0.967	0.937	133.77	135.42	262.41

Figure 1 shows the a priori charts of the ranks of the characteristics of the ideal clothing model.

As one can see from the Figure 1, the characteristic X1 is the most important one for all groups of experts. On the other hand, the X4 parameter is the least valued characteristic on the list. The summary of the ranks of the characteristics of the ideal clothing model are shown in Table 4. The coding in the Table 4 refers to the one in the Table 2 and in the Figure 1.

Table 4 Consolidated results of ranking the characteristics

Code	Rank of the characteristic by expert group		
	professionals (20 people)	*consumers (20 people)*	*total group*
X1	1	1	1
X2	7	5	6
X3	6	7	7
X4	8	8	8
X5	4	4	4
X6	3	3	3
X7	2	2	2
X8	5	6	5

The final rank of each characteristic is calculated as an average mean of the ranks those were determined separately by groups of experts.

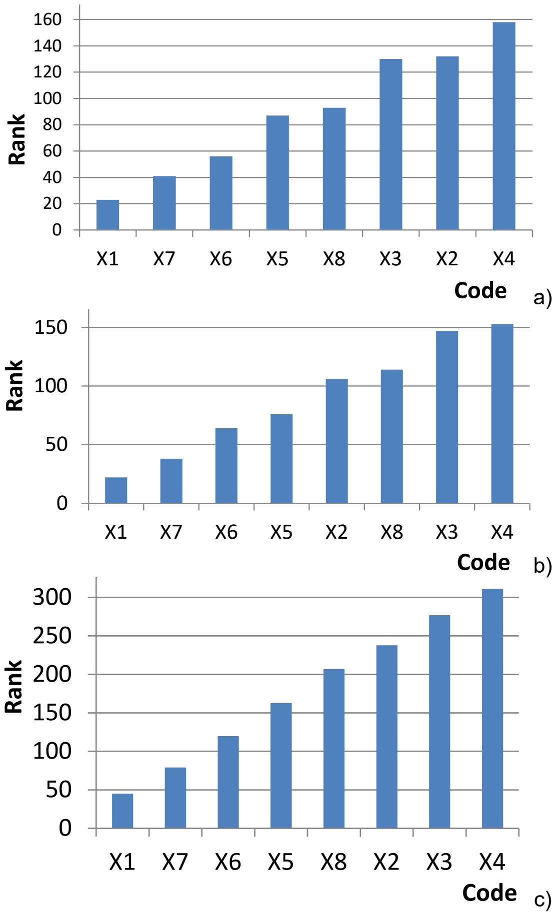


Figure 1 Charts of ranks of the ideal clothing model characteristics: a) experts are professionals; b) experts are consumers; c) total results

4.4 Assessment of the psychological comfort of clothing

Assessment of the psychological comfort of a fashion model might be performed by applying a scale of semantic differential to describe the characteristics of the ideal fashion model and sequential comparing them to characteristics of actual outfit. This allows measuring the perception of the fashion outfit by a particular consumer.

Table 5 Clothing model's characteristics described according to the method of semantic differential

Pair code	KW	Code	Correlated to KW	
			positive	*negative*
UI	Unimpressive - Impressive	X1	bright, expressive, attractive	pale, indecent, inconspicuous
UF	Unfashionable colours - Fashionable colours	X2	actual, modern, fashionable	simple, outdated, boring
IS	Inappropriate - Suitable	X3	appropriate, attractive, refined	inappropriate, aggressive, provoking
DH	Disharmonious - Harmonious	X4	harmonious, exquisite, elegant	disharmonious, provocative
IP	Impractical - Practical	X5	practical, comfortable, functional	impractical, uncomfortable
UC	Uncomfortable - Comfortable	X6	comfortable self-confidence charming	uncomfortable, not practical, vulgar
UN	Unfit - Nice fit	X7	nice look, holistic, organic	too noticeable, tastelessness, not organic
DP	Disproportionate - Proportionate	X8	balanced, agreed, no frills	unbalanced, uncoordinated, overloaded

Since psychological comfort is usually achieved through harmonization of garment colours, form, fabric and proportions with the appearance of consumer the consumer's impression of clothing, which are reflected by typical key emotional words, are collected in the Table 5 [17, 20].

These words are selected in order to obtain an objective assessment of the feelings and impressions of experts from the given dress. The key words (KW) are components of the semantic differential (SD) that is described in [17]. Each pair of KW is the SD poles for a particular attribute of an investigated fashion model. The common practice of coding the KW pairs that is to use the first letters of words with opposite meaning has been used in current work as well. Positive and negative correlations between each word from the SD with words, which express the emotions of consumers from clothing, are given in the columns 4 and 5 of Table 5.

Photos of outfits, which are shown in the Figure 2, were selected out of fashion collections [17] and assessed by experts using the questionnaire, which is shown in the Table 6.

Figure 2 Fragment of database of women's dresses**:** a) ideal clothing model; b) photos of outfits combined with consumer's photo

In a survey, photos of clothes were valued using evaluation factors in bipolar scales defined by verbal antonyms of KW from each end of the scale.

The expert group consisted of 10 experts and 10 consumers. The degree of coherence of the results of evaluation of the photographic material by experts using the semantic differential scales is confirmed by the coefficients of concordance and the Pearson criteria. Tabular value of Pearson criterion for 5 percent of the weight level and the corresponding number of freedom degrees (χ^2_{tabl} = 22.36) is less than the estimated value criterion. Table 7 presents the consolidated results of the degree of harmonization of expert opinions for 18 photos of consumers in clothing models. Number of degrees of freedom is 7.

Table 6 Example of the questionnaire

Negative	1	2	3	4	5	6	7	Positive
	-3	*-2*	*-1*	*0*	*+1*	*+2*	*+3*	
Unimpressive							+	Impressive
Unfashionable colours						+		Fashionable colours
Inappropriate						+		Suitable
Disharmonious						+		Harmonious
Impractical							+	Practical
Uncomfortable							+	Comfortable
Unfit							+	Nice fit
Disproportionate						+		Proportionate

Table 7 The consolidated results of the evaluation degree of coordination of expert opinions

Number of an outfit	ω for the expert group		χ^2_p for the expert group	
	consumers (10 people)	*professionals (10 people)*	*consumers*	*professionals*
1	0.61	0.68	42.10	48.10
2	0.68	0.69	48.10	48.59
3	0.63	0.75	43.86	52.25
4	0.88	0.83	61.44	57.94
5	0.83	0.82	57.94	56.83
6	0.74	0.64	51.91	44.71
7	0.71	0.78	49.42	54.42
8	0.61	0.62	42.10	43.25
9	0.78	0.86	55.23	60.39
10	0.79	0.92	55.45	64.94
11	0.77	0.69	53.96	48.59
12	0.68	0.61	48.10	42.10
13	0.61	0.63	42.10	43.86
14	0.74	0.75	51.91	52.25
15	0.81	0.84	56.78	58.49
16	0.79	0.81	55.45	56.78
17	0.91	0.91	63.65	63.65
18	0.86	0.86	60.48	60.48

Therefore, it is possible to state with 95% probability that the frequency of evaluation ratios of KW pairs in different experts is coordinated in accordance with the calculated rate of concordance.

Mathematical processing of data reduces to the calculation of the Spearman's rank correlation coefficient that is a nonparametric measure of rank correlation (statistical dependence between the rankings of two variables) [23]:

$$r_S = 1 - \frac{6\sum d_i^2}{n\left(n^2 - 1\right)} \tag{11}$$

where: d_i is the difference between the two ranks of each observation; n – number of observations.

The obtained values of correlation coefficients are checked for statistical significance. Then data processing was carried out to assess psychological comfort of clothing. The value of each indicator is counted as the difference between the ranks of perfect clothing and the photo of actual outfit for each characteristic. Thus, for each photo model - the idea of dress characteristics is assigned a certain rank in accordance with the methodology for determining the index of psychological comfort. The coefficients of psychological comfort (PC) are calculated according to the expression 1. They are evaluated as follows:

1) $r_S \geq 0.79$ - high level PC;
2) $0.64 < r_S \leq 0.79$ - middle level PC;
3) $0 < r_S \leq 0.64$ - low level PC;
4) $r_S < 0$ - complete rejection of the proposed style.

Calculated coefficients of psychological comfort (PC) are shown in the Table 8.

Table 8 Results of calculating

Level	Outfit	Coefficient
High	1	0.917
	3	1.00
	6	0.82
	8	0.88
	13	0.976
Middle	2	0.76
	10	0.72
	11	0.74
	12	0.66
	14	0.64
Low	5	0.52
	7	0.60
	9	0.47
	15	0.45
	18	0.48
Complete rejection	4	-0.56
	16	-0.47
	17	-0.30

As one can see in the Table 8, four dresses have high-level PCs. They do not need any improvements. Three dresses were rejected completely (outfits 4, 16, and 17 in the Table 8). For further work the model of dress 18, which received a low level of PC and highlighted in the Table 8 by colour, was chosen by the consumer.

5 GARMENT STYLE ALTERATION

The next stage of the study is the adaptation and harmonization of the artistic and constructive parameters of the product to the individual characteristics of the consumer. It is done in order to increase the psychological comfort of the model specifically in visual perception. The method we used to do so is the one that was described in the previous study [21].

The process of harmonizing the dress is proposed to be performed in the following sequence:

1. To carry out the identification of the consumer, taking into account the psychological characteristics of the individual and the characteristics of the appearance.
2. To make a decision on the need to adapt the chosen form of the product and artistic and constructive parameters, in accordance with the appearance of the consumer.
3. Place the photo of the consumer with the product into a grid of harmonious arrangements.
4. Perform artistic and constructive analysis and harmonization of the garment.

The harmonization of the garment must be performed in accordance to the following order. We put the consumer's photo and the sketch of the dress into the grid of harmonic segmentations as it shown in the Figure 4a. After that, the design parameters of the dress were altered according to the grid limits.

Foremost it is necessary to begin with alteration of the garment length. Then the width parameters would be changed: the shoulders line as well as the hem line. These alterations are shown on the Figure 4c. We can also adjust the degree of fit at the waistline. Finally we have to change a form of the neckline, and the specifics of the decorative parts.

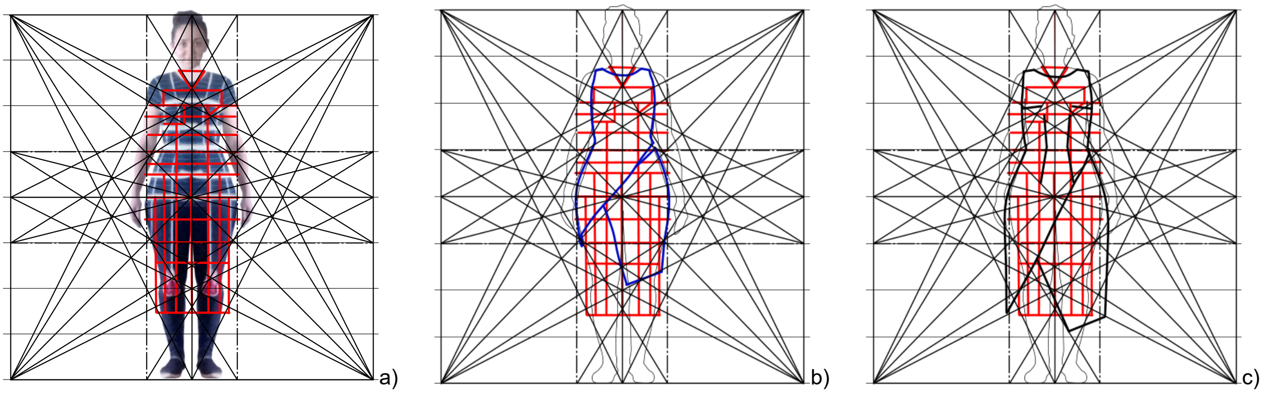


Figure 4 Harmonization of the dress style (outfit 18), a) preferred limits of the harmonic segmentations, b) original dress, c) harmonized dress

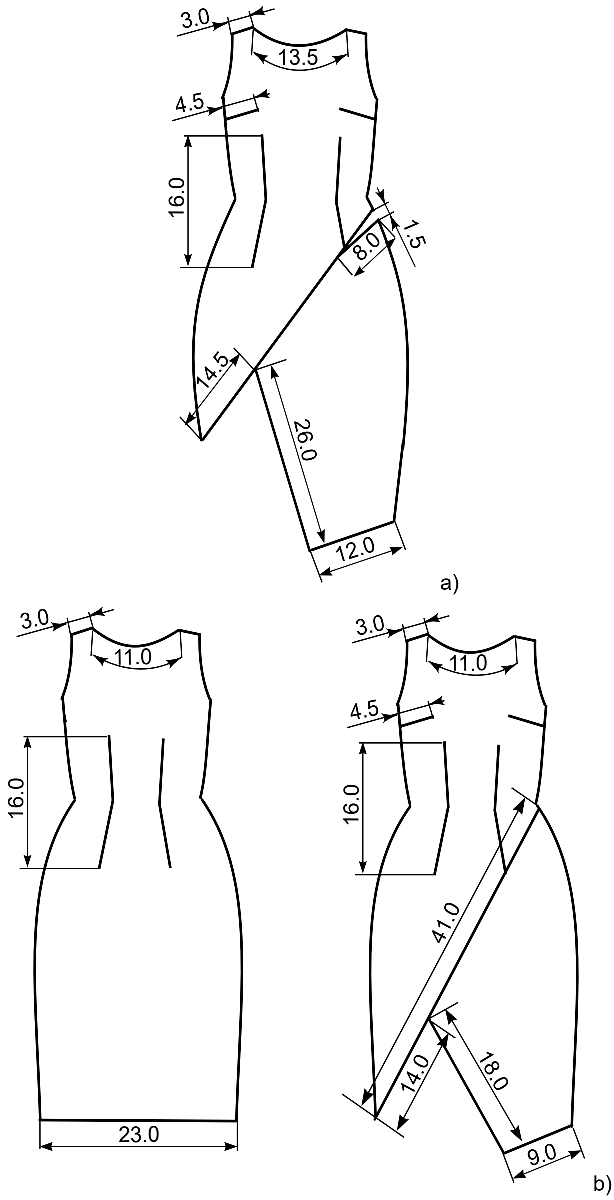


Figure 5 Real and harmonized parameters of composition segmentations of light women dress, a) original dress, b) harmonized dress

In the Figure 5 one can see the differences between the harmonized dress style and the real outfit. As a result of the harmonization, the following characteristics of the dress style have been improved: X5 (ratio of the garment parts measurements to the consumer's height); X6 (concordance of the garment size and human body size); X7 (proportional allocation of the construction lines); X8 (proportion and concordance of the parts sizes to the garment size).

6 RESUTS AND DISCUSSION

In order to confirm the results of the current research the virtual 3D-model of a dress was developed by using pattern design system (PDS) "Julivi". The model is displayed in the Figures 6, 7. Virtual model of the dress is connected to its patterns. Thus, the alteration of the visual characteristics of the garment was performed by altering the patterns (Figure 6a) and simultaneous visualization (Figure 6b). The alterations continued till the dress style reached the parameters shown in the Figure 5.

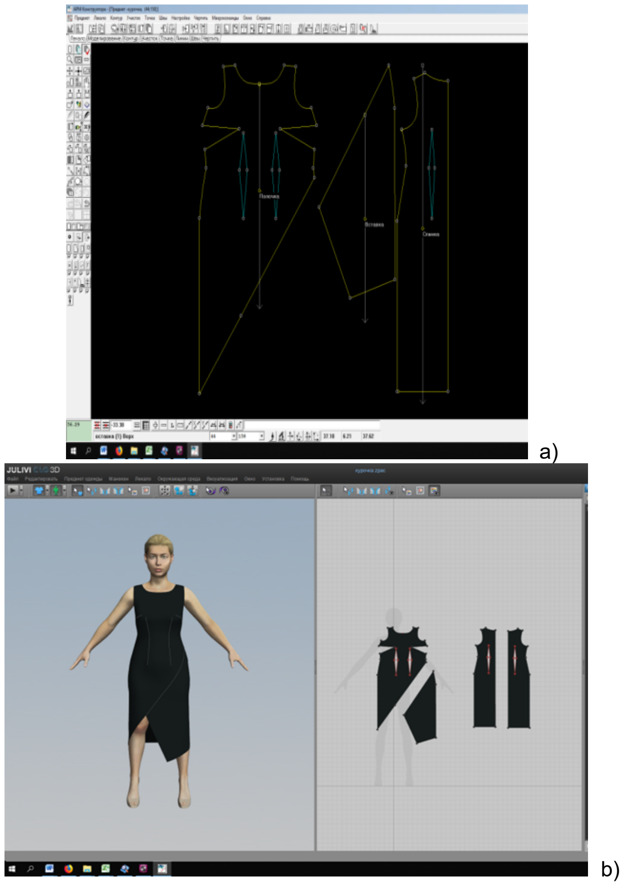


Figure 6 Virtual model of the dress in PDS Julivi: a) patterns, b) visualization process

In order to ensure that the incorrect fit of the garment does not impede the results of the followed PC evaluation the virtual model was assessed in the mesh mode (Figure 7).

Figure 7 Virtual model of the dress in PDS Julivi to assess static compliance of mesh model

According to the work [22] the data obtained are within the permissible range. Thus, the patterns were used to sew the real garment sample. The image of the consumer that is wearing the real sample of the outfit 18 is displayed in the Figure 8.

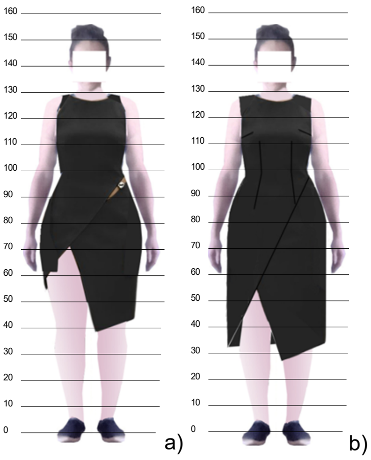


Figure 8 Photos of women's dresses 18**:** a) original dress, b) harmonized dress

The consumer chose a harmonized dress that is displayed in the Figure 8b. It is evident, that after alterations it is hiding the shortcomings and emphasizes the advantages of the body. Comparison of the harmonized dress to the original one was performed by comparing the results of two separately conducted surveys. In the Table 9 one can see the results of the first survey that was conducted using the questionnaire in the Table 6.

Table 9 Results of the survey for the original dress (outfit 18)

Experts		Pair code							
		UI	*UF*	*IS*	*DH*	*IP*	*UC*	*UN*	*DP*
professionals	1	-2	2	2	2	-3	-3	-3	-3
	2	0	0	0	0	-2	-2	-2	-2
	3	-1	3	3	3	-3	-3	-3	-3
	4	-3	1	1	0	-2	-2	-2	-2
	5	-2	2	2	2	-2	-3	-3	-3
	6	-2	2	2	2	-3	-3	-3	-3
	7	-1	1	0	2	-1	-1	-3	-3
	8	-2	0	2	0	-3	-3	-3	-2
	9	0	0	1	2	-3	-3	-3	-3
	10	-1	1	1	0	-1	-2	-3	-1
	Kp	-1.40	1.20	1.40	1.30	-2.30	-2.50	-2.80	-2.50
consumers	1	-1	2	3	3	-3	-1	-2	-1
	2	1	3	3	3	-1	-1	-1	-1
	3	1	3	3	2	-2	-3	-3	-2
	4	-1	3	2	3	-2	-2	-2	-3
	5	0	0	1	2	-2	-2	-2	-2
	6	-1	3	3	3	-1	-2	-3	-2
	7	-2	3	3	2	-2	-3	-3	-2
	8	-2	1	1	0	-1	-2	-3	-1
	9	-1	1	1	0	-1	-1	-1	-1
	10	-2	1	1	1	-2	-2	-3	-2
	Kc	-0.80	2.00	2.10	1.90	-1.70	-1.90	-2.30	-1.70
	K	-1.10	1.60	1.75	1.60	-2.00	-2.20	-2.55	-2.10

The aim of the second survey was to assess psychological comfort of the outfit 18, which has been already harmonized (as one can see in the Figures 5 and 8). The same group of experts evaluated the harmonized dress using the same questionnaire. The results of the assessment are displayed in the Table 10.

Table 10 Results of the survey for the harmonized dress (outfit 18)

Experts		Pair code							
		UI	*UF*	*IS*	*DH*	*IP*	*UC*	*UN*	*DP*
professionals	1	2	2	2	1	2	3	3	2
	2	2	2	1	1	3	2	3	2
	3	3	2	2	1	2	2	3	2
	4	2	2	1	1	3	3	2	2
	5	2	2	2	1	2	2	3	2
	6	3	2	2	1	3	3	3	2
	7	2	2	2	1	2	3	3	2
	8	3	2	2	1	3	2	2	2
	9	2	2	2	1	2	3	2	2
	10	2	2	2	1	3	2	3	2
	Kp	2.30	2.00	1.80	1.00	2.50	2.50	2.70	2.00
consumers	1	3	2	1	2	2	3	3	2
	2	3	2	2	2	3	2	2	2
	3	3	2	2	2	3	3	3	2
	4	3	2	2	2	2	3	2	2
	5	3	2	1	2	2	3	3	2
	6	3	2	2	2	3	2	3	2
	7	3	2	2	2	2	3	2	2
	8	3	3	2	2	3	3	3	2
	9	3	2	2	2	2	3	3	2
	10	3	2	2	2	3	2	3	2
	Kc	3.00	2.10	1.80	2.00	2.50	2.70	2.70	2.00
	K	2.65	2.05	1.80	1.50	2.50	2.60	2.70	2.00

The results of the data processing are displayed in the Table 11. The columns 3 to 5 refer to the first survey (Table 9), which was carried out before the alterations of the models. The columns 6 to 8 refer to the second survey, which was carried out after the harmonization (Table 10).

Table 11 Example of data processing

No	IC (rank)	Ph_{18o} (rank)	K_{18o}	d_{18o}	Ph_{18g} (rank)	K_{18g}	d_{18g}
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	8	5	-1.10	3	7	2.65	1
2	4	6	1.60	-2	4	2.05	0
3	2	8	1.75	-6	2	1.80	0
4	1	7	1.60	-6	1	1.50	0
5	5	4	-2.00	1	5	2.50	0
6	6	2	-2.20	4	6	2.60	0
7	7	1	-2.55	6	8	2.70	-1
8	3	3	-2.10	0	3	2.00	0

Code: IC – ideal clothing model; Ph_i – photo; K_i – the average value of expert assessments; d_i – difference of ranks; o – original dress; g – harmonized dress.

The results of mathematical processing of evaluation data and qualitative analysis of the results of evaluation of psychological comfort of the dress model 18 showed an increase in the PC ratio from r_{S18o} = 0.48 (low level) to r_{S18g} = 0.98 - high PC level.

As one can see in the Table 11 the coefficient of the psychological comfort has increased to 0.98 that refers to the high level of the comfort.

7 CONCLUSIONS

In the current work the task of studying and assessing of psychological aspects of quality and comfort is solved by creating a harmonious image of a garment.

As a result of theoretical and analytical studies of consumer segmentation in relation to clothing, a conceptual model of class stratification of consumers is proposed. The obtained connections provide an opportunity to trace the consumer's attitude to clothing. They might be used as source information for solving the problem of ensuring the psychological comfort of garments.

The emotional component of psychological comfort is studied and its characteristics at visual perception of model of clothes are defined.

The methodology for assessing the clothing psychological comfort was improved based on visual perception of the garment. The results of the assessment are confirmed by designing the experimental garment sample for the specific consumer.

The ability to assess the psychological comfort on a virtual mannequin before and after the patterns' alterations and harmonization of visual characteristics of the outfit gives one the opportunity to correct the work of a designer before the garment is sewn.

8 REFERENCES

1. Norman D.A.: Emotional design: Why we Love (or Hate) Everyday Things, New York: Basic Books, 2005, 268 p., ISBN: 978-0465051366
2. Schutte S.: Engineering Emotional Values in Product Design, - Kansei Engineering in Development, Linkoping University, Department of Mechanical Engineering, Disertation 951, 2005, 106 p., ISBN 91-85299-46-4
3. Nagamachi M.: Kansei / Affective Engineering, Taylor & Francis Group, 2010, 334 p., https://doi.org/10.1201/EBK1439821336
4. Wages T.B.: The Design and Development of a Measure for Comfort in Clothing, A thesis in Clothing and Textiles, Graduate Faculty of Texas Technical University, Master of Science in Home Economics thesis, 1974
5. Korobtseva N.A.: Feelings are measurable. Psychophysical approach to assessing the quality of garments, Qualification and quality 4, 2003, pp. 32-35 (in Russian)
6. Zymogliad N.: Assessment of psychological comfort of clothes in the course of training of future stylists, Problems of engineering and pedagogical education 40/41, 2013, pp. 42-48 (in Ukrainian)
7. Matte L.L., Broega A.C.: The evaluation of (social-) psychological comfort in clothing, a possible approach, IOP Conference Series: Materials Science and Engineering 254(18), https://doi.org/10.1088/1757-899X/254/18/182008
8. Brauning M., Frick J.E., Melnikov J., Lubben J., Keck A., Tchouboun Ch.: Smart solutions to improve wearing comfort, Journal of Fashion Technology & Textile Engineering 0(4), 2018, 2 p., doi: 10.4172/2329-9568.S4-011
9. Uemae T., Uemae M., Kamijo M.: Evaluation of psychological and physiological responses under gradual change of thermal conditions with aim to create index to evaluate thermal comfort of clothes, 7th International Conference on Kansei Engineering and Emotion Research 2018, March 19-22, 2018, Kuching, Malaysia, pp. 495-503
10. Selezneva A.V., Slavinskaya A.L.: Designing effect of woman's figure, created corset, consider psikhofiziologic comfort, Proceedings of Higher Education Institutions, Textile Industry Technology 2(350), 2014, pp. 102-106 (in Russian)
11. Soroka M., Zinko R., Zakharkevich O., Kuleshova S., Hasanova O.: Assessment of the clothing comfort, In Proceeding of the International Conference on Technics, Technologies and Education ICTTE 2019, Yambol, Bulgaria, pp. 352-359
12. Anderson W.T., Golden L.L.: Lifestyle and psychographics: a critical review and recommendation, Advances in Consumer Research 11, 1984, pp. 405-4011
13. "Psychographics" Merriam-Webster.com Dictionary, Merriam-Webster, accessed: June 28, 2017, available from https://www.merriam-webster.com/dictionary,
14. Savelieva N.Yu.: Management and marketing in the fashion industry, Rostov-on-Don: Phoenix, 2004, 288 p. (in Russian)
15. Samuel A.: Psychographics are just as important for marketers as demographics, Demographics, accessed: June 30, 2017, available from https://hbr.org/2016/03/psychographics-are-just-as-important-for-marketers-as-demographics
16. Boeree C.G.: Personality Theory: A Biosocial Approach, Psychology Department, Shippensburg University, 2009, Accessed May 7, 2016 http://webspace.ship.edu/cgboer/pttemp.html
17. Kuleshova S.G., Zakharkevich O.V., Koshevko J.V., Ditkovska O.A.: Development of expert system based on Kansei engineering to support clothing design process, Vlakna a textil (Fibres and Textiles) 24(3), 2017, pp. 30-41
18. Zakharkevich O., Zhylenko T., Koshevko Y., Kuleshova S., Ditkovska O., Shvets G.: Expert system to select the fabrics for transformable garments, Vlakna a textil (Fibres and Textiles) 25(2), 2018, pp. 105-112
19. Slavanskaya A., Syrotenko O., Zasornova I., Zasornov A.: Ethnic designer component of clothes' decoration techniques using, Vlakna a textil (Fibres and Textiles) 26(4), 2019, pp. 69-83
20. Kuleshova S.G.: Color in the art of designing clothes: study guide, Khmelnytskyi: KhNU, 2016, 395 p. (in Ukrainian)

21. Kuleshova S.G., Slavinska A.L., Zakharkevich O.V., Shvets G.S.: Evaluation of the level of harmonisation of clothes, In: Proceeding book of International Conference on Research in Education and Science, Bodrum: Gaziantep University, 2016, pp. 1514-1522
22. Slavinska A., Syrotenko O., Zakharkevich O., Kuleshova S.: Development of a technology of interactive design of garments using add-ons of virtual maneken, Eastern-European Journal of Enterprise Technologies. Engineering technological system 6(1) (96), 2018, pp. 28-39, https://doi.org/10.15587/1729-4061.2018.148984 (in Ukrainian)
23. Osgood C.E.: Method and Theory in Experimental Psychology, Hardcover - Import, Oxford University Press, 1968, 800 p.

EXPERIMENTAL STUDY ABOUT INFLUENCE OF REPEATED WASHING ON THE AIR-PERMEABILITY OF COTTON WOVEN FABRICS IN THE DRY AND WET STATE

Jana Novotná, Blanka Tomková, Jiří Militký and Dana Křemenáková

Department of Material Engineering, Technical University of Liberec, Faculty of Textile Engineering, Liberec, CZ
jana.novotna3@tul.cz

Abstract: *This work deals with the influence of washing and moisture on the change of air-permeability of cotton fabrics and the impact of different types of seams on air-permeability. It turns out that the effect of the kind of seams does not significantly affect the air-permeability. Repeatable washing has a much more significant impact when the fabric is in a dry or wet state.*

Keywords: *air-permeability, cotton woven fabrics, repeated washing.*

1 INTRODUCTION

Air permeability is one of the basic textile properties that affect the comfort of textile users [1]. Currently, thanks to the COVID - 19 pandemic, knowledge of these phenomena is gaining importance. It turns out that home-made face masks did not achieve additional effectiveness of protection against the penetration of viruses as disposable masks or as respirators. Medical [2] and physical studies [3] show that maintain an additional distance of 2 meters are not sufficient to prevent the transfer of aerosol droplets containing viruses. Regulating the wearing of masks by the public may increase the demand for respirators and disposable masks, which are especially important for healthcare professionals. Extending knowledge of the physical phenomena to them during the use of woven fabrics cotton masks could help their widespread use, which is not least more economical [4] and more environmentally friendly than the use of disposable masks.

This study aims to compare the effect of moisture on the change in the air-permeability of cotton woven fabrics, as the formation of condensation due to respiration occurs during the wearing of the mask. It is generally known that the wet strength of cotton fibers increases. It is also known that the moisture content of fabric can significantly change its properties. Currently, there is no standard defining this issue, so the experiment was designed to compare the air-permeability of selected woven fabrics in extreme humidity cases. There were two experimental woven fabrics evaluated in this work. Both fabrics were made of 100% cotton fibers, 120-130 g/m^2 mass. The chosen weave was plain weave, as this weave shows the densest weave of warp and weft threads in comparison with the twill or satin weave [5]. Therefore, in the experimental part of this work, only samples of fabrics with plain weave were used to suppress the effect of fabric weave on its air-permeability. The work also evaluates the influence of three types of fabric seams on the air-permeability of the fabric. The types of seams were selected concerning the currently most frequently used seams in the production of masks.

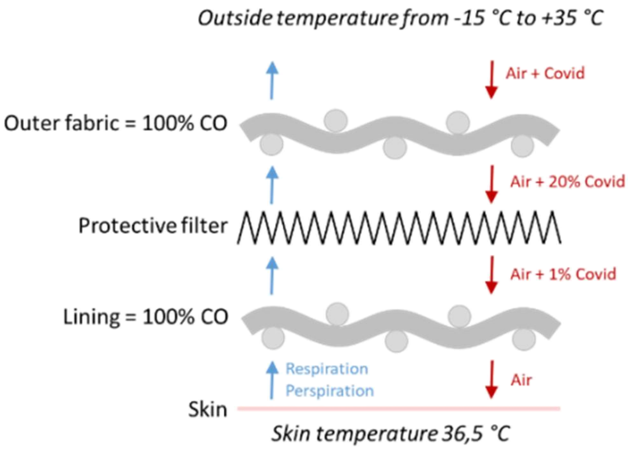


Figure 1 Scheme of an ideal face mask (section cut)

One of the factors influencing the suitability of fabrics for masks may be resistance to water vapour penetration. Permeability depends mainly on the fabric structure, which can be described by linear yarn density, type of yarn, warp/weft density and weave. When comparing the air-permeability of polymeric fiber fabrics, the air-permeability decreases rapidly with the density of the fabric, proving that pores are the primary route of penetration through these materials.

In the case of cotton, the permeability of high-density fabrics is about twice as low as that of conventional fabrics used in the clothing industry (mass 140-210 g/m^2) suggesting that a considerable amount of water vapour passes through the fibrous material itself, as confirmed in 1947 by Lyman [6].

Figure 1 shows a possible scheme of a suitable cover, and it is understood that the face mask. The masks play an important role in reducing the penetration of pathogens into the respiratory system through the nose or mouth and thus minimize the transmission of diseases. According to WHO guidelines, wearing masks in public, together with sufficient social distance, is the most accessible and easiest means of preventing the transmission of COVID-19 [7].

1.1 Material

Woven fabrics in a plain weave of 100% cotton were chosen for the experiment. Cotton is one of the natural fibers. The average composition of cotton fibers is: cellulose 94.0%, protein 1.3%, pectins 1.2%, mineral salts 1%, org. acids 0.75%, waxes 0.6%, sugars 0.3% and a further 1.4% [5]. The wet ductility of cotton fibers increases. Dry elasticity is usually 3-10% and wet elasticity is 11%. The moisture content at 65% RH is 8.5% [8]. The fiber length is on average 10-60 mm, fiber diameter ≈26 μm [8]. It is important to be aware, in particular, of the dimensions of the individual cotton fibers, since these fibers form the cotton yarn from which the cotton fabric is woven and their tendency to moisture substantially affects the wet permeability of cotton fabrics.

1.2 Air-permeability of fabrics

Air-permeability is one of the physiological and hygienic properties. Passages can generally be realized in both directions but the direction from the organism to the surrounding environment prevails. Air -permeability in fabrics occurs when there is a different pressure *p* [Pa] on both sides of the fabric and when the fabric has non-zero porosity. The air-permeability of textile materials can be characterized as the ability to permeate air under specified conditions. It is defined as the velocity of the airflow passing perpendicular to the test specimen under the specified requirements for the test area, pressure drop and time. In the fabrics, the air-permeability is determined primarily upon the fabric's weight and construction (thickness and porosity). The size of the voids, their shape, the arrangement of individual pore types and voids frequency are decisive characteristics of fabrics in terms of their air-permeability. Air-permeability also depends on the humidity. In the case of fabrics made of cotton fibers, the air-permeability usually decreases with increasing humidity. As the voids are filled with water, the fibers swell and thus prevent the passage of air. Moisture sorption also depends on temperature. At higher temperatures, the moisture content of the fiber decreases as the fibers dry out. Conversely, at higher relative humidity, the fiber moisture may be slightly higher. Moisture significantly affects the mechanical properties of the fibers.

The essence of the test for measuring the air-permeability of fabrics is the suction of air through the surface of the tested fabric at a specified pressure drop. Air-permeability is then expressed as the speed of airflow through a given area of fabric.

1.3 Porosity

In terms of air-permeability, porosity is considered one of the most critical parameters of the fabric structure. Porosity can be determined by several theoretical methods as well as by various experimental techniques. Due to the complexity of the textile structure, each of the methods contains some simplifying assumptions. It is therefore difficult to find the best variant for expressing the porosity of a textile material. Porosity also affects the use of fabrics for masks, where low porosity can cause small comfort for wearers of masks.

The volume porosity *P* [%] is essentially the opposite of the cover factor of textile structures. Interpretation of porosity based on density of fibers ρ_{fibre} [g/m^3] and fabric density and is given by [9-10]:

$$P = \left(1 - \frac{\rho_{fabric}}{\rho_{fibre}}\right).100 \quad (1)$$

$$\rho_{fabric} = \frac{\rho_{mass}}{t} \quad (2)$$

where the density of the fabric ρ_{fabric} [g/m^3] is given by the ratio of the mass ρ_{mass} [g/m²] and the thickness of the fabric *t* [m].

The mass of a fabric expresses the weight per unit area of the fabric. The bulk density of a fabric expresses the weight of a volume unit of the fabric. The thickness of the fabric is defined as the vertical distance between the two fabric surfaces, measured under the prescribed pressure, which is usually 1 kPa [11]. The thickness of the fabric depends not only on the warp and weft threads' diameter but also on the used weave and used production technology.

There are three types of pores = voids in the fabric: 1) pores inside the fibers, 2) voids inside the yarn formed between the fibers and 3) voids formed between the warp and weft yarns. The pores inside the fibers can be neglected entirely in terms of the fabrics' air-permeability because they do not pass through the fabric and are negligible in size. The literature [12] states that the air-permeability of yarns is 200 to 2000 times less than the air-permeability of woven fabrics. It follows that the voids between the fibers in the woven fabric may also be omitted for this article.

2 EXPERIMENT

2.1 Characteristics of used materials

Two 100% cotton (CO) woven weaves were selected for experiments. The used weave was plain. The warp and weft yarns were of the same linear density for both fabrics: warp for sample A 13 tex and for sample B 19 tex. A number of turns were for sample A 1042 turns/m and for sample B 896 turns/m. Physical density of the cotton fibres was constant 1.52 g/cm^3. All samples were woven using classical ring technology and yarns have a right turn. Results of the actual warp/weft density measurements and physical characteristics of samples (mass per square meter and thickness) are shown in Table 1. Porosity and bulk density of fabric were calculated using equations (1) and (2).

Table 1 Basic properties of used fabrics

Properties of fabrics	Fabric	
	A	B
Mass per square meter [g/m^2]	130	120
Bulk density of fabrics [g/m^3]	0.59±0.03	0.43±0.01
Warp density [cm^{-1}]	45.8±0.8	35.4±1.1
Weft density [cm^{-1}]	40.8±1.1	24.0±0.4
Thickness of fabrics [cm]	0.0220±0.0010	0.0270±0.0001
Porosity [%]	60.62±1.65	71.45±0.71

Three types of seams were compared: back seam, overlapped seam and double-sided back seam, and there was always one sample without a seam from each fabric (Figure 2). A total of 8 types of samples were measured. All samples were measured in dry and wet conditions.

2.2 Testing methodology

The study investigated the following properties of woven samples: physical properties (mass per unit area ČSN 12127:1999, the thickness of textiles ČSN ISO 5084:1998). Furthermore, the porosity of the fabrics was determined using equations (1) and (2). In the next part of the experiment, the air-permeability of the fabrics was evaluated.

2.2.1 Air-permeability measurement

The measurement was performed on an FX 3300 Air Permeability Tester III instrument (TexTest company) according to the standard ČSN ISO 9237:1996 [13] and according to the standard DIN 53 887 [14] at a pressure drop of 100 Pa (recommended for clothing textiles), 150 and 200 Pa (recommended for technical textiles). The measurement was performed on samples with an area of 20 cm². The seam was guided through the center of the test area.

2.2.2 Conditioning of samples

The experiment included two sets of samples. One set of fabrics A, B was washed and dried once. The second set of fabrics A, B was washed, dried and ironed 5 times. The minimum number of washes was chosen to be 1x, as this assumption was based on the fact that the drape will be washed by the user before the first use. The maximum number of washes was set at a total of 5 washes according to the knowledge obtained from the shrinkage of the yarns [15], the dimensions of the fabric stabilize after the fifth wash and the fabric usually does not coagulate.

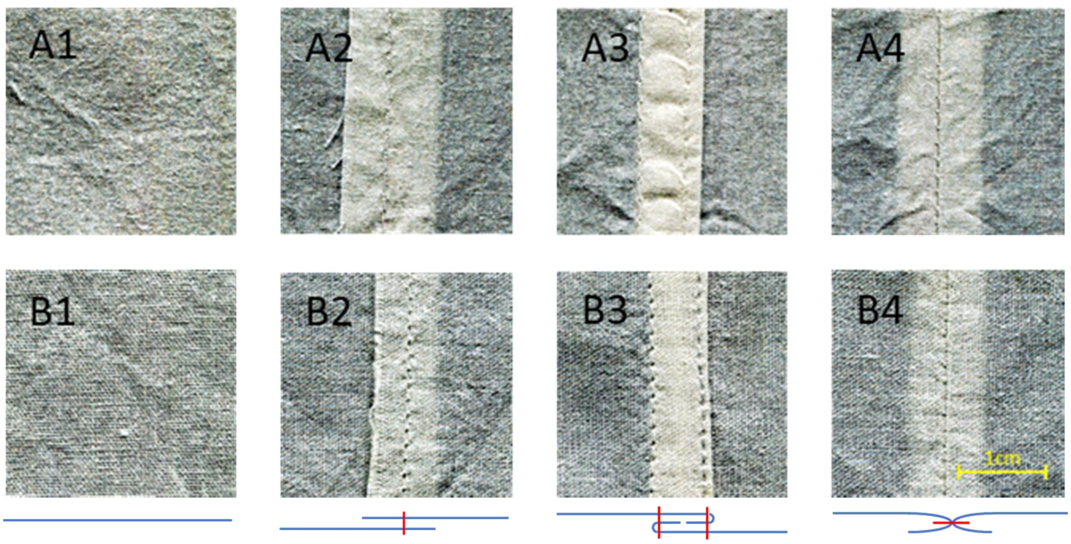


Figure 2 Overview of used fabrics - types of used seams: A1, B1 - without seam, A2, B2 - overlapped seam, A3, B3 - back seam bent on both sides, A4, B4 - back seam; at the bottom of the figure, cross-sectional drawings of the seams are shown schematically

The standard: EN ISO 6330: 2000 "Domestic washing and drying procedures for textile testing" was used for the domestic washing and drying procedure of tested textiles. An automatic washing machine was used for washing; a washing cycle of 2 hours at 90°C. After the complete wash cycle, the material was removed from the washing machine without being stretched or deformed. Subsequent drying took place in a horizontal position in the spread state. The ironing was carried out as follows: the temperature was set at 150±15°C without steaming applied. The iron was laid gradually over the entire surface of the sample for 5 s each without sliding motion. After washing, drying and ironing, the samples were always conditioned according to EN ISO 139:2005 "Standard atmospheres for conditioning and testing before measurement". The selected temperature and washing time were intentionally chosen as the limit for 2 hours at 90°C. Although in the literature [16] the thermal deactivation of the virus is already mentioned at 56°C after 30 min exposure time and in the literature [17] is reported as the deactivation temperature of 70°C with a shorter exposure time.

A Kern DLB 160-3A halogen analyser with a halogen emitter using the thermogravimetric method was used to analyse fabric moisture. In accordance with this method, the sample was weighed before and after heating and the moisture content of the material was determined by calculating the difference in weight. The applied radiation penetrated the sample, where it was transformed into thermal energy, so the heating took place from the inside outwards. Testing procedure: dry, air-conditioned samples with an RH of 65±2% were sprayed with water and dried the material to the humidity of RH 88±2% (Table 2).

Table 2 Climatic conditions during measurement

	RH [%]	T [°C]
standard environment	65±2	20±2
humid environment	88±2	20±2

3 RESULTS AND DISCUSSION

In the case of fabrics made of cotton fibers, the air-permeability decreases with increasing humidity; as the pores are filled with water, the fibers swell and prevent the passage of air.

Based on the experimental measurements, the mechanism of dimensional changes due to moisture is the swelling of cellulose-based fibers. These differences are particularly evident by fabrics' sample A. By cotton fabrics, the axes of the warp and weft yarns are deflected due to the swelling of the fibers [18] and the fabric shrinks. In Figure 3 we can see how the porosity decreases with increasing bulk density.

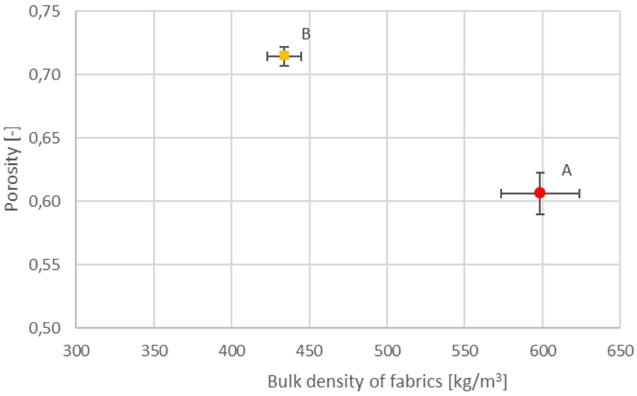


Figure 3 Dependence of bulk density on porosity of both types of fabrics

A comparison of the air-permeability of both types of 1x and 5x washed fabrics in the dry and wet state is shown in Figure 4. It is evident that the air-permeability increases linearly with increasing pressure for all types of fabrics and seams. As seen from Figure 4, the air-permeability of samples washed 5x almost always decreases compared to samples washed 1x. Comparing Figures 4 and 5, it is evident that the air-permeability of cotton woven fabrics generally decreases due to washing. During repeated washing, the fabrics shrinkage and thus the overall pores between the warp and weft threads are reduced.

In general, shrinkage prevention can be only achieved by preventing the swelling of the cotton fibers, which seems unrealistic for textile technology. By performing repeated precipitation of the fabric at such a stage of technology where this phenomenon is not complication, a large reduction in the manifestations of dimensional changes of the cotton fabric can be achieved. However, it is necessary consider the fact that cotton fabric usually reacts with moisture throughout its life. If the masks made of 100% cotton were used in the future, it would be appropriate to precipitate before using the fabric, for example, through a sanforization process, as repeated washing will shrink the fabric. Sanforization [18] is one of the most important precipitation processes. It is controlled pressure precipitation where the whole process is based on mechanical action without chemicals. The essence of the sanforization process is the precipitation of the fabric before its further use what guarantees the stability of the finished textile product during washing. Another solution to shrinkage may be treating the cotton fibers with various chemicals [19, 20] what increases the cross-section of the cotton fibers and thereby reducing the porosity of the yarn, in a manner very similar to mercerization.

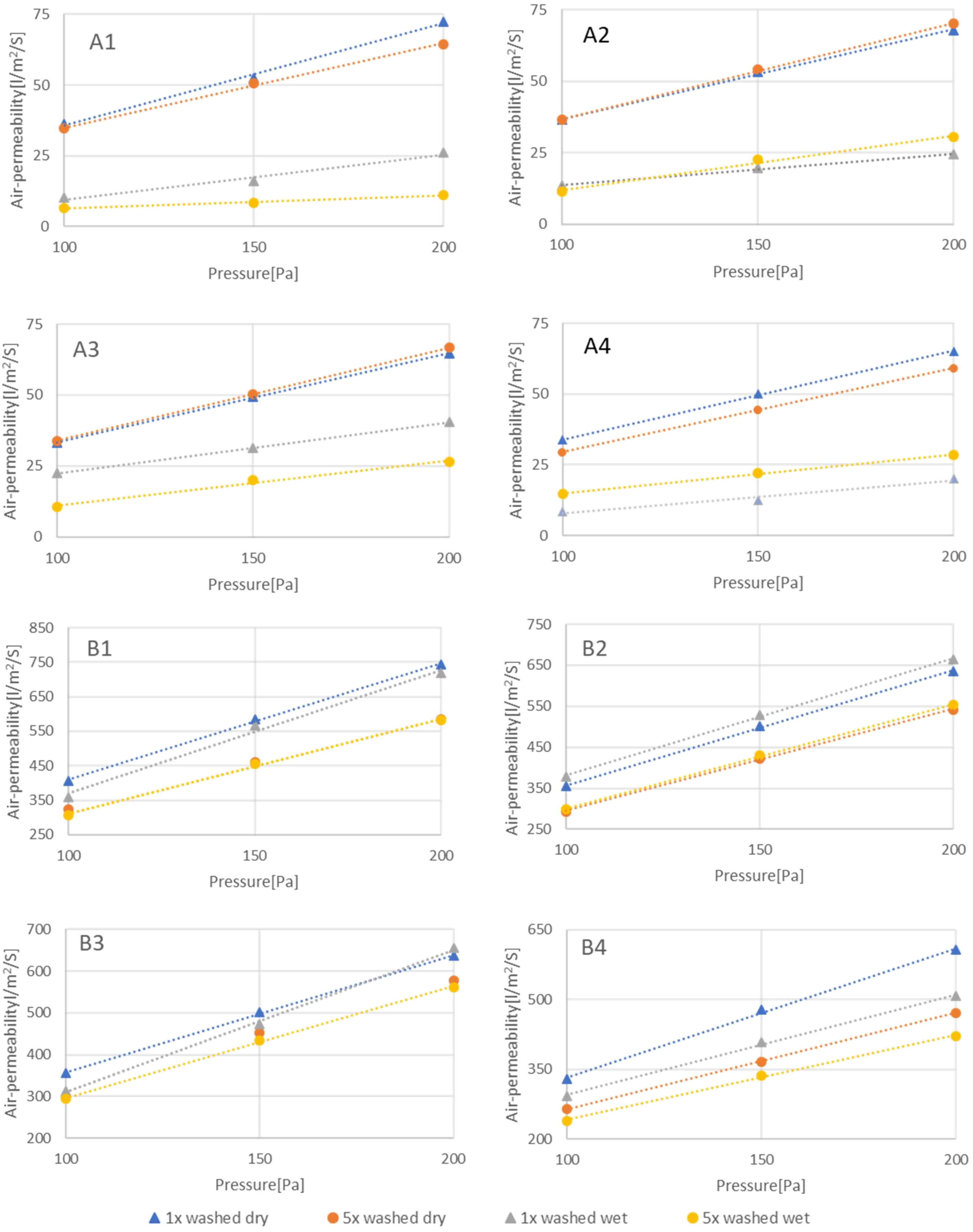


Figure 4 Effect of pressure on air-permeability of 1x and 5x washed fabrics in the dry and wet state: A1, B1 - without seam; A2, B2 - overlapped seam; A3, B3 - double-sided curved back seam; A4, B4 - back seam

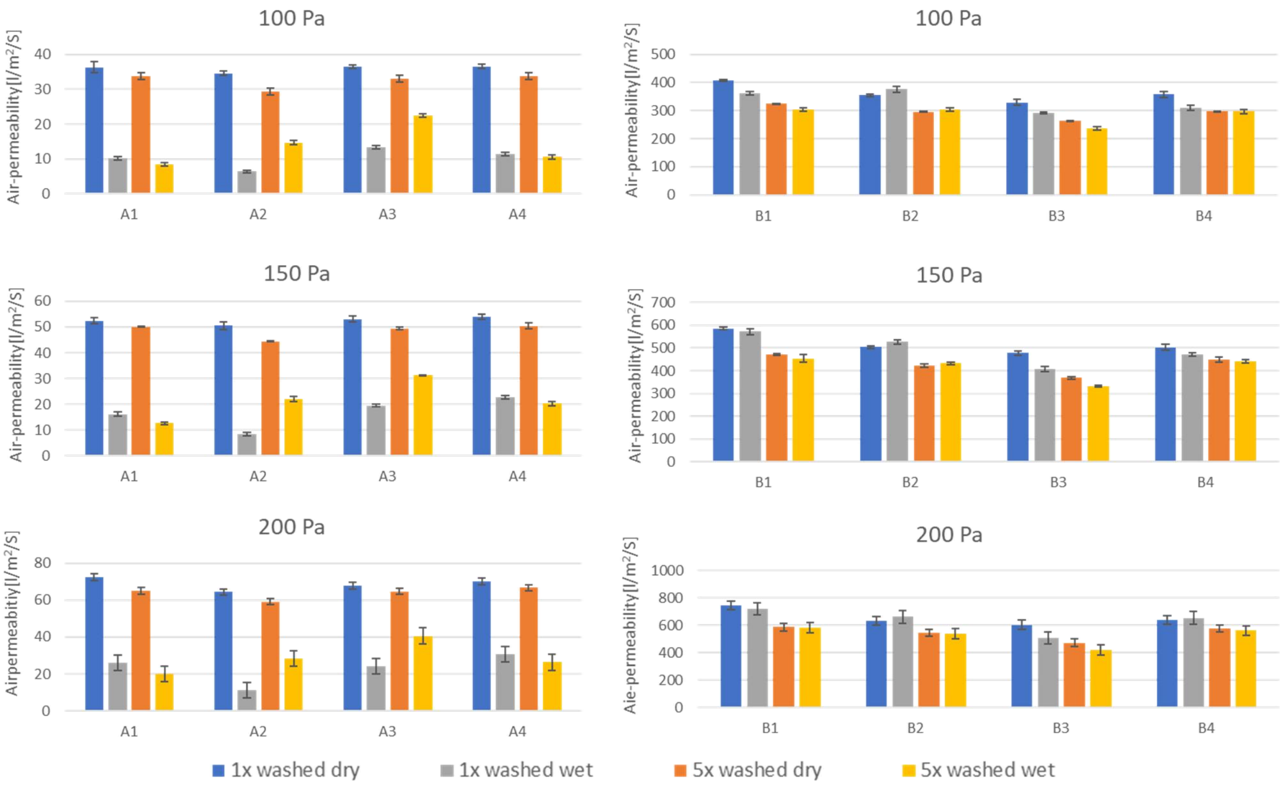


Figure 5 Comparison of air-permeability at three different pressures of both types of 1x and 5x washed fabrics in the dry and wet state: A1, B1 - without seam; A2, B2 - overlapped seam; A3, B3 - bent back seam; A4, B4 - back seam

4 CONCLUSION

Based on the performed experiment, the type of seams has a minimal effect on the air-permeability and can be neglected. However, what cannot be neglected is the influence of the used woven fabric with low porosity, the impact of repeated washing, humidity and pressure. With increasing humidity, the air-permeability of cotton fabric with lower porosity (61%), represented by the type A samples, deteriorates rapidly. The difference between the samples with higher porosity (72%), represented by the type B samples, is less clear. On the contrary, with increasing pressure, the air-permeability improves for all types of samples. Therefore, this type of mask could be suitable for sports exercise because with accelerated breathing, the pressure on the fabric increases due to breathing. Due to washing, both types of samples reduce the air-permeability caused by the shrinkage of cotton fibers.

Since the main topic of this work was to analyze the effect of fabric wetting on its air-permeability, two types of woven fabrics with different porosity were chosen for the experiment. In densely packed cotton samples A, where moisture is held not only in the inter-fiber voids but the fiber is likely to absorb it into its structure. As a result of its diameter increases, there is more significant difference in air-permeability between dry and wet samples, as shown in Figures 4 and 5. Thus, the air-permeability decreases with increasing warp/weft density because the fabric contains fewer pores. In terms of air-permeability, fabrics with lower porosity have lower air-permeability and this dependence increases even more when wet.

Acknowledgement: *This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic and the European Union - European Structural and Investment Funds in the frames of Operational Programme Research, Development and Education under project Hybrid Materials for Hierarchical Structures [HyHi, Reg. No. CZ.02.1.01/0.0/0.0/16_019/0000843]. The authors thank Ing. Jitka Nováková for useful help.*

5 REFERENCES

1. Mukhopadhyay A.J., Midha V.K.: A Review on Designing the Waterproof Breathable Fabrics Part I: Fundamental Principles and Designing Aspects of Breathable Fabrics, Journal of Industrial Textiles 37(3), 2008, pp. 225-262, https://doi.org/10.1177/1528083707082164
2. Feng Y., Marchal T., Sperry T., Yi H.: Influence of wind and relative humidity on the social distancing effectiveness to prevent COVID-19 airborne transmission: A numerical study, Journal of Aerosol Science 147, 2020, No. 105585, https://doi.org/10.1016/j.jaerosci.2020.105585

3. Iannone P., Castellini G., Coclite D., Napoletano A., Fauci A.J., Iacorossi L., D'Angelo D., et al.: The need of health policy perspective to protect Healthcare Workers during COVID-19 pandemic. A GRADE rapid review on the N95 respirators effectiveness, PLoS One 15(6), 2020, pp. 1-13, https://doi.org/10.1371/journal.pone.0234025
4. Abaluck J., Chevalier J.A., Christakis N.A., et al.: The case for universal cloth mask adoption and policies to increase supply of medical masks for health workers, 2020, Available at SSRN: http://dx.doi.org/10.2139/ssrn.3567438
5. Ondryášová M.: The influence wetting of the fabric at its air permeability, Diploma thesis, Technical University of Liberec, 2015 (in Czech), https://dspace.tul.cz/bitstream/handle/15240/17953/Ondry%C3%A1%C5%A1ov%C3%A1.pdf?sequence=1
6. Fourt L., Harrist M.: Diffusion of water vapor through textiles, Textile Research Journal 17(5), 1947, pp. 256-263, https://doi.org/10.1177/004051754701700502
7. O'Dowd K., Nair K.M., Forouzandeh P., et al.: Face masks and respirators in the fight against the COVID-19 pandemic: A review of current materials, advances and future perspectives, Materials 13(15), 2020, pp.1-27, https://doi.org/10.3390/ma13153363
8. Militký J.: Textile fibers (Textilní vlákna), TU Liberec, 2002, 238 p., ISBN 807083644X (in Czech)
9. Křemenáková D., Militký J., Šesták J.: Fiber structures for special applications (Vlákenné struktury pro speciální aplikace), Liberec 2013, pp. 229-233, ISBN 978-80.87269-32-9 (in Czech)
10. Dubrovski D.P., Ziberna-Sujica M.: The connection between woven fabric construction parameters and air permeability, Fibres &Textiles in Eastern Europe 11(4), 1995, pp. 37-41
11. ČSN EN ISO 5084 Determining the thickness of textiles and textile products (Zjišťování tloušťky textilií a textilních výrobků), 1998 (in Czech)
12. Gooijer H., Warmoeskerken M.M.C.G., Groot Wassink J.: Flow resistance of textile materials: Part II: Multifilament fabrics, Textile Research Journal 73(6), 2003, pp. 480-484, https://doi.org/10.1177/004051750307300603
13. ČSN EN ISO 9237 Determination of breathability of fabrics (Zjišťování prodyšnosti plošných textilií),1996 (in Czech)
14. DIN 53887:1986-08 Prüfung von Textilien; Bestimmung der Luftdurchlässigkeit von textilen Flächengebilden, 1986 (in German)
15. Nohejlová M.: Contractility of cotton fabric in washing process (Sráživost bavlněných tkanin), Diploma thesis, Technical University of Liberec, 2006 (in Czech), https://dspace.tul.cz/bitstream/handle/15240/3385/mgr_12324.pdf?sequence=1&isAllowed=y
16. Rabenau H.F., Cinatl J., Morgenstern B., Bauer G., Preiser W., Doerr H.W.: Stability and inactivation of SARS coronavirus, Medical Microbiology and Immunology 194(1-2), 2005, pp. 1-6, doi: 10.1007/s00430-004-0219-0
17. Leclercq I., Batéjat C., Burguière A.M., Manuguerra J.C.: Heat inactivation of the Middle East respiratory syndrome coronavirus, Influenza and Other Respiratory Viruses 8(5), 2014, pp. 585-586, doi: 10.1111/irv.12261
18. Matějková K.: The changes of proportions of cotton textile fabric after having been washed (Rozměrové změny bavlněných tkanin v důsledku praní), Diploma thesis, Technical University of Liberec, 2006 (in Czech), https://dspace.tul.cz/bitstream/handle/15240/8251/mgr_11740.pdf?sequence=1&isAllowed=y
19. Moore A.T., Scott L.W., deGruy I.V., Rollins M.L.: The swelling of cotton in water: A microscopical study, Textile Research Journal 20(9), 1950, pp. 620-630, https://doi.org/10.1177/004051755002000904
20. Remadevi R., Gordon S., Wang X., Rajkhowa R.: Investigation of the swelling of cotton fibers using aqueous glycine solutions, Textile Research Journal 87(18), 2017, pp. 2204-2213, https://doi.org/10.1177/0040517516665267

STRATEGIC INDUSTRY OF SADEWA BATIK IN DEVELOPING BATIK IMAGES VIEWED FROM CORPORATE AND PRODUCT IMAGE

Tri Nurhayati, Mulyanto and Adam Wahida

Universitas Sebelas Maret, Surakarta, Indonesia
nurhayatitri05@gmail.com; mulyanto@staff.uns.ac.id; adamwahida@staff.uns.ac.id

Abstract: *Image or imaging is a communication that is intended to create a good concept for something. It can be a product, person, place and so on. A corporate or industry must have a good image in society, the government and especially customers. Image is needed as an effort and strategy in developing industry. This research was conducted to identify the strategies employed by the Sadewa batik industry in building batik images in terms of corporate and product image. This is important to conduct because, through a good image, the industry will develop more easily, gain more trust from the public, establish relationships with outsiders and attract customers' attention to buy the products. The corporate image can be built through rebranding or changing the logo, ongoing cooperative relationships with other parties, and media involvement in encouraging the corporate image in various events. Meanwhile, product image can be created through product quality, satisfying service and affordable prices. The results of the various efforts and strategies undertaken by the Sadewa batik industry in building such a good image, nowadays its products have been widely spread in the community, both local and international markets; even their products have been able to attract customers, ranging from great businessmen to prominent figures - figures of state officials and obtain a good image from the public, stakeholders, government and customers.*

Keywords: *strategy, image, batik industry, product image, corporate image.*

1 INTRODUCTION

Image or imaging according to Affanti and Nurcahyanti [1] is "a method in communication science that aims to create a good concept in terms of meaning, cultural, visual, and language discourse for products, humans, fashion and so on". Each batik industry must have a good image in society, especially in its customers. Image is needed as an effort to develop a managed batik industry. It takes effort and hard work, a long time and a lot of money to build a good batik image. People's trust in products will automatically grow with a good image. If there is a sense of trust, the public will be more interested and will not hesitate to buy batik products offered by the batik industry.

This research is important to conduct as a strategy in developing a batik image. Efforts that can be done in creating a batik image are the theory of Affanti and Nurcahyanti [1], namely corporate and product image. They are two things that are very important and interrelated in imparting an image in batik products. The corporate image can be created through rebranding or changing the logo, ongoing cooperation with other parties and media involvement in encouraging the corporate image in various events. Meanwhile, product image can be created through product quality, satisfying service and affordable prices. Through this strategy, batik imaging can be well-created in front of the community, customers, stakeholders and even the government. Meanwhile, the theory of Bidin, et al. [2], reveals that corporate communication, corporate strategy, corporate behavior and industrial identity are factors that have positive implications for the perception of corporate images.

2 METHODS

This research was conducted at Sadewa batik industry, which is located in Dukuh Kuyang No 12, rt 05 Kliwonan Village, Masaran District, Sragen Regency. It employed descriptive qualitative methods. The data in this study were the strategies applied by the Sadewa batik industry in building batik images in terms of corporate and product image. Sources of data were obtained through informants, places and events and documents. The informant in this research was Nugroho, as the owner of Sadewa batik. The place and event were at Nugroho's house which was also the place for batik production, batik showroom and Nugroho's production and performance activities.

The documents were in the form of photographs and archives related to batik imaging. Data collection techniques were in-depth interviews, observation and document analysis. The researchers employed triangulating sources and reviewing informants to obtain data validity. The analysis technique was the flow model analysis technique, which consisted of data reduction, data presentation and drawing conclusions or verification. The procedures in this study were preparation, which included observing the research location and compiling research instruments; the data collection which was applied through interviews, observations and document analysis; the data analysis stage consisted of analyzing the initial data that has been collected, developing data and concluding the data; the final report preparation stage consisted of compiling the initial report, reviewing, revising and compiling the final report. This method was employed t formulate strategies used by the Sadewa batik industry in building good batik images viewed from the corporate and the product image.

3 RESULTS AND DISCUSSION

Industry or currently often referred to as Small and Medium Enterprises (SMEs) according to Abraham and Ramli [3] is viewed as the main industry players in the overall economic growth of the country [4]. As the backbone of the country, SMEs must aggressively focus on increasing their productivity, competitiveness and efficiency [5, 6]. This is because SMEs can generate large employment opportunities, stimulate competition, improve the quality of human resources, foster an entrepreneurial culture, support large-scale industries and open up new business opportunities [6]. However, in this study, the term used in industry, namely in the Sadewa batik industry.

Every batik industry must have a good image in the eyes of the community, especially in the eyes of its consumers. Nugroho, as the next generation of the Sadewa batik industry, requires a lot of effort, time and costs to create a good image for the Sadewa batik industry. Two things must be built in creating an image of an industry or corporate, namely corporate image and product image. The following are the explanation of two things that cannot be separated into building a good image.

3.1 Corporate images

Corporate image is an image or a good view of the public on a company. Based on the theory of Affanti and Nurcahyanti [1], strategies that can be done in creating a good corporate image are rebranding or changing the logo, continuous collaboration with other parties and media involvement in encouraging the corporate image at various events. This is what the Sadewa batik industry is doing as a strategy to develop the batik industry. Another opinion from Gray and Balmer [7] cited by Balmer [8] regarding the principle of double processing theory, it can be argued that there is a tripartite explanation of how brand image, corporate brand image and corporate image are formed. First, an image is formed based on immediate, effortless, unconscious, fast and automatic individual mental attributions (system process 1); second, if an individual has the necessary abilities and motivational needs, an image is formed based on a significant cognitive consideration of the individual's working memory which results in more considered mental attributions (system process 2); third, a combination of systems 1 and 2.

Based on the results of observations and interviews during the research, it is known that the Sadewa batik industry has an industrial logo that has survived from its inception until now. The brand or logo is in line with the name of the industry, which is taken from a puppet character named "SADEWA".

Figure 1 Logo of Sadewa *batik tulis* industry (Documentation: Tri Nurhayati, 2020)

The word "SADEWA" is taken from one of the Pandawa Lima puppet figures, Sadewa. It was taken and used as the brand name for his batik industry because, in a puppet story moment, Sadewa became a savior in a riot. Sadewa was a way out of a riot and he was the winner. Based on that story, Nugroho's parents gave the name Sadewa as the brand of their batik industry. They expect that the Sadewa batik industry can be a savior and a solution to problems in his family.

The use of a logo in the industry has an important role as a corporate identity. This logo will be known and remembered by the public when they are looking for batik products. A good logo is a logo that has meaning for a corporate. Ind [9] reveals that a corporate brand is more than just a name or logo but is related to the corporate values of the organization. Hatch and Schultz [10, 11] assert that it is fundamentally related to mission, culture and image, but is not involved with the notion of corporate brand promise. Rebranding activities and changing the logo are the agenda that has been planned by Nugroho. The logo will be made simpler by including the word Nugroho in it. This aims to inform the public that the product comes from Nugroho's Sadewa batik industry because the brand with the name Sadewa has been widely used by other batik companies or industries out there.

The change in the logo is only limited to visuals or appearance so that it is easier for the public to recognize, without changing the meaning or philosophy of the logo given by the Nugroho family.

Currently, corporate branding is very crucial in the marketing canon as stated by recent literature [12-26]. Another strategy to create a corporate image is through cooperative relationships with other parties, such as businessmen and state figures. This is because the target market of the Sadewa batik industry is those from the upper-middle class, namely entrepreneurs and national figures. National figures who have bought and liked batik products from Nugroho are Mr. Yusuf Kala and his wife, Mr. Susilo Bambang Yudhoyono and his wife, Mr. Joko Widodo and his wife, and those who recently purchase sadewa batik products are Sragen Regent, Mrs. Yuni. In addition to establishing relationships with national leaders and entrepreneurs, Nugroho also cooperates with several batik shops/galleries in Jakarta and Solo as its target market. For Solo area, the target market is Batik Keris, Semar, Danar Hadi shops, as well as several businessmen in Klewer Market. Through this continuous collaboration, it can indirectly improve the corporate image in the eyes of the public and its customers.

Collaborative and other media involvement used in building a corporate image through participation in exhibitions and sponsoring events. The exhibition is used as a promotional media and introduces batik products to the outside community, both nationally and internationally. The exhibitions that have been attended by Nugroho include the title of Nusantara Batik, Inakram, Adiwasta, and IndoCraft. On average, Nugroho can participate in the exhibition 3 times a year. Besides, being a sponsor in an event is also an effective way of building an image. Through this activity, the community can find out what kind of written batik products are made, their concern for the community and how to preserve batik in Indonesia. Major activities or events that have been sponsored by Sadewa's written batik industry include the Solo Menari Event, Solo Batik Carnival and other events held in the area of Sadewa's hand-written batik industry.

This branding activity, consciously or not, can have a good and significant impact. If a corporate has a good image with the community, consumers, or other parties, it will be easier to gain more trust and it will be easier to develop a written batik industry business.

3.2 Product image

A product is something that results from the production process, both in the form of goods and services offered to the market. Asri [27] states that a product is a pile or unit of attributes that can meet a person's needs, such as color, packaging, price, usability and others. Product planning is necessary to increase sales need to make improvements and product development to be more profitable and satisfying [28].

A product image in a corporate can be created through product quality, satisfying service and affordable prices. In building a product image of Sadewa *batik tulis*, Nugroho pays close attention to the quality of hand-written batik products with natural dye of *tegeran* wood that has been passed down from generation to generation from his family. According to him, customer satisfaction with his products is the main thing, because if the customer is satisfied and is fond of the product, then he will be a loyal customer. Sirdeshmukh [29] also state that a pleasant service can increase consumers' trust in the corporate.

The following are the strategies that can be conducted in marketing *batik tulis* product to get a good image in the customers' eyes:

a) *Product differentiation*

Product differentiation is a process of distinguishing a product from others, to make it more attractive to a particular target market. It requires high creativity to create unique, creative, refined, comfortable and high-quality products. As much as possible, Nugroho as the owner of the Sadewa batik industry tries to innovate in creating batik products that are different from other industries, both in terms of motifs and colors. This has been conveyed by Booz, Allen and Hamilton [30-32] that identifying 6 (six) new product categories based on their novelty for corporations and markets, including:

1) products that are completely new, it means new products of innovation that create new markets;
2) new product lines, it means new products that allow corporations to enter the market for the first time even though they had previously existed;
3) addition of existing product lines, it means new products to complement existing product lines;
4) improvements as a revision of the current product;
5) repositioning;
6) reducing costs [28].

Batik tulis products produced by Sadewa *batik tulis* industry have distinctive characteristics that differentiate them from other products, namely in terms of their motifs and colors as well as the old impression of the batik. The motifs produced by Nugroho include modern or contemporary motifs combined with traditional motifs, which are mostly inspired by the surrounding environment. Motifs that are made uniquely and eccentrically are different from the motifs on the market because Nugroho's designs are based on his creativity.

In terms of color uniqueness, Nugroho uses natural dyes that are starting to be abandoned by people at this time, namely the natural dye of *tegeran* wood which produces a brown color. The advantages of using natural dyes include environmentally friendly, cheaper raw material prices, better market prospects and having many fans. Borshalina [28] reveals that today's international market orientation, especially the Japanese and European markets, wants environmentally friendly batik products [33]. This is based on the fact of how bad the impact of the excessive use of synthetic dye-based chemicals in the batik industry is. Besides, the “back to nature” slogan cannot be separated from the reasons why Batik Trusmi players make innovations with their products. The same research is conducted by Borshalina [28] which reveals that to minimize the waste problem, Trusmi Batik SMEs players in Cirebon district, especially in the processing of superior batik coloring in these villages, use various plant parts such as mango leaves, mahogany tree bark, tobacco, indigo bark and *jengkol* tree bark.

Nugroho reveals that using brown natural dye *tegeran* wood can create a color that had an old impression. So that, batik cloth combines modern motifs with old batik impression. This uniqueness must be preserved, even improved continuously to create a good image of *batik tulis* products in the eyes of the public, customers, outsiders and the government. So that it can increase sales of *batik tulis* products.

b) <u>Service quality differentiation</u>

In this case, service quality is related to a promotional strategy in building the image of a product. Chien and Chi [34], the American Marketing Association defines service quality as "a field of study developed to determine and describe how services can be provided in such a way to satisfy recipients".

Talking about the quality of services provided by industry or company, this will have an impact on customers’ satisfaction. Satisfaction is a dynamic and concrete concept [35, 36] which is influenced by service quality, product quality, price and contextual and personal factors [37]. This is expressed by Valaei and Baroto [38] and Chien and Chi [34], which essentially reveals that service quality leads to satisfaction, which ultimately results in behavioral intentions. This means that satisfied customers have a higher probability to repurchase or reuse the service than those who express dissatisfaction. Related research also shows the fact that improving service quality becomes one of the main management methods to increase customer loyalty and satisfaction [39]. Besides, it is one of the important factors that influence company success [40].

Good and satisfying service quality is a priority of the Sadewa batik industry. Nugroho as the owner of the batik industry believes that good service quality can satisfy customers to attract customers to repurchase the products. Becerril-Arreola [41] reveals that companies can increase sales volume by offering quality services, both to increase market share and the effectiveness of their service environment.

Promotional activities carried out by Nugroho as the owner of Sadewa *batik tulis* industry are publicity, public relations (PR) and personal selling. The strategy of publicity and PR is implemented through communication media and public relations. Currently, the communication media as a promotional strategy is WhatsApp (WA) and Instagram, but their use is not very optimal. Even though in this modern era, especially during the Covid 19 pandemic, the use of social media as a promotional media and online shopping features is very effective for selling batik products via the internet. This is expressed by Castellacci and Tveito [42] who identify four main ways of using the internet in subjective welfare in the scope of consumption:

1) increasing spending efficiency
2) enabling the emergence of new consumption activities,
3) facilitating access to information,
4) improving communication between consumers and producers [43].

On the other hand, the internet through blogs and social networks, for example, can act as an "agenda-setter" [44] which may disseminate information that changes the initial preference for products.

Even though there are many advantages of online shopping and most people tend to do it. Suyanto [45] in his research reveal the advantages of online shopping, including the large variety of products in an unlimited number, can be done while relaxing at home or in the bedroom, allowing people to buy things from anywhere, explore the virtual world without limits, only with a laptop or mobile phones and internet access, people can choose and buy products just by playing their fingers, seeing the desired product and buying it. Besides, the product is qualified and has cheaper prices. However, Nugroho has not utilized and maximized this in marketing in his business. Currently, sales are prioritized by meeting the customers directly.

Nugroho meets directly with his prospective customers and forms business collaboration in selling *batik tulis*. The strategy is influencing consumers to buy their products by showing the uniqueness and advantages of his product compared to others. This is a promotional strategy undertaken by Nugroho in binding a consumer from the upper classes, without intending to differentiate between lower and upper class because everyone has their way and tricks in promoting their batik products.

Meanwhile, personal selling carried out by Nugroho is through exhibition activities and sponsoring an event. The exhibitions that have been attended by Nugroho include the Nusantara Batik carpet, Inakram, Adiwasta, and IndoCraft. On average, Nugroho can participate in the exhibition 3 times a year. Several things that must be considered in this activity are service quality and customer satisfaction. Jin [46] reveals that in an exhibition, service quality and customer satisfaction are the main factors in determining success. Through the exhibition, Nugroho can meet directly with the public, so that he can find out what response is given to his batik products, as well as knowing what his customers want. Hsu [47] reveals that understanding what customers value and expect from the services can help companies in allocating resources and help them make improvements based on customers' demand.

Moreover, several activities or events that have been sponsored by Sadewa's written batik industry include the Solo Menari Event, Solo Batik Carnival and other events held in Sadewa's batik industry area.

c) <u>Image differentiation</u>

Image is identical with attributes, namely characteristics, appearance as a differentiator from a person or object. The image differentiation of the Sadewa batik industry is created through a unique and distinctive hand-written batik product. Sadewa hand-written batik with modern motifs combined with traditional motifs of his creations creates quirky motifs, with natural dyes from *tegeran* wood so that the batik cloth has an old impression. It is a prominent product of Sadewa hand-written batik industry which differentiates it from other batik industries. Even, this characteristic has stuck in the minds and hearts of its consumers.

Moreover, the image of a product can also be created through a price. Price is an important factor in competitiveness. Affordable prices are the main attraction for the public and customers. Mat'ova [48] states that corporate image is the result of many factors that affect customers. Some of these factors are not under management control. Price and price policies are important factors for competitiveness, but it is impossible to create an image only on "price". This is a concern for Nugroho as the owner of the Sadewa batik industry. The price offered for a piece of hand-written batik cloth with *tegeran* wood dye varies, ranging from 4 000 000 to 15 000 000 Rp, depending on the complexity of the motive. This price is quite affordable for some because Nugroho's target market is for those from the middle to the upper class.

This image differentiation strategy must build, exploit and maximize the strengths and weaknesses of the image elements to ensure that batik products with distinctive motifs with natural dye *tegeran* wood have good prospects in the future.

4 CONCLUSION

Imaging or batik image for industry is an important thing in developing a medium industrial business. It takes effort and hard work, a lot of time and a lot of money in developing an industrial image. Two things are used in creating an image of an industry or corporate, namely corporate image and product image. The corporate image can be created through rebranding or logo renewal with the aim of refreshing and making the logo more easily recognized by the public, sustainable cooperative relationships with other parties by establishing relationships with businessmen and state officials, as well as with famous batik shops in the region Solo and Jakarta, as well as media involvement in encouraging the corporate image at various events, is carried out through participation in batik exhibitions, both national and international, as well as sponsoring various events. Meanwhile, the product image is created through product quality, satisfying service, and affordable prices. Sadewa batik industry has a prominent product, namely unique, distinctive and high-quality batik because it has contemporary motifs and has an old impression. These strategies turned out to be effectively conducted in developing a batik image so that currently the batik production of the Sadewa batik industry has been recognized and in demand by the wider community.

ACKNOWLEDGEMENT: *The researchers would like to express gratitude to prof. Dr. Mulyanto, M.Pd. and Dr. Adam Wahida S.Pd., M.Sn. for guidance in this research; and Nugroho as the owner of Sadewa batik industry for his cooperation. Hopefully, this research will be useful and contribute as a reference for further research.*

5 REFERENCES

1. Affanti T.B., Nurcahyanti D.: Batik Girli, Kekata Publisher, Surakarta, 2017
2. Bidin R., Muhaimi A., Bolong J.: Strategising corporate identity for the perception of corporate image in the selected government-linked companies (GLCs) in Malaysia, Procedia - Social and Behavioral Sciences 155, 2014, pp. 326-330, https://doi.org/10.1016/j.sbspro.2014.10.300
3. Ab Rahmam N.A., Ramli A.: Entrepreneurship management, competitive advantage and firm performances in the craft industry: concepts and framework, Procedia - Social and Behavioral Sciences 145, 2014, pp. 129-137, https://doi.org/10.1016/j.sbspro.2014.06.019
4. Hashim H.: Innovation, High-Growth and Productivity, World Folio.co.uk, 2012, retrieved from www.smecorp.gov.my/vn2/node/143

5. Rusconi R.: National Annuity Markets: Features and Implications, OECD Working Papers on Insurance and Private Pensions 24, OECD Publishing, 2008, 61 p., DOI: 10.1787/240211858078
6. Weerakkody D.: SME: Backbone of an economy, 2013, retrieved from: http://www.sundaytimes.lk/130303/business-times/sme-backbone-of-an-economy-34565.html
7. Gray E.R., Balmer J.M.T.: Managing corporate image and corporate reputation, Long Range Planning 31(5), 1998, pp. 695-702, https://doi.org/10.1016/S0024-6301(98)00074-0
8. Balmer J.M.T., Lin Z., Chen W., He X.: The role of corporate brand image for B2B relationship of logistics service providers in China, Journal of Bussines Research 117, 2020, pp. 850-861, https://doi.org/10.1016/j.jbusres.2020.03.043
9. Ind N.: The Corporate Brand, Palgrave Macmillan UK, 1997, 184 p., DOI: 10.1057/9780230375888, ISBN: 978-0-333-67472-7
10. Hatch M.J., Schultz M., Are the strategic stars aligned for your corporate brand?, Harvard Business Review 79(2), 2001, pp. 129-134
11. Hatch M.J., Schultz M.: The dynamics of corporate brand charisma: Routinization and activation at Carlsberg IT, Scandinavian Journal of Management 29 (2), 2013, pp. 147-162, https://doi.org/10.1016/j.scaman.2013.03.005
12. Muzellec L., Lambkin M.C.: Corporate branding and brand architecture: a conceptual framework, Marketing Theory 9(1), 2009, pp. 31-54, https://doi.org/10.1177/1470593108100060
13. Balmer J.M.T.: Corporate brand management imperatives: custodianship, credibility, and calibration, California Management Review 54(3), 2012, pp. 6-33, https://doi.org/10.1525/cmr.2012.54.3.6
14. Balmer J.M.T.: Strategic corporate brand alignment: Perspectives from identity based views of corporate brands, European Journal of Marketing 46(7/8), 2012, pp. 1064-1092, https://doi.org/10.1108/03090561211230205
15. Balmer J.M.T.: Corporate brand orientation: What is it? What of it? Journal of Brand Management 20(9), 2013, pp. 723-741, https://doi.org/10.1057/bm.2013.15
16. Gyrd-Jones R., Merrilees B., Miller D.: Revisiting the complexities of corporate branding: Issues, paradoxes, solutions, Journal of Brand Management 20(7), 2013, pp. 571-589, https://doi.org/10.1057/bm.2013.1
17. Liu Y., Foscht T., Eisingerich A.B., Tsai H.-T.: Strategic management of product and brand extensions: Extending corporate brands in B2B vs. B2C markets, Industrial Marketing Management 71, 2018, pp. 147-159, https://doi.org/10.1016/j.indmarman.2017.12.016
18. Mohan M., Voss K.E., Jiménez F.R., Gammoh B.S.: Corporate brands as brand allies, Journal of Product & Brand Management 27(1), 2018, pp. 41-56, https://doi.org/10.1108/JPBM-01-2016-1080
19. Sevel L., Abratt R., Kleyn N.: Managing across a corporate and product brand portfolio: evidence from a large South African service organization, Journal of Product & Brand Management 27(1), 2018, pp. 18-28, https://doi.org/10.1108/JPBM-05-2016-1182
20. Silva R., Gerwe O., Becerra M.: Corporate brand and hotel performance: A resource-based perspective, Journal of Business Research 79, 2017, pp. 23-30, https://doi.org/10.1016/j.jbusres.2017.05.019
21. Törmälä M., Gyrd-Jones R.I.: Development of new B2B venture corporate brand identity: A narrative performance approach, Industrial Marketing Management 65, 2017, pp. 76-85, https://doi.org/10.1016/j.indmarman.2017.05.002
22. Törmälä M., Saraniemi S.: The roles of business partners in corporate brand image co-creation, Journal of Product & Brand Management 27(1), 2018, pp. 29-40, https://doi.org/10.1108/JPBM-01-2016-1089
23. Tuškej U., Podnar K.: Consumers' identification with corporate brands: Brand prestige, anthropomorphism and engagement in social media, Journal of Product & Brand Management 27(1), 2018, pp. 3-17, https://doi.org/10.1108/JPBM-05-2016-1199
24. Essamri A., McKechnie S., Winklhofer H.: Co-creating corporate brand identity with online brand communities: A managerial perspective, Journal of Business Research 96(3), 2019, pp. 366-375, https://doi.org/10.1016/j.jbusres.2018.07.015
25. Greyser S., Urde M.: What does your corporate brand stand for? Harvard Business Review 97(1), 2019, pp. 80-88,
26. Iglesias O., Markovic S., Singh J.J., Sierra V.: Do customer perceptions of corporate services brand ethicality improve brand equity? Considering the roles of brand heritage, brand image, and recognition benefits, Journal of Business Ethics 154(2), 2019, pp. 441-459, https://doi.org/10.1007/s10551-017-3455-0
27. Asri M.: Marketing, AMP YKPN, Yogyakarta, 2001
28. Borshalina T.: Marketing strategy and the development of batik Trusmi in the regency of Cirebon which used natural coloring matters, Procedia - Social and Behavioral Sciences 169, 2015, pp. 217-226, https://doi.org/10.1016/j.sbspro.2015.01.305
29. Sirdeshmukh D., Singh J., Sabol B.: Consumer trust, value, and loyalty in relational exchanges, Journal of Marketing 661, 2002, pp. 15-37, https://doi.org/10.1509/jmkg.66.1.15.18449
30. Hiam A., Schewe C.D.: The Portable MBA Pemasaran, Jakarta, Binarupa Aksara, 2004
31. Kotler P., Keller K.L.: Marketing Management, Pearson Education International, New Jersey, 2012
32. Stanton W.J, Futrell C., Walker B.J.: Fundamentals of Marketing, McGraw-Hill, Singapore, 2004
33. Clean Batik Initiative (CBI), Achievement report in the year of 2011-2012 of the second year, EU Switch-Asia Program, Jakarta, 2013

34. Chien L.H., Chi S.Y.: Corporate Image as a mediator between service quality and customer satisfaction: difference across categorized exhibitors, Heliyon 5(3), 2019, e01307, https://doi.org/10.1016/j.heliyon.2019.e01307
35. Cronin J.J., Taylor S.A.: Servperf versus servqual: reconciling performance-based and perceptions-minus-expectations measurement of service quality, Journal of Marketing 58(1), 1994, pp. 125-131, https://doi.org/10.1177/002224299405800110
36. Giese J.L., Cote J.A.: Defining consumer satisfaction, Academy of Marketing Science Review 4(1), 2000, pp. 1-24, http://www.amsreview.org/articles/giese01-2000.pdf
37. Zeithaml V.A., Bitner M.J.: Services Marketing: Integrating Customer Focus across the Firm, 2nd ed., Irwin/McGraw-Hill, Boston, 2000, 620 p. ISBN: 9780072312218
38. Valaei N., Baroto M.B.: Modelling continuance intention of citizens in government Facebook page: a complementary PLS approach, Computers in Human Behavior 73(C), 2017, pp. 224-237, https://doi.org/10.1016/j.chb.2017.03.047
39. Su Y.G., Teng W.C.: Contemplating museums' service failure: Extracting the service quality dimensions of museums from negative on-line reviews, Tourism Management 69, 2018, pp. 214-222, https://doi.org/10.1016/j.tourman.2018.06.020
40. Ahuja I.P.S., Khamba J.S.: Assessment of contributions of successful TPM initiatives towards competitive manufacturing, Journal of Quality in Maintenance Engineering 14(4), 2008, pp. 356-374, https://doi.org/10.1108/13552510810909966
41. Becerril-Arreola R., Zhou C., Srinivasan R., Seldin D.: Service satisfaction-market share relationships in partnered hybrid offerings, Journal of Marketing 81(5), 2017, pp. 86-103, https://doi.org/10.1509/jm.15.0537
42. Castellacci F., Tveito V.: Internet use and well-being: A survey and a theoretical framework, Research Policy 47(1), 2018, pp. 308-325, https://doi.org/10.1016/j.respol.2017.11.007
43. Guillen-Royo M.: Sustainable consumption and wellbeing: Does on line shopping matter?, Journal of Cleaner Production 229, 2019, pp. 1112-1124, https://doi.org.10.1016/j.jclepro.2019.05.061
44. Reisch L.A.: The Internet and sustainable consumption: Perspectives on a Janus face, Journal of Consumer Policy 24(3/4), 2001, pp. 251-286, https://doi.org/10.1023/A:1013977509623
45. Suyanto B., Subiakto H., Srimulyo K.: Data of the patterns of youth local brand product consumption through online shopping, Data in Brief 23, 2019, 103723, https://doi.org/10.1016/j.dib.2019.103723
46. Jin X., Weber K., Bauer T.: Relationship quality between exhibitors and organizers: A perspective from Mainland China's exhibition industry, International Journal of Hospitality Management 31(4), 2012, pp. 1222-1234, https://doi.org/10.1016/j.ijhm.2012.02.012
47. Hsu S.H., Chen W.H., Hsueh J.T.: Application of customer satisfaction study to derive customer knowledge, Total Quality Management & Business Excellence 17(4), 2006, pp. 439-454, https://doi.org/10.1080/14783360500528197
48. Mattova H., Dzian M., Triznova M., Palus H., Parobek J.: Corporate image profile, Procedia Economics and Finance 34, 2015, pp. 225-230, https://doi.org/10.1016/S2212-5671(15)01623-8

MULTILAYER TEXTILE MATERIAL COATED WITH NANOPARTICLES OF ELECTROCONDUCTIVE POLYANILINE

Ya.V. Red'ko[1], O.O. Garanina[1], A.B. Brik[2] and Ye.O. Romanyuk[1]

[1]Kyiv National University of Technologies & Design, N.-Danchenko str. 2, 01011 Kyiv, Ukraine
[2]Institute of Geochemistry, Mineralogy and Ore Formation by M.P. Semenenko of the NAS of Ukraine
82yanet@gmail.com, helgaranina@gmail.com, evromanuk@gmail.com

Abstract: *The article is devoted to the study of self-organization processes of conductive layers of polyaniline nanoparticles in heterocoagulation on polyamide textile material. It is shown that the particle size distribution of the polyaniline dispersion has a normal distribution with a maximum of 150 nm. It is found that the electrical resistance of the multilayer textile material with a polyaniline coating obtained by method of the layer-by-layer depends on the number of layers and the type of the surfactants. The process of a heterocoagulation of polyaniline particles on the polyamide textile material is described by the quasi-chemical reaction model.*

Keywords: multilayer textile materials, polyaniline, heterocoagulation, self-organization, nanoparticles.

1 INTRODUCTION

Electroconductive nanostructured materials not containing metals are of interest in several areas of their use [1]. This is possible due to the self-organization of nanoparticles formation of different structures. The character of formed structures, the ability to control their formation is of interest as from the scientific [2-4], and from a practical point of view because of the influence on the properties of nanosystems. The possibility of obtaining electroconductive fibers by deposition of nanoparticle layers of polyaniline on the surface of nonconductive fabric by heterocoagulation mechanism (the term firstly was used in [5]) is demonstrated in [56].

The use of deposition of nanoparticles that provide special properties of textile material as a substrate is important for many reasons. Textile material provides a much larger surface area than a smooth surface, which is extremely important for their use. The particle size applied to the surface of the textile material should be smaller than for particles forming a conventional coating of the solution. The nanoparticles deposited on the textile material can be used as a substrate for the subsequent formation of the next layer of nanoparticles by the layer-by-layer method.

The saturation of nanoparticles of a particular substrate can be regulated by changes in physical parameters (pressure, temperature) or changes in chemical composition [2]. The result of these new synthetic methods is the development and synthesis of a much larger range of polymers with the possibility of self-organization. This is the essence of the new approach and the key aim of nanotechnology is to form a highly organized structure [1].

The purpose of this work is: 1) to characterize the process of self-organization of the electrically conductive layer of nanoparticles in the process of heterocoagulation on the example of polyamide textile material – nanosize polyaniline; 2) to obtain multilayer textile materials with electroconductive properties.

2 EXPERIMENTAL

Polyamide (PA) yarn with a linear density of 15.6 tex was used for the study. Knitted PA fabric obtained from this polyamide yarns was used as a textile substrate for the experiments.

Conductive textile material was prepared as follows. Aniline is subjected to oxidation in a processing solution at a certain bath module in the presence of surfactant (SAS) and textile material.

Non-ionic OS-20 (NSAS), cationic alkamon OS-2 (CSAS) and anionic sulfonol (ASAS) were used as surfactants. Ammonium peroxysulphate was used as an oxidizer. Equivalent oxidizer/aniline ratio was 1:1.3. The treatment process lasted for 15-30 min at the temperature of 18-22°C. Thus, nanodispersed aniline was formed on the polyamide textile by heterocoagulation mechanism [5, 6]. Next, the conductive textile material was washed with distilled water and dried. The specific electrical resistance of the processed textile material was determined by a two-zone compensating method which allows determining both bulk and surface resistance (*R*) using ohmmeter.

The particle size distribution was determined using Mastersizer 2000 (Malvern, UK) with appropriate software which includes the Mie theory. Using the device allows to obtain the size distribution curves as a function of the numerical fraction of particles according to their size.

The surface morphology of the treated polyamide materials was characterized by scanning electron microscopy (SEM) MIRA 3 LMU, Tescan with a resolution of ±1 nm and energy-dispersive spectroscopy (EDX) with chemical analysis Oxford X – MAX 80 mm^2 with appliance uncertainty ±1%.

The amount of polyaniline on the textile substrate was determined by photocolorimetry. The concentration of polyaniline in the bath is assumed to be proportional to the concentration of aniline before synthesis (characterized by optical density *D*).

3 RESULTS AND DISCUSSION

3.1 The self-organization of the conductive nanoparticles on the textile material

Polymers capable of self-organization, on the one hand, can form stable nanostructures, on the other – easily change the form of self-organization, even under the influence of external factors [7, 8]. Usually, the synthesis of nanostructured polymers is carried out in the presence of hard or soft (micelles, surfactant solutions, polymer gels, emulsions) template. In our case, the controlled synthesis of nanostructured polyaniline is carried out in the presence of surfactants.

It was established that the deposition of polyaniline particles on polyamide textile material is carried out from the nanosystem: dispersion of polyaniline nanoparticles in the treatment bath. Figure 1 shows the distribution curve of the particle size of polyaniline dispersion in a numerical proportion of particles depending on their size.

According to the formal features, the nanoparticles are particles which particle size is less than 100 nm. In fact, there is a more correct approach: a particle belongs to a colloidal particle (nanoparticles), if the reduction of size affects the achievement of new properties.

Nanosystems usually have wide size distribution of particles: the multiple dispersed or reversible process of aggregation is realized by a lognormal particle size distribution. In many cases, a set of particles with an average size between 100 and 1000 nm is also considered as nanoparticles, because part of the particle size is within the range less than 100 nm and a part of the particles can be as dynamic agglomerates consisting from particles smaller than 100 nm. Therefore, the investigated dispersion studied in this work was found as nanosystem.

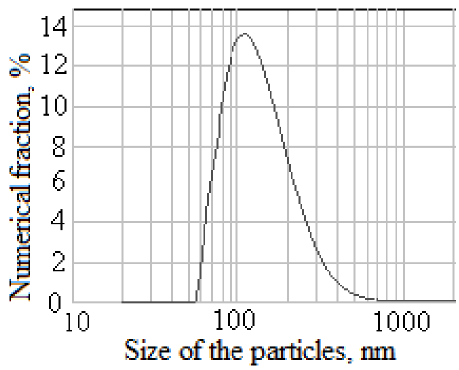


Figure 1 Differential curve of polyaniline particles sizes distribution

Figure 2 shows the dependence of the optical density *D* of the solutions of polyamide materials on the concentration of aniline *C* in a presence of OS-20 preparation (1) and alkamon OS-2 (2), in the coordinates of Langmuir equation [5]. Langmuir equation is derived and is used to describe of the adsorption, for example, the molecules on the surface as a monomolecular layer [9]. It is well known [7, 8] that the deposition of nanoparticles on the surface can be in the form of monolayers by self-organization and multilayer coatings [10].

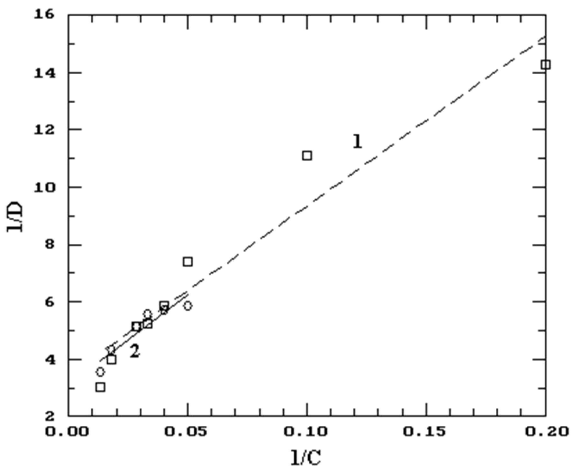


Figure 2 The dependence of the optical density *D* of the solutions of treated polyamide materials on the concentration of aniline *C* in presence of OS-20 (1) and alkamon OS-2 (2), in the coordinates of Langmuir equation

The balance between the process of peptization and heterocoagulation (sorption - desorption) of colloidal particles on the surface, in the form of a quasi-chemical reversible reaction (possibly at a relatively small depth of the second minimum in the area of potential energy of interaction between particles), is presented. The using of reversible quasi-chemical reactions is generally accepted in the study of molecular adsorption processes [9].

The equilibrium between the surface "active" centers A, the nanoparticles of dispersion NP and temporarily settled on the surface of the nanoparticles A NP is determined by quasi-chemical equation of reversible reaction:

$$A + NP \leftrightarrow A \cdot NP \quad (1)$$

If the maximum of concentration A (the active sites of surface), with the potential to form compounds with the nanoparticles in the 1: 1 ratio, is $C_{A,\infty}$, the concentration of active centers remaining free is determined as value ($C_{A,\infty}$ - $C_{A\ NP}$). The equilibrium constant for reaction (1) at a concentration of nanoparticles in the dispersion C_{NP} is:

$$K = \frac{C_{A \cdot NP}}{C_{NP}(C_{A,\infty} - C_{A \cdot NP})} \quad (2)$$

The equation (2) at the coordinates $1/C_{A\ NP} = f(1/C_{NP})$ is converted into a linear equation:

$$\frac{1}{C_{A \cdot NP}} = \frac{1}{C_{A,\infty}} + \frac{1}{KC_{A,\infty}} \cdot \frac{1}{C_{NP}} \quad (3)$$

Analysis of the equations (2) and (3) shows that the formation of particles' monolayer of the dispersed phase in the reverse process of heterocoagulation of the isotherm sorption equation has similar shape as the Langmuir monomolecular adsorption equation on the interface. This equation is characteristic for monolayer adsorption [9]. In the process of heterocoagulation of nanoparticles on the surface of textile material, a compound with a limited lifetime is formed (reverse process). This creates the conditions for the process of self-organization with the emergence of an orderly structure.

The polyamide textile material (TM) in acidic media (pH<5) has a positive surface charge, polyaniline nanoparticles synthesized in the presence of anionic surfactant – sulfonol have a negative charge as a result of heterocoagulation and in this case, interactions between particles with opposite charges occur according to the classical mechanism [5].

The electrostatic interaction of the particles in this case is sufficiently intense to the irreversibility of the process. As a result of the use of sulfonol stabilizer, the dependence of the amount of polyaniline on the fabrics and the concentration of polyaniline in the bath cannot be described by an equation identical to the Langmuir equation. The absence of restructuring possibilities of the deposited layer can apparently lead to a layered structure similar to fractal structure in the limited aggregation diffusion.

It is determined that the main mechanism of formation of polyaniline coating in the process of aniline oxidation in the presence of surfactants is heterocoagulation of polyaniline nanoparticles on the surface of textile material. In this regard, it is necessary to establish the possibility of achieving self-organization of nanoparticles by the layer-by-layer method [11–13] to obtain multilayer textile materials with electrically conductive properties. The formation of nanostructured surface layers provides multi-stage synthesis of polyaniline nanoparticles with a change in the surfactant type and, as a consequence, with a change in the surface charge of the polyaniline nanoparticles. It is interesting to study the effect of the process of multistage heterocoagulation of polyaniline nanoparticles on the conductive properties of polyamide textile material.

The results of morphological studies indicate the uniform deposition of polyaniline particles on the surface of textile materials (Figure 3). Perhaps, this is due to the increased affinity of the organic substrate and the organic disperse phase. The proposed method for polyaniline synthesis ensures the formation of polyaniline particles with bimodal size distribution, namely, isomorphic particles of polyaniline of small size (87±15 nm) and anisomorphic particles in the form of plates with an average linear size of 496 nm – 180 nm and a thickness of about 90 nm.

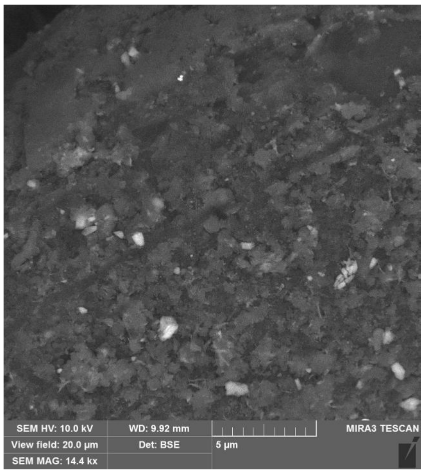


Figure 3 The SEM images of the treated polyamide materials with polyaniline nanoparticles

The relatively high content of nitrogen in the surface layer of the composite (experimentally 6.8%, theoretically 15.3%), obtained from the results of elemental analysis by the method of energy-dispersion spectroscopy, confirms the high degree of coating the surface of the textile material with particles of polyaniline.

Small-size particles also practically do not form aggregates, as evidenced by their distribution on the histogram and low polydispersity (Figure 4).

When the ratio between the aggregation and sorption stability of micelles with solubilized polyaniline changes, the particles, which are stabilized by adsorption of ASAS, cause the transition to the heterocoagulation mechanism of treatment with nanostructured polyaniline instead of possible absorption (dissolution) of polyamide. Management of sorption stability is also required for other processing processes that occur in different ways of nanoscale processing in order to obtain special properties of textile materials.

Thus, the distribution of the polyaniline particles (conjugated organic polymer), synthesized in the presence of ASAS according to its sizes in the initial dispersion (Figure 1), shows the synthesis of nanoparticles in the treatment bath and the distribution of polyaniline particles on the polyamide textile material (Figures 3 and 4). It also shows the detection of sorption affinity of the particles of the dispersed phase to the surface of the polyamide textile material.

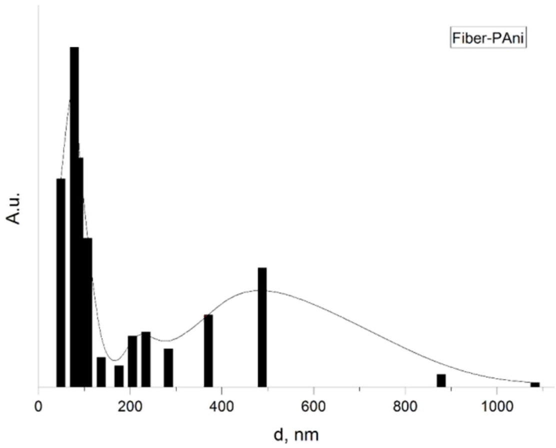


Figure 4 The histogram of distribution of the polyaniline particles in sizes on the textile material

However, high frictional properties are evident from the deposited polyaniline nanoparticles on the surface of PA textile material by the heterocoagulation mechanism.

It should be noted that the surface layer of polyaniline forms the plates of polyaniline. The formation of aggregates of polyaniline particles, which is associated with the conditions of their synthesis when using surfactants, is uncharacteristic. As a result, a layer of polyaniline on the surface of a textile material consists of a monolayer of planar particles of polyaniline, whose thickness is about 90 nm.

Layer deposition (layer-by-layer) of polyelectrolytes, proteins, colloidal particles, films on a substrate is well known [7, 8, 10-13]. Method of layer-by-layer may be applied to increase the electrical conductivity of essentially textile composite material – electrically conductive polymer layer on the surface. In the method of layer-by-layer of like or different charges and the surface of the deposited particles of different nature plays an important role [10–13].

3.2 The obtaining of the multilayer textile materials with electroconductive properties

In this work, the multistage synthesis of polyaniline conductive layer using at each stage of the dispersions stabilized by surfactants, form micelles with a charge opposite to the charge of the surface of the textile (Figure 5) was carried out.

A multilayer coating on the surface of the textile material was obtained using the layer-by-layer method under the condition of changing the surfactant type. This contributes to the increase of the specific electrical conductivity of TM by an order of magnitude from 1×10^2 S/m to 1×10^3 S/m (Figure 5). The linear dependence of the electrical conductivity of the treated TM on the number of stages of polyaniline deposition in the presence of different types of surfactants was obtained. This indicates that differently charged polyaniline nanoparticles, stabilized alternately ASAS and CSAS, form electrically conductive layers. This is done due to the implementation of the mechanism of self-organization of polyaniline nanoparticles by forming a multilayer coating on the surface of polyamide TM with a stable ordered nanostructure.

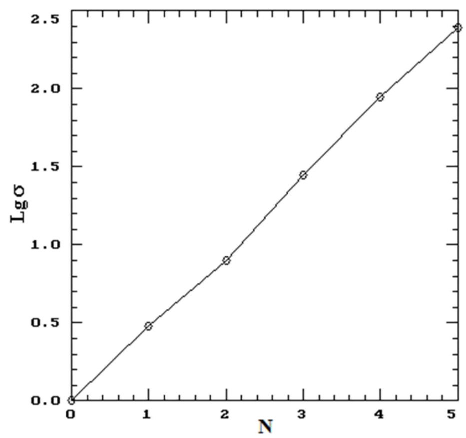


Figure 5 Dependence of the specific electrical conductivity of TM (σ) on the number of stages of deposition of nanoparticles (N) with a change in the type of surfactant (SAS)

Figure 6a shows the change of electrical resistance of the textile material depending on number of stages during realization of deposition of polyaniline multistage treatment process in the synthesis of polyaniline. Each subsequent stage of the deposition was carried out with the change of the type of surfactant, and as a consequence, the change of the charge of polyaniline nanoparticles.

A process of classical heterocoagulation [5, 6] was carried out during the deposition process when the process of heterocoagulation participate oppositely charged surface (in this case the surface of the particles of polyaniline and the textile material). With increasing number of deposited layers, the electrical resistance is decreasing significantly (two orders). The character of the electrostatic interaction assures the regular decrease of electrical resistance with each subsequent layer (by 3 times).

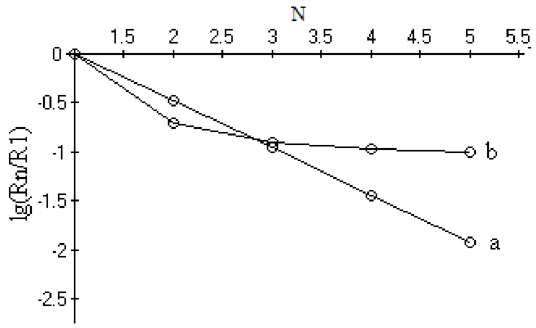


Figure 6 The resistance change of the textile material *R* on the amount of stages of deposition of polyaniline *N*: a) with the change of the SAS type; b) in the presence of ASAS; $Rn/R1$ is the ratio of the polyaniline resistance in N layers deposited (*Rn*) successively to the resistance in the same layer (*R1*)

The dependence of the electric resistance on the number of deposition steps of polyaniline nanoparticles, in the implementation of the multistage process of treatment in the synthesis of polyaniline under conditions of use in each step of the same SAS, is another character.

Figure 6b is characterized by the change in resistance when applied to 5 layers of polyaniline in the presence of anionic surfactant – sulfonol. Constancy charge polyaniline particles leads to an efficient adsorption of the first layer, followed by deceleration resistance decrease with increasing number of layers (and, presumably, with progressive decrease in the quantity of sorbed polyaniline). This situation is similar to the adsorption BET [9] – the interaction energy of the first layer of adsorbed molecules sufficiently greater than the energy of interaction between each successive layer.

4 CONCLUSION

Thus, the example system of polyamide textile material – polyaniline shows that the change in the balance of forces of interaction with the surface of the nanoparticles by changing conditions of heterocoagulation (deposition) may be used for the various structures in the process of self-organization of nanoparticles and, consequently, nanosystems with different properties. The resulting conductive textile material is proposed to be used as a textile neutralizer. A modern highly efficient way of removing static charges of electricity in the finishing industry has been developed. Textile neutralizer is environmentally friendly, inexpensive and easy to use. It is recommended to use electrically conductive textile materials as technical special purpose textiles in the production of clothing for protection against the influence of powerful electromagnetic fields, clothing with antistatic properties, heating of clothing, antistatic and reinforcing additives to fabrics and polymers.

5 REFERENCES

1. Eftekhari A. (Ed.): Nanostructured Conductive Polymers, John Wiley & Sons Ltd, 2010, 800 p., ISBN: 978-0-470-74585-4
2. Kotov N.A. (Ed.): Nanoparticle Assemblies and Superstructures, Boca Raton: Taylor & Francis Group, 2006, 646 p., ISBN 0-824-2524-7
3. Leite E.R., Riberio C.: Crystallization and Growth of Colloidal Nanocrystals, Springer-Verlag New York, 2012, 95 p., doi: 10.1007/978-1-4614-1308-0
4. Born P.G.: Crystallization of Nanoscaled Colloids, Springer International Publishing, 2013, 130 p., doi: 10.1007/978-3-319-00230-9
5. Romankevich O.V., Red'ko Ya.V., Romankevich Ya.O.: Dyeing with polyaniline synthesis in fibers, Fibre Chemistry 40(4), 2008, pp. 349-354, https://doi.org/10.1007/s10692-009-9066-5
6. Red'ko Ya., Brik A., Suprun N.: Investigation of properties of electroconducting nanozones in materials of various nature by the electron paramagnetic resonance method, Eastern-European Journal of Enterprise Technologies 3(5), 2017, pp. 24-30, https://doi.org/10.15587/1729-4061.2017.104055
7. Al-Shamery K., Parisi J. (Eds.): Self-Organized Morphology in Nanostructured Materials, Springer-Verlag Berlin Heidelberg, 2008, 176 p., doi: 10.1007/978-3-540-72675-3
8. Travas-Sejdic J., Soman R., Peng H.: Self-assembled polyaniline thin films: Comparison of poly(styrene sulphonate) and oligonucleotide as a polyanion, Thin Solid Films 497(1-2), 2006, pp. 96-102, https://doi.org/10.1016/j.tsf.2005.10.044
9. Gregg S.J., Sing K.S.W.: Adsorption, Surface Area and Porosity, Academic Press, 1982, 303 p.
10. Decher G., Schlenoff J.B. (Eds.): Multilayer Thin Films, Wiley-VCH Verlag GmbH & Co., 2003, 524 p., doi: 10.1002/3527600574
11. Apaydin K., Laachachi A., Ball V., et al: Layer–by–layer deposition of a TiO_2-filled intumescent coating and its effect on the flame retardancy of polyamide and polyester fabrics, Colloids and Surfaces A: Physicochemical and Engineering Aspects 469, 2015, pp. 1-10, https://doi.org/10.1016/j.colsurfa.2014.12.021
12. Carosio F., Alongi J., Malucelli G.: Layer by layer ammonium polyphosphate–based coatings for flame retardancy of polyester–cotton blends, Carbohydrate Polymers 88(4), 2012, pp. 1460-1469, https://doi.org/10.1016/j.carbpol.2012.02.049
13. Apaydin K., Laachachi A., Ball V., et al: Intumescent coating of (polyallylamine–polyphosphates) deposited on polyamide fabrics via layer–by–layer technique, Polymer Degradation and Stability 106, 2014, pp. 158-164, https://doi.org/10.1016/j.polymdegradstab.2014.01.006

DETERMINATION OF TENSION FOR POLYAMIDE AND BASALT MULTIFILAMENT YARNS WHILE WEAVING INDUSTRIAL FABRICS

Volodymyr Shcherban'[1], Oksana Kolysko[1], Gennadiy Melnyk[1], Marijna Sholudko[1], Yuriiy Shcherban'[2], Ganna Shchutska[2] and Nikita Kolva[1]

[1]Kyiv National University of Technologies and Design, Nemirovicha-Danchenko str., 2, 01011 Kyiv, Ukraine
[2]Department of Light Industry Technologies State Higher Educational Establishment «Kyiv College of Light Industry» Ivana Kudri str., 29, 01601 Kyiv, Ukraine
melnik2000@ukr.net

Abstract: *Resulting from researches aimed at determination of tension for polyamide and basalt multifilament yarns while interacting with guides and operative parts of looms in the process of industrial fabrics formation, yarn tension increase according to filling areas has been found out by applying different geometrical dimensions and due to friction forces in the contact area. It has been proved that tension degree of polyamide and basalt multifilament yarns before industrial fabrics formation area is affected by the following parameters: tension prior going to guide surface, radius of guide surface curve, contact angle with yarns of guide surface, as well as mechanical, physical and structural properties of polyamide and basalt multifilament yarns. Thus, allowing to determine tension of the polyamide and basalt multifilament yarns before industrial fabrics formation area yet at the initial stages of computer aided manufacturing taking into account loom parameters, shape of yarn filling line, mechanical, physical and structural properties of yarns and industrial fabrics. This article represents the experimental research of interaction between polyamide and basalt multifilament yarns having cylindrical surfaces, imitating separating rod of yarn break detector, as well as heddle eye for automatic looms. Based on experimental researches for polyamide and basalt multifilament yarns the regression dependencies between tension degree after guide and guide's curve radius, yarn tension before guide and nominal value of contact angle has been obtained. Consistent application of the data of regression dependencies allows to determine tension of polyamide and basalt multifilament yarns before the industrial fabrics formation area. Analysis of regression dependencies helped to find out values of technological parameters, in case when polyamide and basalt multifilament yarns tension before the industrial fabrics formation areas shall have minimum value. The foregoing will make it possible to apply minimum tension of polyamide and basalt multifilament yarns for their processing at looms. Thus, it leads to reduction in yarn breakages, more efficient performance of production equipment due to reduced downtime, as well as enhanced quality of industrial fabrics. Therefore, we can argue that offered technological solutions are practically attractive. Consequently, it is reasonable to speak of possible guided management as for process of change in tension of polyamide and basalt multifilament yarns when forming industrial fabrics using looms by means of selecting geometrical dimensions for guides.*

Keywords: *tension, polyamide and basalt multifilament yarn, radius of guide surface curve, contact angle.*

1 INTRODUCTION

Technical fabrics made of polyamide and basalt multifilament yarns are widely used for various purposes in different industry fields. Their unique mechanical and physical properties fully explain the previous statement. The technological process of manufacturing of industrial fabrics from polyamide and basalt multifilament yarns requires for improvement enhanced technological efforts based on minimized warp yarn tension in the fabric weaving area. The value of warp yarn tension, before they enter industrial fabric weaving area, determines density of weaving process, as well as compactness of fabric structure [1-3]. Tension of polyamide and basalt multifilament warp yarns, before they enter industrial fabric weaving area, comprises threading tension and additional tension that is driven by friction force between warp yarns and surfaces of a loom guides and operative parts having cylindrical and near-cylindrical form [4].

Progress density of technological process can be measured by determining value of yarn tension (during spun yarn winding) in operative areas of the technological machine [5, 6], loom [7, 8], or knitting machines [2, 9]. Main characteristic property of the most technological processes in textile industry is interaction between yarns and guides and operative parts, when guide's surface curvature radius in the area of contact is comparable to the yarn diameter [10, 11].

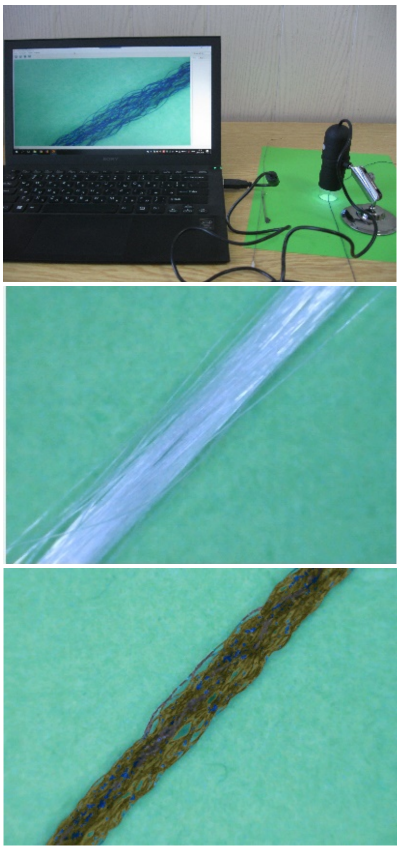
Polyamide and basalt multifilament yarns manufacturing process simulation on a loom involves research of interaction process between warp yarns with cylindrical surfaces imitating ones of back rest, of separating rod of yarn break detector, and of heddle eyes of heald frame for automatic looms [8]. Increase in yarn tension depends on friction forces in the area of contact with guides. The value of friction forces changes with regard to yarns material and guide, their geometrical dimensions ratio (i.e., of yarn diameter radius to guide's curvature radius in the contact area), actual contact angle between a yarn and a guide and radial contact angle between a yarn and a guide surface, mechanical, physical and structural properties of polyamide and basalt multifilament yarns, their tension before guide. When a yarn passes all guides consecutively, from the guide in the threading area and up to the guide in the fabric weaving area, it leads to step-type increase in tension. The value of output tension after previous guide will be the threading parameter for the following guide, thus allowing for use of recursion to determine tension of a yarn before it enters industrial fabric weaving area [12, 13].

Experimental research conducted to determine tension of polyamide and basalt multifilament yarns after guide surface requires designing specific strain-gauge unit. In a proactive planning of the experiment, it is necessary to consider the following: direction of relative shifting of friction surface [14], yarn sliding speed or guide surface movement speed [15, 16], and radius of guide surface curve [17, 18]. The paper [19] emphasizes necessity to consider that spinning of polyamide multifilament yarns affects their bending rigidity. Bending rigidity is significantly affecting the value of actual contact angle between a yarn and guide surface. This has been verified during the research of interaction conditions between polyamide multifilament yarn and guide surface and represented in the paper [10, 11] afterwards.

The papers show results of experimental determining of yarn tension with the use of specific units [8-12]. To increase accuracy of measured polyamide and basalt multifilament yarn tension and possibility of ensuring the metrological self-verification it is better to rely on the method of redundant measurements, which ensures that results of measurements are independent from conversion function parameters, and their deviations are independent from reference values [21, 22]. Design of the experimental unit measures accuracy of the obtained results while determining yarn tension. The paper [17] shows the scheme, which helps to determine yarn tension, and includes cylinders with long radius as guides. As its deficiency, it is important to consider inability to simulate actual conditions of interaction between yarn and guide and operative parts of looms and knitting machines. Experimental unit with revolving cylinder has the same deficiency [18]. Papers [2, 8-10, 15, 20] represent tension determinations for a variety of cylindrical guide surfaces.

2 EXPERIMENT

The paper had the four variants of research planned. For variant 1A the polyamide multifilament yarn 29x6 tex was chosen. For variant 2B the polyamide multifilament yarn 93.5x3 tex was chosen. For variant 3C the basalt multifilament yarn 250 tex was chosen. For variant 4D the basalt multifilament yarn 330 tex was chosen. USB Digital microscope Sigeta (Figure 1a) was used to determine dimensions of yarns diameters. The number of experiments to determine diameter for each multifilament yarn depended on value of confidence factor ($\alpha = 0.95$) and value of confidence error for the average result $\varepsilon_{(\overline{X})} = 0.1\overline{X}$, where $\overline{X}$ is an arithmetic mean value of multifilament yarns diameter. Having reference value of confidence factor, values of confidence error and number of measurements were determined with the help of calculated Student criterion values. Obtained value shall be greater than the one in the table. Figure 1b shows the polyamide multifilament yarn. Figure 1c shows the basalt multifilament yarn.



a)

b)

c)

Figure 1 Determining dimensions of yarns diameters: a) device determining the diameter; b) polyamide multifilament yarn; c) basalt multifilament yarn

Polyamide multifilament yarns 29x6 tex (variant 1A) were used as warp in manufacture of multilayer industrial fabric MTF – 5, which is intended for laying yard-coated pipes. This fabric is manufactured with warp setting of 120 ends per 100 mm and weft setting of 140 ends per 100 mm. Such fabric comprises five layers (Figure 2a), outer layers were formed by plain weave with threading being 400 mm wide [13]. Polyamide multifilament yarns 93.5x3 tex (variant 2B) were used as warp to manufacture multilayer industrial fabric MTF – 7 (Figure 2b), which is intended for laying yard-coated pipes as a bearing in transporting equipment. This fabric is manufactured with warp setting of 110 ends per 100 mm and weft setting of 120 ends per 100 mm. This fabric has five layers and weaving width of 600 mm.

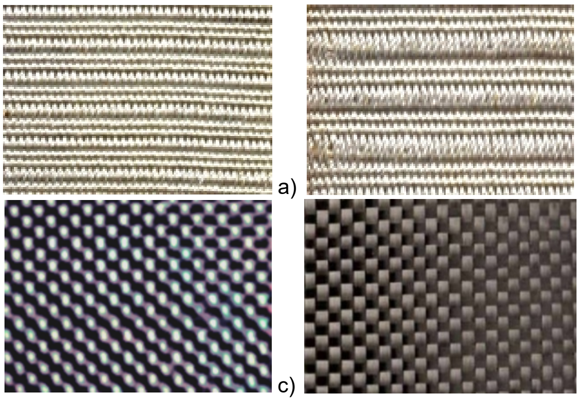


Figure 2 Industrial fabrics of polyamide and basalt multifilament yarns: a) multilayer industrial fabric MTF – 5; b) multilayer industrial fabric MTF – 7; c) basalt fabric of plain weave; d) fire-resistant basalt fabric of plain weave

Basalt multifilament yarns 250 tex (variant 3C) were used as warp to manufacture basalt fabric of plain weave (Figure 2c), which is incorporated into power units and used for thermal insulation of pipelines. This fabric is manufactured with warp setting of 80 ends per 100 mm and weft setting of 60 ends per 100 mm. Basalt multifilament yarns 330 tex (variant 4D) were used as a warp to manufacture fire-resistant basalt fabric of plain weave (Figure 2d). This fabric is manufactured with warp setting of 90 ends per 100 mm and with weft setting 70 ends per100 mm.

Tension of warp yarns (before they enter weaving area) is a value determining density of weaving process. Tension of polyamide and basalt warp yarns (before they enter fabric weaving area) comprises threading tension and additional tension that is driven by friction force between warp yarns and surfaces of a loom guides and operative parts having cylindrical and near-cylindrical form. Warp yarn threading line on a loom is made-up of three areas: I area – between the beam and dropper separating mechanism; II area – between back rest and heald frames; III area – between dropper separating mechanism and fell of the fabric. Warp yarns interact with back rest in I area. In II area a contact between yarns and a dropper separating unit occurs. And warp yarns contact heddle eye of heald frame in III area.

For variants 1A, 2B, 3C and 4D the paper provides a plan and implementation of the second-order orthogonal matrix for three factors to determine combined influence of slack side tension of warp yarn P_0, cylindrical guide radius R, and nominal value of contact angle φ_P to tight side tension of warp yarn P. Overall form of regression equation is as follows:

$$P = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 \quad (1)$$

Range of factors variations in equation (1) was determined under polyamide and basalt multifilament yarns actual weaving conditions on looms.

Factor x_1 is a value of threading tension of polyamide and basalt multifilament yarns in the I area before the back rest. Variant 1A is for polyamide multifilament yarn 29x6 tex and the value ranged within following limits P_{0I1} = 25-35 cN. Variant 2B is for polyamide multifilament yarn 93.5x3 tex and the value ranged within following limits P_{0I2} = 40-55 cN. Variant 3C for basalt multifilament yarn 250 tex and the value ranged within following limits P_{0I3} = 20-30 cN. Variant 4D for basalt multifilament yarn 330 tex and the value ranged within following limits P_{0I4} = 20-30 cN.

Table 1 The scheme of experimental researches

Fabric	Properties	Determining tension in an area [cN]		
Variant 1A Multilayer technical fabric MTF – 5	Warp setting of 120 ends per 100 mm; Weft setting of 140 ends per 100 mm	I area between the beam and the dropper separating mechanism	II area between the back-rest and heald frames	III area between the dropper separating mechanism and fell of the fabric
Variant 2B Multilayer technical fabric MTF – 7	Warp setting of 110 ends per 100 mm; Weft setting of 120 ends per 100 mm			
Variant 3C Basalt fabric of plain weave	Warp setting of 80 ends per 100 mm; Weft setting of 60 ends per 100 mm			
Variant 4D Fire-resistant basalt fabric of plain weave	Warp setting of 90 ends per 100 mm; Weft setting of 70 ends per 100 mm			

Factor x_2 is a cylinder (back rest) radius in I area that ranged within following limits R_I = 35-70 mm. Factor x_2 is a cylinder (left separating rod in dropper mechanism) radius in II area that ranged within following limits R_{II} = 5-15 mm. Factor x_2 is a cylinder (heddle eye of heald frame) radius in III area that ranged within following limits R_{III} = 0.5-1.5 mm.

Factor x_3 is a nominal value of the contact angle between cylinder (back rest) and yarns in I area that ranged within following limits φ_{PI} = 75-125°. Factor x_3 is a nominal value of the contact angle between cylinder (left separating rod in the dropper mechanism) and yarns in II area that ranged within following limits φ_{IIP} = 25-75°. Factor x_3 is a nominal value of the contact angle between cylinder (heddle eye of heald frame) and yarns in III area ranged within following limits φ_{PIII} = 14-20°.

At the first stage, tension in I area after back rest before separating cylindrical rod is determined. Table 2 represents orthogonal matrix for determining polyamide and basalt multifilament yarns tension in I area (variants 1-4).

Table 2 Orthogonal matrix for determining polyamide and basalt multifilament yarns tension in I area

№	Factors								
	Input tension [cN]					Curvature radius		Contact angle	
	x_1	Variants 1-4				x_2	R_I [mm]	x_3	φ_{PI} [°]
		P_{0I1}	P_{0I2}	P_{0I3}	P_{0I4}				
1	+1	35	54	30	40	+1	70	+1	120
2	-1	27	42	22	30	+1	70	+1	120
3	+1	35	54	30	40	-1	40	+1	120
4	-1	27	42	22	30	-1	40	+1	120
5	+1	35	54	30	40	+1	70	-1	80
6	-1	27	42	22	30	+1	70	-1	80
7	+1	35	54	30	40	-1	40	-1	80
8	-1	27	42	22	30	-1	40	-1	80
9	-1.215	26	41	21	29	0	55	0	100
10	+1.215	36	55	31	41	0	55	0	100
11	0	31	48	26	35	-1.215	37	0	100
12	0	31	48	26	35	+1.215	73	0	100
13	0	31	48	26	35	0	55	-1.215	76
14	0	31	48	26	35	0	55	+1.215	124
15	0	31	48	26	35	0	55	0	100

Connection between denominated and coded values for I area is as follows:

variant 1

$$x1 = \frac{P_{0I1} - 31}{4}, x2 = \frac{R_I - 55}{15}, x3 = \frac{\varphi_{PI} - 100}{20} \quad (2)$$

variant 2

$$x1 = \frac{P_{0I2} - 48}{6}, x2 = \frac{R_I - 55}{15}, x3 = \frac{\varphi_{PI} - 100}{20} \quad (3)$$

variant 3

$$x1 = \frac{P_{0I3} - 26}{4}, x2 = \frac{R_I - 55}{15}, x3 = \frac{\varphi_{PI} - 100}{20} \quad (4)$$

variant 4

$$x1 = \frac{P_{0I4} - 35}{5}, x2 = \frac{R_I - 55}{15}, x3 = \frac{\varphi_{PI} - 100}{20} \quad (5)$$

At the second stage, tension in II area after cylindrical separating rod before shedding mechanism on the loom. As input tension $P_{0II1} \div P_{0II4}$, output tension of warp yarns after I area is taken. Table 3 represents orthogonal matrix used to determine polyamide and basalt multifilament yarns tension in II area (variants 1-4).

Table 3 Orthogonal matrix for determining polyamide and basalt multifilament yarns tension in II area

№	Factors								
	Input tension [cN]					Curvature radius		Contact angle	
	x_1	Variants 1-4				x_2	R_{II} [mm]	x_3	φ_{PII} [°]
		P_{0II1}	P_{0II2}	P_{0II3}	P_{0II4}				
1	+1	68	90	35	47	+1	14	+1	70
2	-1	40	50	27	37	+1	14	+1	70
3	+1	68	90	35	47	-1	6	+1	70
4	-1	40	50	27	37	-1	6	+1	70
5	+1	68	90	35	47	+1	14	-1	30
6	-1	40	50	27	37	+1	14	-1	30
7	+1	68	90	35	47	-1	6	-1	30
8	-1	40	50	27	37	-1	6	-1	30
9	-1.215	37	46	26	36	0	10	0	50
10	+1.215	71	94	36	48	0	10	0	50
11	0	54	70	31	42	-1.215	5	0	50
12	0	54	70	31	42	+1.215	15	0	50
13	0	54	70	31	42	0	10	-1.215	26
14	0	54	70	31	42	0	10	+1.215	74
15	0	54	70	31	42	0	10	0	50

Connection between denominated and coded values for II area is as follows:

variant 1

$$x1 = \frac{P_{0II1} - 54}{14}, x2 = \frac{R_{II} - 10}{4}, x3 = \frac{\varphi_{PII} - 50}{20} \quad (6)$$

variant 2

$$x1 = \frac{P_{0II2} - 70}{20}, x2 = \frac{R_{II} - 10}{4}, x3 = \frac{\varphi_{PII} - 50}{20} \quad (7)$$

variant 3

$$x1 = \frac{P_{0II3} - 31}{4}, x2 = \frac{R_{II} - 10}{4}, x3 = \frac{\varphi_{PII} - 50}{20} \quad (8)$$

variant 4

$$x1 = \frac{P_{0II4} - 42}{5}, x2 = \frac{R_{II} - 10}{4}, x3 = \frac{\varphi_{PII} - 50}{20} \quad (9)$$

At the third stage, tension in III area after shedding mechanism before weaving area of polyamide and basalt industrial fabrics. As input tension $P_{0II1} \div P_{0II4}$, output tension of warp yarns after II area is taken. Table 4 represents orthogonal matrix used to determine polyamide and basalt multifilament yarns tension in III area (variants 1-4).

Connection between denominated and coded values for III area is as follows:

variant 1

$$x1 = \frac{P_{0III1} - 65}{20}, x2 = \frac{R_{III} - 1}{0.4}, x3 = \frac{\varphi_{PIII} - 20}{5} \quad (10)$$

variant 2

$$x1 = \frac{P_{0III2} - 85}{25}, x2 = \frac{R_{III} - 1}{0.4}, x3 = \frac{\varphi_{PIII} - 20}{5} \quad (11)$$

variant 3

$$x1 = \frac{P_{0III3} - 35}{6}, x2 = \frac{R_{III} - 1}{0.4}, x3 = \frac{\varphi_{PIII} - 20}{5} \quad (12)$$

variant 4

$$x1 = \frac{P_{0III4} - 47}{7}, x2 = \frac{R_{III} - 1}{0.4}, x3 = \frac{\varphi_{PIII} - 20}{5} \quad (13)$$

Table 4 Orthogonal matrix for determining polyamide and basalt multifilament yarns tension in III area

№	Factors								
	Input tension [cN]					Curvature radius		Contact angle	
	x_1	Variants 1-4				x_2	R_{III} [mm]	x_3	φ_{PIII} [°]
		P_{0III1}	P_{0III2}	P_{0III3}	P_{0III4}				
1	+1	85	110	41	54	+1	1.4	+1	25
2	-1	45	60	29	40	+1	1.4	+1	25
3	+1	85	110	41	54	-1	0.6	+1	25
4	-1	45	60	29	40	-1	0.6	+1	25
5	+1	85	110	41	54	+1	1.4	-1	15
6	-1	45	60	29	40	+1	1.4	-1	15
7	+1	85	110	41	54	-1	0.6	-1	15
8	-1	45	60	29	40	-1	0.6	-1	15
9	-1.215	41	55	28	38	0	1	0	20
10	+1.215	89	115	42	56	0	1	0	20
11	0	65	85	35	47	-1.215	0.5	0	20
12	0	65	85	35	47	+1.215	1.5	0	20
13	0	65	85	35	47	0	1	-1.215	14
14	0	65	85	35	47	0	1	+1.215	21
15	0	65	85	35	47	0	1	0	20

Experimental researches were conducted using a specific strain-gauge unit. Its design is described in details in papers [8-12]. Its peculiar feature is that a simulator of condition of interaction between guides and operative parts of looms comprised a set of cylindrical rods, a backrest, a separating rode of dropper mechanism, and heddles of heald frames of looms, with commensurable diameters.

3 RESULTS AND DISCUSSION

Resulting from implemented plan of the experiment (Table 2) for variant 1 (A), variant 2 (B), variant 3 (C) and variant 4 (D), I area, there were 10 parallel measurements for each variant. Table 5 represents average values of polyamide and basalt multifilament yarns tension for I area.

Known method for determination of coefficients in the regression equation (1) for second-order orthogonal matrix [9-11] was applied taking into account dependencies (2–5), and therefore regression dependencies were obtained for I area:

variant 1A

$$P_{I1} = 3.29 + 0.0008P_{0I1}R_I - 0.001P_{0I1}^2 + 0.0041P_{0I1}\varphi_{PI} + 0.95P_{0I1} - 0.000076R_I^2 + 0.00042R_I\varphi_{PI} - 0.032R_I + 0.00018{\varphi_{PI}}^2 - 0.044\varphi_{PI}, \quad (14)$$

variant 2B

$$P_{I2} = 5.66 + 0.00056P_{0I2}R_I - 0.0001P_{0I2}^2 + 0.0038P_{0I2}\varphi_{PI} + 0.89P_{0I2} - 0.00028R_I^2 + 0.0005R_I\varphi_{PI} - 0.0067R_I + 0.00029{\varphi_{PI}}^2 - 0.062\varphi_{PI}, \quad (15)$$

variant 3C

$$P_{I3} = 1.57 + 0.00021P_{0I3}R_I + 0.00001P_{0I3}^2 + 0.0033P_{0I3}\varphi_{PI} + 0.94P_{0I3} + 0.000004R_I^2 + 0.000042R_I\varphi_{PI} - 0.0064R_I + 0.000078{\varphi_{PI}}^2 - 0.017\varphi_{PI}, \quad (16)$$

variant 4D

$$P_{I4} = 2.33 + 0.0004P_{0I4}^2 + 0.0032P_{0I4}\varphi_{PI} + 0.91P_{0I4} + 0.00005R_I^2 - 0.0021R_I + 0.0001{\varphi_{PI}}^2 - 0.018\varphi_{PI}. \quad (17)$$

Adequacy of obtained regression dependencies were verified through SPSS program for statistical processing of experimental data [8, 10, 12].

Table 5 Results of series of experimental researches for I area aimed at determining combined influence of yarn tension before a guide, guide's surface radius and nominal value of contact angle to polyamide and basalt multifilament yarns tension after a guide for variant 1A, variant 2B, variant 3C and variant 4D

№	Factors			P_{I1}	P_{I2}	P_{I3}	P_{I4}
	x_1	x_2	x_3				
1	+1	+1	+1	52.5	79.4	41.1	54.7
2	-1	+1	+1	41.0	62.5	30.2	41.1
3	+1	-1	+1	51.3	77.8	40.9	54.6
4	-1	-1	+1	40.0	61.1	30.1	41.0
5	+1	+1	-1	45.9	69.9	37.0	49.3
6	-1	+1	-1	35.7	54.8	27.2	37.0
7	+1	-1	-1	45.2	68.9	36.9	49.2
8	-1	-1	-1	35.2	54.0	27.1	36.9
9	-1.215	0	0	36.6	56.7	27.3	37.7
10	+1.215	0	0	50.0	75.3	40.2	53.2
11	0	-1.215	0	42.8	65.2	33.7	45.4
12	0	+1.215	0	43.8	66.6	33.8	45.5
13	0	0	-1.215	40.0	61.2	31.7	42.7
14	0	0	+1.215	46.9	71.2	35.9	48.3
15	0	0	0	43.3	66.0	33.8	45.4

Resulting from implemented plan of the experiment (Table 3) for variant 1A, variant 2B, variant 3C and variant 4D for II area, there were 10 parallel measurements for each variant. Table 6 represents average values of polyamide and basalt multifilament yarns tension for II area.

Table 6 Results of series of experimental researches for II area aimed at determining combined influence of yarn tension before a guide, a guide's surface radius and a nominal value of contact angle to a polyamide and basalt multifilament yarns tension after a guide for variant 1A, variant 2B, variant 3C and variant 4D

№	Factors			P_{II1}	P_{II2}	P_{II3}	P_{II4}
	x_1	x_2	x_3				
1	+1	+1	+1	82.5	108.9	41.9	56.5
2	-1	+1	+1	49.1	61.2	32.3	44.5
3	+1	-1	+1	82.5	109.4	42.2	57.3
4	-1	-1	+1	49.1	61.4	32.5	45.1
5	+1	+1	-1	74.4	98.4	37.9	51.1
6	-1	+1	-1	43.9	54.9	29.3	40.2
7	+1	-1	-1	74.9	99.5	38.2	51.8
8	-1	-1	-1	44.3	55.5	29.4	40.7
9	-1.215	0	0	43.0	53.4	29.7	41.3
10	+1.215	0	0	81.8	108.2	41.1	55.1
11	0	-1.215	0	62.9	81.7	35.6	48.9
12	0	+1.215	0	62.5	80.8	35.3	48.0
13	0	0	-1.215	58.7	76.1	33.3	45.4
14	0	0	+1.215	66.4	85.9	37.6	51.2
15	0	0	0	62.4	80.9	35.4	48.2

Considering dependencies (1, 6-9), the following regression dependencies for II area were obtained:

variant 1A

$$\begin{aligned} P_{II1} = 2.38 + 0.0025P_{0II1}\varphi_{PII} - 0.00022P_{0II1}R_{II} \\ -0.00018P_{0II1}^2 + 1.02P_{0II1} + 0.009R_{II}^2 \\ +0.0005R_{II}\varphi_{PII} - 0.27R_{II} + 0.00013\varphi_{PII}^2 \\ -0.007\varphi_{PII}, \end{aligned} \tag{18}$$

variant 2B

$$\begin{aligned} P_{II2} = 3.41 + 0.0025P_{0II2}\varphi_{PII} - 0.0013P_{0II2}R_{II} \\ -0.00011P_{0II2}^2 + 1.02P_{0II2} + 0.014R_{II}^2 \\ +0.0015R_{II}\varphi_{PII} - 0.35R_{II} + 0.00019\varphi_{PII}^2 \\ -0.014\varphi_{PII} \end{aligned} \tag{19}$$

variant 3C

$$\begin{aligned} P_{II3} = 0.39 + 0.0029P_{0II3}\varphi_{PII} - 0.0024P_{0II3}R_{II} \\ +0.000056P_{0II3}^2 + 1.01P_{0II3} + 0.002R_{II}^2 \\ -0.00016R_{II}\varphi_{PII} + 0.014R_{II} + 0.00007\varphi_{PII}^2 \\ -0.012\varphi_{PII}, \end{aligned} \tag{20}$$

variant 4D

$$\begin{aligned} P_{II4} = 4.43 + 0.0034P_{0II4}\varphi_{PII} - 0.0031P_{0II4}R_{II} \\ -0.0003P_{0II4}^2 + 1.29P_{0II4} + 0.009R_{II}^2 \\ -0.00031R_{II}\varphi_{PII} - 0.15R_{II} + 0.00014\varphi_{PII}^2 \\ +0.002\varphi_{PII}. \end{aligned} \tag{21}$$

Resulting from implemented plan of the experiment (Table 4) for variant 1A, variant 2B, variant 3C and variant 4D for III area, there were 10 parallel measurements for each variant. Table 7 represents average values of polyamide and basalt multifilament yarns tension for III area.

Considering dependencies (1, 10-13), the following regression dependencies for III area were obtained:

variant 1A

$$\begin{aligned} P_{III1} = 15.96 + 0.0028P_{0III1}\varphi_{PIII} \\ -0.27P_{0III1}R_{III} - 0.0005P_{0III1}^2 + 1.50P_{0III1} \\ + 24.61R_{III}^2 - 0.063R_{III}\varphi_{PIII} - 49.13R_{III} \\ -0.016\varphi_{PIII}^2 + 0.70\varphi_{PIII}, \end{aligned} \tag{22}$$

variant 2B

$$\begin{aligned} P_{III2} = 20.03 + 0.0032P_{0III2}\varphi_{PIII} \\ -0.45P_{0III2}R_{III} - 0.0013P_{0III2}^2 + 1.93P_{0III2} \\ + 53.44R_{III}^2 - 0.1R_{III}\varphi_{PIII} - 103.95R_{III} \\ -0.045\varphi_{PIII}^2 + 1.87\varphi_{PIII}, \end{aligned} \tag{23}$$

variant 3C

$$\begin{aligned} P_{III3} = 1.81 + 0.003P_{0III3}\varphi_{PIII} - 0.26P_{0III3}R_{III} \\ +0.0014P_{0III3}^2 + 1.32P_{0III3} + 7.44R_{III}^2 \\ -0.03R_{III}\varphi_{PIII} - 11.04R_{III} - 0.004\varphi_{PIII}^2 \\ +0.18\varphi_{PIII}, \end{aligned} \tag{24}$$

variant 4D

$$\begin{aligned} P_{III4} = 1.89 + 0.0043P_{0III4}\varphi_{PIII} - 0.5P_{0III4}R_{III} \\ -0.0012P_{0III4}^2 + 1.92P_{0III4} + 22.81R_{III}^2 \\ -0.075R_{III}\varphi_{PIII} - 38.05R_{III} - 0.013\varphi_{PIII}^2 \\ +0.56\varphi_{PIII}. \end{aligned} \tag{25}$$

Table 7 Results of series of experimental researches for III area aimed at determining combined influence of yarn tension before a guide, a guide's surface radius and a nominal value of contact angle to a polyamide and basalt multifilament yarns tension after a guide for variant 1A, variant 2B, variant 3C and variant 4D

№	Factors			P_{III1}	P_{III2}	P_{III3}	P_{III4}
	x_1	x_2	x_3				
1	+1	+1	+1	99.7	132.7	46.8	64.9
2	-1	+1	+1	53.0	72.3	32.7	47.6
3	+1	-1	+1	118.6	169.5	52.9	81.3
4	-1	-1	+1	63.1	90.9	36.3	58.3
5	+1	+1	-1	97.5	129.7	45.6	63.1
6	-1	+1	-1	51.8	70.6	31.9	46.3
7	+1	-1	-1	115.8	165.4	51.5	78.8
8	-1	-1	-1	61.5	88.7	35.2	56.5
9	-1.215	0	0	50.1	69.5	32.0	47.0
10	+1.215	0	0	108.1	146.0	49.0	70.6
11	0	-1.215	0	96.9	146.2	45.8	75.0
12	0	+1.215	0	75.0	100.4	39.0	54.9
13	0	0	-1.215	78.1	106.4	39.9	57.8
14	0	0	+1.215	79.4	108.1	40.6	58.9
15	0	0	0	79.2	107.9	40.5	58.8

Table 8 shows values of coefficients in regression equation (1) for variant 1A, variant 2B, variant 3C, and variant 4D for areas **I-III**.

Table 8 Values of coefficients in regression equation (1) for variant 1A, variant 2B, variant 3C, and variant 4D for areas I-III

Area	Variant 1A	Variant 2B	Variant 3C	Variant 4D
I	b_0=43.3164 b_1=10.6505 b_2=0.828585 b_3=5.60057 b_{11}=-0.03459 b_{12}=0.1 b_{13}=0.65 b_{22}=-0.03459 b_{23}=0.25 b_{33}=0.146469	b_0=66.0042 b_1=15.4753 b_2=1.16709 b_3=8.14443 b_{11}=-0.00883 b_{12}=0.1 b_{13}=0.9 b_{22}=-0.12954 b_{23}=0.3 b_{33}= 0.232582	b_0=33.7705 b_1=10.2362 b_2=0.111143 b_3=3.44824 b_{11}=0.0018305 b_{12}=0.025 b_{13}=0.525 b_{22}=0.0018305 b_{23}=0.025 b_{33}= 0.062185	b_0=45.4185 b_1=12.684 b_2=0.093465 b_3=4.63301 b_{11}=0.0213389 b_{12}=0.005 b_{13}=0.65 b_{22}=0.0213389 b_{23}=0.003 b_{33}= 0.0816941
II	b_0=62.4341 b_1=31.4385 b_2=-0.250117 b_3=6.29525 b_{11}=-0.071782 b_{12}=-0.025 b_{13}=1.425 b_{22}=0.290349 b_{23}=0.225 b_{33}= 0.109283	b_0=80.8843 b_1=44.8549 b_2=-0.629054 b_3=7.99286 b_{11}=-0.087629 b_{12}=-0.2 b_{13}=2.05 b_{22}=0.455567 b_{23}=0.25 b_{33}= 0.153791	b_0=35.3991 b_1=9.08171 b_2=-0.22736 b_3=3.47099 b_{11}=0.0018307 b_{12}=-0.075 b_{13}=0.475 b_{22}=0.0621859 b_{23}=-0.025 b_{33}= 0.0621859	b_0=48.2046 b_1=11.3072 b_2=-0.66441 b_3=4.78458 b_{11}=-0.009596 b_{12}=-0.1 b_{13}=0.55 b_{22}=0.292179 b_{23}=-0.05 b_{33}= 0.111114
III	b_0=79.3285 b_1=48.9418 b_2=-15.0595 b_3=1.67467 b_{11}=-0.391306 b_{12}=-4.35 b_{13}=0.55 b_{22}=7.87736 b_{23}=-0.25 b_{33}=-0.813792	b_0=108.604 b_1=65.9854 b_2=-29.7256 b_3=2.33137 b_{11}=-1.66357 b_{12}=-8.95 b_{13}=0.8 b_{22}=17.1069 b_{23}=-0.4 b_{33}= -2.26712	b_0=40.4527 b_1=14.5986 b_2=-4.88838 b_3=0.954776 b_{11}=0.0995578 b_{12}=-1.275 b_{13}=0.175 b_{22}=2.39306 b_{23}=-0.125 b_{33}=-0.202218	b_0=58.8568 b_1=19.4061 b_2=-13.9428 b_3=1.55845 b_{11}=-0.11970 b_{12}=-2.8 b_{13}=0.3 b_{22}=7.30398 b_{23}=-0.3 b_{33}=-0.662904

Nominal contact angle between the guide and the yarns was taken as fixed value to determine combined influence of a polyamide and basalt multifilament yarns tension before the guide, a guide's surface radius, to a tension after the guide for I area in the system of equations (14-17).

The indicated value corresponded to the center of the experiment (Table 2). To get the nominal value of the contact angle in the center of the experiment φ_{PI} = 100° the following system of equations were obtained for I area:

variant 1A

$$P_{I1} = 0.67 + 1.35P_{0I1} + 0.009R_I - 0.0011P_{0I1}^2 \\ -0.0000R_I^2 + 0.00083P_{0I1}R_I, \tag{26}$$

variant 2B

$$P_{I2} = 2.36 + 1.27P_{0I2} + 0.043R_I - 0.00012P_{0I2}^2 \\ -0.00028R_I^2 + 0.00056P_{0I2}R_I, \tag{27}$$

variant 3C

$$P_{I3} = 0.64 + 1.26P_{0I3} - 0.002R_I + 0.000056P_{0I3}^2 \\ +0.0000028R_I^2 + 0.00021P_{0I3}R_I, \tag{28}$$

variant 4D

$$P_{I4} = 1.53 + 1.24P_{0I4} - 0.0021R_I \\ +0.00042P_{0I4}^2 + 0.000047R_I^2. \tag{29}$$

Figure 3 represents graphical dependencies depicting combined influence of polyamide and basalt multifilament yarns tension before the guide, guide's surface radius to the tension after the guide for I area, obtained with the help of equations (26-29), where the value of the nominal contact angle in the center of experiment was fixed φ_{PI} = 100°.

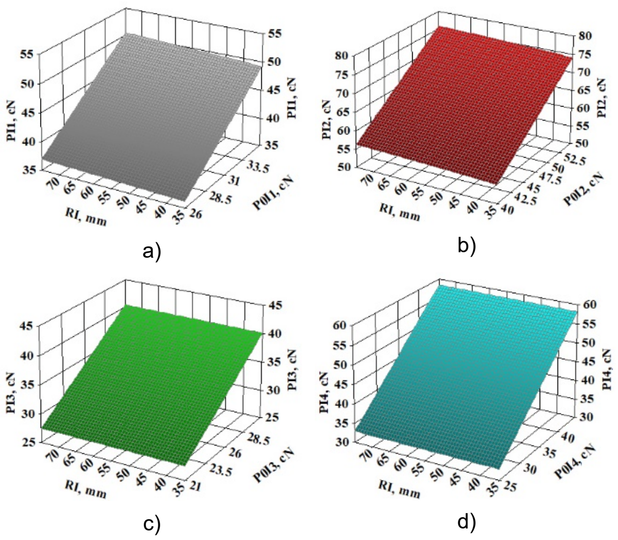


Figure 3 Graphical dependencies depicting combined influence of polyamide and basalt multifilament yarns tension before the guide, guide's surface radius to the tension after the guide for I area: a) polyamide multifilament yarn 174 tex; b) polyamide multifilament yarn 280.5 tex; c) basalt multifilament yarn 250 tex; d) basalt multifilament yarn 330 tex

Nominal contact angle between the guide and the yarns was taken as fixed value to determine combined influence of a polyamide and basalt multifilament yarns tension before the guide, a guide's surface radius, to a tension after the guide for II area in the system of equations (18-21). The indicated value corresponded to the center of the experiment (Table 3). To get the nominal value of the contact angle in the center of the experiment φ_{PII} = 50° the following system of equations were obtained for II area:

variant 1A

$$P_{II1} = 2.35 + 1.15P_{0II1} - 0.20R_{II} \\ -0.00018P_{0II1}^2 + 0.009R_{II}^2 - 0.00022P_{0II1}R_{II}, \tag{30}$$

variant 2B

$$P_{II2} = 3.16 + 1.14P_{0II2} \\ -0.28R_{II} - 0.00011P_{0II2}^2 \\ +0.014R_{II}^2 - 0.0013P_{0II2}R_{II}, \tag{31}$$

variant 3C

$$P_{II3} = -0.015 + 1.15P_{0II3} - 0.0062R_{II} \\ +0.000056P_{0II3}^2 + 0.0019R_{II}^2 - 0.0024P_{0II3}R_{II}, \tag{32}$$

variant 4D

$$P_{II4} = 4.87 + 1.46P_{0II4} - 0.17R_{II} - 0.0003P_{0II4}^2 \\ +0.009R_{II}^2 - 0.0031P_{0II4}R_{II}. \tag{33}$$

Figure 4 represents graphical dependencies depicting combined influence of polyamide and basalt multifilament yarns tension before the guide, guide's surface radius to the tension after the guide for II area, obtained with the help of equations (30-33), where the value of the nominal contact angle in the center of experiment was fixed φ_{PII} = 50°.

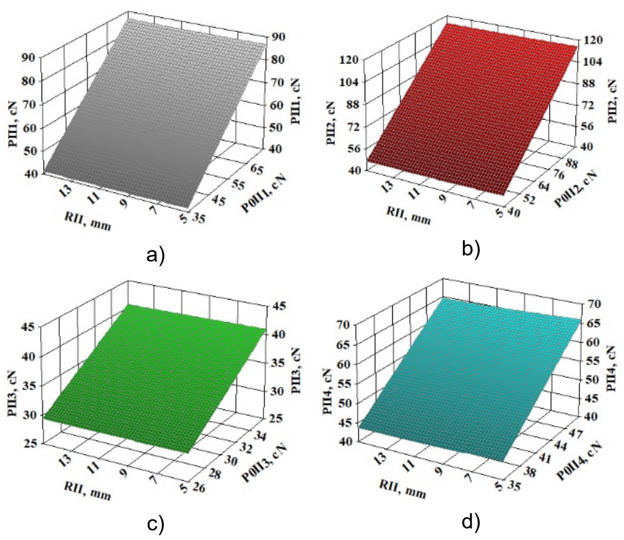


Figure 4 Graphical dependencies depicting combined influence of polyamide and basalt multifilament yarns tension before the guide, guide's surface radius to the tension after the guide for II area: a) polyamide multifilament yarn 174 tex; b) polyamide multifilament yarn 280.5 tex; c) basalt multifilament yarn 250 tex; d) basalt multifilament yarn 330 tex

Nominal contact angle between the guide and the yarns was taken as fixed value to determine combined influence of a polyamide and basalt multifilament yarns tension before the guide, a guide's surface radius, to a tension after the guide for **III** area in the system of equations (22-25). The indicated value corresponded to the center of the experiment (Table 4). To get the nominal value of the contact angle in the center of the experiment φ_{PIII} = 20° the following system of equations were obtained for **III** area:

variant 1A

$$P_{III1} = 23.49 + 1.56P_{0III1} - 50.38R_{III} \\ -0.0005P_{0III1}^2 + 24.61R_{III}^2 - 0.27P_{0III1}R_{III}, \tag{34}$$

variant 2B

$$P_{III2} = 39.35 + 1.99P_{0III2} \\ -105.95R_{III} - 0.0013P_{0III2}^2 \\ +53.44R_{III}^2 - 0.45P_{0III2}R_{III}, \tag{35}$$

variant 3C

$$P_{III3} = 3.83 + 1.38P_{0III3} - 11.64R_{III} \\ +0.0014P_{0III3}^2 + 7.44R_{III}^2 - 0.27P_{0III3}R_{III}, \tag{36}$$

variant 4D

$$P_{III4} = 7.75 + 2.0P_{0III4} - 39.55R_{III} \\ -0.0012P_{0III4}^2 + 22.81R_{III}^2 - 0.5P_{0III4}R_{III}. \tag{37}$$

Figure 5 represents graphical dependencies depicting combined influence of polyamide and basalt multifilament yarns tension before the guide, guide's surface radius to the tension after the guide for **III** area, obtained with the help of equations (34-37), where the value of the nominal contact angle in the center of experiment was fixed φ_{PIII} = 20°.

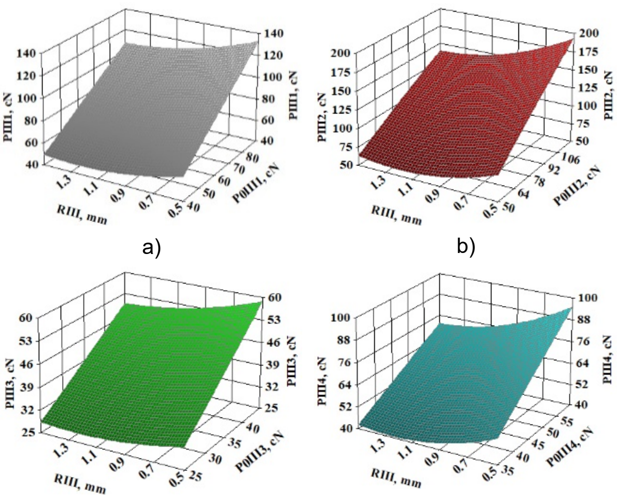


Figure 5 Graphical dependencies depicting combined influence of polyamide and basalt multifilament yarns tension before the guide, guide's surface radius to the tension after the guide for III area: a) polyamide multifilament yarn 174 tex; b) polyamide multifilament yarn 280.5 tex; c) basalt multifilament yarn 250 tex; d) basalt multifilament yarn 330 tex

In order to determine influence of guide's curve radius to polyamide and basalt multifilament yarn tension after the guide, for **I** area, in the system of equations (26-29) the value of tension before the guide was taken as fixed. This value corresponded to the center of experiment (Table 2). For polyamide multifilament yarn 174 tex, tension before the guide in the center of the experiment is P_{0I1}=31 cN. For polyamide multifilament yarn 280.5 tex, tension before the guide in the center of the experiment is P_{0I2}=48 cN. For basalt multifilament yarn 250 tex tension before the guide in the center of the experiment is P_{0I3}=26 cN. For basalt multifilament yarn 330 tex tension before the guide in the center of the experiment is P_{0I4}=35 cN. After inserting the indicated values, the following equations were obtained for **I** area:

variant 1A

$$P_{I1} = 41.49 + 0.035R_I - 0.000076R_I^2 \tag{38}$$

variant 2B

$$P_{I2} = 63.01 + 0.069R_I - 0.00028R_I^2 \tag{39}$$

variant 3C

$$P_{I3} = 33.58 + 0.0032R_I + 0.000004R_I^2 \tag{40}$$

variant 4D

$$P_{I4} = 45.39 - 0.0021R_I + 0.00005R_I^2 \tag{41}$$

Figure 6 represents graphical dependencies depicting influence of guide's curve radius to tension after the guide for **I** area, obtained with the help of equations (38-41), where the value of the polyamide and basalt multifilament yarns tension before the guide was fixed.

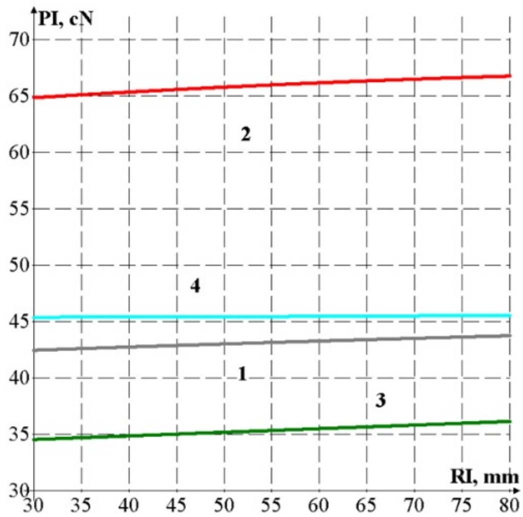


Figure 6 Graphical dependencies depicting influence of guide's curve radius to tension after the guide for I area: 1) polyamide multifilament yarn 174 tex; 2) polyamide multifilament yarn 280.5 tex; 3) basalt multifilament yarn 250 tex; 4) basalt multifilament yarn 330 tex

In order to determine influence of guide's curve radius to polyamide and basalt multifilament yarn tension after the guide, for II area, in the system of equations (30-33) the value of tension before the guide was taken as fixed. This value corresponded to the center of experiment (Table 3). For polyamide multifilament yarn 174 tex, tension before the guide in the center of the experiment is P_{0II1}=54 cN. For polyamide multifilament yarn 280.5 tex, tension before the guide in the center of the experiment is P_{0II2}=70 cN. For basalt multifilament yarn 250 tex tension before the guide in the center of the experiment is P_{0II3}=31 cN. For basalt multifilament yarn 330 tex tension before the guide in the center of the experiment is P_{0II4}=42 cN. After inserting the indicated values, the following equations were obtained for II area:

variant 1A

$$P_{II1} = 63.62 - 0.21R_{II} + 0.009R_{II}^2 \tag{42}$$

variant 2B

$$P_{II2} = 82.85 - 0.37R_{II} + 0.014R_{II}^2 \tag{43}$$

variant 3C

$$P_{II3} = 35.74 - 0.067R_{II} + 0.0019R_{II}^2 \tag{44}$$

variant 4D

$$P_{II4} = 65.73 - 0.29R_{II} + 0.009R_{II}^2 \tag{45}$$

Figure 7 represents graphical dependencies depicting influence of guide's curve radius to tension after the guide for II area, obtained with the help of equations (42-45), where the value of the polyamide and basalt multifilament yarns tension before the guide was fixed.

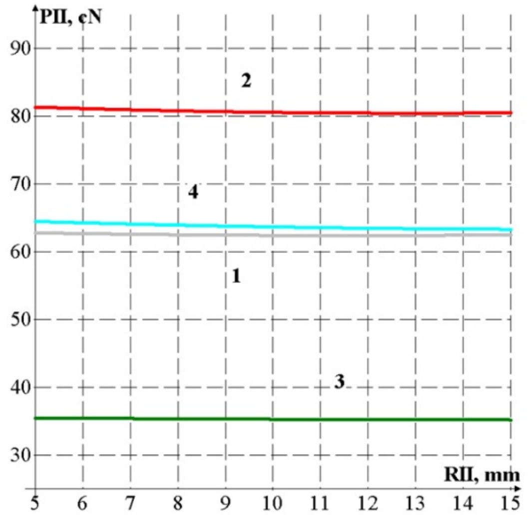


Figure 7 Graphical dependencies depicting influence of guide's curve radius to tension after the guide for II area: 1) polyamide multifilament yarn 174 tex; 2) polyamide multifilament yarn 280.5 tex; 3) basalt multifilament yarn 250 tex; 4) basalt multifilament yarn 330 tex

In order to determine influence of guide's curve radius to polyamide and basalt multifilament yarn tension after the guide, for III area, in the system of equations (34-37) the value of tension before the guide was taken as fixed. This value corresponded to the center of experiment (Table 4). For polyamide multifilament yarn 174 tex tension before the guide in the center of the experiment is P_{0III1}=65 cN. For polyamide multifilament yarn 280.5 tex tension before the guide in the center of the experiment is P_{0II2}=85 cN. For basalt multifilament yarn 250 tex tension before the guide in the center of the experiment is P_{0II3}=35 cN. For basalt multifilament yarn 330 tex tension before the guide in the center of the experiment is P_{0II4}=47 cN. After inserting the indicated values, the following equations were obtained for III area:

variant 1A

$$P_{III1} = 122.76 - 68.05R_{III} + 24.61R_{III}^2 \tag{46}$$

variant 2B

$$P_{III2} = 199.19 - 144.03R_{III} + 53.44R_{III}^2 \tag{47}$$

variant 3C

$$P_{III3} = 53.96 - 20.95R_{III} + 7.44R_{III}^2 \tag{48}$$

variant 4D

$$P_{III4} = 99.08 - 63.05R_{III} + 22.81R_{III}^2 \tag{49}$$

Figure 8 represents graphical dependencies depicting influence of guide's curve radius to tension after the guide for III area, obtained with the help of equations (46-49), where the value of the polyamide and basalt multifilament yarns tension before the guide was fixed.

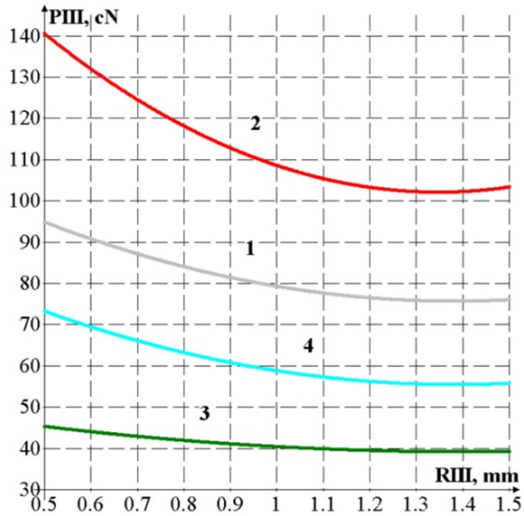


Figure 8 Graphical dependencies depicting influence of guide's curve radius to tension after the guide for III area: 1) polyamide multifilament yarn 174 tex; 2) polyamide multifilament yarn 280.5 tex; 3) basalt multifilament yarn 250 tex; 4) basalt multifilament yarn 330 tex

With the help of regression dependencies (22-25) the value of the warp yarns tension in the III area up to the fell of the multifilament and basalt fabrics were determined for different stages of weaving of the fabric element on the automatic looms. The value of warp yarns distortion at the stage of shedding, battening, and removal of fabric was taken into account as a value of the input tension in I area.

Having been analyzed, graphical dependencies (Figure 9) allowed to determine that the toughest conditions of weaving will be for variant 2B during manufacture of multilayer industrial fabric MTF-7; abovementioned is based on polyamide multifilament yarns 93.5x3 tex. This can be explained by the high value of the threading tension of warp yarns and coefficient of friction on the guide surfaces. When the diameter of warp polyamide multifilament yarns (variant 1A and variant 2B) and basalt multifilament yarns (variant 3C and variant 4D) density of weaving process increases, and such phenomena can be explained by tension in III area, which increases as a result of yarn diameter distortion in the contact area with guide and bending rigidity of yarns.

Obtained results can be applied to improve technological process of weaving, when density of weaving process can be determined yet during the initial stage.

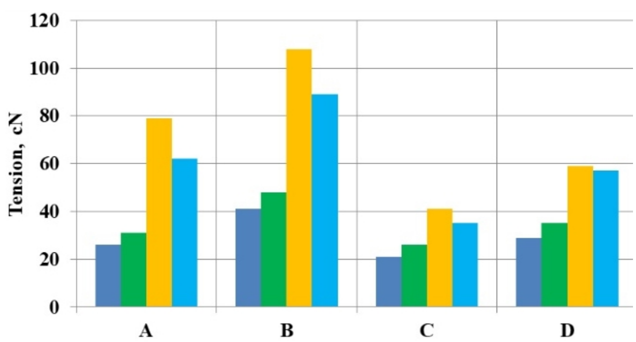


Figure 9 Histogram of warp yarns tension up to fell at the moment of fabric weaving in III area: A) multilayer industrial fabric MTF - 5 (warp – polyamide multifilament yarn 29x6 tex); B) multilayer industrial fabric MTF - 7 (warp – polyamide multifilament yarn 93.5x3 tex); C) basalt fabric of plain weave (warp – basalt multifilament yarn 250 tex); D) basalt fabric of plain weave (warp – basalt multifilament yarn 330 tex); ■ – threading tension of warp yarns; ■ – warp yarns tension working with closed shed; ■ – tension of warp yarns with fully opened shed; ■ – tension of warp yarns during battening

4 CONCLUSIONS

To enhance manufacturing processes of weaving production it is necessary to optimize manufacturing efforts based on maximum reduction of polyamide and basalt multifilament yarns tension in the industrial fabrics formation areas. The researches performed to determine polyamide and basalt multifilament yarns tension when interacting with guides and operative parts of looms established increase in yarn tension according to filling areas. The above comes with change in geometrical dimensions of filling line and friction forces in the contact area.

The regression dependencies were obtained resulting from series of experimental researches performed to determine combined influence of polyamide and basalt multifilament yarns tension prior going to guide, guide's curve radius and nominal value of contact angle to yarn tension after the guide. Consistent use of regression dependencies data enables determining polyamide and basalt multifilament yarns tension before they enter industrial fabrics weaving area. The regression dependencies analysis has made it possible to establish manufacturing parameters, when polyamide and basalt multifilament yarns tension (before they enter industrial fabrics weaving area) will be of minimum value. As a result, it will be possible to minimize tension of polyamide and basalt multifilament yarns during their processing on looms.

Mentioned results, when used, enable efficiency enhancement for polyamide and basalt multifilament yarns manufacturing process on production equipment as far as tension in the operational area of industrial fabrics weaving could be minimized, yarn breakages reduced and performance of textile and knitwear equipment improved.

Mentioned results can be used while enhancing efficiency of manufacturing process for single-layer and multilayer fabrics produced from multifilament yarns, which in terms of their physical and mechanical properties will be similar to polyamide and basalt multifilament yarns.

Acknowledgement: *We are really grateful to Danish Textiles management and Kyiv "Factory of Technical Fabrics TEKHNOFILTR" for raw materials provided for experimental work and possibility to try out results of our research in production environment.*

5 REFERENCES

1. Koo Y., Kim H.: Friction of cotton yarn in relation to fluff formation on circular knitting machines, Textile Research Journal 72(1), 2002, pp.17-20, https://doi.org/10.1177/004051750207200103
2. Vasconcelos F.B., Marcicano J.P.P., Sanches R.A.: Influence of yarn tension variations before the positive feed on the characteristics of knitted fabrics, Textile Research Journal 85, 2015, pp.1864-1871, https://doi.org/10.1177/0040517515576327
3. Shcherban' V.Yu.: Determining the technological forces during beating-up in the production of multilayer industrial fabrics, Technology of Textile Industry (Izvestiya Vysshikh Uchebnykh Zavedenii) 3, 1990, pp.44-47 (in Russian)

4. Weber M.O., Ehrmann A.: Necessary modification of the Euler-Eytelwein formula for knitting machines, The Journal of The Textile Institute 103, 2012, pp. 687-690, https://doi.org/10.1080/00405000.2011.598665
5. Yakubitskaya I.A., Chugin V.V., Shcherban' V.Yu.: Dynamic analysis of the traversing conditions at the end sections of the groove in a winding drum, Technology of Textile Industry (Izvestiya Vysshikh Uchebnykh Zavedenii) 5, 1997, pp.33-36 (in Russian)
6. Yakubitskaya I.A., Chugin V.V., Shcherban' V.Yu.: Differential equations for relative yarn movement in the end sections of the channel in the winding drum, Technology of Textile Industry (Izvestiya Vysshikh Uchebnykh Zavedenii) 6, 1997, pp.50-54 (in Russian)
7. Shcherban' V.Yu.: Interaction of stiff yarns with the working parts of knitting and sewing machines, Textile industry 10, 1988, pp.53 (in Russian)
8. Shcherban' V., Melnyk G., Sholudko M., Kalashnyk V.: Warp yarn tension during fabric formation, Vlakna a textil (Fibres and Textiles) 25(2), 2018, pp.97-104, http://vat.ft.tul.cz/2018/2/VaT_2018_2_16.pdf
9. Shcherban' V., Melnyk G., Sholudko M., Kolysko O., Kalashnyk V.: Yarn tension while knitting textile fabric, Vlakna a textil (Fibres and Textiles) 25(3), 2018, pp.74-83, http://vat.ft.tul.cz/2018/3/VaT_2018_3_12.pdf
10. Shcherban' V., Kolysko O., Melnyk G., Sholudko M., Shcherban' Y. and Shchutska G.: Determining tension of yarns when interacting with guides and operative parts of textile machinery having the torus form, Vlakna a textil (Fibres and Textiles) 27(4), 2020, pp. 87-95, http://vat.ft.tul.cz/2020/4/VaT_2020_4_12.pdf
11. Shcherban' V., Makarenko J., Melnyk G., Shcherban' Y., Petko A., Kirichenko A.: Effect of the yarn structure on the tension degree when interacting with high-curved guides, Vlakna a textil (Fibres and Textiles) 26(4), 2019, pp.59-68, http://vat.ft.tul.cz/2019/4/VaT_2019_4_8.pdf
12. Shcherban' V., Makarenko J., Petko A., Melnyk G., Shcherban' Yu., Shchutska G.: Computer implementation of a recursion algorithm for determining the tension of a thread on technological equipment based on the derived mathematical dependencies, Eastern-European Journal of Enterprise Technologies 2/1, 2020, pp. 41-50, https://doi.org/ 10.15587/1729-4061.2020.198286
13. Shcherban' V., Melnyk G., Sholudko M., Kolysko O., Kalashnyk V.: Improvement of structure and technology of manufacture of multilayer technical fabric, Vlakna a textil (Fibres and Textiles) 26(2), 2019, pp.54-63, http://vat.ft.tul.cz/2019/2/VaT_2019_2_10.pdf
14. Kovar R.: Impact of directions on frictional properties of a knitted fabric, Vlakna a textil (Fibres and Textiles) 14(2), 2007, pp.15-20, http://vat.ft.tul.cz/Archive/VaT_2007_2.pdf
15. Donmez S., Marmarali A.: A Model for Predicting a Yarn's Knittability, Textile Research Journal 74, 2004, pp.1049-1054, https://doi.org/10.1177/004051750407401204
16. Liu X., Chen N., Feng X.: Effect of Yarn Parameters on the Knittability of Glass Ply Yam, Fibres & Textiles in Eastern Europe 16, 2008, pp.90-93
17. Hammersley M.J.: 7-A Simple Yarn-friction Tester for use with knitting yarns, The Journal of the Textile Institute 64, 1973, pp.108-111, https://doi.org/10.1080/00405007308630420
18. Sodomka L., Chrpová E.: Method of determination of Euler friction coefficients of textiles, Vlakna a textil (Fibres and Textiles) 15(2-3), 2008, pp.28-33, http://vat.ft.tul.cz/Archive/VaT_2008_2_3.pdf
19. Vasilchenko V.N., Shcherban' V.Yu.: Effect of the twist of Kapron filament yarn on its bending rigidity, Technology of Textile Industry (Izvestiya Vysshikh Uchebnykh Zavedenii) 4, 1986, pp.8-9 (in Russian)
20. Vasilchenko V.N., Shcherban' V.Yu., Apokin Ts.V.: Attachment for holding multilayer fabrics in the clamps of a universal tensile tester, Textile industry 8, 1987, pp.62 (in Russian)
21. Shcherban' V., Korogod G., Chaban V., Kolysko O., Shcherban' Yu., Shchutska G.: Computer simulation methods of redundant measurements with the nonlinear transformation function, Eastern-European Journal of Enterprise Technologies 2/5, 2019, pp.16-22, https://doi.org/10.15587/1729-4061.2019.160830
22. Shcherban' V., Korogod G., Kolysko O., Kolysko M., Shcherban' Yu., Shchutska G.: Computer simulation of multiple measurements of logarithmic transformation function by two approaches, Eastern-European Journal of Enterprise Technologies 6/4, 2020, pp. 6-13, https://doi.org/ 10.15587/1729-4061.2020.218517

THE USE OF CLOVE LEAVES *(Syzygium aromaticum L.)* AS NATURAL DYE FOR BATIK PRODUCTION IN KASUMEDANGAN BATIK INDUSTRY, INDONESIA

Bandi Sobandi[1], Triyanto[2], Tjetjep Rohendi Rohidi[3] and Syakir[2]

[1]Universitas Negeri Semarang, Doctoral Degree Program in Arts Education, Semarang, Indonesia
[2]Universitas Negeri Semarang, Faculty of Language and Art, Fine Arts Education, Semarang, Indonesia
[3]Universitas Dian Nuswantoro, Faculty of Computer Science, Visual Communication Design, Semarang, Indonesia
bas@students.unnes.ac.id; triyanto@mail.unnes.ac.id; trrohidi@yahoo.com, kirmuharrar@mail.unnes.ac.id

Abstract: *The use of synthetic dyes in the batik production process has an impact on environmental pollution and threatens human health. To overcome this problem, the use of natural dyes as materials for coloring batik cloth is one of the solutions offered. Apart from being environmentally friendly, the use of natural dyes is an effort to preserve ancestral traditions that have local wisdom and as an effort to utilize abundant natural resources. This study used a laboratory experimental method using one fixed variable, namely natural coloring agent from extracted clove leaves and two changing variables, namely the fixator in the form of ferrous sulfate ($FeSO_4$) and lime solution ($Ca(OH)_2$). The test parameters are color resistance through the washing process and color resistance by the solar radiation process. The research was conducted collaboratively between researchers and batik artisans at the Umy May Batik Studio in Tanjungsari, Sumedang Regency. The results showed a variation in color direction based on the type of natural dye and the type of fixator used. The color of Kasumedangan batik cloth in the Cadas Pangeran motif using clove leaf extract with two different fixators produces cream and dark brown colors. Based on the test results, the color resistance to washing 40°C shows the level of color resistance of clove leaves using the ferrous sulfate fixator is good (value 4-5 from a scale of 5) and lime solution fixator is categorized as good (value 4-5 from scale 5). Meanwhile, the results of the color fastness test to light: day light using ferrous sulfate were found to be categorized as quite fairly good (value 3-4 from a scale of 5) and using lime solution was categorized as good (value 4 from a scale of 5). Based on these results, it can be concluded that the clove leaf extract can be used as an environmentally friendly dye for batik cloth and has local wisdom and added value for batik craftsmen.*

Keywords: *clove leaves, Kasumedangan batik, patterned batik, environmentally friendly, natural dyes.*

1 INTRODUCTION

Indonesian batik has experienced rapid growth since its establishment by UNESCO as an intangible cultural heritage in the field of humanity. This recognition is achieved because batik originates from oral traditions and expressions, is used in social practices (rites and celebrations) and is a traditional craftsmanship [1]. Behind the improvement in batik products, new problems have emerged that threaten human health and environmental sustainability, especially water. The batik home industry, which is being developed, can increase environmental pollution of river water which is the main source of agricultural, fishery and drinking water activities [2]. The decline in the quality and quantity of available fresh water which results in harmful effects on human health and/or economic activity is a global issue facing the world community today [3].

Synthetic dyes are widely used by batik craftsmen today. In fact, synthetic dyes containing azo groups with amino aromatic properties are strongly suspected to cause skin cancer (carcinogenic), are toxic and can pollute the environment [4, 5]. Wastewater from the batik industry has an impact on large amounts of organic wastewater, has a thick color, a strong odor and temperature, acidity (pH), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) in high levels, and is harmful to the environment if discharged directly into water [6, 7]. This is reinforced by the findings of the measurement results of batik industrial waste in five locations in the housing ditch in Pekalongan as one of the batik handicraft centers, with average data obtained: Cd 0.07 mg/L, Cr 0.76 mg/L and Pb 0.78 mg/L. These three parameters exceed the maximum level of quality standards stipulated by Government Regulation No. 82 of 2001 concerning water quality management and water pollution control [8].

In the past few years, the revival of natural colors is one of the solutions to reduce the impact of environmental pollution. This condition is a worldwide movement to protect the environment from the process of exploration and pollution by industry. Natural dyes are compatible with nature due to their harmless properties and produce soft and silky colors [9]. The classification of natural dyes based on their source comes from plants (leaves, bark, flowers, fruits, etc.), animals (dried insects, shells of sea snail), minerals (rock, earth crust), and micro-organisms (fungi, algae, bacteria), etc.) [10]. The chemical compounds associated with this dye include carotenoids, flavonoids, tetrapyrroles and xanthophylls. These dyes are applied in the textile, food, pharmaceutical, cosmetic, handicraft and leather tanning industries recommended as a health and environmental awareness and industrial products that can be marketed [11]. Diversification of batik products with natural dyes is one way to create a luxurious effect on hand-made woven products for the changing fashion market, the use of natural dyes in the textile industry can make a valuable contribution to environmental sustainability in the 21st century [12]. However, in certain cases, behind the existence of environmental awareness, natural color batik production tends to be triggered by economic reasons, namely to maintain the economic survival of batik masters [13].

The use of natural dyes has advantages including being less toxic, less polluting, less health hazardous, non-carcinogenic, non-poisonous, more biodegradable, relatively safe, environmentally friendly and easy to obtain with zero liquid waste compared to synthetic variants. The remaining wastewater from the staining stage is then used for other processes, the remaining organic waste from the entire procedure is used as compost and for batik production [14-16]. These findings are in line with previous findings that liquid waste immersed in natural dye extract (ZPA) can be grouped into household groups, furthermore the value of synthetic dye pollution load (ZWS) is 7-20 times greater than natural dyes [17].

One of the potential plant parts for natural dye sources is the leaves. Some sources of natural colorants from leaves include: henna (*Lawsonia inermis L*), teak (*Tectona grandis*), malabar nut (*Adhatoda vasica nees*), chikrasi (*Chukrasia tabularis*), european lily (*Convallaria majalis*), Glastum (*Isatis tinctoria Linn*), mango bark (*Mangifera indica*), peach (*Prunus persica*), stinging nettle (*Urtica dioica*), fire flame bush (*Woodfordia fruticosa*), sweet indrajao (*Wrightia tinctoria*), safed kikar (*Acacia leucophloea*), neel (*Indigofera cassioides Rottl. Ex. DC.*), jamun (*Syzygium cuminii)* and ber (*Ziziphus mauritiana Lam*) [18]. Mango leaves have good potential for dyeing silk fabrics [19], Teak leaves (*Tectona grandis*) can be used for dyeing batik cloth [20]. Indigo (*Indigofera L*) is batik's natural blue dye extracted from the leaves of the indigo plant, which is environmentally friendly and non-carcinogenic [21] and *tanjung* leaf (*Mimusops elengi Linn*) can be an attractive choice for dyeing cotton and silk fabrics in various elegant shades [22]. In particular, several sources of natural dyes from leaves include medicinal plants and spices including leaves: tea (*Camellia sinensis L.*), betel (*Piper betle L*), eucalyptus (*Eucalyptus*), henna (*Lawsonia inermis L*), cardamom (*Elettaria cardamomum*), coral jasmine (*Nyctanthes arbor-tristis*), lemon grass, malabar nut (*Adhatoda vasica nees*) and chikrasi (*Chukrasia tabularis*) [23, 24, 18].

Clove (*Syzygium aromaticum L.*) is a tropical plant which is indigenous to Indonesia and has the ability to grow in several parts of the country including the lowlands, near the coast, and in the mountainous areas at an altitude of 900 m above sea level. These plants grow well when there is enough water and direct sunlight [25] and has also been observed to be a spice plant native to the Maluku Islands which has been traded and cultivated from one generation to another in the form of smallholder plantations. Clove contains saponins, alkaloids, flavonoid glycosides and tannins. Meanwhile, flavonoids are a type of toxic or allelopathic compound usually produced from flavones-bound sugar. The plant has a very sharp odor, bitter taste, soluble in water and organic solvents, and easily decomposes at high temperatures.

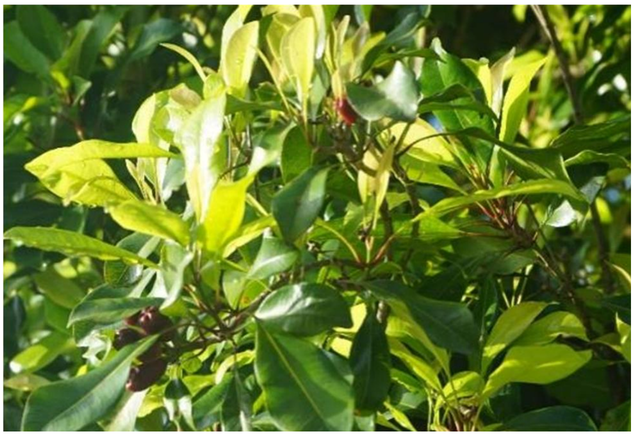


Figure 1 Clove leaves (*Syzygium aromaticum*); source: author's documents

Moreover, the natural herbicide effectiveness of clove leaf extracts at a concentration of 50% can be used as an alternative to inhibit the height growth of nutgrass weeds [26]. This plant represents one of the richest source of phenolic compounds such as eugenol, eugenol acetate and gallic acid and posses great potential for pharmaceutical, cosmetic, food and agricultural applications [27]. Clove is a spice plant that has long been used in the cigarette, food, beverage and medicine industries. The usable plant parts are flowers, flower stalks and clove leaves. The use of cloves has developed in the cosmetic industry and recently there have been several findings that the possibility of developing the use of cloves for other purposes, including as an anesthetic agent for fish and the eradication of pests and plant diseases [28].

Various studies related to the benefits of cloves have been conducted. The presence of cloves as a native Indonesian plant is seen as the champion of all known antioxidants because it has antiseptic, antibacterial, antifungal, antimicrobial, antidiabetic, anti-inflammatory, hepatoprotective, anti-stress, antiviral and insect repellent properties. In the field of medicine, cloves have many uses such as for the treatment of toothache, inflammation of the mouth and throat, treating flatulence, nausea and vomiting and in certain doses can be used to induce anesthesia [29-31]. Apart from the health sector, cloves can also be used as a spice for spices and food preservatives [32, 33]. In particular, clove leaves also have medicinal benefits. Clove leaf oil contains 1-4% of oil by weight, the main component being eugenol (80-88%) with low eugenyl acetate and high content of caryophyllene [34, 35]. Clove leaf extract at a concentration of 10% was the most effective for avoiding fly infestation during the drying process of salted fish [36]. Leaves can be a candidate for producing active compounds to treat dental cavity because they contain bioactive compounds: 3-allyl-6-methoxyphenol-eugenol; caryophyllene 1,4,7-cycloundecatriene; 1,5,9,9-tetramethyl; phenol; 2-methoxy-4-(2-propenyl); and eugenol acetate [37]. Even the flavonoids from clove leaf oil have strong anticancer activity (IC50 <100 µg/mL) so that they are new candidates for liver cancer therapeutic agents [38].

The use of cloves in the fields of medicine, food, beverages, fisheries and agriculture has been widely practiced before both in Indonesia and in several countries as described above. However, the use of clove leaf waste as an extract material for natural dyes to dye batik cloth has not been widely explored, even though clove leaves have anti-microbial and environmentally friendly properties which are considered suitable for dyes in batik. Through this research, the authors want to find the benefits of clove leaves as a local plant that is often found in Indonesia to be used as a dye for batik cloth in the Kasumedangan Batik industry by observing how the color is produced using ferrous sulfate and lime solution fixation and how the color resistance test results are 40°C wash and color fastness to daylight.

In addition to efforts to introduce the benefits of cloves as a biological natural resource in Indonesia, this study was also conducted to expand previous research regarding the use of herbal extracts from cloves applied to fabrics by two methods, namely: Direct application method and Microencapsulation method which showed antimicrobial efficacy and resistance to washing by applying AATCC 147, AATCC Standard 30 and EN ISO 20645. Both treatments showed good antibacterial properties and the microencapsulation method also showed good antifungal properties. Through the direct application method, the washing resistance is only up to 10 washes, while the microencapsulation method shows excellent washing resistance of up to 30 wash cycles [39]. Extract solution of clove using water at 90°C for 90 minutes with an ingredient to water ratio of 1:10 shows that utilizing natural dyes from clove extract as a dyeing agent significantly facilitates obtaining a quality antibacterial cloth [40].

2 EXPERIMENTAL PART

2.1 Methods

This study examines the technology involved in developing natural and environmentally friendly colors for *Kasumedangan* batik dyeing at the Umy May Batik Studio in Tanjungsari, Sumedang Regency. The focus is on determining the technology to be applied by *Kasumedangan* batik craftsmen in batik cloth dyeing process by conducting tests on color resistance against washing and sun radiation. Laboratory experimental methods were implemented using the natural dye from extracted clove leaves as the dependent variable while fixators in the form of ferrous sulfate solution ($FeSO_4.7H_2O$) and lime solution ($Ca(OH)_2$) were used as the independent variables. In addition to using lime solution ($Ca(OH)_2$), the material for fixation or initial mordant can use cow bone ash which has a high potential to be used as a pre-mordant and fixator in the process of dyeing cotton and silk fabrics [41]. Meanwhile, the test parameters were color resistance values obtained against washing and sun radiation.

2.2 Materials

The raw materials used include clove (*Syzygium aromaticum L.*) leaves which were processed by extraction as well as *tunjung*/ferrous sulfate solution ($FeSO_4$) and lime solution ($Ca(OH)_2$) which were used as the fixing materials. Moreover, *tawas/*alum ($Al_2(SO_4)_3.K_2SO_4.24H_2O$), sodium carbonate and Turkey Red Oil (TRO) were applied for auxiliary immersion and *pelorodan* which is the process of removing wax sticking on the cloth. The tools used include a gas stove, a scale, a measuring cup, a dipping tub, a pot for the extraction of natural dyes, a tub for *pelorodan* process, and a color resistance test device through washing and sun radiation.

2.3 Work procedures

This section describes the steps starting from processing cotton fabrics, making natural color extracts from clove leaves, dyeing fabrics with natural color extracts, color fixing processes using *tunjung*/ferrous sulfate solution ($FeSO_4$) and lime solution ($Ca(OH)_2$), *pelorodan* process, testing process, analysis of test results, and determining conclusions. Furthermore, the research steps are presented in Figure 2.

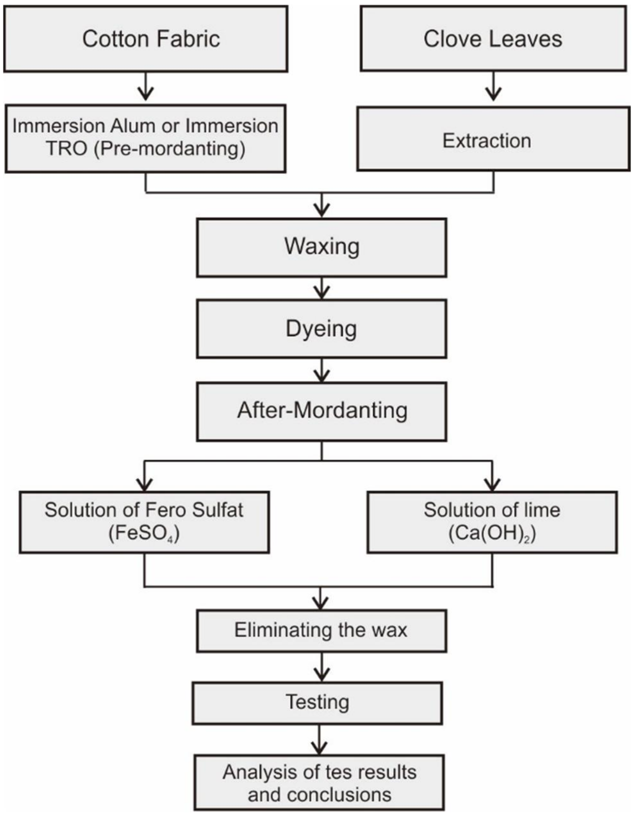


Figure 2 The work process of dyeing batik cloth with natural dye extracts from clove leaves

2.3.1 Preparation stage

There are two activities in the process of activities carried out at the preparation stage, namely:

1) Batik cloth processing

At this stage, the process of soaking the cloth is carried out with the TRO auxiliary substance or with alum solution (6 g/L) for 24 hours, then the cloth is rinsed and dried for the batik process. The use of TRO material aims to improve the quality of the absorption of the natural color of clove leaf extract on the batik cloth.

2) Natural dye processing

The process of processing natural colors into color extracts is carried out in the following stages:

a) Cut the natural dyestuff from the plants (such as: stems, barks, leaves, roots, flower, seeds, fruit and sticky plant-sap) into small and balanced pieces. It needs 1 kilogram the plants of natural dyes for 1-piece fabric (size 2.5 m, or equivalent 500 g).
b) Put the materials in a vessel; add 10 L of water into the vessel, then boiled until the water is about 4-5 L left. Filter the solution from the material after the extraction process.
c) Put the fabric (cotton or silk) to the mordant process (pre-mordanting).
d) Apply the TRO solution on the fabric then dry it before the coloring process with the natural dyestuff, namely *tawas* ($Al_2(SO_4)_3$ $K_2SO_4 24$ H_2O) solution. Repeat the coloring process until the color is getting darker and then dry the fabric.
e) For the last process, the fabric put into “after mordant" or “*sarenan”* (Javanense process) solution, with *quick lime* ($Ca(OH)_2$), or with *tunjung*/ferro sulphate ($FeSO_4.7H_2O$), or with *tawas* ($Al_2(SO_4)_3.K_2SO_4$ H_2O) solution. After the color changes, dry it [42].

The activities carried out at this stage were the researchers boiled clove leaves with a ratio of 1 kg:10 L of water. The boiling process is carried out until the clove leaf dye extract becomes 5 L. The extraction of natural dye pigments can be carried out at various temperatures. Extraction of dye pigments simply by immersing the material in cold water for 24 hours, then heating to boiling (98-100°C), for heat sensitive dyes (usually dyes derived from flowers) to a temperature of 70-80°C [43]. Furthermore, this clove leaf extract material is ready to be used in the next fabric dyeing process.

2.3.2 Waxing process

Writing batik cloth with hot wax can be done using writing techniques using canting, canting cap or a combination of the two to form a batik ornament/pattern based on the desired batik motif design. In this research, the writing of batik cloth with wax uses a canting cap with the Cadas Pengeran batik motif.

2.3.3 Dyeing process

The process of dyeing batik cloth using natural dye extract from clove leaf material is done gradually and repeatedly. The batik cloth is then dyed in some water with enough TRO added so that the wetting process is faster and the dye is evenly distributed. After the cloth is removed, the cloth is hung so that there are no more water drops yet the cloth is still damp. The process of dyeing the batik cloth into the clove leaf extract solution is carried out for ±15 min, then the fabric is dried a little bit before being dyed again. The dyeing and drying process is repeated 5 times.

2.3.4 Fixation/mordanting process

The fixation process serves to determine the direction of the color and adjust the color on the fabric so that it doesn't fade quickly. The fixation auxiliary uses a solution of *tunjung*/ferrous sulfate ($FeSO_4$) with a composition of 30 g/L of lime solution ($Ca(OH)_2$) fixation with a composition of 50 g/L of lime. The two fixation solutions are set for 24 hours and the used part is the clear solution. *Tunjung* and chalk as a fixator function to create color and strengthen color resistance according to the type of metal that binds them and to lock the dye that has entered into the fiber [44, 11]. The use of fixators in the form of heavy metals is very toxic and bad for the environment [45]. Several efforts have been made such as the electron beam radiation with Electron Beam Machine (MBE) which is currently being used as an alternative fixator in natural color batik dyeing process due to its environmental-friendliness, good quality which conforms with the SNI (Indonesian National Standard), and its ability to reduce the concentration of heavy metals in batik waste in order to create a sustainable batik industry [44].

2.3.5 Process of removing wax from batik cloth

The process of decaying the wax (*pelorodan*) of the batik cloth is carried out in boiling hot water on the stove at a temperature of 100°C. To the water, an auxiliary substance is added in the form of *soda ash*/natrium carbonate (Na_2CO_3) (5 g/L). The addition of auxiliary substances aims to make the wax easily separated from the batik cloth. After removing then wax, the cloth rinsed and then dried it.

2.3.6 Testing

The parameters used were color resistances against washing and sun radiation and they were tested at the Yogyakarta Institute of Batik and Handicraft, Yogyakarta. Batik cloth that has been dyed with clove leaf color extract and confirmed with a *tunjung*/ferrous sulfate ($FeSO_4$) solution and lime solution ($Ca(OH)_2$) then two test methods are carried out, namely:

1) Color fastness resistance to washing 40°C (SNI ISO 105 - C06: 2010. Textiles - Color fastness test method - Part C06: Color fastness against household and commercial washing, "2010). In this method, the color change value is also tested (SNI ISO 105-A02:2010. Textiles - Test for colour fastness - Part A02: Grey scale for assessing change in colour (ISO 105-A02:1993, IDT)) and color staining value (SNI ISO 105-A03:2010. Textiles - Tests for colour fastness - Part A03: Grey scale for assessing staining (ISO 105-A03:1993, IDT)).
2) Color fastness resistance to sunlight ("SNI ISO 105 - B01: 2010. Textiles - Color fastness test method - Part B01: Color fastness to light, sun light" 2010), wavelength testing, and absorbance using spectrophotometry. In this method, the color change value is also tested (SNI ISO 105-A02:2010. Textiles - Test for colour fastness - Part A02: Grey scale for assessing change in colour (ISO 105-A02:1993,IDT))

2.3.7 Analysis of test results and conclusions

The test results of color fastness against washing at 40°C and color fastness to light: sun light using ferro sulfate and lime fixation were then analyzed and concluded. Data analysis results and conclusions will be presented in section 3.

3 RESULTS AND DISCUSSION

3.1 *Batik Kasumedangan motif*

Kasumedangan batik development has its own uniqueness. Behind the development process, there is a myth in the form of prohibition/taboo for some people to wear batik. This condition arose since the conflict between the Sumedang Larang Kingdom and the Cirebon Sultanate in the past through the oath of Eyang Jaya Perkosa. This belief continues to this day, every person who goes on a pilgrimage to Patilasan Leluhur Sumedang in the Dayeuh Luhur area is not allowed to wear batik clothes.

The Kasumedangan batik motif design creations come from the physical environment, cultural, social, artistic artifacts and philosophical values of the supporting community. This condition is in line with the view that the visualization and structure of batik motifs that developed from regional icons at the time of making cloth and clothing is now a trend for Indonesian batik [45]. In addition to the initiative and creativity of batik craftsmen, society and community participation, the development of Kasumedangan batik is also closely related to local government support through Regent Regulation No. 113 of 2009 concerning *Sumedang Puseur Budaya Sunda* (SPBS) which explicitly regulates the use of *Kasumedangan* Ornamental Variety, such as: *Binokasih Crown*, *Kujang*, Pajajaran Ornamental Variety, *Lingga*, *Garuda Mungkur*, *Manuk Julang*, *Naga*, *Hanjuang*, *Kembang Cangkok Wijaya Kusumah*, and Lotus.

3.2 *Results of dyeing Kasumedangan batik cloth with clove leaf color extract*

The process of coloring the batik cloth was carried out on the Cadas Pangeran batik motif as one of the Kasumedangan batik motif creations made by the Umy May Batik Studio, in Tanjungsari, Sumedang. The visualization of this motif was inspired by a place and the figure of Pangeran Kornel (Pangeran Kusumadinata IX, Sumedang Regent 1971-1828 was built) shaking hands with Daendels. The results of the coloring of the batik cloth using natural dye extract of clove leaves with different fixers, resulting in different directions and colors.

The results of dyeing batik cloth using dye extracts from clove leaves with the *tunjung/*fixation solution tend to be brown towards black (Figure 3), while the use of lime fixation tends to beige towards brown (Figure 4). Thus, one of the functions of the fixator is to determine the direction of the color. The use of extracts from the same material will produce different colors when using different fixators.

Figure 3 Natural dye of clove leaves in the Cadas Pangeran batik motif by ferro sulfate fixation, source: author's documents

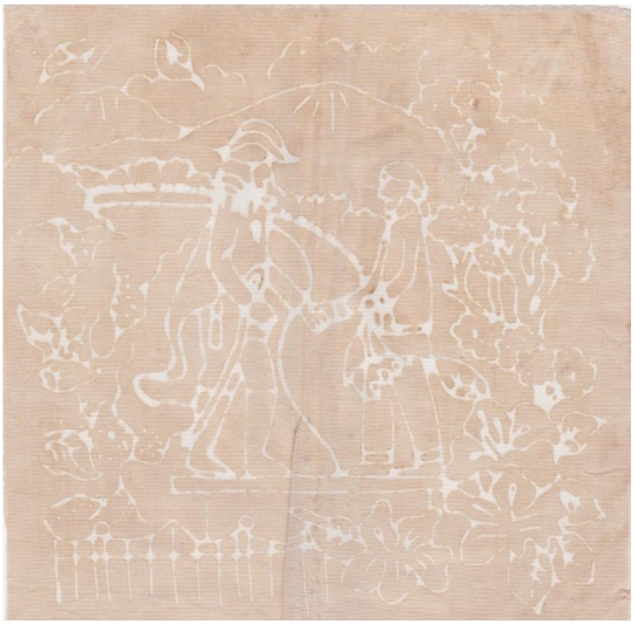


Figure 4 Natural dye of clove leaves in the Cadas Pangeran batik motif lime fixation; source: author's documents

The findings above are in line with the opinion that the fixation material in addition to strengthening the bonds of natural dyes with the fabric also greatly determines the different color directions. Alum produces a light color according to its original color, medium lime or brownish direction, not older or leads to black [46]. The higher the concentration of the fixator, the stronger the color produced because the function of the fixator is not only to cause color but also to strengthen the bonds between fibers and colors so as to prevent dehydration of color pigments [47]. According to Barber (1991), “A mordant is a separate chemical that combines with the dye in such a way as to attach the coloring matter to the fiber by increasing affinity and/or strengthened interactions in some cases via a lasting chemical bond (mordant means ‘biting in’), thereby making the color stand fast against light and washing” [23]

3.3 Color fastness resistance test results

The result of the batik dyeing process that is applied in the process of dyeing the Cadas Pangeran batik cloth as one of the names of the *Kasumedangan* batik motif. Color fastness testing using a test method based on SNI ISO 105-C06: 2010, Textiles-Color fastness test method-Part C06: Color fastness to household and commercial washing and SNI ISO 105-B01-2010, Textiles-Durability test method color fastness - Part B01: Light fastness: Daylight fastness. The reading of the test results is in the form of a gray scale for color staining and color changes on a scale of 1 to 5, in the form of a value of 5 (very good), value 4 (good), value 3 (moderate), value 2 (bad) and value 1 (very bad). The results of the fastness test of cotton batik cloth with clove leaf color against washing and sunlight are presented in Table 1.

Table 1 Natural color resistance of clove leaves

No.	Test type	Test results (fixator type)		Test method
		$FeSo_4$	$CaCo_3$	
1.	Washing resistance 40°C			SNI ISO 105-C06:2010
	Color change value	4-5	4-5	SNI ISO 105-A02:2010
	Color blemishes value			SNI ISO 105-A03:2010
	- acetate	4-5	4-5	
	- cotton	4	4-5	
	- polyamide	4-5	4-5	
	- polyester	4-5	4-5	
	- acrylate	4-5	4-5	
	- wool	4-5	4-5	
2.	Color resistance to light: day light Ray resistant value	3-4	4	SNI ISO 105-B01:2010 SNI ISO 105-B02:2010

Description: 1 = very bad, 1-2 = bad, 2 = bad, 2-3 = moderate, 3 = moderate, 3-4 = fairly good, 4 = good, 4-5 = good, 5 = very good

Table 1 above is the data on the results of testing the natural color of clove leaves applied to the Cadas Pengeran batik motif. The process of immersing the clove leaf extract by immersing the cold technique was carried out five times, which was then confirmed with a solution of ferrous sulfate ($FeSO_4$) and/or lime solution ($Ca(OH)_2$), the results were:

1) Wash fastness 40°C. The batik coloring on the cotton cloth uses the natural color of clove leaves in the cold dyeing method about 5 times dyeing. Based on the table above, it is known that the color fastness resistance to washing is 40°C through the SNI ISO 105 - C06: 2010 testing technique. Textiles - Color fastness test method - Part C06: Color fastness against household and commercial washing, "2010) then the dyeing results batik cloth that uses fixation with *tunjung*/ferro sulfate solution and lime solution fixation is known to be categorized as good (score 4-5 on a scale of 5). Likewise, the value of color change (SNI ISO 105-A02: 2010. Textiles - Test for color fastness - Part A02: Gray scale for assessing change in color (ISO 105-A02:1993, IDT)) and color staining value (SNI ISO 105-A03:2010. Textiles - Tests for colour fastness - Part A03: Grey scale for assessing staining (ISO 105-A03:1993, IDT), these results indicate that the natural dyes from clove leaf extract are categorized as good - very good. From the results of this test it can be concluded that clove leaf extract can be used as a quality dye for batik cloth.
2) Light fastness resistance: day light. The results of the color fastness test to light: day light (SNI ISO 105-B01: 2010) by using the *tunjung*/ferrous sulfate solution were known to be in the fairly good category (score 3 - 4 from a scale of 5) and by using the lime solution in the good category (score 4 from a scale of 5). The same value was also obtained in the Light-resistant value test (SNI ISO 105-A02: 2010. Textiles - Test for color fastness - Part A02: Gray scale for assessing change in color (ISO 105-A02: 1993, IDT)). The results of these findings can be concluded that the use of clove leaf extract has quality light resistance values ranging from moderate to good category.

Based on the findings above, it can be concluded that the use of clove leaf waste as an extract material for natural colors can be used as an alternative to natural dyes for quality and environmentally friendly dyes for batik cloth. The use of abundant clove leaf waste to extract batik dyes is an effort to raise the value of local wisdom through the use of traditional plant commodities that have long and thrived in Indonesia as spices. Not only that, the use of natural colors in the coloring process of batik cloth can increase the economic added value of today's batik craftsmen.

To get a different gradient color, it can be done in several ways, including: 1) adjust the amount of dyeing the batik cloth, the more dyeing process, the stronger the color intensity; 2) adjusting the ratio of the amount of dye and cooking water used (usually 1 kg/10 L), the more the proportion of natural ingredients used, the stronger the color intensity; 3) the time of dyeing the fabric in the color extract, the longer the dyeing time, the stronger the color intensity. In order to obtain the variation and intensity of the batik cloth dyeing results with clove leaf extract, further research is needed, such as the methods above.

4 CONCLUSION

The use of natural color substances in the coloring of batik cloth is the right solution in reducing the current problem of environmental pollution. Processing natural color substances by using the final mordant as a fixator can provide direction and type of color on *Kasumedangan* batik cloth. The test results with the method of testing the resistance of fading to 40°C washing on batik cloth with Cadas Pangeran motif by using clove leaf extract with ferro sulfate and lime fixations are categorized good-very good. Similarly, the test results with the method of color fading resistance to light: day light using *tunjung* fixation is known to be categorized moderate-good and with a good category with lime fixation. Thus, this study recommends the need to use natural color substances from clove leaf extract material for batik fabric dyes as an effort to preserve the value of local wisdom and give added value to *Kasumedangan* batik craftsmen.

Acknowledgment: *The authors would like to thank the Manager of The Domestic Postgraduate Education Scholarship (BPPDN), Directorate General of Science, Technology Resource and Higher Education for the assistance of funds in the further study of the Doctoral Program of the Art Education Study Program for researchers.*

5 REFERENCES

1. UNESCO: Indonesian Batik - Inscribed in 2009 (4.COM) on the Representative List of the Intangible Cultural Heritage of Humanity, 2009, https://ich.unesco.org/en/RL/indonesian-batik-00170
2. Koosdaryani, Masykuri M., Purwanto E., Suranto: Batik industry wastewater treatment using fito remidiation of water hyacinth with adsorbent consist of organic waste bagasse, rice husks and bamboo charcoal, IOP Conference Series: Materials Science and Engineering, 508 012111, 2019, pp. 1-6, https://doi.org/10.1088/1757-899X/508/1/012111
3. World Economic Forum: The Global Risks Report 2020, 15th edition, http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf

4. Lestari K., Riyanto R.: The making of blue natural dye from Indigofera Tinctoria (Pembuatan Pewarna Alam Biru dari Indigofera Tinctoria), Dinamika Kerajinan dan Batik No.21, 2004, pp. 7-15 (in Indonesian)
5. Kant R.: Textile dyeing industry an environmental hazard, Natural Science 4(1), 2012, pp. 22-26, doi: 10.4236/ns.2012.41004
6. Kurniawan M.W., Purwanto P., Sudarno S.: Sustainable wastewater management strategy of batik MSME Center in Sukoharjo Regency (Strategi Pengelolaan Air Limbah Sentra UMKM Batik yang Berkelanjutan di Kabupaten Sukoharjo), Jurnal Ilmu Lingkungan 11(2), 2013, pp. 62-72, (in Indonesian) https://doi.org/10.14710/jil.11.2.62-72
7. Tangahu B.V., Ningsih D.A., Kurniawan S.B., Imron M.F.: Study of BOD and COD removal in batik wastewater using Scirpus grossus and Iris pseudacorus with intermittent exposure system, Journal of Ecological Engineering 20(5), 2019, pp. 130-134, https://doi.org/10.12911/22998993/105357
8. Budiyanto S., Anies, Purnaweni H., Sunoko H.R.: Environmental Analysis of the Impacts of Batik Waste Water Polution on the Quality of Dug Well Water in the Batik Industrial Center of Jenggot Pekalongan City, E3S Web of Conferences 31, 2018, pp. 1-7, https://doi.org/10.1051/e3sconf/20183109008
9. Saxena H.O., Tiwari R., Pandey A.K.: Optimization of extraction and dyeing conditions of natural dye from Butea monosperma (lam.) kuntze flowers and development of various shades, Environment & We an International Journal of Science & Technology 7, 2012, pp. 29-35
10. Adeel S., Rafi S., Mustaan M.A., Salman M., Ghaffar A.: Animal Based Natural Dyes: A Short Review, chapter 4 in Handbook of Renewable Materials for Coloration and Finishing, Yusuf M. (Ed.), Beverly: Scrivener Publishing, 2018, 46 p., https://doi.org/10.1002/9781119407850.ch4
11. Pujilestari T.: The effect extraction method and fixation of natural dyes to color fastness on cotton fabric (Pengaruh Ekstraksi Zat Warna Alam dan Fiksasi Terhadap Ketahanan Luntur Warna pada Kain Katun), Dinamika Kerajianan dan Batik 31(1), 2014, pp. 31-40 http://dx.doi.org/10.22322/dkb.v31i1.1058 (in Indonesian)
12. Maulik S.R., Bhowmik L., Agarwal K.: Batik on handloom cotton fabric with natural dye, Indian Journal of Traditional Knowledge 13(4), 2014, pp. 788-794, http://nopr.niscair.res.in/handle/123456789/29531
13. Handayani W., Kristijanto A.I., Hunga A.I.R.: Behind the eco-friendliness of "batik warna alam", Discovering the motives behind the production of batik in Jarum village, Klaten, Wacana 19(1), 2018, pp. 235-256, http://dx.doi.org/10.17510/wacana.v19i1.673
14. Siva R.: Status of natural dyes and dye-yielding plants in India, Current Science 92(7), 2007, pp. 916-925, https://www.jstor.org/stable/24097672
15. Pujilestari T.: Review: Source and utilization of natural dyes for industrial use (Review: Sumber dan Pemanfaatan Zat Warna Alam untuk Keperluan Industri), Dinamika Kerajinan dan Batik 32(2), 2015, pp. 93-106, http://dx.doi.org/10.22322/dkb.v32i2.1365 (in Indonesian)
16. Martuti N.K., Hidayah I., Margunani M., Alafima R.B.: Organic material for clean production in the batik industry: A case study of natural batik Semarang, Indonesia, Recycling 5(4), 2020, pp. 1-13, https://doi.org/10.3390/recycling5040028
17. Lestari K.W., Sulaeman: Research on the value of pollution load on some extracts of natural dyes (Penelitian Nilai Beban Pencemaran pada Beberapa Ekstrak Zat Warna Alam), Dinamika Kerajinan dan Batik, 18, 2001, pp. 14-18 (in Indonesian)
18. Singh R., Srivastava S.: A critical review on extraction of natural dyes from leaves, International Journal of Home Science 3(2), Part B, 2017, pp. 100-103
19. Uddin M.G.: Extraction of eco-friendly natural dyes from mango leaves and their application on silk fabric, Textiles and Clothing Sustainability 1(7), 2015, pp. 1-8, https://doi.org/10.1186/s40689-015-0007-9
20. Satria Y., Suheryanto D.: The Effect of natural dyes teak leaves extraction temperature to the quality and color direction in batik (Pengaruh Temperatur Ekstraksi Zat Warna Alam Daun Jati terhadap Kualitas dan Arah Warna pada Batik), Dinamika Kerajinan dan Batik 33(2), 2016, pp. 101-110, http://dx.doi.org/10.22322/dkb.v33i2.1628 (in Indonesian)
21. Handayani P.A., Mualimin A.A.: Batik natural dye from nila plants (indigofera) with acid catalyst (Pewarna Alami Batik dari Tanaman Nila (Indigofera) dengan Katalis Asam), Jurnal Bahan Alam Terbarukan 2(1), 2013, pp. 1-6 (in Indonesian)
22. Hossain S., Jalil M.A., Bin Kamal S.A., Kader A.: A natural dye extracted from the leaves of Mimusops Elengi Linn and its dyeing properties on cotton and silk fabrics, Journal of Textile Institute 112(3), 2020, pp. 455-461, https://doi.org/10.1080/00405000.2020.1763057
23. Linh H.T.: Natural Dyes in Eastern Asia (Vietnam and Neighbouring Countries), chapter 6 in Handbook of Natural Colorants, Bechtold T., Mussak R. (Eds.), West Sussex: John Wiley & Sons Ltd, 2009, 66 p., https://doi.org/10.1002/9780470744970.ch6
24. Samanta A.K., Konar A.: Dyeing of Textiles with Natural Dyes, chapter 3 in Natural Dyes, Kumbasar E.A. (Ed.), InTech, 2011, pp. 29-56, http://www.intechopen.com/books/natural-dyes/dyeing-of-textiles-with-natural-dyes
25. Armando R., Asman A.: Producing 15 quality essential oils (Memproduksi 15 Minyak Atsiri Berkualitas), Penebar Swadaya, Jakarta, 2009, ISBN: 978-979-002-363-5 (in Indonesian)
26. Talahatu D.R., Papilaya P.M.: Utilization of clove leaf extract (Syzygium Aromaticum l.) as a natural herbicide against the growth of weeds puzzle grass (Cyperus Rotundus L.) (Pemanfaatan Ekstrak Daun Cengkeh (Syzygium Aromaticum l.) sebagai Herbisida Alami terhadap Pertumbuhan Gulma Rumput Teki (Cyperus Rotundus L.), Jurnal BIOPENDIX: J. Biologi Pendidikan dan Terapan 1(2), 2015, pp. 149-159, https://doi.org/10.30598/biopendixvol1issue2page160-170 (in Indonesian)
27. Cortés-Rojas D.F., de Souza C.R.F., Oliveira W.P.: Clove (Syzygium aromaticum): a precious spice, Asian Pacific Journal of Tropical Biomedicine 4(2), 2014, pp. 90-96, doi10.1016/S2221-1691(14)60215-X

28. Nurdjannah N.: Diversification of clove use (Diversifikasi Penggunaan Cengkeh), Perspektif Review Penelitian Tanaman Industri 3(2), 2004, pp. 61-70, http://dx.doi.org/10.21082/p.v3n2.2004.61-70 (in Indonesian)
29. Milind P., Deepa K.: Clove: a champion spice, International Journal of Research in Ayurveda Pharmacy 2(1), 2011, pp. 47-54, https://ijrap.net/admin/php/uploads/360_pdf.pdf
30. Ayushi, Khan U.A., Danish S.M., Mohamad, Parveen U.: A review on biological and therapeutic uses of Syzygium aromaticum Linn. (Clove): Based on phyto-chemistry and pharmacological evidences, International Journal of Botany Studies 5(4), 2020, pp. 3339, http://www.botanyjournals.com/archives/2020/vol5/issue4/5-3-115
31. Sharma R.K., Jha K.K.: Phytochemistry, pharmacology & medicinal importance of clove: a review, International Journal of Pharma Professional's Research 6(3), 2015, pp. 1283-1291, https://www.ijppronline.in/index.php/IJPPR/article/view/131
32. Gosavi N.S., Koli S.S., Jire D.S., Shaikh A.Z.: Clove (Syzygium Aromaticum): A Miraculous Spice, American Journal of PharmTech Research 8(5), 2020, pp. 1-17, doi: 10.46624/ajphr.2020.v8.i5.001
33. Batiha G.E.S., Alkazmi L.M., Wasef L.G., Beshbishy A.M., Nadwa E.H., Rashwan E.K.: Syzygium aromaticum l. (myrtaceae): Traditional uses, bioactive chemical constituents, pharmacological and toxicological activities, Biomolecules 10(2), 2020, pp. 1-17, doi: 10.3390/biom10020202
34. Nurdjannah N., Bermawie N.: Cloves, chapter 11 in Handbook of Herbs and Spices, Vol. 1, 2nd edition, Peter K.V. (Ed.), Woodhead Publishing, 2012, pp. 197–215, ISBN: 978-0-85709-039-3
35. Handayani P.A., Sofiarani A.W., Kurniawan A.B.: Response surface optimization of essential oils production from clove leaf waste by microwave-assisted hydro distillation, Journal of Physics: Conference Series 1444, 2020, https://doi.org/10.1088/1742-6596/1444/1/012006
36. Indriasih M., Cahaya I., Ashar T.: The utilization of clove leaf (Syzigium aromaticum) extract to reduce the flies' infestation during the salted fish-drying process (Pemanfaatan Ekstrak Daun Cengkeh (Syzigium Aromaticum) sebagai Repellent Nabati dalam Mengurangi Jumlah Lalat yang Hinggap Selama Proses Penjemuran Ikan Asin), Lingkungan dan Keselamatan Kerja 2(3), 2013, pp. 1-10, https://jurnal.usu.ac.id/index.php/lkk/article/view/3285 (in Indonesian)
37. Suhendar U., Sogandi S.: Identification of bioactive compounds in clove leaves (Syzygium Aromaticum) extract as inhibitor Streptococcus Mutans (Identifikasi Senyawa Aktif Ekstrak Daun Cengkeh (Syzygium Aromaticum) sebagai Inhibitor Streptococcus Mutans), AL-KAUNIYAH: Jurnal Biologi 12(2), 2019, pp. 229-239, https://doi.org/10.15408/kauniyah.v12i2.12251 (in Indonesian)
38. Tejasari M., Respati T., Trusda S.A.D., Hendryanny E., Yuniarti L.: Comparison of flavonoid from clove leaf oil cytotoxic activities with doxorubicin and cisplatin on liver cancer cell culture, Journal of Physics: Conference Series 1469, 2020, pp. 1-5, https://doi.org/10.1088/1742-6596/1469/1/012018
39. Ramya K., Maheshwari V.: Analysis of the anti-microbial efficacy of bamboo/cotton knitted fabric finished with the extracts of the Syzygium aromaticum buds, Journal of Textile Science & Engineering 3(3), 2013, pp. 1-5, doi: 10.4172/2165-8064.1000134
40. Lee Y.H., Hwang E.K., Kim H.D.: Colorimetric assay and antibacterial activity of cotton, silk, and wool fabrics dyed with peony, pomegranate, clove, Coptis chinenis and gallnut extracts, Materials (Basel) 2(1), 2009, pp. 10-21, doi: 10.3390/ma2010010
41. Bahari N., Handayani R., Santoso R.E., Prameswari N.S.: Mordant and fixation test of bone ash on natural colours towards cotton and silk fabric, Vlakna a Textil (Fibres and Textiles) 27(4), 2020, pp. 8-16, http://vat.ft.tul.cz/2020/4/VaT_2020_4_2.pdf
42. Suheryanto D., Haryanto T., Rahayu S., Setiadji U., Masiswo, Sudjaka, Hariyati, Budiarti I.: Natural Dyes, Yogyakarta: Institute of Batik and Handicraft Yogyakarta, 2007
43. Visalakshi M., Jawaharlal M.: Healthy hues – status and implication in industries – brief review, Research & Reviews: Journal of Agriculture and Allied Sciences 2(3), 2013, pp. 42-51, http://www.rroij.com/open-access/healthy-hues--status-and-implication-in-industries--brief-review.php?aid=33810
44. Indrayani L., Andriyati W., Nuraini E., Triwiswara M.: Application of Electron Beam Machining (EBM) as alternative fixator for batik with natural dyes (Aplikasi Mesin Berkas Elektron (MBE) sebagai Alternatif Fiksator pada Pewarnaan Batik Warna Alam), Dinamika Kerajinan dan Batik 37(1), 2020, pp. 105-118, (in Indonesian) http://dx.doi.org/10.22322/dkb.v37i1.6199
45. Sugiarto E., bin Othman A.N., Triyanto, Febriani M.: Regional icon motifs: Recent trends in Indonesia's batik fabric development, Vlakna a Textil (Fibres and Textiles) 27(1), 2020, pp. 93-98, http://vat.ft.tul.cz/2020/1/VaT_2020_1_14.pdf
46. Budiyono, Sudibyo W., Herlina S., Handayani S., Parjiyah, Pudiastuti W., Syamsudin, Irawati, Parjiyati, Palupi D. S.: Textile Craft for SMK Volume 1 (Kriya Tekstil untuk SMK Jilid 1), Direktorat Pembinaan Sekolah Menengah Kejuruan, Ditjen Dikdasmen Depdiknas, Jakarta, 2008, 72 p., ISBN: 978-602-8320-66-5 (in Indonesian)
47. Suheryanto D., Haryanto T.: The effect of alum concentration on the age and durability of color fastness in dyeing silk fabric with gambir dyes (Pengaruh Konsentrasi Tawas terhadap Ketuaan dan Ketahanan Luntur Warna pada Pencelupan Kain Sutera dengan Zat Warna Gambir), Dinamika Kerajinan dan Batik, 25, 2008, pp. 9-16, http://dx.doi.org/10.22322/dkb.v25i1.1023.g869 (in Indonesian)

EXPERIMENTAL DETERMINATION OF THE FRICTIONAL CHARACTERISTICS OF FABRICS MADE OF WOOL

Raya Stoyanova

Southwestern University "Neofit Rilski" - Blagoevgrad, Department of Mechanical Engineering and Technology, Bulgaria
raikach@abv.bg

Abstract *In the present work the frictional characteristics of fabrics made of 100% wool and woolen fabrics with admixtures of polyamide and polyester are determined. The test was performed in different directions of the woven textiles and at different compressive force. With friction of surface textile materials, the compressive force affects the coefficient of friction at rest and the coefficient of friction at sliding. This is due to the increase in the actual contact area of the friction surfaces. For accurate study of the frictional behavior of textile products, formulas for friction characteristics are used, derived specifically for fabrics - friction index, friction parameter and friction factor.*

Keywords: *friction index, friction parameter, friction factor.*

1 INTRODUCTION

The frictional characteristics of fabrics are of great importance in the field of technologies available to the sewing industry, in the technologies for textile weaving, as well as in the subjective assessment of it when wearing ready-made clothing and contact with woven surfaces (blankets, upholstery, etc.). In the technology field for sewing industry, friction is carried out during the layering of the fabrics, cutting of many layers of fabric and its subsequent separation. Friction is observed when sewing clothes (with the metal parts of the sewing machines), when packing and storing the finished clothes, etc.

The user's subjective perception of fabric friction is important, but not a method for quantifying the process. For textile technologies, it is important to assess the quantitative parameters of fabric friction, as well as the influencing factors.

It is known that the friction force in textile materials depends on a number of test factors - normal load, contact area, test speed, as well as the nature of the textile surface and the direction of friction - warp by warp, warp by weft. There are numerous publications in the scientific literature related to tissue friction and determination of friction coefficients [1-3, 5-7].

The present paper focuses on the frictional characteristics of fabrics made of wool - friction index, friction parameter and friction factor. The development is part of a larger study of the frictional characteristics of fabrics made of natural materials. The aim of the present study is to investigate the frictional characteristics in different directions of the fabric, as well as the influence on the frictional characteristics of the content of additional impurities to the wool.

2 EXPERIMENTAL

The experimental studies for this working paper are made with textile fabrics containing wool (pure wool and woolen fabrics mixed with polyamide, polyester and elastane). The studied textiles have different characteristics. They are produced in textile factory Mirolio, Bulgaria. The following four types of fabric with different composition, weave, content, surface area, etc., were examined. The characteristics of these fabrics (Figure 1) are presented in Table 1.

a) Delia b) Miss c) Rexos d) Oreste

Figure1 Structure of studied fabrics

Table 1 Characteristics of the studied wool fabrics

№	Item	Weave	Surface area [g/m^2]	Linear density [tex]		Density [thread number/dm]		Composition [%]	Fabric width [cm]
				Warp	Weft	Warp	Weft		
1	Delia	Sn1/4Z	380	105	105	171	160	PA/virgin wool 20/80	150/145
2	Miss	reps trame: 2-2	153	16.7x2	29.4x1	236	215	PE/virgin woo/E 54/44/2	150/145
3	Rexos	Se2/2Z	196	16.7x2	16.7x2	275	270	PE/virgin wool 55/45	153/148
4	Oreste	reps trame: 2-2-1-1	190	21x2	25x1	266	265	virgin wool 100	151/153

Note: PA - polyamide, PE - polyester, E - elastane

Results obtained through experimental studies of the static and dynamic friction coefficients, determined with the use of MXD-02 tribometer from Labthink, China (Figure 2), are used to determine the friction parameter as well as the friction coefficient and the friction index.

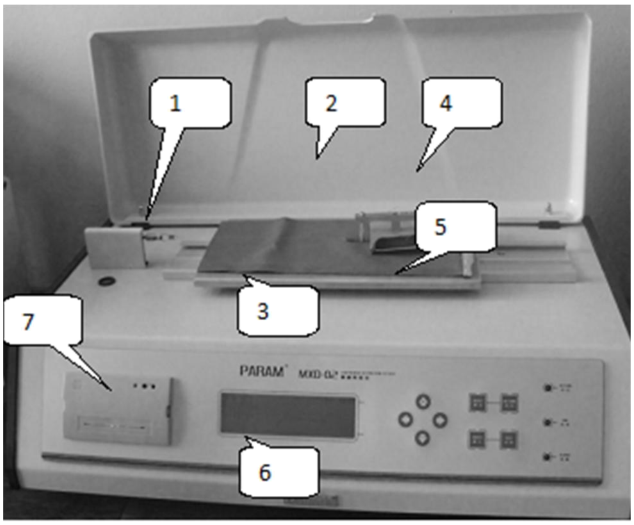


Figure 2 Overall appearance of appliance MXD-02

Force meter (1) measures the friction force that occurs when sled (2) slides on platform (3). The platform moves on guide rail (4) (Figure 2). The change in friction force is shown graphically on display (6). The display shows calculated values of the friction coefficient at rest and of the friction coefficient during sliding. Appliance MXD-02 can work in accordance with different standards. The standard can be selected through control panel (5). The experimental studies in this work paper are performed according to BDS EN ISO 8295: 2006.

The test is performed by placing one layer of the test fabric on sled (2) so that the direction of the warp threads coincides with the direction of movement of the platform. Another layer of fabric is then placed on the sled. The layer of fabric placed on the sled is placed either is in the direction of the warp threads or in the direction of the weft threads.

3 RESULTS AND DISCUSSION

Friction coefficient at rest *μ0* is determined at the moment when the metal thread connecting the force meter and the sled is stretched. When the slide starts sliding on the platform, the tribometer calculates the average value of sliding friction coefficient *μ*, as well as the standard deviations for *μ0* and *μ*. Sliding friction coefficient values as well as standard deviation values *μ0* and *μ*, are visible on the screen and can be printed on paper through mini printer (7).

The results for *μ0* and *μ* are given in Tables 2 and 3.

Table 2 Values of coefficients of friction at rest

Item	Load [g]	Static coefficient of friction	
		Warp FS - Warp FS^1	Warp FS – Weft FS^2
Delia	200	1.164	1.149
	300	1.286	1.487
	400	1.694	1.697
Miss	200	0.590	0.634
	300	0.828	0.885
	400	0.966	1.111
Rexos	200	0.672	0.596
	300	0.876	0.836
	400	1.072	1.060
Oreste	200	1.010	0.924
	300	1.368	1.225
	400	1.497	1.487

Note: Warp FS^1 – Warp face side; Weft FS^2 – weft face side.

Table 3 Values of coefficients of friction at sliding

Item	Load [g]	Dynamic coefficient of friction	
		Warp FS - Warp FS^1	Warp FS – Weft FS^2
Delia	200	1.164	1.149
	300	1.286	1.487
	400	1.694	1.697
Miss	200	0.590	0.634
	300	0.828	0.885
	400	0.966	1.111
Rexos	200	0.672	0.596
	300	0.876	0.836
	400	1.072	1.060
Oreste	200	1.010	0.924
	300	1.368	1.225
	400	1.497	1.487

A study of the available literature shows that no significant differences in friction force are reported [1, 4] when experimenting with low sliding speeds in the range of 10 to 500 mm/min.

The main factor influencing the friction characteristics of the fabric is the actual contact area of friction between fabrics [2]. The actual contact area increases with increased pressure due to flattening of the threads. Due to the insignificant influence of the friction speed of the fabric layers relative to each other, this study is performed at a sliding speed of 100 mm/min. The relationship between friction force and normal load [2, 8-10] is a logarithmic dependence:

$$\frac{F_i}{B} = C.\left(\frac{N_i}{B}\right)^n$$

$$\text{or} \quad log\left(\frac{F_i}{B}\right) = logC + n.lpg\left(\frac{N_i}{B}\right) \tag{1}$$

where: i = 1, 2,…m; B - contact area [m^2]; C - friction parameter [Pa^{1-n}]; n - friction index; N - normal pressure [N]; F - friction force [N]; m - number of experimental observations.

The studies of Das, Sular et al [4, 5, 6] for a mixture of cotton and polyester in different ratios, show that the normal load and the frictional force follow the logarithmic relationship for all the fabrics.

For each of the studied textile products, three experiments were made, and the arithmetic mean value was determined. *Log(Fi/B)* and *log(Ni/B)* are determined in different directions and when the pressure changes. Normal pressure is changed by placing additional weights on the sled. Additional weights are added to the sled's own weight of 200 g. The mass of the test piece mounted on the sled is not taken into account as it is negligibly small. The tests were performed at an average air temperature of about 22°C and humidity ≈70%. The determination of the two parameters - friction index and friction factor is performed and after calculating the normal compressive forces *Ni* and friction forces *Fi*, *log*(*Fi/B)* and *log(Ni/B)* are calculated.

The following linear regression equation is determined:

$$y=a+x.b \tag{2}$$

$x = log(N_i/B)$; $y = log(F_i/B)$; $a = logC$; $b=n$

Friction parameter and friction index are used to determine the friction factor R, also called composite friction coefficient or correlation coefficient of friction [3], the value of which is determined by the dependence:

$$R = \frac{C}{n} \tag{3}$$

The results of the friction parameter, friction factor and friction index for friction at rest and at sliding, are listed in Table 4.

Figures 3-6 show the experimental results for the friction index and the friction parameter depending on the test direction.

Table 4 Values of frictional characteristics at rest and at sliding

Item	Direction of the fabric	Frictional characteristics at rest			Frictional characteristics at sliding		
		Index n	Parameter C [Pa^{1-n}]	Factor R [Pa^{1-n}]	Index n	Parameter C [Pa^{1-n}]	Factor R [Pa^{1-n}]
Delia	Warp FS- Warp FS	0.907	0.716	0.789	0.830	0.684	0.824
	Warp FS - Weft FS	0.905	0.709	0.783	0.820	0.682	0.832
Miss	Warp FS- Warp FS	0.654	0.679	1.038	0.618	0.676	1.094
	Warp FS - Weft FS	0.615	0.676	1.099	0.599	0.674	1.125
Rexos	Warp FS- Warp FS	0.702	0.683	0.973	0.579	0.676	1.168
	Warp FS - Weft FS	0.580	0.674	1.162	0.592	0.676	1.142
Oreste	Warp FS- Warp FS	0.864	0.703	0.814	0.757	0.682	0.901
	Warp FS - Weft FS	0.784	0.688	0.878	0.772	0.685	0.887

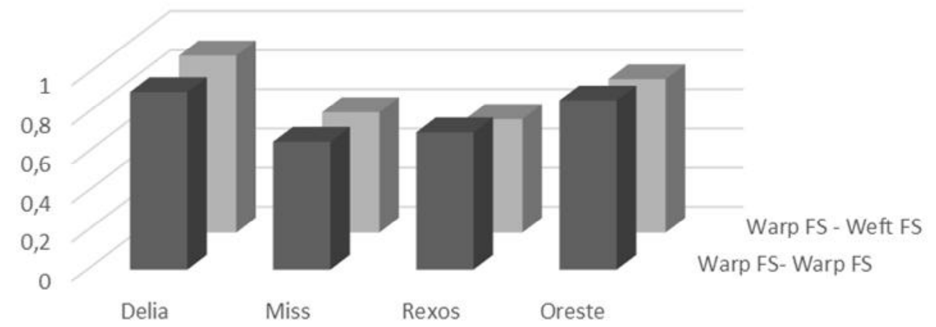


Figure 3 Influence of test direction on friction index at rest

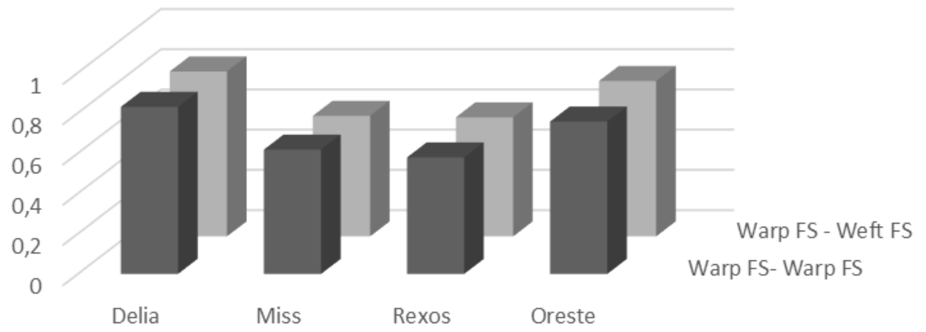


Figure 4 Influence of test direction on friction index at sliding

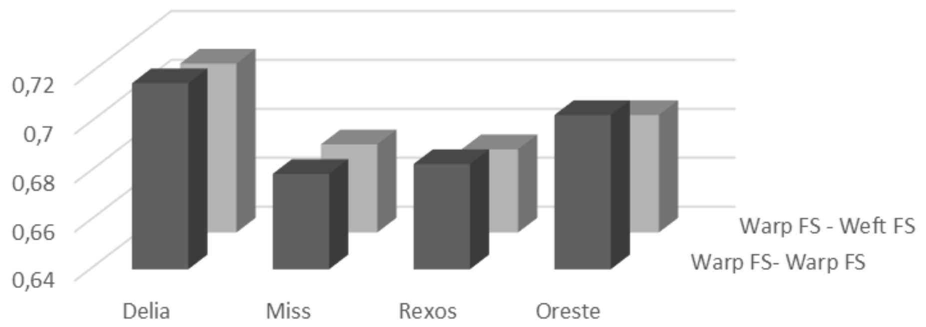


Figure 5 Influence of test direction on friction parameter at rest

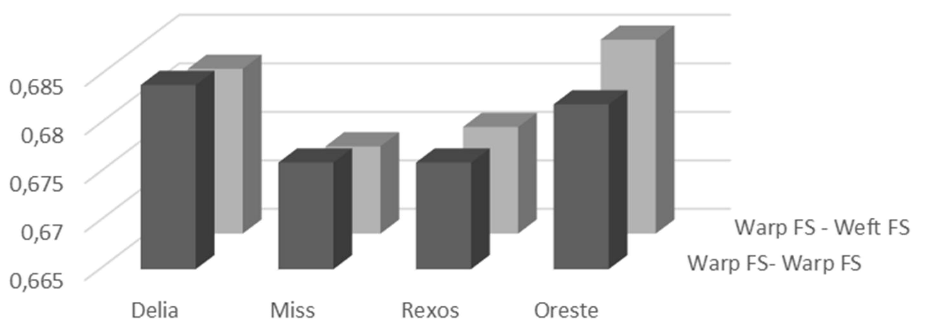


Figure 6 Influence of test direction on friction parameter at sliding

4 ANALYSIS OF THE OBTAINED RESULTS

As a result of the conducted study, the following conclusions can be drawn:

1. Friction indices, parameters and factors at rest and at sliding, for fabrics made of wool and of wool fabrics with admixture of polyamide and polyester are determined. Depending on the structure and direction of friction, the friction index varies from 0.580 to 0.907 at rest and from 0.579 to 0.830 at sliding.
2. The friction index for friction at sliding is lower than the friction index at rest.
3. In terms of arrangement of the threads, the friction index is higher when rubbing with a parallel arrangement of the warp threads of one fabric compared to the weft threads of the other fabric.
4. As expected, higher friction parameters are observed for the Delia item, which has a 20% polyamide content and 80% wool content, as well as for the Oreste article, which is made of 100% wool. Their friction parameters are larger when the warp threads of one fabric are parallel to the weft threads of the other fabric. These two items of woolen fabrics have the highest wool content out of the four studied items, which provides volume and increased resistance.
5. Friction parameters for both slide and rest for Miss and Rexos items which are high in polyester and below 50% wool are expected to be lower than the other two items higher in wool content.

5 CONCLUSION

New data has been obtained on the frictional characteristics of wool and wool fabrics with admixture of polyamide and polyester. Trends for the influence of the direction of friction, established for fabrics with other structures and composition, have been confirmed. It was found that the studied woolen fabrics increase the friction factor with an increase in the composition of the woolen content of the fabric. Influence of the test direction on the friction index and the friction factor was established, as the friction index is higher at friction with parallel arrangement of the warp threads of one fabric compared to the weft threads of the other fabric. The friction index at friction at rest is lower than the friction index at sliding.

6 REFERENCES

1. Bhuvana, Dev G., Raghunathan, Subramaniam: Studies on frictional behaviour of chitosan-coated fabrics, AUTEX Research Journal 6(4), 2006, pp. 216-222, http://www.autexrj.org/No4-2006/0178.pdf
2. Wilson D.: Study of fabric-on-fabric dynamic friction, Journal of the Textile Institute Transaction 54(4), 1963, pp. 143-155 , https://doi.org/10.1080/19447026308660165
3. Hermann D.B.: Mathematical Characterization of Frictional Properties, Master of Science thesis, Texas Technical University, 2003, 64 p.
4. Das A., Kothari V.K., Vandana N.: A study on frictional characteristics of woven fabrics, AUTEX Research Journal 5(3), 2005, pp. 133-140, http://www.autexrj.org/No3-2005/0124.pdf
5. Sülar V., Öner E., Okur A.: Roughness and frictional properties of cotton and polyester woven fabrics, Indian Journal of Fibre & Textile Research 38(4), 2013, pp. 349-356
6. Das A., Kothari V., Nagaraju V.: Frictional characteristic of woven suiting and shirting fabrics, Indian Journal of Fibre & Textile Research 32, 2007, pp. 337-343, http://hdl.handle.net/123456789/342
7. Moorthy R.R., Kandhavadivu P.: Surface friction characteristics of woven fabrics with nonconventional fibers and their blends, Journal of Textile and Apparel, Technology and Management 9(3), 2015, pp. 1-14
8. Germanova-Krasteva D., Chingova R, Aleksandrov S., Kapanyk U.: Study of the effect of finishing treatment on the coefficients of friction of fabrics from natural silk, Textile and Garment Magazine (ТЕКСТИЛ И ОБЛЕКЛО), 2019, p. 318
9. Chingova R., Germanova-Krasteva D.: Experimental study of the frictional characteristics of cotton fabrics with twill 3/1, Journal of Mechanics of Machines, Book 1, ISSN 0861-9727, 2019, pp. 27-33
10. Chingova, R., Taneva L., Kapanyk U.: Experimental study on the friction characteristics of cotton fabrics with cloth twill 3/1 before and after finishing, 16th International Conference on Tribology “SERBIATRIB ’19”, Kragujevac, Serbia, 15-17 May 2019, pp. 413-417

ENHANCEMENT OF DYE-ABILITY OF VISCOSE FABRIC VIA MODIFICATION WITH FIBROIN REGENERATED FROM WASTE SILK COCOONS

Nguyen Ngoc Thang[1] and Vo Thi Lan Huong[1, 2]

[1]*School of Textile – Leather and Fashion, Hanoi University of Science and Technology, Hanoi, Vietnam*
[2]*Department of Fibre and Textile Technology, Hanoi Industrial Textile Garment University, Hanoi, Vietnam*
thang.nguyenngoc@hust.edu.vn

Abstract: *This work demonstrated the possibility of enhancing the dye-ability of viscose fabric via surface modification with silk fibroin. Herein, silk fibroin from waste Bombyx mori cocoons was degummed and then dissolved in a lithium bromide/ethanol/water solution. The silk fibroin solution was purified using the QuixStand Benchtop system equipped with the microfiltration and ultrafiltration of hollow-fiber cartridges to gather the fibroin segments with molecular weight over 10 kDa. The obtained silk fibroin was coated onto a viscose woven fabric via the padding method. The fibroin treated and untreated viscose fabrics were stained with C.I acid blue 203 (0.5% on the weight of fabric (wof) and dyed with C.I reactive yellow 176 (0.1, 0.5 and 1.0 %wof). The presence of silk fibroin on the viscose fabric was confirmed by scanning electron microscopy (SEM), Fourier transform infrared (FT-IR) analysis and color measurement. The dyed treated viscose fabrics revealed a higher color strength (K/S) than that of the dyed untreated ones at the same initial dye concentration. The color fastness to washing of the fibroin treated and untreated viscose fabrics after dyeing with the reactive dye were good to very good. The physical analysis results indicated a decrease in the air permeability and the horizontal wicking values of the silk fibroin treated fabrics compared to the untreated fabrics.*

Keywords: *Bombyx mori cocoons, regenerated fibroin, LiBr, viscose, dyeing.*

1 INTRODUCTION

Viscose is the most of the world's man-made cellulose fibers because it can be engineered chemically and structurally in many ways [1]. Viscose fibers have inherent properties of cellulosic fibers including breathability, high moisture regime, softness, drapability and biodegradation [1]. Due to these desirable properties, the demand of viscose fibers for the textile industry is ever-growing in the global market. However, the disadvantages of viscose fabrics include easy wrinkle, low dimensional stability and poor protection against UV radiation [1]. To overcome and enhance these properties of viscose fabrics, some special finishes have been applied on such materials to achieve specific end uses such as wrinkle free effect, UV-protection and antibacterial activity [2, 3]. However, conventional finishes had been used for textiles which generally employed synthetic polymers for certain outcomes. Toward the trend of sustainable development, the finishing of textile materials using natural polymers has gained rapid progress during the last few decades [4-6]. One of the natural polymers recently attracted the attention of researchers all over the world is the regenerated silk fibroin [7-9].

Fibroin is the main component of silk fiber containing up to 90% of the amino acids (glycine, alanine and serine) leading to formation of microcrystalline β-sheet in the fibers [10]. Silk fibroin could be dissolved in various highly concentrated salt solutions including LiBr, NaSCN, N-methyl morpholine N-oxide and $CaCl_2$/water/ethanol (CWE) [7, 8, 10-13]. Among them, LiBr/ethanol and N-methyl morpholine N-oxide are the best solutions to dissolve silk fibroin. Depending on application purpose, regenerated silk fibroin could be shaped into many different structures: fibers, membrane, sponge scaffolds, hydrogels, microspheres, coating on the materials [7, 9, 10, 14].

Finishing textile materials using fibroin solution has been reported in numerous works [7-9, 15-20]. Surface modification of textile material through deposition of regenerated silk fibroin indicated that the potential of such fibroin films to be developed further as antistatic finishing for synthetic textiles [7]. The use of fibroin as additive with citric acid for the crease resistant finishing of cotton fabrics not only improved the wrinkle property but also avoided the fabric yellowing problem [8, 17, 19]. The fibroin formed a film onto the wool surface was responsible for the anti-felting, thus grafting such a natural biopolymer onto wool would enhance this feature [15].

Finishing textile by silk fibroin would bring new perspectives in the application of regenerated silk fibroin on textile materials. Silk fibroin solution applied to the cellulose fabric surface can significantly improve the wrinkle recovery angle as well as other properties while slightly effect to the color of the treated fabrics [9, 16]. This process could make such the material of high interest for wound dressing and clothing required in therapy of skin diseases. To expand the applications of the fibroin treated viscose fabric in the apparel industry, it needs to diversify in color. In textile processes, dyeing is one of the most important procedures to enhance aesthetics value of the textile materials.

In this paper, the processes of degumming *Bombyx mori* silkworm cocoons, dissolving silk fibroin in lithium bromide salt solution and finishing woven viscose fabric were studied. To evaluate the impact of the fibroin on the dyeing behavior of the fibroin treated viscose fabric, the untreated and treated samples were dyed using C.I. acid blue 203 and C.I. reactive yellow 176. The efficiency of the process implementation was determined by measuring the color coordinates and analyzing the physical properties of dyed samples. The results provided the understanding of deposition and dyeing properties of the viscose fabric treated silk fibroin. This is a new approach to finishing textiles in a sustainable development trend.

2 MATERIALS AND METHODS

2.1 Materials

Waste *Bombyx mori* silkworm cocoons were collected from Vong Nguyet village, Bac Ninh province, Vietnam. Plain woven viscose fabric (staple viscose, Ne 30/1) was scoured and supplied by Nam Dinh Textile Garment Co. Ltd., Vietnam. C.I. acid blue 203 (Telon Blue M-BLW) and C.I. reactive yellow 176 (Remazol Yellow 3RS) dyestuffs were obtained by DyStar Pte. Ltd., Singapore. Other chemicals (Na_2CO_3, C_2H_5OH, CH_3COOH, LiBr, $Al_2(SO_4)_3.18H_2O$) were purchased from Aladdin Shanghai Biochemical Technology Co. Ltd, China. Double distilled water from an EYELA Still Ace SA-2100E was used as the solvent in all experiments.

2.2 Experimental methods

<u>*Degumming*</u>

Bombyx mori silkworm cocoons were degummed in a solution of 5 g/L Na_2CO_3 at 98°C for 30 min at a liquor ratio of 1:20 (mass in gram per volume in mL) [7, 9]. The silk fibroin was rinsed five times by warm and cold distilled water, then dried at 40°C and stored at 65% relative humidity and 20°C.

<u>*Dissolution of silk fibroin*</u>

The dissolution of silk fibroin procedure has been reported in our previous work [16]. In a typical experiment, 2.8 g degummed silk fibroin was dissolved in a triangular flask containing 10 mL solution of Lithium bromide/Ethanol/Water (LiEtW) with a mass ratio of 45:44:11, at 80°C for 60 min. The obtained fibroin solution was diluted 15 times with double distilled water to reduce the viscosity. The fibroin solution was then removed excess LiBr and ethanol through microfiltration and ultrafiltration systems with hollow-fiber cartridges in the QuixStand Benchtop system (Watson-Marlow 323 peristaltic pump, UK). In the first stage of the filtration, 0.2 µm hollow-fiber cartridge was used to remove impurities and high molecular weight fibroin segments. Next stage, the fibroin solution was subsequently filtered through a 10,000 NMWC (nominal molecular weight cutoff) hollow fiber ultrafiltration cartridge to get the fibroin segments with molecular weight over 10 kDa retaining inside the filter tube. The solution passed through the ultrafiltration system contained low molecular weight fibroin segments, excess LiBr, ethanol and water. The fibroin content in the obtained solution was measured using an infrared moisture analyzer (MA35, Sartorius). The scheme of degumming, dissolving and filter silk fibroin was illustrated in Figure 1.

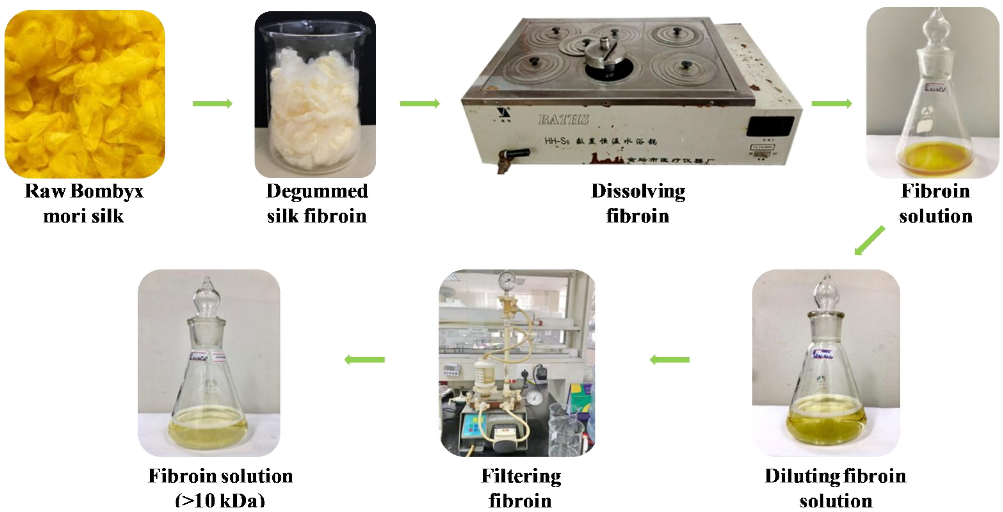


Figure 1 Scheme of degumming, dissolving and filtering silk fibroin

Treatment of viscose fabric with silk fibroin solution

Viscose fabric samples with size of 35×35 cm were impregnated in 100 mL fibroin solutions (>10 kDa) with different concentrations of 1.0, 2.5 and 5.0%. After that, the fabric samples were padded using Atlas D394A laboratory padder, and the padding pressure was adjusted at 3 kg/cm^2 to allow a pickup of 80%. The padded fabrics were dried for 2 min at 110±3°C using SDL mini-drier 398 laboratory thermo-fixation. The dipping–padding–drying processes of viscose fabrics were repeated 2 times. In the following step, the dried samples were soaked in a 10 g/L aluminum sulfate solution and then padded at 80% wet pickup to regenerate and fix silk fibroin onto viscose fabrics. The treated fabrics were dried at 60°C in an electric heated oven. The process of viscose fabric treated with silk fibroin solution was presented in Figure 2.

Dyeing of viscose fabric with the acid dye

The untreated and treated viscose fabrics were dyed in an aqueous solution with 0.5 %wof acid dye C.I. Acid Blue 203 under acidic conditions (pH = 4 with acetic acid) at a fabric to liquor ratio of 1:20, for 45 min at 80°C in an infrared dyeing machine (Figure 3a). The dyed samples were thoroughly rinsed with warm and cold water then air-dried.

Dyeing of viscose fabric with reactive dye

The untreated and treated viscose fabrics were dyed with a reactive dye C.I. Reactive Yellow 176. To investigate the effect of dye concentration, the fabrics were dyed in aqueous solutions containing different dye concentration (0.1, 0.5 and 1.0 %wof), Na_2SO_4 20 g/L, Na_2CO_3 15 g/L, at a liquor ratio of 1:20. The dyeing process was started by raising the temperature to 80°C and dyed for 45 min in an infrared dyeing machine (Ti-Color dyeing machine, ICL, Prato, Italy), (Figure 3b). After dyeing, the dyed samples were rinsed with warm and cold water then air-dried.

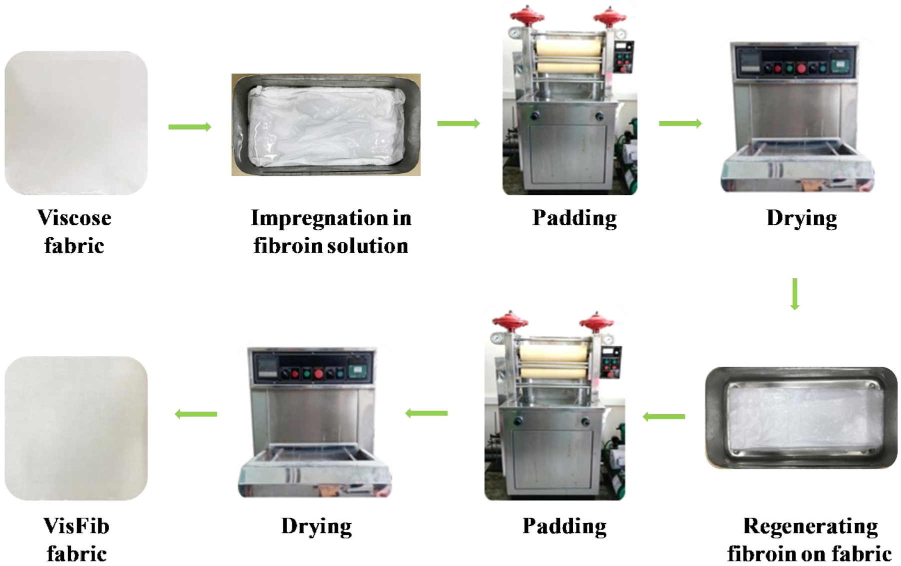


Figure 2 Scheme of viscose fabric treated with silk fibroin solution

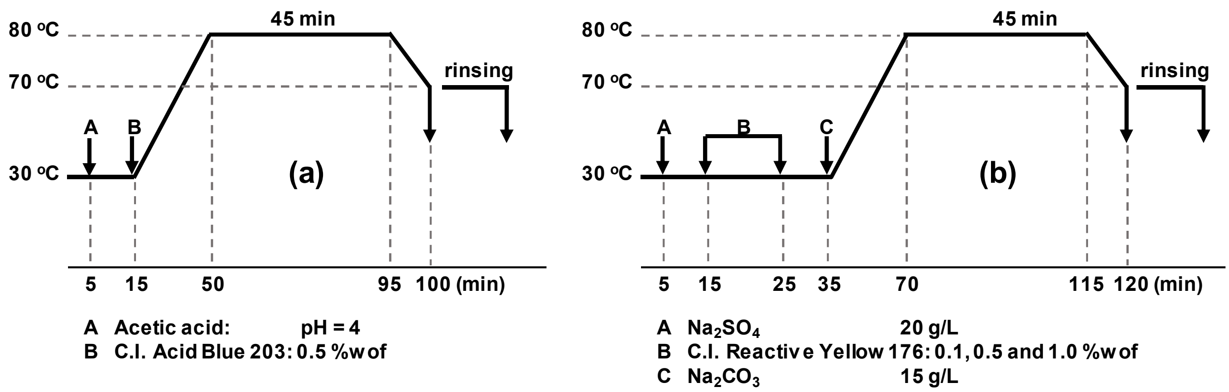


Figure 3 Exhaust dyeing line diagrams of the untreated and treated viscose fabrics with (a) acid dye and (b) reactive dye

2.3 Analytical methods

Morphological analysis: The morphologies of the untreated and treated viscose fabrics with silk fibroin were characterized via a scanning electron microscope (SEM) SM-6510LV Jeol, Japan.

FT-IR analysis: Fourier transform infrared spectrophotometry (Thermo Nicolet 6700 FT-IR spectrometer, USA) was used to confirm the regeneration of silk fibroin onto viscose fabric.

Color analysis: To evaluate dyeing performance, the color strength (*K/S*) and CIELAB of the dyed samples were determined using a reflectance spectrophotometer (X-rite, Ci4200) with D65 illumination, 10° observer. The *K/S* was calculated by the Kubelka–Munk equation (1).

$$K/S = (1-R)^2 / 2R \tag{1}$$

where K is the absorption coefficient, S is the scattering coefficient and R is the fractional reflectance.

The color difference was expressed as ΔE^* and was calculated by the following equation (2):

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5} \tag{2}$$

where ΔE^* is the CIELAB color difference between batch and standard. ΔL^* denotes the difference between lightness (where $L^* = 100$) and darkness (where $L^* = 0$), Δa^* is the difference between green ($-a^*$) and red ($+a^*$) and Δb^* is the difference between yellow ($+b^*$) and blue ($-b^*$).

Color fastness test: Color fastness to washing of the dyed samples was conducted following standard test method ISO 105-C10:2006 using a color fastness to washing tester (Changzhou, China).

Physical property measurements: The horizontal wicking of the fabrics was evaluated according to AATCC 198-2013. The air permeability of the samples was performed according to ASTM D737-04 using a MOZIA Air Permeability Tester (USA).

3 RESULTS AND DISCUSSION

3.1 Evidence of silk fibroin adhered on viscose fabric

To demonstrate the deposition of silk fibroin on viscose fabric, the samples were conducted by SEM analysis and the results were shown in Figure 4. At the magnification of over ×1000, SEM images of the 2.5 wt% fibroin treated viscose fabric revealed clearly the fibroin films covered viscose fibers, while the fiber surface of untreated viscose fabric was smooth. The SEM images confirmed the existence of the silk fibroin adhered onto viscose fibers after padding and aluminum salt treating processes.

In order to determine the change of functional groups of silk fibroin during its dissolution and regeneration, the FT-IR measurements of degummed silk fibroin (DeSilk), regenerated silk fibroin in $Al_2(SO_4)_3$ aqueous solution (ReFib), viscose fabric (Vis) and fibroin treated viscose fabric (VisFib) samples were carried out, and the spectra were given in Figure 5. The characteristic peaks of the DeSilk at 3280, 1621, 1513, 1228 and 1065 cm^{-1} were assigned to N-H (amino), C=O (amide I), C-N and N-H (amide II), C-N and N-H (amide III) and O-C-N groups, respectively [7-16]. Compare to the degummed silk fibroin, the regenerated silk fibroin in $Al_2(SO_4)_3$ aqueous solution revealed a slight shift in the characteristic peaks. The peaks of the functional groups in the ReFib shifted toward higher wavenumbers at 1622, 1515, 1231 and 1068 cm^{-1}, respectively, while the peak of N-H in amino group shifted to lower wavenumber at 3273 cm^{-1}. Moreover, the intensity of the absorption peaks in the ReFib spectrum was significantly decreased. These imply that the interaction of Li^+ and Al^{3+} ions with amino and amide groups of fibroin molecules to form the fibroin-Li^+ and fibroin-Al^{3+} complexes took place.

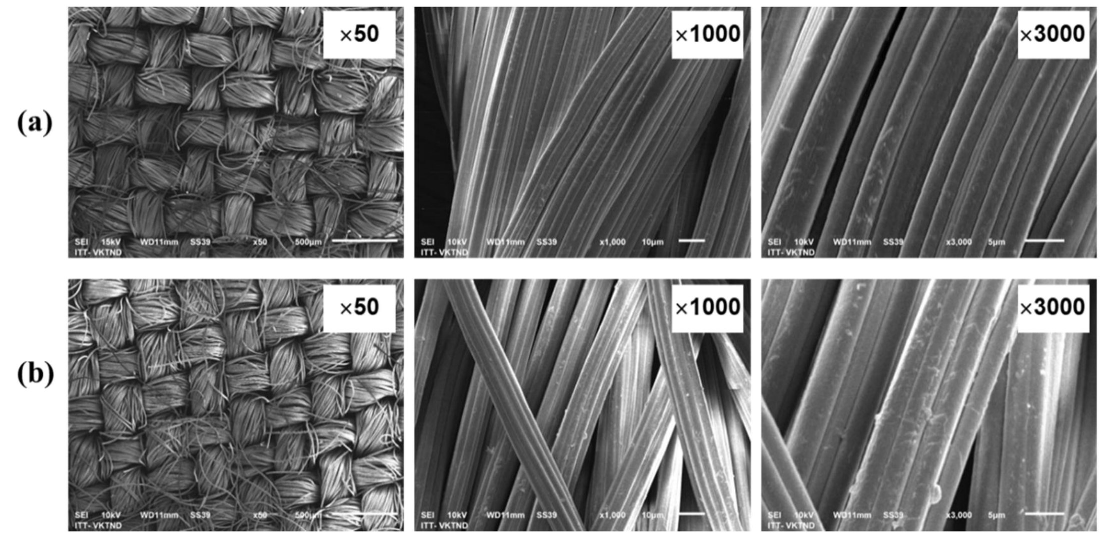


Figure 4 The SEM images of (a) untreated viscose fabric and (b) treated viscose fabric with 2.5 wt% fibroin at magnification of ×50, ×1000 and ×3000

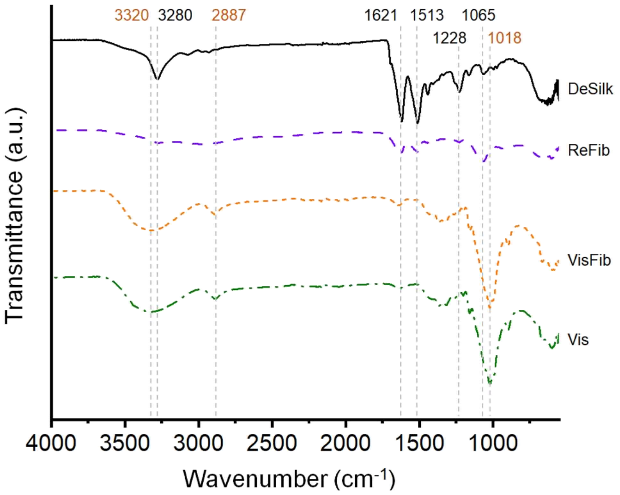


Figure 5 FT-IR spectra of the samples: (DeSilk) degummed silk fibroin; (ReFib) regenerated silk fibroin in $Al_2(SO_4)_3$ aqueous solution; (Vis) viscose fabric and (VisFib) fibroin treated viscose fabric

The characteristic peaks corresponding to viscose appeared at 3332 cm^{-1} (O-H stretching), 2887 cm^{-1} (C-H stretching), 1639 cm^{-1} (C=O bending), 1364 cm^{-1} (C-H bending) and 1018 cm^{-1} (C-O-H stretching) [1-3, 7-9]. These peaks were also seen in the VisFib spectrum, suggesting the chemical structure of the VisFib was mostly unchanged. Despite the spectral similarity, the differences in the intensity between the higher Vis peaks and the lower VisFib peaks at 3332, 1639 and 1018 cm^{-1} were noticeable, indicating that the interactions might be occurred via formation of hydrogen bonding between fibroin's amide groups and viscose's hydroxyl groups, and/or via complexation of Al^{3+} ions with appropriate functional groups of fibroin and viscose. On the basis of the FT-IR observations, the mechanism of fibroin regeneration and deposition onto viscose fabric was elucidated in light of Figure 6.

3.2 *Dyeing behavior of fibroin treated viscose fabric*

Dyeing with the acid dye

In order to evaluate the effect of the silk fibroin deposited onto viscose fabric, the samples were dyed by C.I. Acid Blue 203. The color difference (*ΔE**) of the viscose fabrics before and after dyeing were evaluated using X-rite, Ci4200 spectrophotometer. The values of *L*, a*, b** and *K/S* of the neat viscose fabric (Vis), the fibroin treated fabric (VisFib), the dyed untreated fabric (VisA) and the dyed treated fabric (VisFibA) were presented in Table 1.

The obtained values show that it is difficult to distinguish the color difference of the untreated and treated fabric samples with silk fibroin by naked eyes (*ΔE** = 0.48).

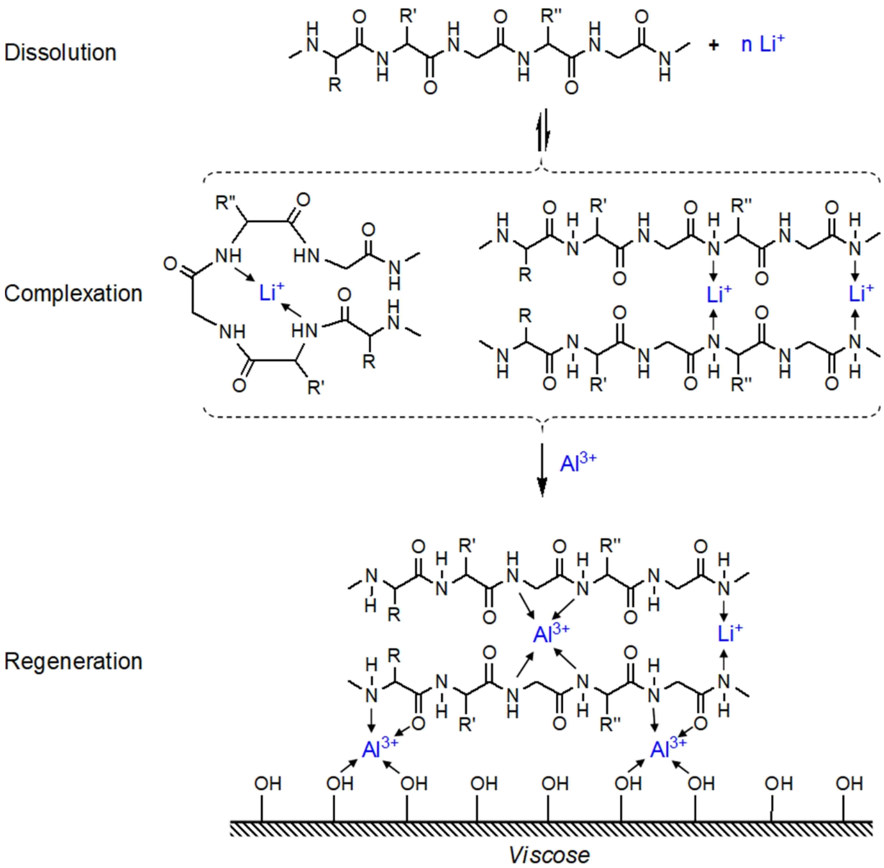


Figure 6 The proposal mechanism of fibroin regeneration and deposition onto viscose fabric

Table 1 *L*, a*, b** and *K/S* values of the fabric samples dyed with acid dye

Sample	L*	a*	b*	C*	H*	ΔE*	K/S	Scan sample
Vis	93.69	-0.58	4.78	4.82	96.93	0	0.06	
VisFib	93.00	-0.84	5.03	5.11	97.15	0.48	0.09	
VisA	85.82	-4.63	-7.21	8.56	109.02	16.54	0.15	
VisFibA	69.76	-0.32	-22.55	22.55	117.73	34.26	0.72	

Table 2 *L*, a*, b** and *K/S* values of the fabric samples dyed with reactive dye

Sample	L*	a*	b*	C*	H*	ΔE*	K/S	Scan sample
VisR1	87.81	2.91	37.79	37.91	94.26	35.91	0.75	
VisFibR1	87.09	4.30	39.10	39.34	93.76	37.52	0.84	
VisR2	77.77	16.36	58.35	60.61	90.86	61.05	3.52	
VisFibR2	79.30	16.83	62.18	64.42	90.18	65.07	3.69	
VisR3	75.58	22.47	68.86	72.44	88.84	73.95	6.33	
VisFibR3	75.55	22.54	69.25	72.83	88.83	74.37	6.44	

However, the *K/S* and *ΔE** values of the VisFibA fabric were 4.8 and 2.1 times higher than those of the VisA fabric, respectively. Thus, it could be concluded that the silk fibroin has been regenerated onto the viscose fabric, and it strongly effected on the dye uptake due to the ionic interaction between acid dye molecules and protonated amines of fibroin. The neat viscose fabric is lack of sufficient functional groups for binding to the acid dye molecules, thus the acid dyes was only stained on the surface of fabric VisA resulting in its very poor washing fastness.

Dyeing with the reactive dye

To investigate the dye-ability of the fibroin treated viscose fabrics, the untreated and treated samples were dyed with a reactive dye C.I. Reactive Yellow 176 at various concentrations (0.1, 0.5 and 1.0 %wof). The obtained values (Table 2) show that increasing reactive dye concentrations increased the color strength (*K/S* values) of both the dyed untreated fabric samples (VisR1, VisR2, VisR3) and the dyed treated fabric samples (VisFibR1, VisFibR2, VisFibR3). Furthermore, the color strength of the dyed treated samples was higher than that of the dyed untreated samples.

This observation was similar to the color difference (*ΔE**) values of the samples. It could be explained by the formation of covalent bonding of amine groups in fibroin adhered on viscose fabric with reactive dye molecules which supplemented to the linkage of hydroxyl groups of cellulose in viscose fabric with the dye molecules. Therefore, the fibroin treated viscose fabric could improve the reactive dye uptake to compare with the untreated fabric.

3.3 Evaluation of color fastness to washing

The washing fastness property of the various viscose fabrics dyed with the reactive dye was evaluated and given in Table 3. The washing fastness of the fabrics was evaluated in terms of the degree of color change and color staining. As shown in Table 3, the color fastness to washing of both the untreated and treated fabric samples were good to very good (4 to 4-5). Additionally, the color fastness to washing of the dyed treated viscose fabrics was the same as it of the dyed untreated samples at a given reactive dye concentration.

Table 3 The washing fastness of the samples

Sample	Color fastness to washing	
	Changing	Staining
VisR1	4-5	4-5
VisFibR1	4-5	4-5
VisR2	4	4
VisFibR2	4	4
VisR3	4	4
VisFibR3	4	4

3.4 Physical properties of fibroin treated viscose fabric dyed with a reactive dye

We have found that the formation of silk fibroin layer on viscose fiber was responsible to the change of physical properties of the treated fabric including air permeability, wrinkle recovery angle and breaking strength [16]. In this research, the impact of reactive dye concentration (0.1, 0.5 and 1.0 %wof) in the dyebath on the air permeability and horizontal wicking of the dyed viscose fabrics untreated and treated with silk fibroin. It is clearly observed from Figure 7 that the air permeability of the neat viscose fabric decreased slightly and gradually after dyeing by the reactive dye with an increase in initial dye concentration. However, after dyeing, the air permeability of the fibroin treated viscose fabric decreased obviously with increasing the initial dye concentration.

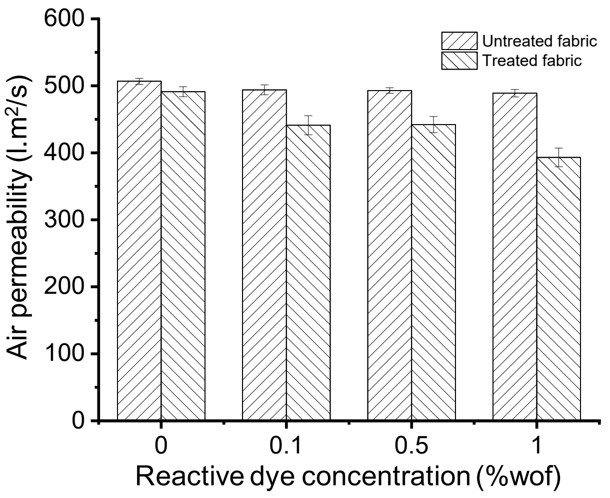


Figure 7 The air permeability of the fibroin treated and untreated viscose fabric dyed with C.I. reactive yellow 176 at 0.1, 0.5 and 1 %wof

The decrease in the air permeability of the dyed fabric with the increase in the initial dye concentration could be due to adsorption and permanent interaction of dye molecules onto the fabric. For the fibroin treated fabric, the dye uptake was not only by the interaction of dye molecules with hydroxyl groups of celluloses but also by the covalent bonding between dye molecules and amines of silk fibroin. The higher dye uptake of the dyed fabric could lead to the lower its air permeability. These findings were correlated with the observations of SEM analysis and color measurement.

To determine the influence of the silk fibroin treatment and the initial reactive dye concentration on the water-transporting property of viscose fabric, a horizontal wicking test was conducted as shown in Figure 8.

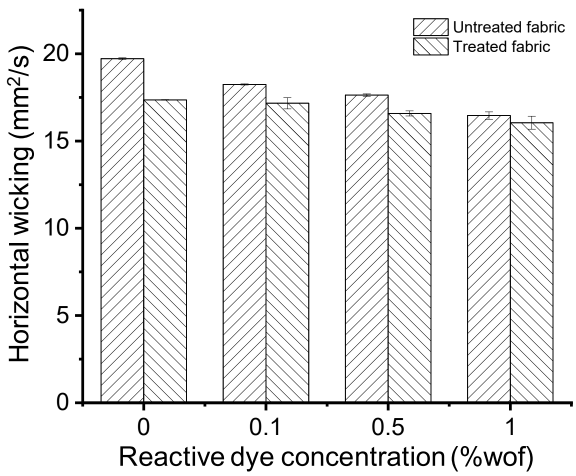


Figure 8 The horizontal wicking of the fibroin treated and untreated viscose fabric dyed with C.I. reactive yellow 176 at 0.1, 0.5 and 1.0 %wof

The results show that the neat viscose fabric revealed the highest horizontal wicking among other samples, while the dyed fabrics showed gradually a decrease in the wicking ability together with increasing the dye concentration. The horizontal wicking of the fibroin treated fabric declined about 12% in comparison with the untreated fabric, indicating the possibility of the silk fibroin deposited on the surface of fibers to hinder capillary flow of water through inter-fiber or inter-yarn spaces in the fabric. Comparing to the dyed untreated fabrics, the horizontal wicking of the dyed treated fabrics with C.I. reactive yellow 176 at different concentrations (0.1, 0.5 and 1.0 %wof) decreased 5.91, 5.95 and 2.48%, respectively. The decrease in the wicking ability of fabric after dyeing could be attributed to the adsorption of dye molecules into the micro capillaries' surface and the formation of covalent bonding with hydroxyl groups of cellulose, subsequently resulting in the decrease of water absorbency and wicking ability of the dyed fabrics.

4 CONCLUSION

In this study, the dissolution of silk fibroin obtained from the waste *Bombyx mori* cocoons in LiBr/ethanol/water solution (45:44:11) and the regeneration of purified fibroin onto viscose fabric have been investigated. The QuixStand Benchtop system equipped with the microfiltration and ultrafiltration of hollow-fiber cartridges was used to remove excess LiBr and ethanol and to obtain the fibroin segments with molecular weight over 10 kDa. The deposition of fibroin on the treated fabric was evidenced via SEM analysis and color measurement using an acid dye labeled fibroin on the fabric. The dye-ability of the fibroin treated viscose fabric with a reactive dye was enhanced in comparison with the untreated fabric through the increasing color strength. The color fastness to washing for both the untreated and treated fabrics colored with the reactive dye were good to very good. The air permeability and horizontal wicking of the fabrics were decreased after finishing fabrics with silk fibroin and/or dyeing them with the reactive dye. In view of the attractive finishing technique, dye-ability improvement and sustainable development, the regenerated silk fibroin could be utilized as a potential finishing agent for the textile industry.

ACKNOWLEDGEMENT: *The authors would like to thank colleagues from School of Textile - Leather and Fashion, Hanoi University of Science and Technology for their efforts in supporting this work.*

5 REFERENCES

1. Lewin M., Pearce E.M.: Handbook of Fiber Chemistry, 2nd edition, revised and expanded CRS press, 1998, 1114 p., ISBN: 9780824794712
2. Mostafa K., El-Sanabary A.: Innovative ecological method for producing easy care characteristics and antibacterial activity onto viscose fabric using glutaraldehyde and chitosan nanoparticles, Pigment & Resin Technology 49(1), 2020, pp.11-18, https://doi.org/10.1108/PRT-02-2019-0020
3. Sarkar A.K., Appidi S.: Single bath process for imparting antimicrobial activity and ultraviolet protective property to bamboo viscose fabric, Cellulose 16(5), 2009, pp. 923-928, https://doi.org/10.1007/s10570-009-9299-8
4. Xu Q., Xie L., Diao H., Li F., Zhang Y., Fu F., Liu X.: Antibacterial cotton fabric with enhanced durability prepared using silver nanoparticles and carboxymethyl chitosan, Carbohydrate Polymers 177, 2017, pp. 187-193, https://doi.org/10.1016/j.carbpol.2017.08.129
5. Ibrahim H.M., Aly A.A., Taha G.M., Ibrahim H.I.: Production of antibacterial cotton fabrics via green treatment with nontoxic natural bio-polymer gelatin, Egyptian Journal of Chemistry 63(2), 2020, pp. 655-696, DOI: 10.21608/ejchem.2019.16972.2040
6. Rani S., Kadam V., Rose N.M., Jose S., Yadav S., Shakyawar D.B.: Wheat starch, gum arabic and chitosan biopolymer treatment of wool fabric for improved shrink resistance finishing, International Journal of Biological Macromolecules 163, 2020, pp.1044-1052, https://doi.org/10.1016/j.ijbiomac.2020.07.061
7. Ngo H.T., Bechtold T.: Surface modification of textile material through deposition of regenerated silk fibroin, Journal of Applied Polymer Science 134(29), 2017, pp. 45098 (1-11), https://doi.org/10.1002/app.45098
8. Kosawatnakul S., Nakpathom M., Bechtold T., Aldred A.K.: Chemical finishing of cotton fabric with silk fibroin and its properties, Cellulose Chemistry and Technology 52(1-2), 2018, 123-128
9. Vo T.L.H., Duong T.T., Nguyen N.T.: Morphological and physico-mechanical properties of finished cotton fabric by regenerated Bombyx mori silk fibroin, Proceeding Book of Proceeding Indonesian Textile Conference: Textile 4.0 clothing and beyond 1(3), 2019, pp. 84-93, DOI 10.5281/zenodo.3470883
10. Sashina E.S., Bochek A.M., Novoselov N.P., Kirichenko D.A.: Structure and solubility of natural silk fibroin, Russian Journal of Applied Chemistry 79(6), 2006, pp. 869-876, https://doi.org/10.1134/S1070427206060012
11. Chen X., Knight D.P., Shao Z., Vollrath F.: Regenerated Bombyx silk solutions studied with rheometry and FTIR, Polymer 42(25), 2001, pp. 09969-09974, https://doi.org/10.1016/S0032-3861(01)00541-9
12. Li S., Chen C., Zhang D., Zhang X., Sun B., Lv S.: Microwave-assisted fast and efficient dissolution of silkworm silk for constructing fibroin-based biomaterials, Chemical Engineering Science 189, 2018, pp. 286-295, https://doi.org/10.1016/j.ces.2018.06.003
13. Mehrabani M.G., Karimian R., Mehramouz B., Rahimi M., Kafil H.S.: Preparation of biocompatible and biodegradable silk fibroin/chitin/silver nanoparticles 3D scaffolds as a bandage for antimicrobial wound dressing, International Journal of Biological Macromolecules 114, 2018, pp. 961-971, DOI: 10.1016/j.ijbiomac.2018.03.128
14. Ngo H.T., Bechtold T.: Analysis of the fibroin solution state in calcium chloride/water/ethanol for improved understanding of the regeneration process, Fibers & Textiles in Eastern Europe 26(132), 2018, pp. 43-50, DOI: 10.5604/01.3001.0012.5174
15. Thakur V.K.: Biopolymer Grafting: Applications, Chapter 10 - Fibroin Grafting Onto Wool Fibers: Recent Advances and Applications, Elsevier, 2017, pp. 391-429, ISBN: 9780128104620
16. Nguyen N.T., Vo T.L.H.: Finishing viscose woven fabric using regenerated Bombyx mori silk fibroin, Journal of Science and Technology, (in press)
17. Ahmed M., Sukumar N., Gideon R.K.: Crease resistance finishing optimization of citric acid and fibroin solution for cotton fabrics, Journal of Natural Fibers 18(2), 2021, pp. 297-307, https://doi.org/10.1080/15440478.2019.1623740
18. Zhang Z., Zhao Z., Zheng Z., et al.: Functionalization of polyethylene terephthalate fabrics using nitrogen plasma and silk fibroin/chitosan microspheres, Applied Surface Science 495, 2019, pp. 143481, https://doi.org/10.1016/j.apsusc.2019.07.223
19. Lu M.: Crease resistant finishing of cotton fabric with a complex of fibroin and citric acid, Fibers & Textiles in Eastern Europe 18(3), 2010, pp. 86-88
20. Xu Y., Chen D., Du Z., Li J., Wang Y., Yang Z., Peng F.: Structure and properties of silk fibroin grafted carboxylic cotton fabric via amide covalent modification, Carbohydrate Polymers 161, 2017, pp. 99-108, https://doi.org/10.1016/j.carbpol.2016.12.071

REGIONAL FEATURES OF INDUSTRIAL PRODUCTION DYNAMICS IN THE RESEARCH OF TEXTILE ENTERPRISES` FINANCIAL SECURITY IN UZBEKISTAN

Elena V. Zarova[1] and Bobir O.Tursunov[2]

[1]*"Analytical Center" of Moscow Governance, Russian Federation*
[2]*"Economic security" Department, Tashkent State University of Economics, I. Karimov Street 49, 100003 Tashkent, Republic of Uzbekistan*
zarova.ru@gmail.com; tursunov-bobir@mail.ru

Abstract: *The financial stability of a textile industry enterprise in a particular region is determined both by the results of the production and economic activities of the enterprise itself and by factors external to this enterprise, including the level of economic development of the region, the potential of industrial production on its territory, cyclical fluctuations in the economic environment and other macroeconomic factors. The initial stage of a quantitative study of the financial stability of textile enterprises in the Republic of Uzbekistan at the regional level should be the stage of clustering regions in order to identify groups that include homogeneous regions in terms of industrial growth rates, phases of economic cyclicality of industrial dynamics. This will allow, when comparing the financial sustainability of textile enterprises located in different regions, to take into account similar or different conditions of industrial development in the respective territories. The article presents a theoretical justification, a set of algorithms, as well as the results of calculations based on data from the State Statistics Committee of the Republic of Uzbekistan, which made it possible to systematize regions according to the characteristics of growth and cyclicality of industrial production for the period 2010-2018. The typologization of the regions of the Republic of Uzbekistan is relevant for a comparative assessment of changes in the financial stability of textile enterprises under the influence of the crisis caused by the coronavirus pandemic, as well as in the post-crisis period.*

Keywords: *textile, dynamics of industrial production, financial stability of textile enterprises, trend-cyclical component, clustering regions, financial security.*

1 INTRODUCTION

1.1 Actuality of theme

The economic literature presents works on the analysis of the financial stability of enterprises, taking into account the impact of macroeconomic conditions in specific time periods. For example, in the work "Modeling the financial stability of an enterprise taking into account macroeconomic indicators" [1], the authors investigate the financial stability of metallurgical enterprises using mathematical models that include the parameters of dynamic models of macroeconomic indicators characterizing their fluctuation in time. This provided the authors with the opportunity to take into account in the specification of models of financial stability of enterprises the special conditions of their activities in different periods of time.

The main hypothesis adopted by the authors during this study was as follows: the financial stability of enterprises at the regional level is determined not only by the peculiarities of the manifestation of general macroeconomic factors in time and in a given territory, but also by the specifics of mesoeconomic factors that determine the growth and cyclical dynamics of production by industry and sectors of the regional economy. For enterprises of the textile industry on the territory of the regions of the Republic of Uzbekistan, an assessment of the impact of mesofactors on financial stability can be obtained by examining the dynamics of industrial production as a whole.

1.2 Scope of research

The purpose of the study was to identify and assess the territorial specifics of the economic dynamics of industrial production in the Republic of Uzbekistan. A mathematical and statistical decomposition of the investigated dynamics of industrial production in the regions of the Republic of Uzbekistan is carried out, with the allocation of a trend-cyclical component of dynamics, which is a combination of the main trend (trend) and a cyclical component due to market factors [2]. This allows us to identify regions that have general and specific characteristics of the trend-cyclical components of the dynamics of industrial production as a whole, which will allow taking these features into account in the study of the factors of financial security of textile enterprises located in these regions.

2 DATA COLLECTING

2.1 Used statistics

When carrying out the study, we used data on the growth rates of industrial production in the regions of the Republic of Uzbekistan for 2000-2018, published on the website of the State Statistics Committee of the Republic of Uzbekistan. We also used data on the growth rates of textile production in the Republic of Uzbekistan as a whole for 2010-2018.

3 LITERATURE REVIEW

3.1 Researches in textile

The last twenty years have been studies in the study of production capacity, the organization of production at industrial enterprises and the management of production processes were analyzed by Levin, et al [3], Sebastiano, et al [4], Chien, et al [5], Davis, et al [6], Huang, et al [7], Shao, et al [8], Koltai, et al [9], Tursunov and others [12, 13].

Some of these scientists have been investigated, interrelated functions had been examined, the implementation of which is the management of production capacity. Methodology for assessment the efficiency of production capacities management at textile enterprises were investigated by Tursunov in other works [13] and this research is logic continue of last research part.

Uzbek professor Burkhanov [10] researched main indicators of textile enterprises' financial security assessment. Kalandarovna [11] and others studied methodical aspects of establishing a control system over compliance with principles of decent work and social security in textile enterprises. But in upper researches have not been studied regional features of industrial production dynamics in the research of textile enterprises` financial security in Uzbekistan.

3.2 Researches dedicated to financial security

The Saaty method was successfully applied by Tsibizova and Karpunin [20] in assessing the quality of management processes, in particular to assess the quality of the work of teachers. The proposed approach provides an objective assessment of the quality of the daily work of a teacher associated with the current performance and student attendance, and not only with the results of intermediate final assessments. But in all the above-mentioned research papers, the mechanism for determining the optimal management of the use of production capacity at the textile industry enterprises was not considered, and we made an attempt to develop a mechanism for determining the optimal management of the use of production capacity, which was tested on the textile industry. The mechanism is based on a hierarchy method that uses the choice of a Pareto-effective set of alternatives, which allows interested parties to express a subjective view of an enterprise's value system. On the other hand, on the contrary, the method minimizes subjectivity with respect to specific alternatives.

4 METHODOLOGY

4.1 Research methods and approximation models of the trend-cyclical component of the dynamics of industrial production in the Republic of Uzbekistan

The study is based on a set of mathematical and statistical methods, including:

- assessment of the parameters of the trend-cyclical component of the dynamics of industrial production in the regions of the Republic of Uzbekistan;
- a combination grouping of the regions of the Republic of Uzbekistan by the parameters of the trend-cyclical components of the dynamics of industrial production, combining:
  - grouping of regions according to the type of linear trend (upward or downward);
  - grouping of regions according to the parameters of the cyclical components of the time series of industrial production growth rates.
- determination of specific economic types of regions, taking into account the results of the combination grouping.

4.2 Econometric model of the dynamics of industrial production in the Republic of Uzbekistan

The initial model for approximating the time series of industrial production growth rates in the *j*-th region of the Republic of Uzbekistan:

$$\bar{y}_j = a_0 + a_1.t + a_2\,sin(k.t) + a_3\,cos(k.t) \qquad (1)$$

where: $\bar{y}_j$ – calculated values of the trend-cyclical component of the time series of the annual growth rates of industrial production in the *j*-th region of the Republic of Uzbekistan; *t* - year number, t = 2000,…., 2018 yy; a_0, a_1 – model parameters that determine the trend component of the time series; *k* – parameter determining the wavelength (period) of cyclic oscillations; a_2, a_3 – parameters of the contribution of harmonic vibrations to the general model.

To determine the wavelength (period, years), the formula is used:

$$L = 2\pi/k \qquad (2)$$

The quality of the model is assessed using the multiple correlation coefficient *R*, as well as the multiple determination coefficient *D*, which makes it possible to determine the specific weight of the explained variation (the percentage of the actual values of industrial production growth rates in the region corresponding to the model trend-cyclical values).

5 ANALYSIS AND RESULTS

5.1 Estimation of the parameters of the models of the trend-cyclical component of the dynamics of industrial production in the regions of the Republic of Uzbekistan

Based on the results of building models, it was found that the above formula describes the trend-cyclical component of the studied time series rather reliably: the explained variation across regions was 55-78%.

The graphs of the most reliable models are shown on Figures 1-4.

The resulting model for the Republic of Uzbekistan looks like:

$$\bar{y}_j = 108.19 + 0.096.t + 1.912\,sin(-0.679.t) - 1.155\,cos(-0.679.t) \quad (3)$$

This model explains 66% of the variation *D* in the actual annual growth rate of industrial production in the Republic of Uzbekistan as a whole.

The wavelength is 9.25 years, i.e. its half-life is approximately 4.5 years (Figure 1).

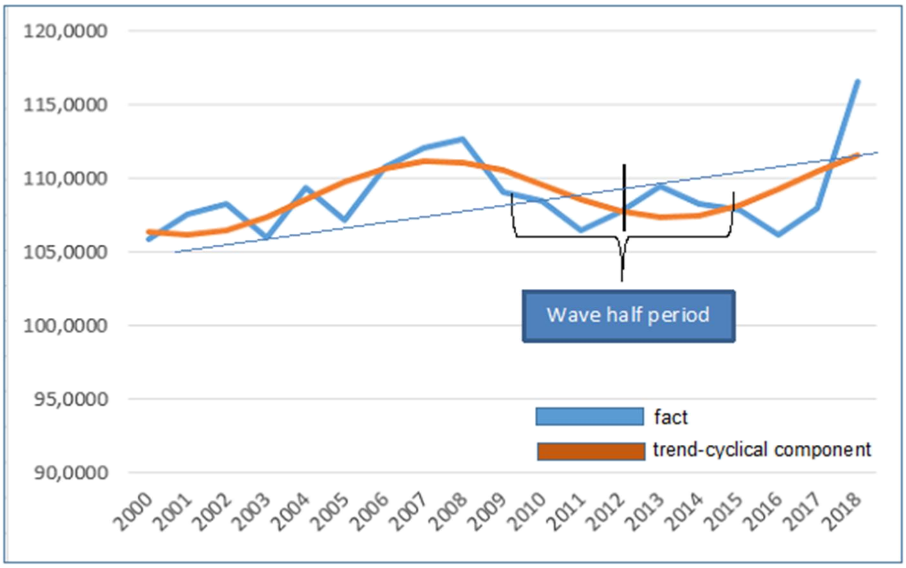


Figure 1 Graph of the trend-cyclical component of the time series (orange line) of the annual rates of industrial production in the Republic of Uzbekistan, 2000-2018 [14]

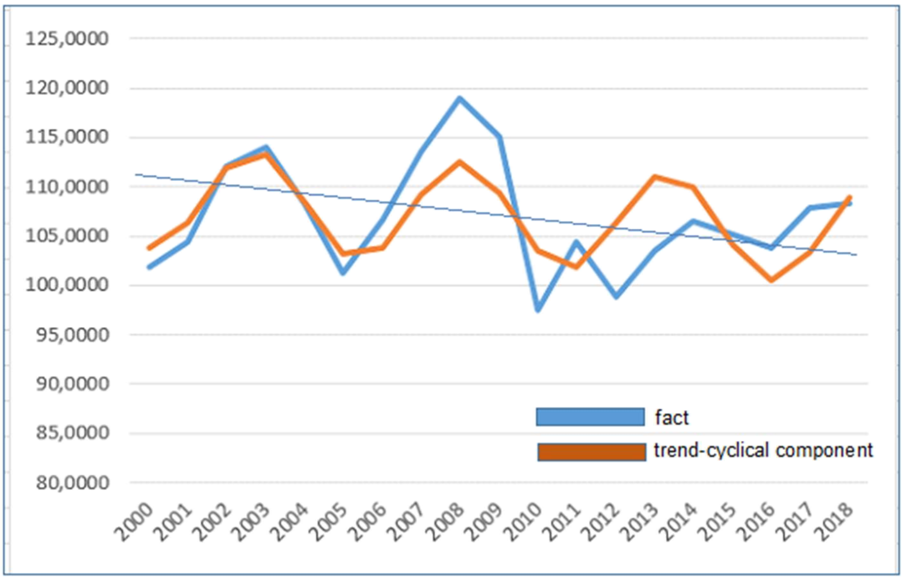


Figure 2 Graph of the trend-cyclical component of the time series of the annual rates of industrial production in the Kashkadarya region, 2000-2018, (D=76%) [14]

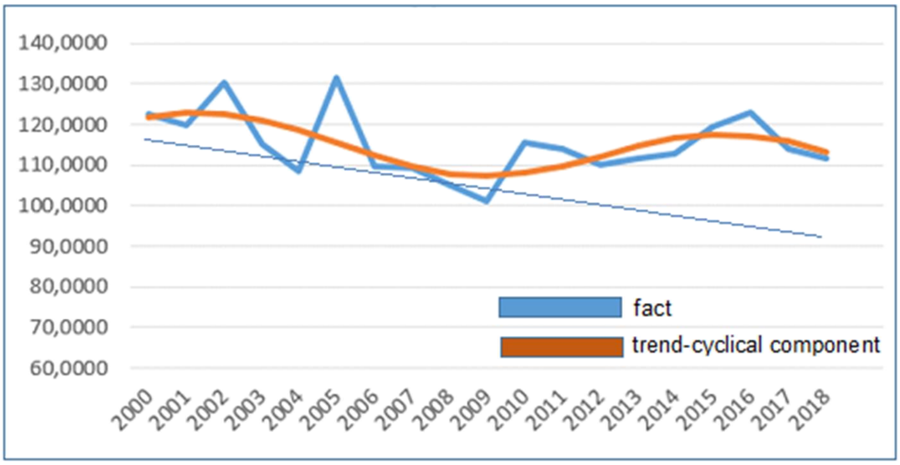


Figure 3 Graph of the trend-cyclical component of the time series of the annual rates of industrial production in the Jizzakh region, 2000-2018, (D=71%) [14]

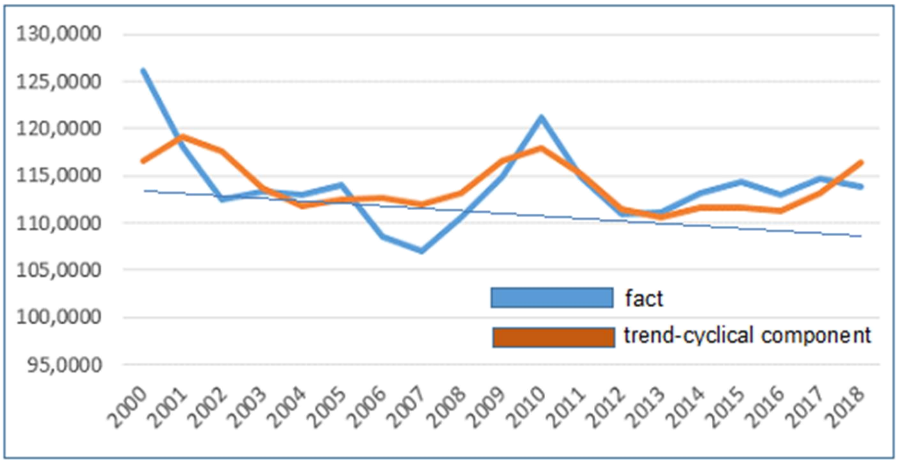


Figure 4 Graph of the trend-cyclical component of the time series of the annual rates of industrial production in the Namangan region, 2000-2018, (D=78%), [14]

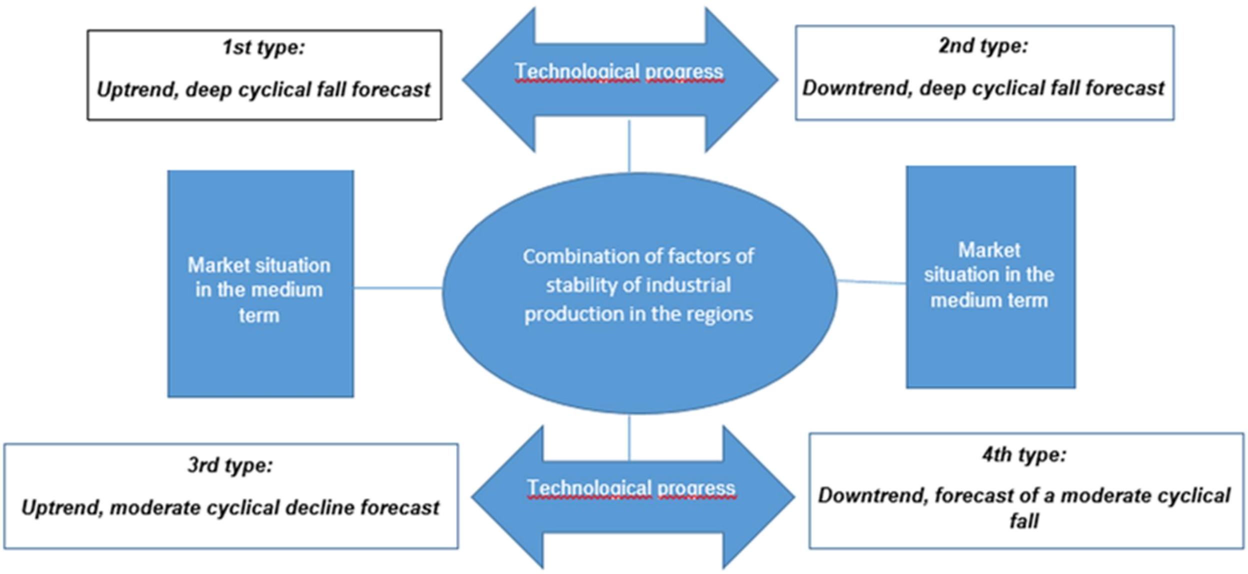


Figure 5 Factors that determine the special types of regions of the Republic of Uzbekistan, determined by the specifics of the long-term growth trend and cyclical dynamics of industrial production

5.2 *Cluster analysis based on the parameters of trend-cycle models*

Based on the data presented in Table 1, a cluster analysis was carried out, which made it possible to determine the regions of Uzbekistan that are homogeneous in terms of the characteristics of the trend-cyclical components of dynamics (parameters a_0, a_1, a_2, a_3, k).

The resulting dendrogram (Figure 5) allows us to conclude that the regions of the Republic of Uzbekistan are divided into two groups, which are similar in the type of the main trend of industrial production and the form of conjuncture cycles.

However, the inclusion of the linear trend parameter in the cluster analysis is impractical, since its positive and negative values will cancel each other out when determining the average values o the cluster-forming variables. Therefore, the regions were subdivided into two groups: with an upward and downward linear trend (in Table 1, they are marked with the corresponding graphic symbols).

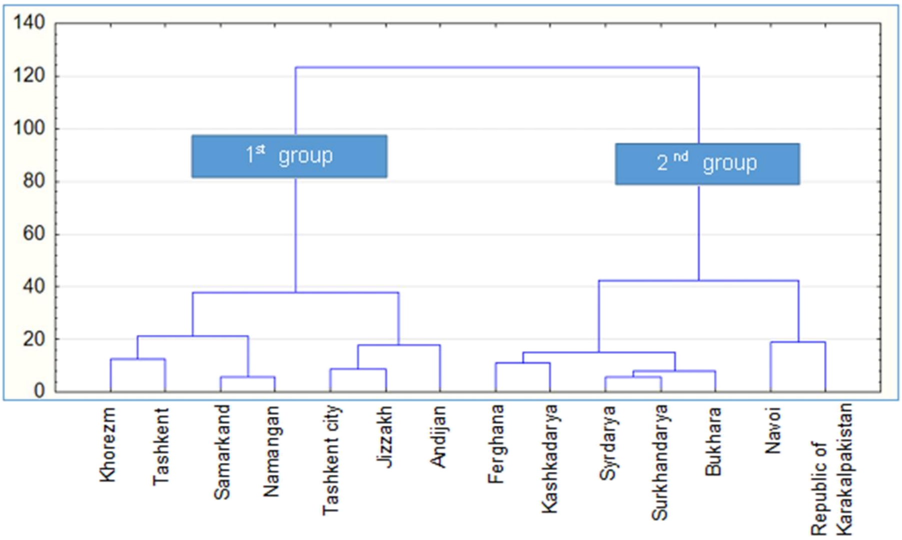
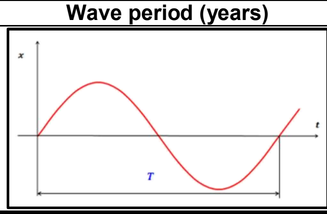


Figure 6 Dendrogram of the distribution of regions of the Republic of Uzbekistan into homogeneous groups according to the parameters of the trend-cyclical components of the dynamics of industrial production

Table 1 Parameters of the models of trend-cyclical components of the dynamics of industrial production in the regions of the Republic of Uzbekistan, built according to data on annual growth rates for 2000-2018

Regions	Type of trend*	Model parameters				Wave period (years)
		a1	*a2*	*a3*	*k2 (abs.)*	
Republic of Karakalpakstan	↘	1.199	-6.687	6.971	2.346	4.94
Andijan	↘	-0.329	9.411	-7.224	5.484	5.72
Bukhara	↗	0.169	1.836	-2.828	2.026	4.46
Jizzakh	↘	-0.294	7.169	-6.88	2.512	8.94
Kashkadarya	↘	-0.287	-5.894	7.649	1.79	4.62
Navoi	↗	0.0009	-1.505	-0.747	3.376	9.37
Namangan	↘	-0.125	2.903	-1.604	0.573	5.47
Samarkand	↗	0.537	2.055	-6.461	5.906	5.31
Surkhandarya	↗	0.515	4.491	2.305	0.471	6.66
Syrdarya	↘	-0.151	2.773	3.885	4.376	7.17
Tashkent	↗	0.621	-1.091	4.057	0.233	7.25
Fergana	↗	-0.094	-1.605	1.001	5.891	5.33
Khorezm	↗	1.02	-4.285	8.115	1.506	6.96
Tashkent city	↗	0.722	7.017	0.982	0.746	4.21

*type of trend: ↗ ascending; ↘ descending

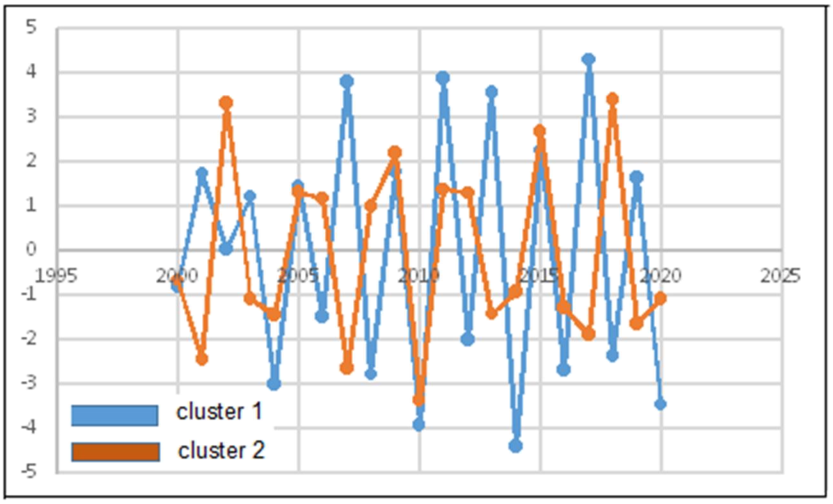


Figure 7 Estimated for 2000-2020 values of deviations of industrial production rates for selected clusters of regions from the average annual level for 2000-2018, % - points

The established average values of cluster-forming variables make it possible to determine the calculated values of the rates of industrial production for the selected clusters of regions (Figure 7). It should be noted that in the regions of the 1st cluster and in the regions of the 2nd cluster (Figure 8), the forecast for the trend-cyclical model for 2020 gives a drop in the growth rates of industrial production relative to the average annual level, respectively, by 3.5 and 0.4% points. It follows from this that the situation of the coronavirus crisis coincided with a drop in industrial production in the regions of both groups due to the regular cyclicality.

Figure 8 shows the results of the final combination grouping of the regions of the Republic of Uzbekistan by the type of economic dynamics of industrial production.

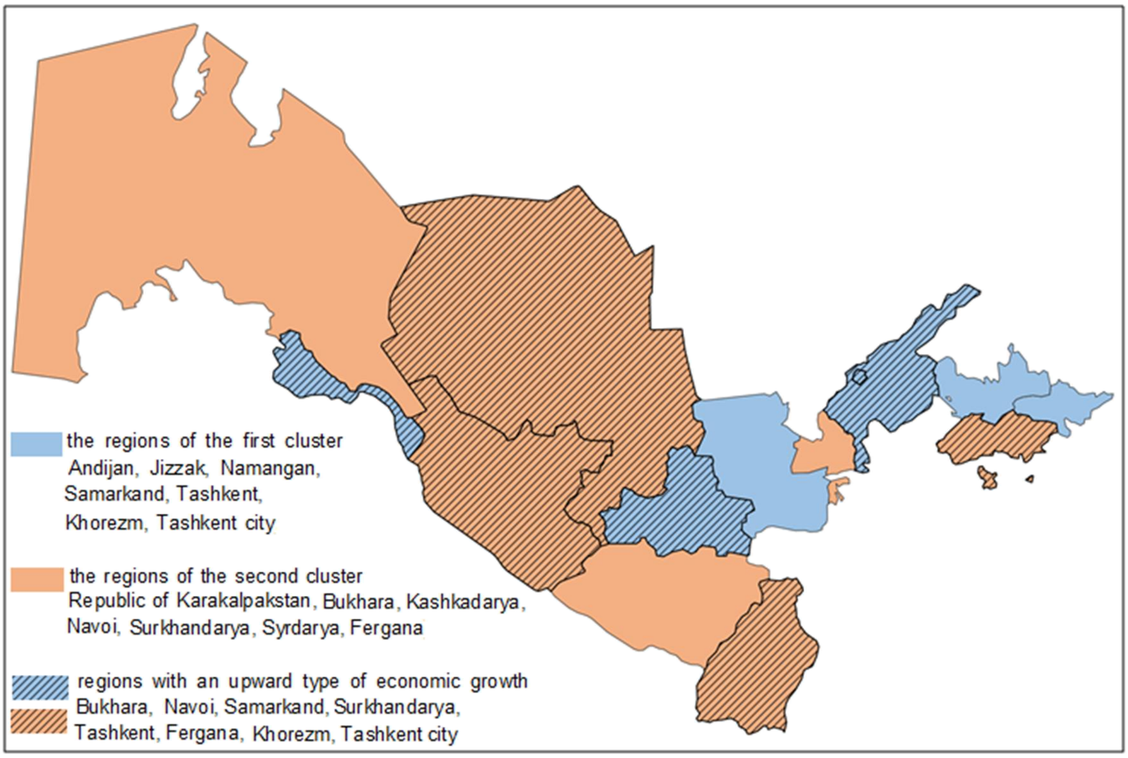


Figure 8 Results of the final combination grouping of the regions of the Republic of Uzbekistan by the type of economic dynamics of industrial production

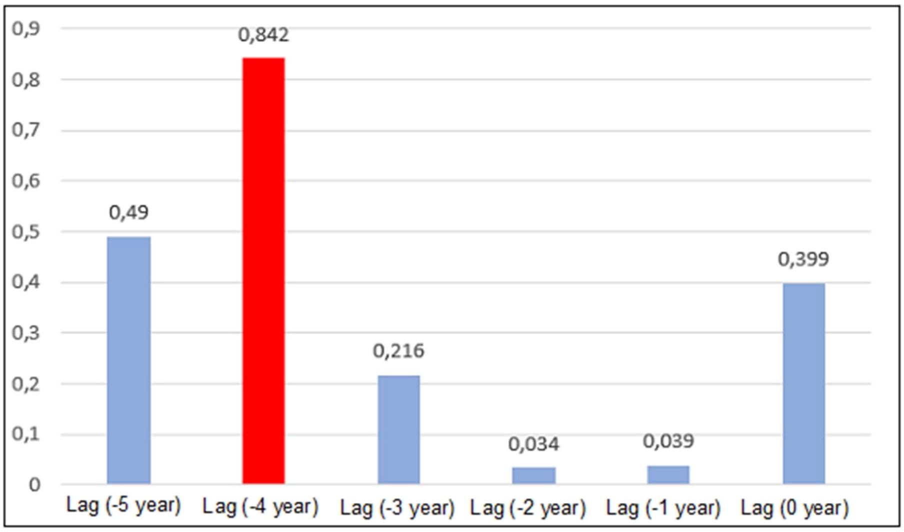


Figure 9 Paired correlation coefficients of the growth rates of industrial production in general and the production of textiles with lags of lagging influence, according to the data of the Republic of Uzbekistan for 2010-2018

5.3 The results of typologization of the regions of the Republic of Uzbekistan based on the estimation of the parameters of dynamic models of industrial production

Based on the results of evaluating the parameters of the dynamic models presented above, four types of regions have been identified that have the specifics of long-term dynamics of industrial production, determined by the features of the main trend (trend), the form of cyclicality and a combination of these components of dynamics. The composition of these regional distinguished types is presented below:

1st type: Samarkand, Tashkent, Khorezm, Tashkent;

2nd type: Andijan, Jizzak, Namangan,

3rd type: Bukhara, Navoi, Surkhandarya

4th type: Republic of Karakalpakstan, Kashkadarya, Syrdarya, Fergana.

Based on data on the growth rates of industrial production by type of economic activity for 2010-2018 it was found that the general situation of industrial growth in the regions significantly affects the situation in the production of textiles. The influencing factors in this case are the general technical and technological development, improvement of infrastructure, improvement of the quality of labor, changes in the market environment, due to general market factors of supply and demand for industrial products. Calculations of the paired correlation coefficients of the annual growth rates of industrial production by type of economic activity show that the greatest response of the volume of textile production to industrial growth in the region occurs with a lag of 4 years (Figure 9).

6 CONCLUSION

The performed calculations confirm the initial hypothesis about the need to take into account the spatial and dynamic features of industrial production in general, which are determined by both general industrial factors of technological progress and specific regional factors of cyclicality in the dynamics of the ratio of supply and demand for industrial products, in studies of the financial stability of textile enterprises in the regions of the Republic of Uzbekistan.

7 REFERENCES

1. Bidzhoyan D.S, Bogdanova T.K.: Modelling the financial stability of an enterprise taking into account macroeconomic indicators, Business Informatics 3(37), 2016, pp. 30-37, doi: 10.17323/1998-0663.2016.3.30.37
2. Zarova E.: Statistical Methodology for Evaluating Business Cycles with the Conditions of their Synchronization and Harmonization, chapter in Statistics - Growing Data Sets and Growing Demand for Statistics, IntechOpen, 2018, pp. 27-48, https://www.intechopen.com/books/statistics-growing-data-sets-and-growing-demand-for-statistics/statistical-methodology-for-evaluating-business-cycles-with-the-conditions-of-their-synchronization-
3. Levin Y., Nediak M., Topaloglu H.: Cargo capacity management with allotments and spot market demand, Operations Research 60(2), 2012, pp. 351-365, https://doi.org/10.1287/opre.1110.1023
4. Sebastiano A., Belvedere V., Grando A., Giangreco A.: The effect of capacity management strategies on employees' well-being: A quantitative investigation into the long-term healthcare industry, European Management Journal 35(4), 2017, pp. 563-573, ttps://doi.org/10.1016/j.emj.2016.12.001

5. Chien C., Dou R., Fu W.: Strategic capacity planning for smart production: Decision modeling under demand uncertainty, Applied Soft Computing 68, 2018, pp. 900-909, https://doi.org/10.1016/j.asoc.2017.06.001
6. Davis M., Dempster M., Sethi S., Vermes D.: Optimal capacity expansion under uncertainty, Advances in Applied Probability 19(01), 1987, pp. 156-176, https://doi.org/10.2307/1427378
7. Huang D., Lin Z., Wei W.: Optimal production planning with capacity reservation and convex capacity costs, Advances in Production Engineering & Management 13(1), 2018, pp. 31-43, https://doi.org/10.14743/apem2018.1.271
8. Shao J.F., Li Y.: Multi-agent production monitoring and management system for textile materials and its applications, Journal of Industrial Textiles 40(4), 2010, pp. 380-399, https://doi.org/10.1177/1528083710380428
9. Koltai T., Stecke K.: Route-independent analysis of available capacity in flexible manufacturing systems, Production and Operations Management 17(2), 2008, pp. 211-223, https://doi.org/10.3401/poms.1080.0017
10. Burkhanov A., Tursunov B.O.: Main indicators of textile enterprises' financial security assessment. Vlakna a textil (Fibres and Textiles) 27(3), 2020, pp. 35-40, http://vat.ft.tul.cz/Archive/VaT_2020_3.html
11. Kalandarovna A.G., Gaibnazarovich G.S., Turgunovna S.N., Shuxratovna F.D., Ortikmirzaevich T.B.: Methodical aspects of establishing a control system over compliance with principles of decent work and social security in textile enterprises, Journal of Advanced Research in Dynamical and Control Systems 12(5), 2020, pp. 73-81, https://doi.org/10.5373/JARDCS/V12I5/20201691
12. Tursunov B.O.: Mechanism for determining optimal management of use of production capacity at the textile enterprises, Vlakna a textil (Fibres and Textiles) 27(1), 2020, pp. 99-106, https://doi.org/10.5281/zenodo.3787291
13. Tursunov B.O.: Methodology for assessment the efficiency of production capacities management at textile enterprises, Vlakna a textil (Fibres and Textiles) 26(2), 2019, pp. 74-81, https://doi.org/10.5281/zenodo.3756262
14. http://www.stat.uz

INSTRUCTIONS FOR AUTHORS

The journal ,,**Vlákna a textil**" (**Fibres and Textiles**) is the scientific and professional journal with a view to technology of fibres and textiles, with emphasis to chemical and natural fibres, processes of fibre spinning, finishing and dyeing, to fibrous and textile engineering and oriented polymer films. The original contributions and works of background researches, new physical-analytical methods and papers concerning the development of fibres, textiles and the marketing of these materials as well as review papers are published in the journal.

Manuscript

The original research papers are required to be written in English language with summary. The advertisements will be published in a language according to the mutual agreement.

The first page of the manuscript has to contain:

The title of the article (16 pt bold, capital letters, centred)

The full *first name* (s) and also *surnames* of all authors (11 pt, bold, centred).

The complete address of the working place of the authors, e-mail of authors (9 pt, italic, centred)

Abstract (9 pt, italic)

Key words (9 pt, italic)

The manuscript has to be written in A4 standard form, in **Arial, 10 pt**.

The text should be in ***one-column format in single line spacing***.

Page margins: up and down 2.5 cm; left and right 2.0 cm.

Do not number the pages and do not use footnotes. Do not use business letterhead.

Figures, tables, schemes and photos (centered) should be numbered by Arabic numerals and titled over the table and under the figure or picture.

Photos and schemes have to be sufficiently contrastive and insert in text as pictures.

Mathematical formulae should be centred on line and numbered consecutively on the right margin.

Physical and technical properties have to be quantified in **SI units**, names and abbreviations of the chemical materials have to be stated according to the IUPAC standards.

References in the text have to be in square brackets and literature cited at the end of the text. References (9 pt), have to contain names of all authors.

[1] Surname N., Surname N.: Name of paper or Chapter, In Name of Book, Publisher, Place of Publication, YYYY, pp. xxx-yyy, ISBN

[2] Surname N., Surname N.: Name of paper, Name of Journal Vol. (No.), YYYY, pp. xxx-yyy, doi number

[3] Surname N., Surname, N.: Title of conference paper, Proceedings of xxx xxx, conference location, Month and Year, Publisher, City, Surname N. (Ed.), YYYY, pp. xxx-yyy

[4] Surname N., Surname N.: Name of Paper, Available from http://www.exact-address-of-site, Accessed: YYYY-MM-DD

The final template of manuscript is available on **http://www.vat.ft.tul.cz**

Authors are kindly requested to deliver the paper (in Word form) to be published together with information about at least 3 recommended reviewers from institutions others than the parent (name, e-mail, institution and department) by e-mail: marcela.hricova@stuba.sk

After successful review procedure there is charged fee (article processing charge) of EUR 100. All articles after review process are freely available online and this fee helps to cover the costs of taking a manuscript and turning it into a finished article.

Address of the Editor Office:

Marcela Hricová

Faculty of Chemical and Food Technology,

Slovak University of Technology in Bratislava

Radlinskeho 9

812 37 Bratislava,

Slovakia