ANNALS
OF THE
UNIVERSITY OF ORADEA

FASCICLE OF TEXTILES, LEATHERWORK

VOLUME 23

No. 2

EDITURA UNIVERSITĂȚII DIN ORADEA

2022

ISSN 1843 – 813X

ANNALS
OF THE
UNIVERSITY OF ORADEA

FASCICLE OF TEXTILES, LEATHERWORK

VOLUME 22
No. 2

EDITURA UNIVERSITĂȚII DIN ORADEA

2022

Contact and Editors' Address:
Liliana INDRIE
UNIVERSITATEA DIN ORADEA,
FACULTATEA DE INGINERIE ENERGETICĂ ŞI MANAGEMENT INDUSTRIAL
DEPARTAMENTUL: TEXTILE- PIELĂRIE ŞI MANAGEMENT INDUSTRIAL
Str. B.St.Delavrancea nr. 4,
Oradea, 410058, Romania,
Tel.: 00-40-259-408448
E-mail : lindrie@uoradea.ro

Published by
Editura Universităţii din Oradea
Universitatea din Oradea, Str. Universităţii Nr. 1, 410087, Oradea, Bihor, Romania
P- ISSN 1843 – 813X
E - ISSN 2457-4880
CD- ISSN 2068 – 1070

Indexed in:

EBSCO-Textile Technology Complete
Index Copernicus (ICV 2018: 97,58)
Directory of Open Access Journals (DOAJ)
Ulrich's Update - Periodicals Directory

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

A NEW REALITY: SMART FABRICS AND WEARABLE TECHNOLOGY

BRAD Raluca

Lucian Blaga University of Sibiu, Faculty of Engineering, Industrial Machinery and Equipments Department,
B-dul Victoriei 10, 550024 Sibiu, Romania, E-Mail: raluca.brad@ulbsibiu.ro

Abstract: *The paper presents relevant aspects related to smart fabrics, e-textiles and smart clothing, current implementations of high textile technology, wearable electronics and wearable computers respectivly. Shape Memory Materials have the potential to return to their original form, due to external stimuli and therefor can have multiple applications to functional textile as presented in the second chapter. Phase Change Materials are a solution for energy management, storage and generation of energy appearing when changing the state of aggregation, being influenced by the temperature, with current usages in the aerospace industry or other, as shown in the same chapter. The property of chromatic textiles was also investigated as well as the huge potential of conductive textiles. Electronic systems integrated in textiles are used for image sensors, flexible displays, biomedical devices and other emerging applications. The possibility of such a combination has motivated researchers and companies to offer on the market jackets with remote controls, embedded displays and even airbags. Structural features and technologies for production were described, emphasizing their most important applications, such as medical, sports or military. Maintenance operations of smart products must ensure their repeated utilization and do not degrade their electrical components. Several products proposed by well-known IT companies in collaboration with textile brands or by research laboratories were presented in the last part of the paper.*

Key words: *e-textile, smart clothing,* conductive textile, *wearable electronics*

1. INTRODUCTION

In our daily lives, we are in contact with textiles up to 98%, and they have become adaptive, receptive, interactive or connected, extending their traditional functions and having the capacity to do many things that traditional materials cannot do: communicating, transforming, directing energy or growing [1], [2].

In the current conditions in which the products must be attractive, as well as to function properly in the most diverse situations, including those that have an effect on the safety and security of people, textile designers have a new alternative in choosing a textile material that follows to be processed: in addition to appearance, resistance or price, is added its ability to conduct electricity. This property is characteristic of e-textiles, electronic textiles or smart clothing, which must keep pace with the revolution in wearable electronics.

The terms “e-textiles” and “smart clothing” refer to textile fabrics and garments made of high-tech textiles in which new technological elements have incorporated, including electrical parts. ISO/PRF TR 23383:2020 and ASTM D8248:2020 define a smart textile as a functional textile that interacts with the environment, reponds to the action of external stimuli (temperature, chemicals, magnetic field or mechanical actions), but does not necessarily contain an electronic element in its structure.

E-textiles are a combination of advanced textile technology and information technology and electronics. Electronic textiles are distinct from wearable computers because they contain textiles integrating with electronics such as microcontrollers, sensors and actuators. In addition, e-textiles do not have to be wearable. For example, e-textiles can be used in interior design.

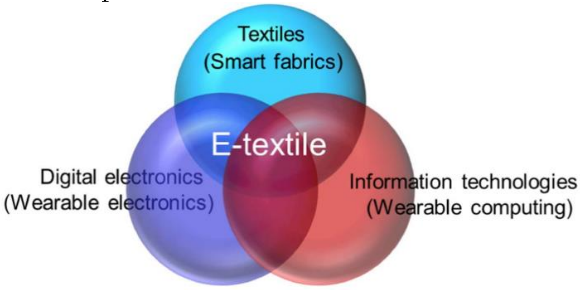


Fig. 1*: Relations between e-textile and wearable technologies [3]*

Some components and interconnections can be hidden in the material by the way the structures themselves are built. A wide range of textile fabrics have been used as base layers for smart products. Accordingly, new production processes have been developed and specific techniques have been adapted to obtain wearable intelligent textile systems [4]. New fibers and yarns, together with electronic microcomponents make it possible to create products that are truly useful to people. The use of metal yarns or especially nanotube-based in woven fabrics improve the portability and flexibility of these intelligent textile systems, participating in attached or laminated circuits [5], [6]. Medical applications have been made based on textile platforms in which the knitted material is improved with new redundant detection capabilities, preserving the mechanical properties of structure that make the material durable, breathable, elastic and soft [7].

Some textiles, such as warm blankets and clothing, have developed over the past 20 years, integrating into notable markets, where millions of products are sold each year. But the range of e-textiles is extremely diverse: from clothing to medical products, bedding to industrial fabrics; and as this technological area explores more and more, other new products are emerging. But regardless of the application itself, they put together one or more defining components of smart textiles (Fig. 2).

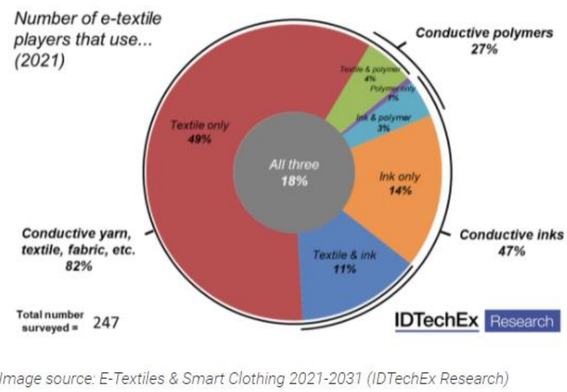


Fig. 2*: Distribution of raw materials for e-textiles [8]*

Considering a wide range of raw materials (polymers, metals, fibers, yarns, knitted, woven, embroidered and nonwoven fabrics) and components (sensors, connectors and interface with traditional electronics, etc.) used for e-textiles and smart clothing in [8], one can observe a priority of conductive textile threads and structures, followed by conductive inks and polymers, respectively, which are also an important alternative for e-textiles.

The e-textile industry influences and is influenced by the emerging technological ecosystem (production of conductive inks, extensible electronics, wearable technology, printed electronics and and flexible sensors, Internet, emerging energy storage, healthcare and life sciences, etc.). Every these individual product ecosystems has its own needs and expectations, thus "being e-textile" is not necessarily sufficient to be a successful product.

2. SMART FABRICS

The first research on smart adaptive systems was recorded in the 1980s in the U.S. as part of a Smart Skin Program that focused on military aircraft and the integration of projectors on their outer surface. In 1985, the New Glass Forum was established in Japan, with the field of research being the sensory ceramic materials, which are obtained by varying their properties.

The concept of smart fabrics was developed in the 90's with the aim of materials (textiles, plastics, metals, etc.) which, when stimulated by action, change their properties, by adding substances with specific properties (paraffin, metal alloys, polymers, etc.).

Both the nature of the stimulus and the response can be diverse, and hence a classification of smart fabrics. Thus, the stimuli can be electrical, magnetic, mechanical, thermal, etc., and the response of the material may consist in changing the phase, dimensions, electrical properties, appearance etc. [9].

Smart systems perform functions similar to those of living organisms, actuators, sensors or controls. To these, in the case of very intelligent materials, is added the function of learning and adapting to variations in the environment by changing their own characteristics [10].

Actuators refer to smart materials that can respond by thermal stimuli, electric or magnetic field variations. They are able to change their shape (with the formation of kinetic energy), stiffness, position, frequency of internal vibrations, damping capacity, internal friction or viscosity, as a reaction to variations in temperature, electric or magnetic field. This category includes shape memory materials, piezoelectric materials, electrostrictive and magnetostrictive materials, as well as electro and magnetoreological materials. Sensors refer to detection systems that identify changes in the environment and transmit signals depending on the structure of the material. They can perform the following functions: defect control, vibration damping, noise attenuation and data processing. A structure can have external or internal sensors, and sensory materials refer to shape memory materials, piezoelectric materials, electrostrictive materials, optical fibers and marking particles [11].

Control systems or the processors ensure communication between sensors and actuators, including their reaction and control. They classify the information received from the sensors and protect by reducing the accuracy of the processing their operation. The simplest smart material structure (a set of smart materials) is that which consists of a sensor, an actuator and a feedback amplifier. The concept of "a-life" characterizes such a structure that is also adaptive (reactive or can learn), but also ensures the transmission of information to people [10].

Smart textiles are those textile materials capable of sensing environmental stimuli, reacting to them and adapting their behavior to circumstances by integrating functionalities into the textile structure. Stimulus and response can have an electrical, thermal, mechanical, chemical, magnetic origin. External conditions can be felt by smart textiles in three distinct ways: passive (textiles that only detect the external stimulus: portable sensors, built-in GPS), active (due to sensors and actuators, textiles have the ability to detect and operate or move part of their environment: chromatic materials, shape memory materials, phase change materials, hydrogels and membranes, clothing that changes the density of the material according to the outside temperature) and very intelligent (it is about the third generation of textiles that can feel, react and adapt to external conditions or stimuli, based on previous experience, and which are able to respond to perform a function in a pre-programmed way: space suits, thermoregulatory clothing, health-monitoring clothing, shirts containing a keyboard embedded in material to which information can be sent via Bluetooth to a computer) [12].

2.1. Shape Memory Materials in textiles

Shape Memory Materials (SMM) may return to their original form from a form in which they are due to external stimuli, such as temperature, mechanical stress (pseudoelastic applications), pH, light, magnetic or electric field, water or various chemicals. In this case, the material acts as an actuator for the textile product.

There are several types of alloys (SMA) that help to monitor the shape of a material, but the best known is the Nitinol alloy, Ni-Ti. It has been estimated that 50 l of Nitinol can store as much energy as a car engine [10]. Other alloys with shape storage properties are those based on Au, Ag or Cu (these being the cheapest). When it comes to textiles, it is a challenge, as the incorporation of excessive use of alloys will reduce the feel of this fabric.

In the case of a stimulus, such as temperature, 2 phases of the material can be identified: austenite and martensite, being characterized by a certain molecular structure (order) (Fig. 3). Figure 4 shows the principle of memorizing the shape of a material. Below the MF temperature, the alloy is completely in a martensitic phase; above the AF temperature, it is an austenitic state. AF temperature is the critical temperature for modeling, so when we heat the material over AF, it will return to its original shape. This specific alloy has very good electrical and mechanical properties and a high corrosion resistance. Moreover, Nitinol has the quality of inducing transformation through electricity. When enough electricity is transmitted through the wire, the heat generated will cause the transformation [13].

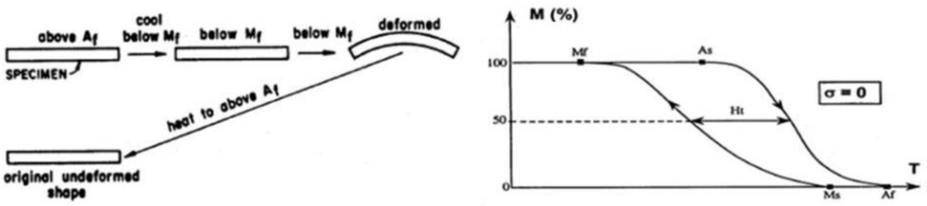


***Fig.3**: The principle of memorizing form [14]*

An application conected with the textile field is made up of bras with shape memory (support wire), products that have both aesthetic and structural requirements. NiTi alloy support wires offer high comfort due to their much lower modulus of elasticity than conventional steel wires, while Cu-Zn alloy lamellar springs have a flat shape at a lower temperature and are arched at a upper temperature [9].

The longitudinal modulus of elasticity (Young's modulus) is the main characteristic regarding the deformability (rigidity) of a material. Of the two identical and stressed parts with equal stresses, the one whose material has the lowest modulus of elasticity will deform the most: a material is stiffer if it has a higher modulus of value E [15]:

$R = E * I_z$, where **(1)**

R - bending stiffness [Nmm^2]; E - Young's modulus [N/mm^2]; I_z - moment of inertia [mm^4]

In the case of knitwear used for clothing / footwear [16]:

$I_z = l_t * g_t^3 / 12$, where **(2)**

l_t – knit width [mm]; g_t – knit thickness [mm]; I_z – moment of inertia [mm^4]

An additional advantage is that the elastic NiTi alloy wires counteract the permanent deformation that can occur after washing and drying cycles.

An application for SMA is represented by a shirt designed by Corpo Nove from Italy (Fig. 4), which shortens its sleeves when the temperature rises and does not require its ironing.

Fig.4: *Oricalco shirt [17]*

Laminated or polyurethane films (Shape-memory polymer) can be used to obtain vapor, water and air impermeable clothing. They give good flexibility, hence the belong to the category of "flexible materials" [18], a higher extensibility, softer touch, low specific mass and they are considered very suitable for the garment industry. In the case of segmented polyurethane, the specific shape recovery temperature varies over a wide range, and the permissible shape recovery deformations can reach 400%, with low manufacturing costs. These textiles are mainly used for functional textiles, with special properties, most often using the laminated complex of polyester fibers and SMP in garments with controlled permeability and insulation, as well as an increased comfort.

An example is the DiAPLEX material, designed by Mitsubishi Heavy Industries, using a polyurethane polymer on the textile material for waterproofing in case of intense physical activity or sudden climate change. The laminated complex made of 2 component layers: the fabric and the Diaplex membrane, respectively, have special characteristics: elasticity, texture, durability, wind resistance, thermal insulation, water resistance [19], [20].

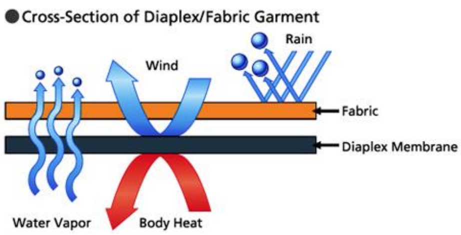


Fig.5: *Diaplex Layered Complex Section [19]*

When the temperature in the clothing is low, the Diaplex membrane responds by lower permeability to prevent the passage of air and water molecules through it, thus maintaining body temperature. As the temperature inside the garment increases, the microbrownian movement will increase the permeability of the membrane, causing the expulsion of water vapor into the outside air and increasing the volume of air absorbed. This "flexible barrier function" allows clothing to adjust its insulating properties in response to temperature changes, ensuring optimum comfort in any possible environment, especially at extreme temperatures [21].

In the case of a protective clothing product for firefighters, the fibers with the shape memory inserted between the thermally insulating layers of the laminate complex will influence the amount of embedded air and thus will more effectively protect the body at high temperatures (Fig. 6) [22].

Shape-changing textiles are used for fireproof underwear or clothing (using of alloys), as well as for footwear, high permeability products, with good thermal insulation and resistant to bending (with polymer films).

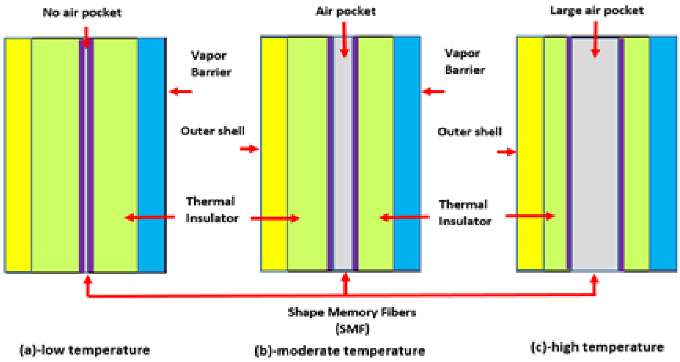


Fig.6*: Adaptation to temperature of smart textile product [23]*

2.2. Phase Change Materials in textiles

These materials (PCM) are also called stored latent energy materials, due to their availability to store energy when there is no demand for it and to generate it for consumption when the demand exceeds its production [24]. They are one of the solutions for energy management, storage and generation of energy appearing when changing the state of aggregation (melting / solidification). The behavior of PCM materials can be described as follows: upon solidification, the material releases large amounts of latent heat of solidification, while with its melting, an equal amount of energy is consumed from the environment. A thermal cycle can be established. Water is a PCM, it becomes ice or vapor when energy is added or consumed. PCM technology benefits from exactly the same law of physics, and other such substances would be inorganic salts, mixtures of wax and paraffin.

There are several types of phase change, such as: solid-gas and liquid-gas transformations with latent heat with the highest value, complemented by a considerable change in volume; solid-solid transformation with the lowest latent heat, as well as minimal volume variation at the change of phase. The latent heat in case of solid-liquid transformation (the most important PCM) has a higher value, while the volume variation is approx. 10%.

PCM materials are therefore directly influenced by the temperature factor, ensuring its regulation and being used in the aerospace industry, textile industry (clothing, linen and footwear), construction, agriculture, telecommunications etc.

To keep the body temperature constant and ensure the comfort of the wearer in varying environments, Burlington Worldwide, Outlast Technologies and Ciba have designed Smart Fabric technology based on the use of versatile materials to adapt to changes in outside temperature.

This technology is based on the introduction into the fibers and structures of some PCM microcapsules (Thermocules) (Fig. 7). They maintain a constant body temperature, by absorbing and releasing heat for increased comfort, without compromising the characteristics of the fabric [25]. The technology is used for outdoor sporting goods, bedding, mattresses, blankets, duvets and pillows, clothing (T-shirts, blouses, dresses, fabrics or knitwear), footwear, but also packaging, military or medical applications, as well as car covers (Fig. 8) [26].

A PCM paraffin absorbs 20kJ / kg of heat during the melting process, which is then released into the environment during cooling. More recently, this technology is used for clothing for motorcyclists, snowboard boots, cushions and wheelchair covers, which keep the skin drier and cooler to prevent pressure escares.

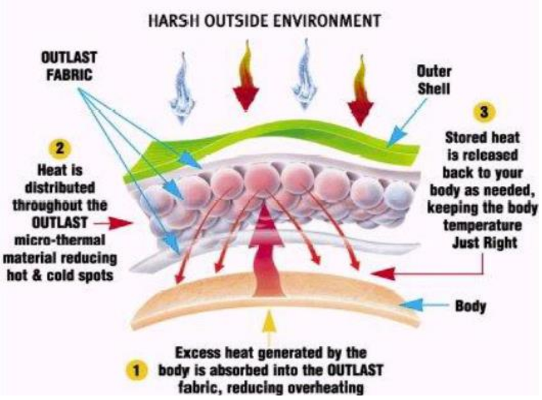


Fig.7: *Smart Fabric technology principle [9]*

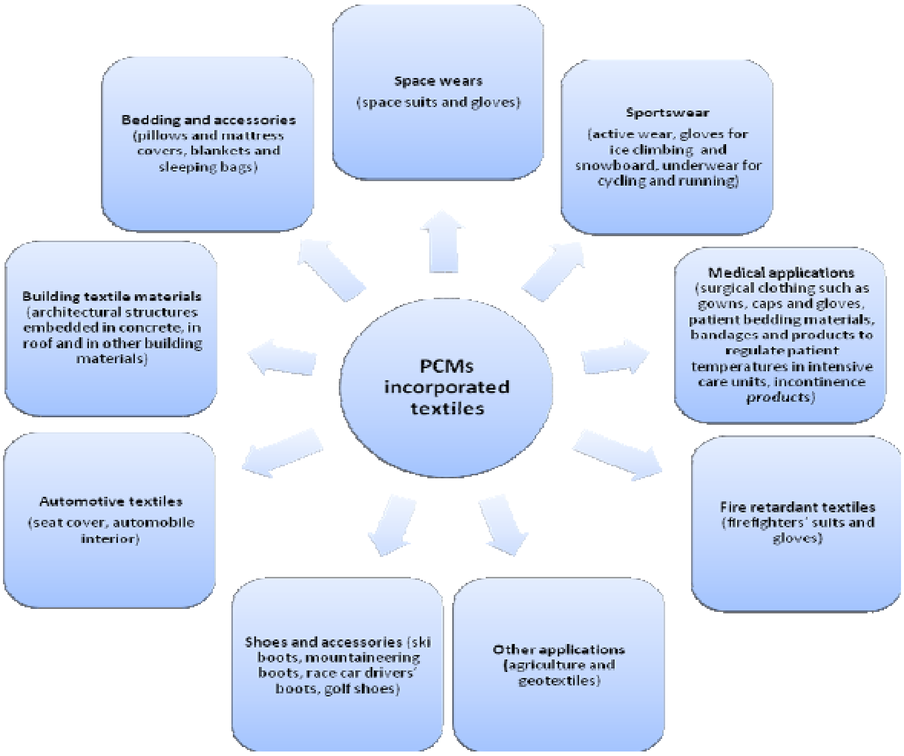


Fig.8: *PCM applications [26]*

There are certain limitations in clothing products from PCM materials design, the most important issue being the phase change temperature (approximately 30-35°C, close to body temperature).

2.3. Chromatic textiles

These materials have the ability to change color due to external stimuli. Depending on the nature of the external stimulus, chromatic materials can be classified into:

• Photochromic: reacting to external light stimulus
• Thermochromatic: external stimulus - heat
• Electrochromic: external stimulus - electricity
• Piezochromatic: external stimulus - pressure
• Solvatochromatic: external stimulus - liquid or gas

Photochromic materials change color under the action of light, an example known for them being sunglasses lenses, but also other products, T-shirts or footwear, reactive in the presence of this factor (Fig. 9) [28].

***Fig.9**: Changing the color of an umbrella to a) shadow and b) in sunlight [28]*

Thermochromatic materials are influenced by heat in the presence of cells with thermochromic dyes, which are activated when certain temperature levels are reached. They are used in the case of protective clothing in low visibility conditions, clothing for firefighters, for signaling emergency routes, making toys, etc.

Figure 10 [27] shows the color change cycle of a printed knit using the Americos Thermochromic Red pigment.

a) b) c) d)

***Fig.10**: Stages of thermochromatic material under the action of temperature [27];*
a) original printed drawing at a temperature below 31 ° C
b), c) discoloration of colors towards white after ironing; d) cooling with return to the original colors

Electrochromatic materials change their appearance repeatedly and reversibly under the action of electric current. One way to make electrochromic textiles is to cover the conductive nanofibers with specific dyes (Fig. 11).

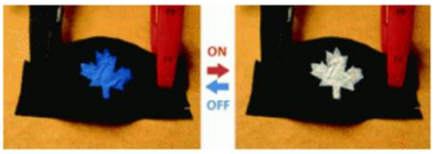


***Fig.11**: PEDOT carpet with thermochromic dye [28]*

2.4. Conductive textiles

Conductive textiles allow the passage of electricity through them, having properties such as: low mass, durability, low production costs, high flexibility, having the ability to be glued and subjected to textile processing. It is made using conventional technologies made of synthetic yarn with particles of carbon, nickel, gold, silver or metal or coated with conductive polymers.

As cotton, polyester or nylon are not conductive and therefore cannot perform the communication and power supply functions necessary for smart clothing, it is preferable to combine them with metallic wires, such as copper.

In this direction, researchers at MIT Media Lab used silk threads wrapped in copper foil. The wires thus made have a high conductivity. The warp thread (called organzin) is obtained by two simple threads, twisted in the opposite direction of the twisting of the threads and wrapped with a thin strip of copper. This band gives the assembly increased conductivity and flexibility, and the design is similar to a telephone cord. Because the construction thus made is durable, the thread can be used for sewing or embroidery operations with the help of industrial machines.

The addition of Ni, Cu or Ag as surface layers with different thicknesses in a textile material gives it special electrical and physical properties, such as thermal conductivity, which, in the case of fabrics, will increase substantially after the process of metallization of fibers.

An example is the wires made of synthetic and metallic fibers produced by DuPont, which can conduct electricity. Aracon fibers are made of a Kevlar core (an amide with special mechanical properties, being 5 times stronger than steel, considered at an equal weight) coated with silver, nickel, copper, gold or tin. They combine the strength of the core with the conductivity of metals, the result being stronger than steel, more flexible and lighter than copper and a good conductor of electricity. The yarns can be woven or knitted together with cotton or polyester in e-textiles.

Fig 12:*Textile electrode for ECG measurements [48]*

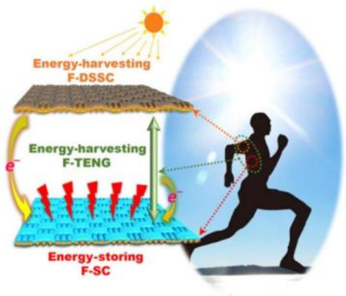
In order to create and combine properties such as flexibility, user comfort and the ability of the device to be miniaturized and fashionable, the designers use different solutions such as carbon nanotubes, graphene, polymers and elastomers and dielectric composites, depending on the requirements of the applications and of their behaviors to different stimuli.

ECT (Electric Conductive Textiles) are the materials made of glass fibers coated with a few nanomers of carbon and which can be woven or knitted with any type of glass fibers or yarns. Carbon provides electrical conductivity and electrical resistance, and the latter can be a source of electric heating.

3. E-TEXTILES

E-textiles can be defined as textile fabrics with additional functions determined by the conductive elements or electronical components (sensors, actuators and control units) [29], [30]. Suplimentar caracteristics for the new functions can be sensitivity, heating, lighting, parameter measurment and recording. In the same time, e-textiles can be considered electronic products with textiles properties derived from the textile platform. Conventional textile features are needed to assure the mechanical properties during use and maintenance: tensile, abrasion, shearing, torsion, compression, bending. If the e-textile is designed to be worn close to the body, it had to satisfy the requirement of the wearer: to be comfortable and breathable.

a)



b)

***Fig.13**: a) E-textiles applications; b)Principle of the fiber-based, self-charging power system consisting of fiber-shaped triboelectric nanogenerator, fiber-based, dye-sensitized solar cell energy harvesting fabric, and fiber-based supercapacitor energy-storing fabric [31]*

E-textiles have the great advantage of the flexibility and, in some cases, extensibility, which means that they can be processed, tailored to the human body like conventional textiles for clothing (such as shirts, dresses), allowing a person to "wear" electronic devices effectively. At the same time, they can take the form of household or even decorative objects. Regardless of their destination, one can notice properties and functions that they must fulfill and which are typical of conventional textiles (aesthetics, comfort and protection), but unlike traditional electronic devices, e-textiles must have different properties:

• Low power consumption. Due to the impossibility of having external energy sources and high mass accumulators, the energy consumption must be very low. Finding an architecture that minimizes the number of processing and communication nodes is required. There are also methods of generating energy, including photovoltaic or solar cells, thermoelectric generators, piezoelectric nanogenerators, triboelectric nanogenerators, biofuel cells, electromagnetic generators and radio frequency harvesters, kinetic or thermal energy, but the energy consumption of smart clothing must be as low as possible [31]. The energy sources structure, size, power density and energy output are designed according to the type of product. They have to conform to the body and be flexible, resistent and nontoxic.

• Distributed processing capacity. The limitation of the processing power of a single node is due to constraints such as cost, size and consumed energy. Modern techniques such as parallel processing will be needed to maximize the computing power of existing nodes. At the same time, the constraint related to energy consumption implies finding optimal processing solutions and optimal use of computing power.

• Multiple communication channels. The existence of several processing nodes implies the use of several communication channels. The presence of faults requires a topology and protocol that take into account both communication errors and the reconfiguration of the network.

The complex nature of smart textiles requires special attention in cutting operation, which must consider the arrangement of integrated circuits on the material and the right connections. Simple devices such as resistors, capacitors or coils can be sewn directly onto the fabric. Other components, such as LEDs, quartz crystals, or surface mount components (SMDs), are tinned to the existing metal structure. Devices such as integrated circuits can take the form of staples or buttons. They can use fabric-mounted plinths to be removed during the cleaning process.

Electronic systems integrated in textiles are used for image sensors, flexible displays, biomedical devices and other emerging applications. In this regard, organic conductors and semiconductor materials with good flexibility and processability at low temperatures are designed. The deposition of thin films of inorganic materials or carbon nanotubes, graphene wafers, nanoparticles, nanowires, nanoribbons or semiconductor nanomembranes allow the obtain of high performance circuits that are not only flexible but are, in some cases, reversibly extensible, with elastic responses to compression and tensile deformations of 100% or more [32].

Figure 14 shows an example of a fabric-fixed CMOS (complementary metal-oxide semiconductor) inverter. Even after bending by about 5 mm, the inverter works well, as shown in the lower right frame of Figure 15 bottom. This type of e-textile offers better performance than yarn or fiber-based alternatives, but there is a limitation given by the manufacturing process. PDMS (Polydimethylsiloxane) adhesion layer covers the fibers of the fabric to achieve pasting without forming chemical bonds with the fibrous substance [33].

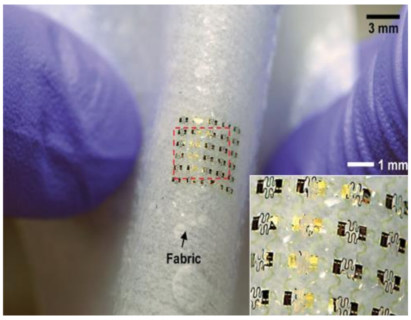


Fig.14*: Electronic circuit integrated on a laminated complex with a thin layer of PDMS [33]*

As the existing metal structure in some e-textiles cannot be rebuilt as a result of cutting and sewing operations, it is preferable to design intelligent products from as few parts as possible. However, by synchronizing the conductive network with the fabric design, the electrical network of the product can be reconnected by sewing. The endurance of wearing and washing smart clothes can be improved by protecting the metal wires and components with a synthetic polymer. It has been found that the adhesives and the conventional way of gluing cause the connections between the fibers and the chips to break under conditions of automatic washing. A viable alternative to these may be dry cleaning.

Because most applications of e-textiles are used in the medical field, protective clothing and sportswear, special attention is paid to product maintenance activities. For repeated use of e-products, both household and industrial washing are required, especially for medical and protective equipment. Sometimes, an operation is required to restore the serviceability of the products after cleaning.

Regarding the production process of e-textiles, testing must be done to ensure client compliance. The life of the products is influenced by the washing resistance, evaluated in relation to the most appropriate standards. Standards for household washing of textile materials (ISO 6330:2021) industrial washing of work equipment (ISO 15797:2017) or leisurewear and sportswear e-textile systems (IEC 63203 204-1:2021) are used. IPC 8981 are new standards that clarify the issues of washability and reliability [29].

4. SMART CLOTHING SYSTEMS

The most popular products that work as wearable technology are:

• Smart watches: Connected watches, such as the Apple Watch or Samsung Galaxy Watch, that allow the wearer to answer phone calls, track fitness, track sleep, and more.

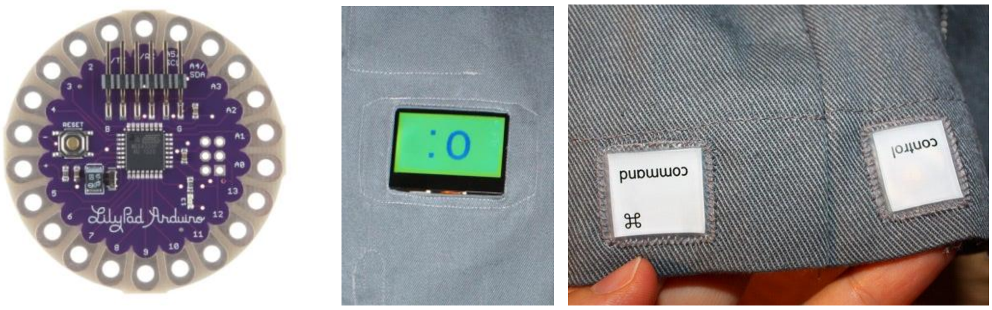
• Smart rings: technical jewelry that concentrates the functions of a smart watch in a ring.

• Smart clothing: clothing made of technologically advanced material or incorporating electronic command, control or monitoring devices.

• Advanced medical technology: "holter" type systems that allow the monitoring of the electrocardiogram or other physiological parameters and that transmit data to the cardiologist or to the first aid units.

• Head-mounted displays (HMDs): VR virtual reality headsets or other types of displays (on glasses) that allow you to identify, recognize various objects and situations, or interact in a game.

Many smart clothing and wearable technology projects involve the use of e-textiles [34]. They fulfill their main role, that of barrier for the human body, but they extend their functionality by informing, protecting and relaxing the wearer. By integrating electronic components, sensors and interconnectivity directly into garments, the number of functions of traditional clothing is increasing, creating new applications. Smart clothing products have a new property; they allow the exchange of information. They participate in the recording, analysis, storage, sending and display of information, with applications in protection (danger detection and request for help), medicine (for monitoring health and treatment of injuries), army (uniforms with motion detection, temperature measurement, health assessment), sports (monitoring parameters), IT (textile keyboard, computer interface and games).



a) *b)*

***Fig.15**: a) LilyPad Arduino [39]; b) Jacket with an LCD display [38]*

The hardware based on Arduino micro-controllers has remarkable potential [35]. LilyPad Arduino 328 is a microcontroller programmed by Arduino, designed to be easily integrated into e-textiles and wearable technologies. It offers the same functionality as the Arduino, in a lighter, round wiring, designed to minimize clamping with a profile with wide ears that can be sewn and connected with conductive thread. It works with supply voltages from 2V to 5V and has large fixing holes that make it easy to sew and connect. Each of these pins, except (+) and (-), can control an attached input or output device (such as an LED, motor, or switch) [37].

LilyPad (Fig. 15a) was developed by Leah Buechley and designed in cooperation with SparkFun, which allows the connection of a limited number of input, output and sensor devices, but with the great advantage that it is washable.

The web page from [37] presents a jacket that integrates a LilyPad, two buttons and a display to select and display emoticons (fig. 15b). In addition, in the direction of making interactive clothing or for expressing emotions using Arduino controllers, an evening dress was implemented that achieves various lighting effects using LEDs. Another example would be the use of an accelerometer to detect gestures and the display of groups of LEDs in the form of constellations on a dress (Fig. 16) [39].

Fig.16*: An evening dress with light effects depending on the condition of the wearer and an example of a dress that displays constellations [39]*

Levi’s Trucker jacket with Google Project Jacquard technology (Fig. 17b) is the second version (2017) of the smart jacket designed for cyclists, after The Commuter line (Fig. 17a) developed in conjunction with Schoeller in 2011. This jacket applies built-in Jacquard technology, which allows it to be used without looking at the screen. It is equipped with a touch-sensitive remote control element for phones in the cuff of the left sleeve that connects wirelessly to the phone. The technology allows using touch gestures, such as swiping and tapping on the left cuff of the jacket to give commands about taking photos, requesting useful information, visual and haptic timing, pausing music, or choosing a song. In terms of maintenance, the denim jacket is usually washed after removing the Jacquard label [40], [41].

Dainese Airbag D-Air Smart Jacket [42] (Fig. 17c) monitors the rider 1,000 times a second with a waterproof sensor. The D-air airbag system at the rear and front offers maximum protection to the rider. It is well ventilated and easily foldable. The material is abrasion resistant, tear resistant and antipiling and has a rechargeable battery of up to 26 hours.

Project One is the world's first smart sailing jacket (Fig. 17d), produced by Plastic Logic and 878, including a small rectangular display in the sleeve with navigation information. The jacket is made of graphene material, with a high flexibility and weather resistance, and a low weight. This material fits the display, which also has high flexibility and low power consumption. The information will be obtained from the on-board systems of the boat and will be transmitted in real time on the display via Bluetooth. The display is powered by a small system that is built into the jacket, with an integrated battery, requiring the jacket to be charged from time to time. A mobile application allows users to choose the information they want to see on the sleeve screens in almost any visibility condition. [43]

The heated jacket has five heated areas, 2 at the front, 2 at the back and 1 at the neck. By pressing a button on the jacket, one can choose three temperatures. The Bluetooth application sets the heating time on the mobile phone. The base material of the jacket is made of DuPont Eco Cotton, being also waterproof. Washing can be done manually or by machine at a temperature of up to 30 C, with the specification that the battery must be removed from the jacket pocket before washing. The filling of this jacket is made of nylon / polyester and 80% duck down and contains carbon fiber heating elements with a fast warm-up time of 10 seconds.The jacket is resistant to cold wind and good thermal insulation, promoting blood circulation [44].

a) b) c) d)

***Fig.17**: a) Levi's – Commuter Jacket; b) Smart Denim Jacket, from Google and Levi's; c) Dainese Airbag D-Air Smart Jacket; d) Project One, the smart sailing jacket; e) Heated Jacket*

Additional functions of intelligent systems refer to the continuous monitoring of vital signs (breathing, heartbeat, and temperature), biosensors (sweating, dehydration, and stress indicators), position and activity control. Communications uses low power wireless devices, including integrated fiber antennas, which automatically transmit data to a monitoring station, improved visibility, external chemical detection, including toxic gases and vapors, flexible displays integrated with sensor output display, power generation and storage [45]. These functions are noticeable both in protective equipments and in military and medical applications.

***Fig.18**: Wearable antennas and military applications [46]*

The military uniform can be developed by creating a textile that detects noise with the help of microphones, which can be replaced by film-type piezoelectric sensors. Antennas built into military uniforms are made of a cloth with conductive threads, which is the radiant part of the antenna and is sewn over the uniform. Fire protection equipment, equipped with gas and temperature sensors can be another application of smart textiles.

Ordinary clothing usually dries naturally and requires a period of drying depending on environmental factors. In this case, it is passive drying. The presence of a moisture sensor in the fabric that measures the increase in humidity and activates an internal heat source defines an active drying process (Fig. 19).

Athletes' suits (jackets, pants or underwear) equipped with motion, temperature and impact sensors, as well as GSM and GPS systems may in an emergency send location and fitness information directly via SMS to a control center [34].

The Luminex material madely first in Italy is realized by inserting LED fibers of different colors in the fabric (Fig. 20a). A certain position of the switch will activate the LEDs in one of the available colors. The lighting effect can be created with optical fibers that have a long length and a thickness comparable to that of human hair, which can be woven into a fabric and connected to LEDs.

***Fig.19**: Smart textile clothing; a),b) jacket with Airvantage insulation (Goretex); c) MET5 heated jacket (North Face)*

Philips, in collaboration with Photonic Textile Group, has designed Lumalive technology that allows the wearer to change the appearance of the clothing product (mutant clothing) to convey messages or emotions, using different combinations of colors, light and textures (Fig. 20b) [47].

The technology refers to the incorporation of LEDs with three basic colors in a flexible polymeric support and the introduction of the laminated complex inside the various subassemblies of clothing products. Connecting it to an electric system and covering it with layers of textile fabric allow light to diffuse and highlight different motifs on the surface of the material (fig. 20b).

a) b)

***Fig.20**: LED technology a) Luminex garments; b) shirt created using Lumalive, developed by Philips*

Medical products are the main concern of researchers in the field of smart textiles. Levi Strauss has designed anti-radiation clothing to protect against possible radiation emitted by mobile phones, and the Hohenstein Institute Textile Research Center has developed products that combat dermatitis and rheumatism. The power supply problem for medical and sports equipment has found a practical solution in using a semiconductor as a heat generator (according to Infineon Technologies). Its operation is based on the transformation of the temperature difference between the human body and clothing into electricity.

Newborn clothing is another example of the use of e-textiles. They detect when the child is out of breath or need care and send the alarm to the parents. By monitoring heart function, respiratory function, and body temperature, sudden death syndrome can be prevented.

Nuubo had designed a medium / long-term ECG monitoring system that replaces the classic electrode application and connection technology with textile electrode technology embedded in a stretchable vest (Fig. 21a). The Nuubo textile electrode is a Silver textile-electrode composite with ECG cream and avoid the skin allergies. The seamless elastic fabric in both axes has flexibility and allows patients to move freely, beeing comfortable and washable. NuuboREC with two ECG Leads allows up to 30 days continuous recording, Bluetooth low energy transmission for real-time monitoring and signal evaluation [48]. The system allows a remote diagnostic in order to improve the early illness detection.

a) *b)* *c)*

Fig.21*: a) Nuubo ECG patient monitor; b) Weartech Men's Gow Smart T-Shirt; c) Xiaomi Mijia ECG T-shirt*

Another medical application is consisted by Weartech Men's Gow Smart Sports T-Shirt (Intergrated Cardiac Sensors) [49]. Seamless fabric of 92% Polyamide and 8% Elastane technical yarns with Bosy thermoregulation ensures good comfort and moisture transfer to the outside. The T-Shirt has integrated textile sensors to measure heart rate, calorie, fat and carbohydrate burn (Fig.21b).

Xiaomi Mijia Sports ECG T-shirt (Fig. 21c) made of 49% cotton, 48% polyester and 3% spandex has completed with Mijia ECG Bean connected by Bluetooth 4.0. The T-shirt monitors the heart rate in real time during a 1-minute exercise with a high sampling rate of 250 times per second. The smart ADI ECG chip is attached to an elastic Co-tech nylon band on the chest of the shirt and signals the heart rate in different colors to prevent injury. The shirt can be washed and the waterproof rating is IPX7 [50].

5. CONCLUSIONS

The e-textiles are combining the warp or weft structure with electronics devices in order to control, measure, communicate, command and serve the purpose of the owner. As most of the textile products are washable, versatile, lightweight and cheap, their incorporated electronic components are the opposite, unwashable, delicate, fragile and electrically powered. Therefore, the future e-textiles must be water and mechanical resistant, in order to comply with the traditional textiles qualities.

In comparison with electronic sensors, the composite textile equivalent have many advantages. For instance, e-textiles are malleable and subtle; therefore, they can pass unobserved by the bearer or the observer. Depending on the base material, the can be also smooth and breathable offering an important advantage. Nowadays, most of the smart textiles are embedded in high-technology products and could be found on the shelf of many stores. Although, the medical application are still subject to approval and standard compliancy by the national authorities.

However, reusing them without losing their qualities is a significant concern. One of the most significant issues for e-textiles is to make them reusable and efficient enough, as well as to make them durable and reusable beyond the washing process. Another challenge with electronic textiles is figuring out how to combine the best materials to achieve the needed properties and produce hybrid materials from both a textile and an electrical standpoint. Because of the miniaturization of the electronics industry, these electrical components are now available on the market, and study into their inclusion into textiles has piqued academics' attention. In addition, by developing methods for incorporating electronic chemicals into fabrics, some of the disadvantages that come from the maintenance process of e-textiles can be eliminated.

REFERENCES

[1] Rai, P., Oh, S., Shyamkumar, P., Ramasamy, M., Harbaugh, R., Varadan, V. (2013). Nano- Bio- Textile Sensors with Mobile Wireless Platform for Wearable Health Monitoring of Neurological and Cardiovascular Disorders. Journal of the Electrochemical Society. 161. B3116-B3150. 10.1149/2.012402jes.

[2] Gaddis, R. (May 7, 2014). "What Is The Future Of Fabric? These Smart Textiles Will Blow Your Mind". Forbes.

[3] Kunal Mondal, Recent Advances in Soft E-Textiles, Inventions, vol. 3, no. 2/23, 2018

[4] Burcu Arman Kuzubaşoğlu, Meltem Tekçin, Senem Kurşun Bahadır, Electronic Textiles (E-Textiles): Fabric Sensors and Material-Integrated Wearable Intelligent Systems, Reference Module in Biomedical Sciences, 2021

[5] P.K. Hari, Types and properties of fibres and yarns used in weaving, Wov. Textiles, 2012

[6] Victorino, M.N. & Jiang, Xianta & Menon, Carlo. (2018). Wearable Technologies and Force Myography for Healthcare. 10.1016/B978-0-12-811810-8.00007-5

[7] Rita Paradiso, Laura Caldani, Maria Pacelli, Knitted Electronic Textiles, Wearable Sensors, Pages 153-174, ISBN 9780124186620, 2015

[8] https://www.idtechex.com/en/research-report/e-textiles-and-smart-clothing-2021-2031-technologies-markets-and-players/828

[9] http://www.sinuc.utilajutcb.ro/SINUC-2010/SECTIA--IV/10.IV.22.pdf

[10] Bujoreanu, Leandru-Gheorghe, Materiale inteligente, Editura Junimea, Iaşi, 2002

[11] Roberts, C.A., Intelligent material systems – The dawn of a new materials age, Journal of Intelligent Material Systems and Structures, 4-Jully, 1993, ISSN 1045-389X, 4-12

[12] Subrata C. D., Debasree P., S. K. Mahamudul H., Nasif C., Smart Textiles-New Possibilities in Textile Engineering, 2013 International Conference on Mechanical Engineering

[13] Clevertex Development of a strategic Master Plan for the transformation of the traditional textile and clothing into a knowledge driven industrial sector by 2015

[14] Gök, M., Bilir, M., Gurcum, B. (2015). Shape-Memory Applications in Textile Design. Procedia - Social and Behavioral Sciences. 195. 2160-2169. 10.1016/j.sbspro.2015.06.283

[15] https://mec.tuiasi.ro/rm/incercari/5.htm

[16] Manualul Inginerului Textilist, Ed. AGIR, Bucureşti, 2003

[17] https://www.gzinnovation.eu/material/7/shape-memory-materials

[18] E. Carpus, R. Scarlat, E. Visileanu, A. Ene, C. Mihai, Textilele tehnice – Directie prioritara de dezvoltare a sectorului textile – confectii, Buletinul AGIR nr. 4/2014

[19] http://www.amaterrace.com/product/dl_2.html

[20] https://www.mcf.co.jp/en/service/diaseries/diaplex.html

[21]E. Ursu, M. Cazac, Studiul materialelor textile performante utilizate in imbracamintea “inteligenta”, Conf_UTM_2010_III_pg_164-165.pdf

[22] https://www.nasa.gov/pdf/413410main_PhaseChange.pdf

[23] https://www.textiletoday.com.bd/smm-creates-sensing-adapting-reacting-capabilities-smart-textile/

[24] C. Grigorasenco, C. Chelmenciuc, Avantajele utilizarii materialelor cu schimb de faza pentru stocarea frigului, Conf_UTM_2016_I_pg358_362.pdf

[25] https://www.outlast.com/en/technology/

[26] Onofrei, Elena & Rocha, A. & Catarino, André. (2010). Textiles integrating PCMs – A review. Buletinul Institutului Politehnic din Iasi. Tom LVI (LX). 99-110.

[27] https://www.fibre2fashion.com/industry-article/3059/thermochromic-colors-in-textiles

[28] A. Laforgue, Electrically controlled colour-changing textiles using the resistive heating properties of PEDOT nanofibers, J. Mater. Chem., 2010, 20, 8233-8235

[29] S. Rotzler, M. von Krshiwoblozki, M. Schneider-Ramelow, Washability of e-textiles: current testing practices and the need for standardization, Textile Research Journal 91(19-20), 2021

[30] X.X. Zhang, X.M. Tao, Smart textiles (1): Passive smart, January 2001Textile Asia 32(6):45-48

[31] Rong, Guoguang and Zheng, Yuqiao and Sawan, Mohamad, Energy Solutions for Wearable Sensors: A Review, Sensors, vol. 21, no.11/3806, 2021

[32] D.-H. Kim, J. Song, W. M. Choi, H.-S. Kim, R.-H. Kim, Z. Liu, Y. Y. Huange, K.-C. Hwang, Y.-W. Zhang, J. A. Rogers, Proc. Natl. Acad. Sci. USA 2008, 105, 18675

[33] D.-H. Kim, Y.-S. Kim, J. Wu, Z. Liu, J. Song, H.-S. Kim, Y. Y. Huang, K.-C. Hwang, J. A. Rogers, Ultrathin Silicon Circuits With Strain-Isolation Layers and Mesh Layouts for High-Performance Electronics on Fabric, Vinyl, Leather, and Paper, Adv. Mater. 2009, 21, 3703–3707

[34] A. Lymberis, "Wearable smart systems: From technologies to integrated systems," 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2011, pp. 3503-3506, doi: 10.1109/IEMBS.2011.6090946

[35] https://www.bbvaapimarket.com/en/api-world/smart-textiles-lilypad-arduino-heart-clothes-can-think/

[36] https://www.sparkfun.com/products/13342

[37] https://www.instructables.com/How-to-make-an-Emoticon-Jacket-with-LCD-screen/

[38]https://www.bbvaapimarket.com/wp-content/uploads/2015/02/buechley_ISWC_06.pdf

[39] https://create.arduino.cc/projecthub/projects/tags/wearables?page=1

[40] https://www.innovationintextiles.com/levis-and-google-launch-new-smart-denim-jacket/

[41] https://shellzine.net/levis-icd/

[42] https://www.motomus.ro/airbag-moto

[43] https://goodereader.com/blog/e-paper/plastic-logic-powers-the-worlds-first-smart-sailing-jacket

[44] https://sidiougroup.com/products/sidiou-group-anniou-duck-down-heated-jacket-with-10000mah-usb-rechargeable-battery-smart-phone-app-control-temperature-electric-heating-jacket-coat-for-women-and-men

[45] https://www.nanowerk.com/smart/smart-clothing.php

[46] https://www.mistralsolutions.com/blog/wearable-antennas-applications-technologies-impact-human-body/

[47] http://digicult.it/design/fluctuating-intelligences/

[48] https://www.nuubo.com/en-us/health-professionals/nuubo-system

[49] https://www.amazon.co.uk/Weartech-T-Shirt-Intergrated-Cardiac-Sensors/dp/B00DM8A7EG?th=1

[50] https://www.aliexpress.com/item/1005001284842633.html

RAW MATERIAL BEHAVIOUR ANALYSIS OF THE PARACHUTE SYSTEM RECOVERY AT LANDING

ENE Alexandra Gabriela[1], MIHAI Carmen[1], JOMIR Mihaela[1], SCARLAT Razvan[1], GROSU Catalin[1]

[1] The National R&D Institute for Textiles and Leather, IT Research Department in Industrial Engineering, 6 L. Patrascanu Street, postal code: 030508, Bucharest, Romania, E-Mail: alexandra.ene@incdtp.ro

Corresponding author: Jomir Mihaela, E-mail: mihaela.jomir@incdtp.ro

Abstract: *For the stabilization and braking of military aircraft during operations, special parachutes are used, which the pilot decouples, thus allowing the restoration of the flight attitude. The parachutes used for landing drag of MiG 29 Sniper supersonic aircraft are made of p-aramid yarn fabrics. The paper presents the experiments performed in the accredited laboratories of INCDTP regarding the analysis of the behavior of p-aramid fibers and threads in order to obtain the fabric that is used to make the braking systems. The stretching behavior of the para-aramid filament in the conditioned and wet state showed that it has a rectilinear path of the curves, different from the curvilinear and continuous one of the usual textile fibers, and the high elastic modulus will cause small deformations under the action of a force. The decrease in the values of resistance and elongation at break and the mechanical breaking work for the para-aramid filament in the wet state is determined by the penetration and attack of water in the amorphous phase in the microcapillaries of the fiber. On the other hand, the behavior of the para-aramid thread after the winding and weaving operations highlighted the fact that very large deformations of some constituent filaments appeared, in some cases even their rupture (reaching the limit load), which determines a redistribution of tensions throughout the yarn, avoiding breakage and the yarn proves that it no longer has a brittle material behavior.*

Key words: *parachute, canopy, deceleration system, para-aramidic yarn, statistical data.*

1. INTRODUCTION

In the aeronautical field currently are used a wide range of parachutes, differentiated in terms of raw material, shape, as well as aerodynamic performance: stability, air resistance, air drag resistance, opening speed and altitude. The most important application of textile materials is the one in which they are integrated in the set of recovery systems for supersonic aircraft, bumpers and space capsules (planetary parachutes). The aerodynamic characteristics of a deceleration system refer to the value of: the ratio Dc / D_0 (Dc = diameter of the parachute, obtained from the design and D_0 = nominal diameter of the parachute); ratio Dp / D_0 (Dp = projection diameter in the opened state); air drag coefficient and oscillation angle. $\propto$ [1,2] Thus, for the main parachute canop y, p-aramid yarn fabrics are used if the application of the deceleration system aims at:

- break (**Fig. 1**) the shape of the main parachute is surface guidance without ribbons, with D_c/ D_0 = 0,66; D_p / D_0 = 0,62; C_{x0} = 0,30 – 0,34; $\propto$ = 0° ÷ ± 3°). They operate very well at speeds from 0,1 Mach (34,0 m/s) pînă la 1,4 Mach (476,53 m/s). [1,2]

- stabilization - deceleration bombers (**Fig. 2**) with a mass of 160,000 lbs (72,480 kg) at altitudes of at least 30,000 ft (9,150 m). [3] For these parachutes the shape is surface guidance with ribbons which allows to obtain the following aerodynamic characteristics: D_c/ D_0 = 0,63; D_p / D_0 = 0,62; C_{x0} = 0,28 – 0,42; ∝ = 0° ÷ ± 2° [2,3].
- for the descent of space shuttles from an altitude of 18,000 ft (5490 m) and dynamic pressures of at least 90 lb/ ft^2 (4.87 kg / m2). (**Fig. 3**) [1.5]. The aerodynamic characteristics of these types of parachutes - parawing - are: D_c/ D_0 = 1,0; C_{x0} = 1,1 (MIL –C – 38351) [4,6].

Fig. 1*: Surface guidance without ribbons parachute*

Fig. 2: *Surface guidance witht ribbons parachute*

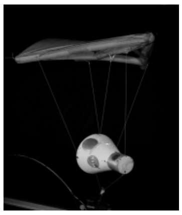


Fig. 3: *Parawing*

- stabilization - deceleration on landing supersonic aircraft, due to the excellent aerodynamic characteristics: high forward resistance coefficient and stability, which do not allow the intervention of the system in the stability of the aircraft. (**Fig.4**) The shape of these parachutes is cross and the following aerodynamic characteristics can be obtained: D_c/ D_0 = 1,15 - 1,19; D_p / D_0 = 0,66 - 0,72; C_{x0} = 0,60 – 0,85; ∝ = 0° ÷ ± 3° [4]
- descents - planetary braking of capsules and space modules (**Fig. 5**), when it comes into operation from altitudes of 100,000 ft (30,500 m), at speeds higher than 3 Mach (1021.14 m / s). These parachutes are hemispherical and have the following aerodynamic characteristics: D_c/ D_0 = 0,62; D_p / D_0 = 0,62; C_{x0} = 0,30 – 0,46; ∝ = ± 2° [4.7]. Space shuttles are also used for deceleration on landing, with a maximum landing mass of 240,000 pounds (108720 kg), a maximum opening speed of 230 kts (118.4 m / s) (Img. 5). [1,4,7] and supersonic aircraft to a maximum landing mass of 45,000 pounds (20,385 kg), at a maximum opening speed of 173 kts (89.02 m / s). [1].

Fig. 4*: Cross parachutes for deceleration and stabilization*

Fig. 5*: Hemisflo parachute for space probe, capsule or module and shuttle deceleration*

- lowering the space shuttle modules (**Fig. 6**) because the following performances are required: gliding ratio: 0.85; turn: 180 ° in 3 seconds, plus landing requirements in a preset area at a wind speed of min. 30 kts (15.44 m / s), the opening forces should be from 3 to 4 g, the landing impact forces should allow 4 g to be reached and obstacles from the ground could be avoided. These parachutes are known as Le Moigne (Paracommander) and have the following aerodynamic characteristics: D_c/ D_0 = 1,0; C_{x0} = 0,9 – 1,0. [6,7,8]
- deceleration on landing of supersonic bombers (**Fig. 7**) [6,7] Parachutes for supersonic aircraft have diameters of 14.5 - 16 ft (4.42 - 4.88 m), for landing speeds of 180 - 200 kts (333.5 - 370.6 km / h). [6,8,9] Canopies must meet MIL-C-8021 requirements. The parachute used in bombers is 15.6 ft (4.76 m) in diameter to decelerate 128,000lb (57,984 kg) at 30,000 ft (9,150 m) and must meet the

requirements of MIL 3835. The design for these types of applications is annular [9, 10] and must develop the following aerodynamic characteristics: $D_c/ D_0 = 1{,}10$; $D_p / D_0 = 0{,}67 - 0{,}69$; $C_{x0} = 0{,}45 – 0{,}50$; $\propto = 0° \div \pm 3°$ [10]

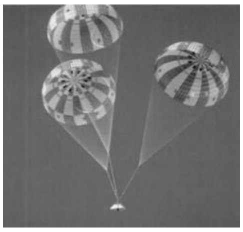


Fig. 6*: Le Moigne (Paracommander)*

Fig. 7*: Annular parachute*

2. MATERIAL AND METHOD

2.1. Analysis of the behavior of para-aramid fiber

The design criteria for the parachute recovery system of MiG 29 Sniper supersonic aircraft were based - by INCDTP specialists - on the physical phenomena underlying the deceleration on landing, namely turbulent motion and air velocity in front of the canopy tending to zero at a point of stagnation in front of the leading edge of the wings of the main parachute. The structural analysis of the canopy was performed using a specialized software The structural analysis of the deceleration parachute canopy was performed through a specialized program that allowed the identification of the values of the main parameters for the woven structure and the raw material from which it is made. In this respect, the fabric must meets the following requirements: - temperature resistance developed behind the aircraft engines: min. 300 ° C; - resistance to difficult weather conditions; - small mass and volume, determined by the aircraft configuration. These extremely restrictive requirements for a textile material can be met by using a raw material with special characteristics, represented by para-aramid yarns. In order to establish the main directions regarding the behavior on the technological flow from the weaving preparation, the behavior of a yarn with a density density of 220 dtex/f 134 was analyzed, as well as of the constituent filaments. Additionally, in order to highlight the changes in the characteristics of the yarn on the technological flow of processing, physical-mechanical analyzes were performed after dyeing and warping operations. The determinations were performed in INCDTP accredited laboratories according to SR EN ISO / CEI 17025: 2001. Para-aramid filaments with a fineness of 1.64dtex (average diameter of 12.79µm) were tested to the tensile stress in a wet and conditioned state. The stress / strain diagrams were drawn (**Fig. 8** and **Fig. 9**).

To verify the behavior in the technological processes, as well as the fragility of this type of filament, the breaking strength, the elongation at break and the mechanical work of breaking in the form of a loop were determined. The stress/strain diagrams resulting from the determinations are shown in **Fig. 10.**

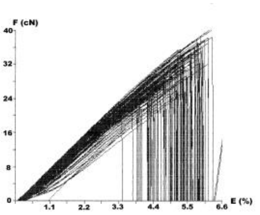


Fig. 8*: Stress-strain diagram – conditioned state testing*

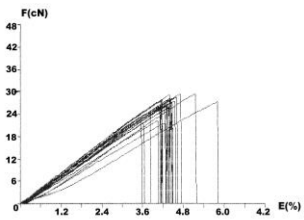


Fig. 9*: Stress-strain diagram – wet state testing*

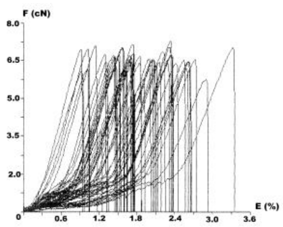


Fig. 10*: Stress-strain diagram – loop testing*

2.2. Para-aramid yarn behavior analysis

To demonstrate the tensile behavior of p-aramid yarn, the para-aramid yarn 220dtex / f134 was tested, in a conditioned, wet state and after heat treatment at 250°C. The obtained stress / strain diagrams are illustrated in **Fig. 11, Fig. 12** and **Fig. 13.**

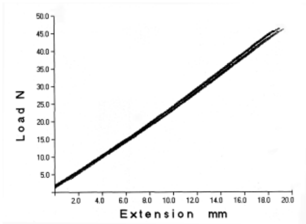


Fig. 11*: S*tress-strain diagram – conditioned state testing

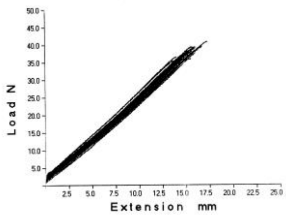


Fig. 12*: S*tress-strain diagram – wet state testing

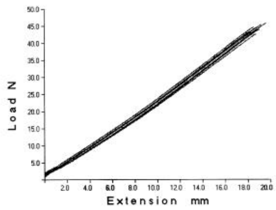


Fig. 13*: S*tress-strain diagram – loop testing after heat treatment

In order to highlight the level of characteristics of the p-aramid yarn, the yarn went through a series of operations such as winding and warping using machines from the weaving preparation within the microproduction weaving department of INCDTP. The winding operation was performed on with a speed of 6000 rpm and a tension of 0.4 cN/dtex. The warping was performed for a warping speed of 250 m/min and a folding speed of 25 m/min. 40 determinations were performed, the tests being performed within INCDTP, according to SR EN ISO 2062-2000. The diagrams of the values obtained for the wound yarns are shown in **Fig. 14** and the diagrams of the values obtained for the the warped yarn are shown in Fig. **15**.

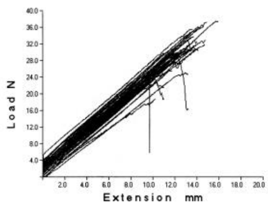


Fig. 14*: Stress/strain diagram - testing after winding operation*

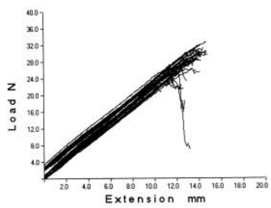


Fig. 15*: Stress/strain diagram - testing after warping operation*

3. RESULTS

The values resulting from the database processing, regarding the behavior of the para-aramid filament tested in the conditioned, wet and loop state are presented in Table 1.

Table 1: *Behavior of the para-aramid filament in conditioned state, wet state and in the loop test*

Statistical data	conditioned state		wet state		loop test	
	x_{med}	CV	x_{med}	CV	x_{med}	CV
breaking strength, cN	31.33	14.98	28.77	8.68	6.59	8.67
Elongation at break, %	5.10	13.05	4.34	10.39	1.87	29.06
Mechanical work, cN.cm	0.81	30.03	0.63	15.96	0.04	17.69

Analyzing the resulting data, it can be highlighted that:

- Para-aramid filaments, both in the conditioned and wet state, have a rectilinear path of the curves - similar to steel - very different from the curvilinear and continuous one of the usual textile fibers, which leads to the conclusion that there is a proportionality between resistance and elongation. rupture, so we cannot speak of a limit of elasticity, but only of a limit of rupture.
- The loop strength is 10.51% compared to a polyamide filament in which the loop strength is 80-85%, which shows that the para-aramid filament will behave like a fragile material with a low capacity to take over complex stress (stretching and compression).
- The radius of the working hand that could cause the breaking of the filament due to bending is 119 μm (for an elongation at break of 5.1% and a diameter of 12.79 μm), so the yarn can be processed on machines in the textile industry, in practice there are no working hands with such a small radius.

For the para-aramid yarn, the large number of determinations (40) regarding the tensile behavior in the conditioned state, wet state and after heat treatment at 250°C, the Grubbs test was used to eliminate the aberrant values. The calculated values of the statistic g were compared with the tabulated value, $g_{50,\ 0.95}$ = 2.956, respectively $g_{40,\ 0.95}$ = 2.866 for the verification of the null hypothesis. Absolute errors for tensile strength and elongation were determined with a statistical certainty of 95% for $t_{1-\alpha/2;\ \nu} = t_{0.975;\ 49}$ = 2009 and 0.975, respectively $t_{0,975;\ 39}$= 2.021. The values resulting from the tests are presented in Table 2.

Table 2: *Behavior of para-aramid yarn in conditioned state, wet state and after heat treatment at 250°C*

Statistical data	**conditioned state**		**wet state**		**afret heat treatment**	
	x_{med}	CV	x_{med}	CV	x_{med}	CV
Breaking strength, cN	44.70	1.25	44.37	1.95	43.19	3.02
Elongation at break, %	3.47	3.66	3.70	2.80	3.65	4.10
Initial modulus, mN/tex	0.1958	1.43	0.1882	2.55	0.778	2.42

From the analysis of the resulting data the following aspects can be highlighted:
- Applying the aberrant values test shows that the null hypothesis is not rejected, because the values calculated for the assumed minimum and maximum aberrant values are smaller than the tabulated value ($g_{calc} < g_{50;\ 0.95}$, $g_{calc} < g_{40;\ 0.95}$), so should not be excluded from the series of determinations.
- Exposure of the para-aramid yarn to 250°C did not result in significant changes in the values of breaking strength and elongation at break compared to the values recorded for the tested yarn in the conditioned state. The statistical data resulting from the mechanical stress on the machines from the weaving preparation (winding and warping) are presented in Table 3.

Table 3: *The behavior of the para-aramid yarn after the warping and winding operations*

Statistical data	**after warping**		**after winding**	
	x_{med}	CV	x_{med}	CV
Breaking strength, cN	27.95	9.78	28.83	9.00
Elongation at break, %	2.65	9.24	2.62	6.53
Initial modulus, mN/tex	0.1963	3.45	0.1944	4.68

From the data analysis it is observed that:
- the decrease of both the breaking strength and the elongation at break after the stress in the technological processes on the weaving preparation machines can be attributed to the fact that the polymer based on p-phenylene terephthalamide has more accentuated chemical creep caused by the breaking of the bonds in the molecular chain.
- the para-aramid yarn "keeps the information induced" (presents memory) by the fatigue phenomenon due to the mechanical stresses which caused changes in the structure of the filaments,

which explains reductions in breaking strength and elongation at break.

5. CONCLUSIONS

The prediction of the raw material to meet the imposed technical-functional requirements, as well as the prediction of the phenomena that take place during the rolling on landing, were made by the complex structural analysis of the main parachute canopy.

To establish the technological process line of the components, as well as of the assembly parameters and adjustment of the equipment specific to the technological flow of the fabric for the main parachute canopy there were used the results obtained after implementing a complex program for the characterization of the para-aramidic filament/yarn.

In order to carry out the structural analysis of the main parachute canopy, a specialized program was used which allowed: the determination of the unit effort on the surface of the canopy: max. 1238 daN/m^2, visualization of the distribution of the displacement vectors that allow to determine the shape of the canopy and to highlight the deformation of the canopy of the main parachute under the effect of the dynamic pressure.

ACKNOWLEDGEMENTS

This scientific paper is funded by the Ministry of Research and Innovation within Program 1 - Development of the national RD system, Subprogram 1.2 - Institutional Performance - RDI excellence funding projects, Contract no.4 PFE/2021.

REFERENCES

[1] Tihgdahl, M.A., "*Cargo Handling System A/A32H, United States Air Force",* USAF Report AFTC-TR-72-52, 1994.

[2] Menard, G.R.C., "*Performance Evaluation 35-Foot Diameter Extended Skirt Maneuverable Personnel Parachute – Naval Weapons Center"*, (NWC TR-8-66), 2017.

[3] Poynter, D., "*The Parachute Manual,"* Para – Publishing, Santa Barbara, California, 2020, pp 185 - 360.

[4] Morris, F.B, "*Development of a high-speed, low Altitude, Aerial Delivery Parachute System for Use with a Modified C-130 Aircraft*," United States Air Force, USAF Report AFTC-TR-70-33, 2011.

[5] Pepper, W.B. et al., *"Adaptation of a 15-Foot-Diameter Ribbon Parachute and a 73-Foot Cross Main Recovery Parachute for Cargo Delivery Fron High Altitude*", presented at American Institute of Aeronautics and Astronautics, (AIAA 84-0790), 2018.

[6] Peterson, C.W., Johnson, D.W., "*Parachute Materials. Course on Parachute Systems* Technology University of Minnesota, pp 53 – 120, 2018.

[7] Pepper, W.B., Fellerhoff, R.D., "*Parachute System to recover of A Spinning (250RPS) 155-mm Shell Subjected to 20,000 gs Launch Condition*", Sandia National Laboratory Report, (SNL Report SC-R-68-1806), 2020.

[8] Buckley, J.A., *"Missile Recovery System for High-Speed Small-Caliber Missiles,"* American Institute of Aeronautics and Astronautics, , (AIAA 86-2462), 2021.

[9] Brown, W.D., *Parachute,* vol.I,II, London, Cambridge University Press, 1989, pp. 10-30

[10] Knacke, T.W., *"Technical – Historical Development of Parachutes and Their Applications,"* American Institute of Aeronautics and Astronautics, (AIAA 86 – 2423), 1986.

DEFINITION OF ASSESSMENT CRITERIA FOR NESTING SOFTWARE TOOLS IN TEXTILE PRODUCTION

INDRIE Liliana[1], ILIEVA Julieta[2], RUSEVA Irina[2], ZLATEV Zlatin[2], HORA BODEA Simina[1], HORA Horea[3]

[1]University of Oradea, Faculty of Energy Engineering and Industrial Management, Department of Textiles, Leather and Industrial Management, B.St.Delavrancea Str., no. 4, 410058, Oradea, Romania

[2]Trakia University, Faculty of Technics and technologies, 38 Graf Ignatiev str., 8602, Yambol, Bulgaria

[3]University of Oradea, Faculty of Management and Texhnological Engineering, Department of Mechanical Engineering and Vehicles, B.St.Delavrancea Str., no. 4, 410058, Oradea, Romania

Corresponding author: Zlatev, Zlatin, E-mail: zlatin.zlatev@trakia-uni.bg

Abstract: *The arrangement of textile sewing patterns for cutting aims to minimize the amount of residual material, which in most cases is unusable and discarded. This paper proposes criteria for evaluating software products for arranging elements that are suitable for textile production. These criteria are related to the degree of use of the material, the overall efficiency of the algorithms, and the time for their execution. Data on dress, coat, and blouse were used. A software tool for complex, express, automated evaluation of algorithms for arranging elements has been developed, including software modules for research, analysis, and categorization of software products. A comparative analysis is made of software products for arranging cutting elements, depending on their use and availability. It has been found that the choice of appropriate software for arranging elements depends on the complexity of the items to be arranged and on what evaluation criterion is appropriate for the respective production of garment patterns. The obtained results can be used to develop systems to evaluate the performance of algorithms and software tools. Also, they can be used in the training of future specialists in the subject area.*

Keywords: *Computational simulation, Compaction behavior, Fabrics, Image processing, 2-dimensional nesting problems, Genetic algorithm*

1. INTRODUCTION

The arrangement of textile elements for cutting is a widely studied problem. This task aims to minimize the amount of residual material, which in most cases is unusable and discarded. The reduction of this type of waste has an impact on production costs [1]. This is an important factor in textile production [2].

The process of arranging elements on a cutting fabric is in most cases automated. In some of the smaller textile industries, manual arrangement by an operator is still used. This can lead to longer cutting times and increase the amount of waste material.

People can solve problems with the arrangement of cutting elements relatively well through the use of intuition and spatial thinking. In a production environment, solving such problems by people is usually not feasible or cost-effective. Also, it is not profitable if you have to hire several employees to perform this activity.

Computer-aided automation of tasks for arranging textile cutting elements offers a variety of solutions to this problem. Academic and industrial teams have conducted research in this regard for over fifty years [3].

Unlike humans, computers do not have intuition or spatial thinking. For this reason, algorithmic strategies for generating solutions have been developed. In textile production, the problem is often more complex and requires additional presentation and modeling of additional constraints and objectives.

Effectively arranging the cutting patterns is a difficult problem to solve. This is because the elements have an irregular shape, specific to each product. For this reason, the search for an optimal solution in most cases is impossible, as the cases are specific, it takes a long time to perform optimization procedures, and a large number of possible solutions are obtained. For this reason, software products and computational algorithms are proposed, through which sufficiently acceptable solutions are achieved for more groups of possible problems in the arrangement of textile patterns for cutting.

From the analysis of the available sources, several groups of software products can be summarized. They are summarized in Table 1. There are three main groups of software. Browser-based applications work directly in an Internet browser and do not require additional installation on a local device such as a personal computer, laptop, tablet, or mobile phone. The second group is computer programs that need to be installed on a local device. Finally, there are scientific developments that present solutions to problems related to the arrangement of patterns.

The main subgroups in which the product programs can be summarized are open access and paid. Free products usually have limited functionality. They have a small number of settings and use one optimization method. Due to the limitations of the specific method used, it is not applicable in some specific cases. The advantage is that the authors provide information about the algorithm used. For example, the DeepNest application (https://deepnest.io) uses a genetic algorithm. The principle of "box packing" is applied, in which objects are approximated to rectangles, which simplifies the calculation process and reduces the time for decision-making by the algorithm. To reduce errors, a rounding tolerance is used for the corners of the rectangles.

More than one optimization algorithm is used for paid software products. The difference is that the manufacturer does not say what algorithm is used in their product. For example, for Nest & Cut (https://nestandcut.com), the manufacturer states that the application uses "advanced optimization algorithms", without specifying which ones. Paid software products can also be linked to the purchase of fabric cutting equipment. An example of such a product is CutNest (https://www.mirisys.com), which comes with the manufacturer's cutting equipment.

The advantages of using software products for arranging details are:

- ✓ Reduce the operating time of the machine. It is realized by reducing the path of the cutting tool, double cutting to avoid the appearance of hanging threads;
- ✓ Effective use of textile material. Reducing the residual material leads to a reduction in waste. In the case of high-cost materials, this also leads to a reduction in production costs;
- ✓ Reduction of manual labor. By automating processes such as importing CAD files, you can drastically reduce CAM preparation time. The time to convert from CAD file to NC code can be significantly reduced.

Table 1. *Types of software tools for arranging sewing patterns for cutting*

Type	Subtype	Advantages	Limitations	Reference
Internet browser-based	Free	Direct access from anywhere in the world	Require an Internet connection	[4]
	Commercial	Requires registration, trial versions available	The limited-time of use; Requires an Internet connection	
Computer software	Free	They are installed and work without additional requirements	A limited set of features	[3]
	Commercial	Greater functionality; Trial versions are available	In most cases, they are related to the purchase of equipment	
Scientific research		Effective methods for arranging irregularly shaped elements	Only pseudocode algorithms are available	[5]

The third important group is the scientific developments in the field of optimization of the available cutting sewing patterns. The research is aimed at modifying to improve the existing optimization algorithms for arranging irregularly shaped textile details. Optimization algorithms such as “Genetic algorithm (GA)”, “Ant colony optimization (ACO)”, “Particle Swarm Optimization (PSO)”, and “Imperialist Competitive Algorithm (ICA)” are used for this purpose.

Table 2 summarizes the analysis of the most commonly used algorithms. They are grouped into six groups. These programming procedures have been studied since the problem of arranging cutting elements was defined. Some algorithms offer high-speed data processing, but low efficiency and obtain large amounts of waste material. Due to the limitations of the independent use of algorithms, they are suitable for solving specific tasks. Hybrid algorithms, which combine the work of several algorithms, have a more universal application. Of course, at the expense of longer execution time, compared to the independent use of algorithms for arranging elements.

Table 2. *Nesting algorithms*

Name	Advantages	Limitations	Reference
Rectangular parts nesting algorithms	Practical algorithm	The high complexity of the calculations works only with rectangular details	[6]
Enclosure algorithms	Wide application	A large amount of waste material, low efficiency	[7]
Heuristic nesting algorithms	Wide application	It is limited to a small number of elements	[8]
Bottom-left nesting algorithm	High-speed data processing simplified computational procedures	They need to work together with search algorithms	[9]
Space searching algorithms	They use any process to find the optimal location of the elements	They do not detect the gaps between the elements effectively enough	[10]
Hybrid algorithms	Combine the advantages of several algorithms	Longer calculation time	[11]

In summary, the problem of cutting textile elements can be defined as arranging irregularly shaped elements in a rectangular field of known dimensions without overlapping. They should take up little space in the field.Irregularly shaped elements are defined as simple polygons. In cases where the elements include curves, they are approximated by their minimum polygon. In it, a series of tangents to the curve form the polygonal edges.

Whether it is a software product or a research development, there is a need to evaluate the results obtained.

Comparative analyzes of the presented algorithms have been performed [12], [6]. Different authors point to different accuracy within their study. This is indicative that the accuracy of the application of an algorithm depends largely on the type of problem to be solved by arranging elements for cutting textiles.

More commonly used criteria in practice are the calculation time and the efficiency of the arrangement of the elements, which is the ratio between the area filled by the elements and the empty fields between them, expressed as a percentage [5]. It is necessary to look for more evaluation criteria that would give a more complete picture of the work of the respective software product or the proposed algorithm. The use of evaluation criteria has the potential to show the limitations of the software product used, within the solved problem of arranging textile elements for cutting. This thesis was confirmed by Breaz et al. [13]. The authors propose to use image processing techniques in assessing the effectiveness of arranging elements in a given field. Such techniques can also be used to evaluate the performance of algorithms for arranging textile elements.

The purpose of this paper is to define criteria for the evaluation of software products for the arrangement of elements that are suitable for textile production.

2. MATERIAL AND METHODS

The software products Gemini CAD, Nest&Cut, DeepNest, SVGNest were used. *Gemini CAD* (Gemini CAD Systems SA LECTRA company, Iași, Romania) is a commercial software product for clothing design. It offers functions for arranging patterns that are optimized for cutting textile fabrics. *Nest&Cut* (ALMA, France) is a commercial online tool that has a 30-day trial. The tool arranges the elements using several optimization algorithms. It has functions for simulation of textile cutting. Also, the obtained result can be downloaded as a DXF file. *DeepNest* (https://deepnest.io) is a free application. It has many setup functions, such as several processor cores, allowable error values, and sorting methods. He uses the Genetic Algorithm to arrange the elements. The result can be downloaded as a DXF or SVG file. SVGNest (https://svgnest.com). Free online tool. Works only with SVG files. It offers several setup functions.

The test of the software products is made by patterns for dresses, coats, and blouses.
Criteria presented in the available literature were used to evaluate the performance of software products [13], [5]. These criteria are relationships that do not depend directly on the unit of measure in which the variables involved are measured. For this reason, image processing techniques can be easily applied and the number of pixels can be used. These pixels can be converted to distance and area, for example in mm.

*Height of filling with elements **(H)***. Represents the ratio between the previously mentioned area of textile material and that filled with elements, expressed as a percentage. This ratio is defined by the following formula:

$$H = \frac{H_e}{H_T} * 100, \% \quad \textbf{(1)}$$

where H_e is the height filled with elements; H_T – the height of the area set by the operator.*Fill function **(F)***. It describes the empty space between the elements. The parameters of the area filled with elements and that of the empty space between them are included in the fill function, in the form of a weighted sum. The function is calculated as follows:

$$A_F = L * W \qquad (2)$$

$$F = a * \left(\frac{\sum_{i=1}^{N} A_{e(i)}}{A_F}\right) + b * \left(1 - \frac{A_S}{A_F}\right) \qquad (3)$$

where A_s is the area of the empty space between the elements; A_F – an area filled with elements; L – length, W – width of the rectangle described around the elements; Ae is the area of an element; the values a=0,7 and b=0,3 were determined by Hopper [14].

*Degree of use of the material **(D_F)***. It presents the relationship between the difference in the areas of the elements, that of the empty space between them, and the area of the area selected by the operator for the placement of the elements. the degree of use of the material is described by the formula:

$$D_F = \frac{(A_e - A_S)}{A_T} * 100, \% \qquad (4)$$

where A_e is an area filled with elements; A_s – the area of the empty space between the elements; A_T – the area of the area set by the operator.

*The overall efficiency of the algorithm **(E_T)***. Represents the ratio of the sum of the areas of the elements and the total area they occupy, expressed as a percentage. The mathematical dependence of this relation has the form: of placement

$$E_T = \frac{\sum_{i=1}^{n} A_{e(i)}}{A_F} * 100, \% \qquad (5)$$

where A_e is the area of an element; n – number of elements; A_F – an area filled with elements.

*Execution time **(t)***. Represents the time from the start of the sorting algorithm to the result measured in s.

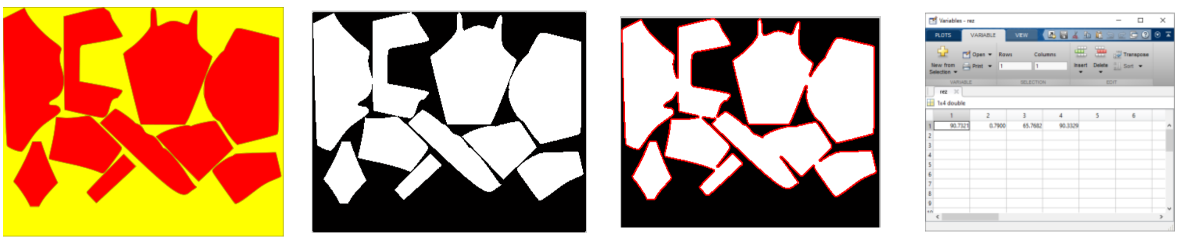
In the present work, an algorithm for evaluating the performance of software products for arranging elements is proposed. Image processing and analysis techniques were used. The algorithm is implemented in the Matlab software system (The MathWorks Inc., Natick, MA, USA). In general, it is presented in Figure 1.

Stage 1. Includes loading the RGB image of the solution for arranging elements of the corresponding algorithm.

Stage 2. Convert the image to black and white and filter. The filter adjustment factors have been experimentally established. A Disk filter is used.

Stage 3. Determining the areas occupied by the elements in the image. The Regionprops function is used.

Stage 4. Defining the criteria for evaluating the arrangement of the elements of the image.



Stage 1 Stage 2 Stage 3 Stage 4

Fig. 1: *Visualization of the main stages of the work of an algorithm for evaluating the work of software products*

The algorithm is presented as pseudocode in Table 3. After loading the image, it is converted to black and white. This is followed by filtering and clearing the image. Finally, the area of the elements is determined and the parameters for evaluating the sorting algorithm are examined.

Table 3. *Pseudocode of the proposed algorithm for evaluating the work of software products*

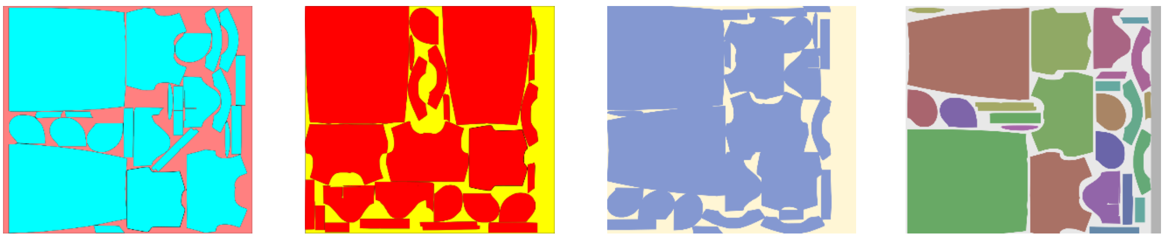
Stage	Function	Pseudocode
A	Loading image	i=imread('n2.png')
B	Convert to black and white image	i1=im2bw(i)
C	Filter and clear the image	h = fspecial('disk', 2); i2=imfilter(i1,h); i2=imfill(i2,'holes'); i2=double(i2)
D	Determining the characteristics of the area with elements	s = regionprops(i2,'all');
E	Height of filling with elements	he=s.MinorAxisLength; ht=length(i2(:,1)); h=(he/ht)*100
F	Fill function	a=0.7; b=0.3; ae=s.Area; af=s.MajorAxisLength*s.MinorAxisLength abb=s.BoundingBox(3)*s.BoundingBox(4) as=abs(ae-abb); f=a*(ae/af)+b*(1-(as/af))
G	Degree of use of the material	at=ht*length(i2(1,:)); df=((ae-as)/at)*100
H	Overall efficiency	et=(ae/abb)*100

A summary analysis of the obtained results was made with the method "Correspondence Analysis" [15]. The method is a technique for visualizing, detecting, and presenting the relationship between categories of data. It uses a graph called the Correspondence Map, which depicts the relationships between the data. The method is implemented in a software product Statistica 12 (TIBCO Software Inc., Palo Alto, CA, USA).

3. RESULTS AND DISCUSSION

As a result of the performed analyzes and calculations, visualizations of the work of the compared nesting software tools are presented. The results of the evaluation of the operation of these Internet tools and computer programs are shown and commented on. Finally, the results obtained are compared with those of the available literature.

Figure 2 shows the results of arranging elements of a dress. It consists of 25 elements. The efficiency of filling the fabric is shown, which determines the respective software used. It can be seen that Gemini CAD, SVGNest, Nest & Cutwork with the highest efficiency. The lowest efficiency was obtained with DeepNest.



a) Gemini CAD 80%　b) DeepNest 77%　c) SVGNest 81%　d) Nest&Cut 81%

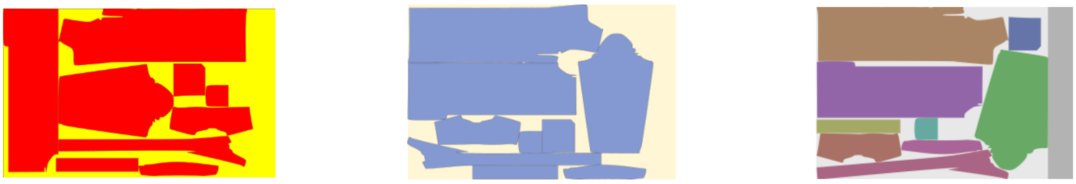
Fig. 2: *Comparative analysis of software products for arranging elements of a dress*

Table 4 shows the results of a comparative analysis of the arrangement of elements of a dress. The highest value of H – the height of filling with elements, relative to the height of the fabric is obtained with Gemini CAD, followed by SVGNest. Again, the Gemini CAD shows the appropriate value of the weighted ratio between the empty space and the one filled with elements (F). Next on this indicator is Nest & Cut. As can be seen from the table, the material utilization rate (D_f) and the overall efficiency of the algorithms (E_t) are highest with SVGNest and lowest with Nest&Cut. The set data processing time is 120 s for the three algorithms and 10 s for Nest&Cut.

Table 4. *Results of a comparative analysis of the arrangement of patterns for a dress*

Parameter / Software	H, %	F	D_f, %	E_t, %	t, s
Gemini CAD	89,76	0,77	79,80	89,37	120
DeepNest	89,27	0,79	80,91	93,44	120
SVGNest	91,00	0,81	79,72	94,29	120
Nest&Cut	88,43	0,76	74,03	89,32	10

Figure 3 shows the results of arranging elements of a coat. It consists of 9 elements.



a) DeepNest b) SVGNest c) Nest&Cut

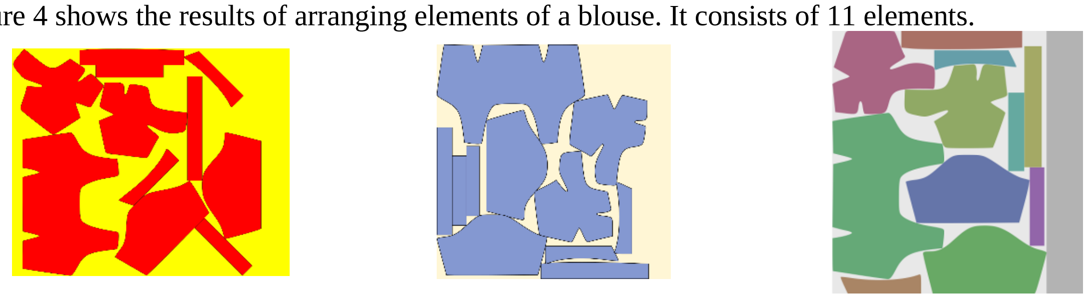
Fig. 3: *Comparative analysis of software products for arranging elements of a coat*

Table 5 shows the results of a comparative analysis of the arrangement of elements of a coat. The highest value of H – the height of filling with elements, relative to the height of the fabric is obtained at SVGNest. Both SVGNest and Nest&Cut show appropriate values of the weighted ratio between the empty space and the one filled with elements (F). Last in this indicator is DeepNest. As can be seen from the table, the material utilization rate (D_f) and the overall efficiency of the algorithms (E_t) are highest with SVGNest and lowest with DeepNest. The set data processing time is 120 s for the three algorithms and 10 s for Nest&Cut.

Table 5. *Results of a comparative analysis of the arrangement of patterns for the coat*

Parameter / Software	H, %	F	D_f, %	E_t, %	t, s
DeepNest	89,84	0,71	55,48	80,51	120
SVGNest	95,08	0,79	63,34	85,10	120
Nest&Cut	93,72	0,79	80,36	88,72	10

Figure 4 shows the results of arranging elements of a blouse. It consists of 11 elements.



a) DeepNest b) SVGNest c) Nest&Cut

Fig. 4: *Comparative analysis of software products for arranging elements of a blouse*

Table 6 shows the results of a comparative analysis of the arrangement of blouse elements. The highest value of H – the height of filling with elements, relative to the height of the fabric is obtained at DeepNest. Both SVGNest and Nest&Cut show appropriate values of the weighted ratio between the empty space and the one filled with elements (F). Last in this indicator is DeepNest. The results show that the material utilization rate (D_f) and the overall efficiency of the algorithms (E_t) are the highest in Nest & Cut and the lowest in DeepNest. The set data processing time is 120 s for the three algorithms and 10 s for Nest&Cut.

***Table 6**. Results of a comparative analysis of the arrangement of patterns for the blouse*

Parameter / Software	H, %	F	D_f, %	E_t, %	t, s
DeepNest	93,53	0,57	21,63	62,14	120
SVGNest	91,76	0,75	57,96	81,96	120
Nest&Cut	90,27	0,77	80,24	88,93	10

Figure 5 shows a map of compliance for software products and evaluation criteria. The two dimensions on which the data are presented accurately describe 99,9% of their inertia. This shows that two dimensions are sufficient to evaluate the operation of the algorithms for arranging elements. The evaluation criteria stand out for the individual software products. The material utilization rate (D_f) is closest to Gemini CAD. The fill height with elements (H) has the highest values for DeepNest. The weighted ratio between the empty space and that filled with elements (F), as well as the overall efficiency of the algorithms is closest to SVGNest and Nest & Cut.

The results of the "Correspondence Analysis" show that the choice of the appropriate algorithm will depend on the type of elements to be arranged and on what evaluation criterion is appropriate for the respective production of garment patterns.

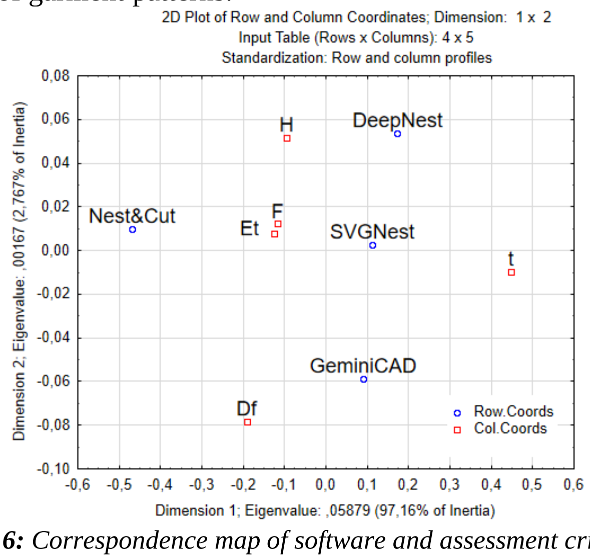


***Fig. 6:** Correspondence map of software and assessment criteria*

The results obtained in the present work complement those of the available literature. Comparative analyzes of software tools are presented, which can be summarized in two groups, depending on their use and availability: online based and local; commercial and free.

The DeepNest software, which uses a basic Genetic Algorithm, uses a method to approximate rectangles. For this reason, it performs less efficiently when arranging elements with a complex shape than other algorithms. This result complements the claim of Xie et al. [2008] that algorithms with an approximation of elements to rectangles have a high complexity of the computing apparatus and are effective when working only with rectangular details.

Although SVGNest has only a few possible settings, this online tool can be successfully used to arrange complex shapes, using the material much more efficiently than the other free DeepNest tool.
The two commercial software Gemini CAD and Nest&Cut are comparable in terms of results, but Gemini CAD is optimized for the arrangement of textile elements for cutting, which is its main advantage in the task solved in this paper.

The proven effectiveness of CAD systems for clothing design and offers functions for arranging cut elements, complement the claims of Kazlacheva [3], according to which the design of clothing is the most important process in clothing design. Mistakes made during the development of basic structures can hardly be avoided in the next stages of design and technological production. The importance of design makes it the last automated stage in the whole sequence of activities that make up the design of clothing.

The results obtained in this way complement the conclusions of Sasikala et al. [10], who points out that combining several algorithms is much more efficient than using stacking algorithms alone, but on the other hand, it takes longer to calculate.

4. CONCLUSION

In the present paper, a total of five criteria are proposed for the evaluation of software products for the arrangement of elements that are suitable for textile production. These criteria are related to the degree of use of the material, the overall efficiency of the algorithms, and the time for their execution.

Developed, researched, and used in the work software tool for complex, express, automated evaluation of algorithms for arranging elements, including software modules for research, analysis, and categorization of nesting software products. The software includes tools for processing and analyzing digital images and calculating criteria for evaluating nesting software.

A comparative analysis is made of software products for nesting cutting elements, depending on their use and availability.

It has been shown that the choice of an appropriate nesting algorithm depends on the complexity of the items to be arranged and on what evaluation criterion is appropriate for the respective production of garment patterns.

The main reasons for the inefficient operation of nesting algorithms for cutting textile fabrics are analyzed. It was found that the effectiveness of software products mainly depends on the complexity of the ordered elements and the optimization algorithm used.

The results reported in the available literature have been supplemented. Procedures suitable for evaluating software products and algorithms for arranging textile elements are proposed.

The following developments may be related to reducing the limitations of the proposed algorithm and the inclusion of more reasonable criteria to participate in the evaluation of software products for arranging elements.

The results obtained in the present work can be used in the development of systems for evaluating the performance of algorithms and software tools. They can be used in the training of future specialists in the subject area.

Acknowledgments

The work in this article is supported by project 2.FTT/2020, on the topic: "Design solutions for sustainable fashion".

Also, the authors would like to express appreciation for the co-funding of the Erasmus+ Programme of the European Union [Project Fashion DIET "Sustainable fashion curriculum at textile Universities in Europe – Development, Implementation, and Evaluation of a Teaching Module for Educators" / Erasmus+ Programme 2020-1-DE01-KA203-005657] by the NA DAAD.

REFERENCES

[1]. T., Spahiu, A., Manavis, Z., Kazlacheva, H., Almeida, P. Kyratsis (2021). *Industry 4.0 for fashion products – Case studies using 3D technology*. IOP Conference Series: Materials Science and Engineering, Vol. 1031, Iss. 1, Art. 012039, pp.1-9.

[2]. A., Siasos, G., Vosniakos (2014). *Optimal directional nesting of planar profiles on fabric bands for composites manufacturing*. CIRP Journal of Manufacturing Science and Technology, 2014, Vol. 7, No. 3, pp. 283-297.

[3]. Z., Kazlacheva (2010). *Construction and modeling of clothing with CAD systems*. Publishing house of Technical College of Yambol, Bulgaria, ISBN 978-954-9999-75-4, p. 8. (in Bulgarian)

[4]. J., Bishop, N., Horspool, D. Syme (2011). *Browser-based Software for Technology Transfer*. SAICSIT '11: Proceedings of the South African Institute of Computer Scientists and Information Technologists Conference on Knowledge, Innovation, and Leadership in a Diverse, Multidisciplinary Environment, October 2011, pp. 1-3.

[5]. M., Kargar, P., Payvandy (2015). *Optimization of fabric layout by using imperialist competitive algorithm.* Journal of textiles and polymers, Vol. 3, No. 2, pp. 55-63.

[6]. S., Xie, G., Wang, Y., Liu (2008). *Nesting of two-dimensional irregular parts: an integrated approach*. International Journal of Computer Integrated Manufacturing, Vol. 20, Iss. 8, pp. 741-756.

[7]. A., N., Ramesh, Ramesh (2001). *A generic approach for nesting of 2-D parts in 2-D sheets using genetic and heuristic algorithms*. Computer-Aided Design, Vol. 33, pp. 879-891.

[8]. E., Hopper, B., Turton (2001). *An empirical investigation of metaheuristic and heuristic algorithms for a 2D packing problem*. European Journal of Operational Research, Vol. 128, pp. 34-57.

[9]. S., Nandy, B., Bhattacharya (2003). *On finding an empty staircase polygon of the largest area (width) in a planar point-set. Computer Geometry: Theory and Applications,* Vol. 26, pp. 143-171.

[10]. S., Sasikala, S., Balamurugan, S., Geetha (2016). *Multi-Filtration Feature Selection (MFFS) To Improve Discriminatory Ability in Clinical Data Set*. Applied Computing and Informatics, Vol. 12, No. 2, PP. 117-127.

[11]. S., Binitha (2012). A Survey of Bio-inspired Optimization Algorithms. International Journal of Soft Computing and Engineering, Vol. 2, pp. 137-151.

[12]. J., Bennell, J., Oliveira (2008). *The geometry of nesting problems: A tutorial*. European Journal of Operational Research, Vol. 184, pp. 397-415.

[13]. R., Breaz, O., Bologa, S., Racz (2015). *Method for estimating the manual nesting process efficiency for profiling machines, based upon image processing techniques*. Applied Mechanics and Materials, Vol. 808, pp. 86-91.

[14]. E., Hopper (2000). *Two-dimensional packing utilizing evolutionary algorithms and other meta-heuristic methods*. Ph.D. Thesis, Department of Textile Engineering, University of Wales, Cardi.

[15]. Z., Kazlacheva, (2017): *An investigation of the application of the golden ratio and Fibonacci sequence in fashion design and pattern making*. IOP Conference Series: Materials Science and Engineering, 254, 17, 172013, 1-7.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

REFLECTIONS OF ECOLOGICAL TEXTILES (GREEN TEXTILE) ON CLOTHING DESIGNS

KOC Tugce[1], TIRYAKI Nurcan[2], OZER CEBI Mevsim[3], CANOGLU Suat[4]

[1] Vakko, Business Development Department, Esenyurt/İstanbul/Turkey, tugcek@vakko.com.tr

[2] Vakko, Nakkaştepe Design Center, Üsküdar/İstanbul/Turkey, nurcant@wcollection.com.tr

[3] Vakko, Nakkaştepe Fashion Center, Üsküdar/İstanbul/Turkey, mevsim.cebi@wcollection.com.tr

[4] Marmara University, Faculty of Technology, Department of Textile Engineering, Göztepe/İstanbul/Turkey, scanoglu@marmara.edu.tr

Corresponding author: Koç, Tuğçe, tugcek@vakko.com.tr

Abstract: *With the understanding of the effects of the natural thing on the environment and human health, the importance given to ecological products by manufacturers and end-users has increased. While fashion designs vary depending on time and place, affected by the cultural environment, social behaviors, and economy. Today's fashion designers try to use raw materials that are organic and/or can be recycled in works. Reasons such as low water and energy consumption and no use of chemicals during production have intensified research on nettle fiber and fabrics. Its most important features are that it has a feeling of coolness, irons quickly, and does not cause allergic conditions in contact with the skin thanks to its natural antibacterial properties. The use of chemicals is prohibited in the production of organic cotton, so clothes made of organic cotton are less likely to cause allergies. This women's capsule collection study which focuses on sustainable design approaches presents life-cycle processes. Hand-knitted details from hand-spun nettle yarn are used, the main fabric content is organic cotton and nettle fiber, and organic buttons used as accessories are obtained from coconut shells.*

Key words: *Nettle fiber, organic cotton, sustainability, fashion design*

1. INTRODUCTION

Sustainability is a systemic concept related to the continuity of the economic, social, institutional, and environmental aspects of human society. Sustainability aims to be a means of structuring civilization and human activities to protect biodiversity on the one hand and to meet the needs of society and the economy on the other. Sustainability, the ability to sustain these ideals indefinitely, affects every level of the organization, from the local environment to the entire planet [1]. Directly or indirectly, we must take care of our environment if we want to live in prosperity; this is the simplest principle of Sustainability [2]. Sustainability is making it possible for us to have water, energy resources, and materials both today and in the future to protect human health and the environment.

2. SUSTAINABILITY COMPONENTS

For sustainability to be realized, it must be in balance by providing three main elements, namely environmental, social/ethical, and economic [3].

Environmental Sustainability is the realization of human activities with the economic use of soil, air, and water resources in the world. It is the fact that people take care of the needs of nature while meeting their own needs [4]. Social Sustainability, which is the need to protect the integrity of society, can also be defined as the ability to work for the common goals of social values, relationships, and identities [5]. Efforts to reuse natural resources with depletion potential in alternative ways are within the scope of Economic Sustainability, which deals with the justice between human-human and human-nature [6].

3. LIFE CYCLE PROCESSES FOR A TEXTILE PRODUCT

The “Product Lifecycle” is a process that refers to the successive and interconnected multifactorial stages of a product or service system, from its extraction from its natural resources to its final destruction.

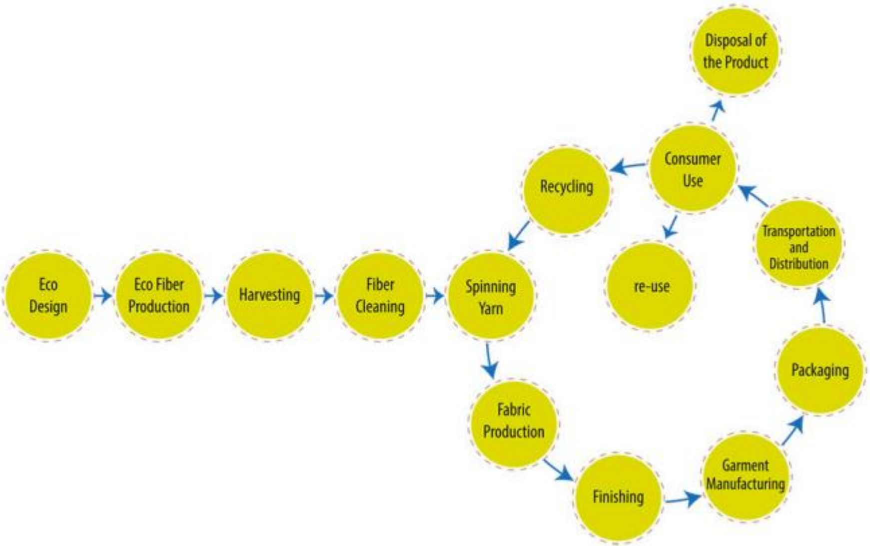


Fig. 1: *Life cycle processes for a textile product [7]*

4.1. NETTLE FIBER

In our age when ecological textiles are prominent, the Stinging Nettle, which is widely grown in the geography of Turkey and the highest quality ones are grown in the Black Sea Region, is an important plant that can set an example for natural fibers.

4.1.1. Structure

Its family is Nettles, known as Urticaceae in Latin; there are 48 genera and 1050 species known [8]. Three types of Stinging Nettle can be mentioned, which spread in the Anatolian geography and can be used as a textile fiber; these are the annual Urtica urens, Urtica pilulifera, and the perennial Urtica dioica [9].

***Fig. 2**: Female (a) and Male (b) flowering stinging nettle (U.dioicia) [9]*

***Fig. 3**: General view of plants Urtica dioica (a), Urtica urens (b) and Urtica pilulifera (c) [9]*

Nettle fibers are cellulose-based, fibers obtained from plant stems such as jute and ramie, namely bast fibers. It is difficult to distinguish bast fibers such as flax, nettle, hemp, jute, and ramie, but easy to distinguish from fibers such as wool, silk, and cotton. To distinguish the bast fibers from each other, the "method of detecting calcium oxalate crystals under polarized light microscope" found by Holst and Bergfjord in 2010 is the most advantageous [10].

4.1.2. General Features

Due to its morphological structure and varying length, it does not have a mechanized production. Cutting and sliding tools, which are also used in the harvest of hemp, are used in the harvest of Stinging Nettle. For these reasons, its production is technically difficult and costly. Its strength is strong due to the high fiber content it contains. It is a natural insulation material due to the gaps in its fiber structure [10]. It has natural antibacterial properties like bamboo. It is protective against ultraviolet rays. It is sensitive to heat and can be ironed quickly [8].

The comparison of nettle fibers with vegetable fibers such as flax, hemp, ramie, jute, and cotton, and animal fibers such as wool, in terms of some physical parameters, are as follows:
Thickness: Thicker than Linen and Jute, thinner than Ramie
Tensile Strength: Stronger than Hemp, more brittle than Flax and Ramie
Elongation: More than Flax, Hemp, and Ramie
Roughness (Irritation in contact with the skin): It has a softer texture than Hemp and Ramie, but it is more needle-like than Linen
Moisture Conductivity: Better than Wool, Cotton, Hemp, Linen, and Ramie
Evaporation of Water: Same as Flax and Hemp, lower than Wool and Ramie [10].

4.1.3. Usage Areas

Stinging Nettle is a natural plant used in the treatment of many diseases such as diabetes, kidney, and intestinal disorders, hair diseases, and rheumatism.

The fibers obtained from the stems of the plant are used in textiles; the remaining parts are used in industries such as pharmaceuticals, cosmetics, and food. Summer clothes are produced by twisting the fibers of Stinging Nettle, which is used as an insulation material, and winter clothes are produced by preserving their natural structure without twisting the fibers.

The roots of Stinging Nettle are used as a natural dye; yellow and green colors are obtained. Green-colored commercial dye known as E140 is obtained from chlorophyll extraction [10].

4.1.4. Methods of Obtaining Fiber From Stinging Nettle

I. Harvest: The best time is in the third year, but it can also be done around August of the second year. Side sprouting is undesirable, this does not affect the fiber quality, but it prolongs the processing time as it will require sorting. *II. Softening & Rotting: Using “water” (the process takes about 1 month, the stems of the plant are used), Using “Rain or Dew” (the most superior method in terms of the color of the fiber obtained, the processing time is about 2 months, the stems and herbs are used together), Using “Chemicals” (high cost requires, it is the shortest method, but it is also the method most damaging to the fiber, the stems of the plant are used). *III. Glue Removal: Physical and chemical processes are carried out together; they are boiled in water, treated with acid, and washed in the water again, the gum is removed by using the pectin enzyme, and the enzyme is removed by washing with water, the gum is removed by using a chemical containing sodium hydroxide and sodium silicate and it is cleaned from residues by washing again, The fibers are mixed by pounding and combed. *IV. Crushing and Cleaning *V. Scanning: Centrifugation, bleaching, and lubrication processes are carried out. *VI. Spinning [10].

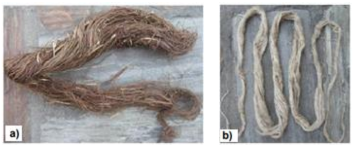


Fig. 4*: Raw, shelled nettle fiber (a), Raw, processed nettle fiber (b) [12]*

4.2. ORGANIC COTTON

No chemicals are used in the production of organic cotton, only natural fertilizers and natural medicines are used, so clothes made of organic cotton are less likely to cause diseases such as allergies. Organic cotton is the right choice in terms of health as well as the environment. Clothes that use organic cotton in their production are more flexible and much softer than those made from regular cotton [11].

Fig. 5*: Organic Cotton [12]*

5. FIGURES AND TABLES WOMEN'S CLOTHING DESIGNS FROM FABRICS MADE FROM NETTLE AND ORGANIC COTTON FIBER

Clothing design; It is a disciplined phenomenon that aims to meet people's need for dressing and that occurs with the interaction of elements such as technology and art. From the drawing of a garment to its sewing, it is a process work done by considering fashion trends and user requests [13].

Fig. 6: *Design Process in 9 Simple Steps [14]*

In this study, modular, seasonal, and timeless women's clothing was designed from fabrics made of organic cotton and nettle fiber. The product consists of 4 parts; each piece is removable. The main fabric consists of 93% organic cotton and 7% organic nettle fiber. 100% organic cotton was used as lining. Nettle yarn obtained from 100% nettle fiber was used as a garnish. Functionally used button details are made of organic coconut shell.

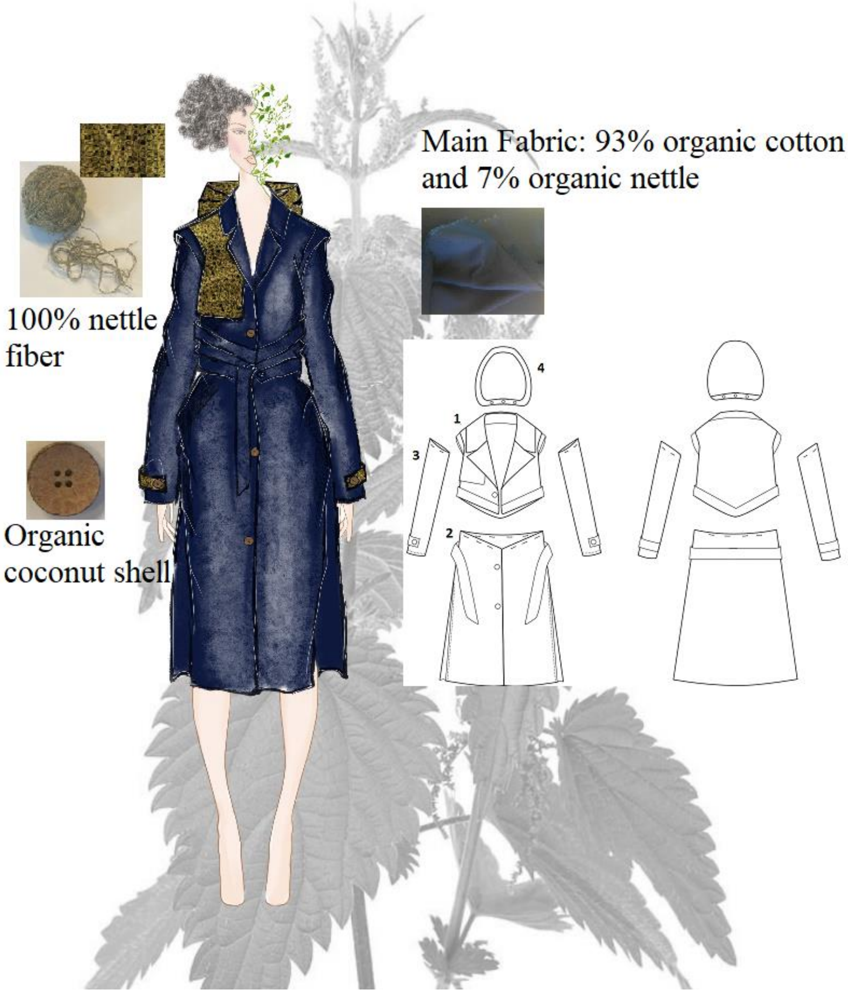


Fig. 7: *Designed clothing silhouette forms*

The first piece is a tailor-made collar cropped vest. Its closure is with a single button in the front center. There are organic buttons on the armhole and hem that allow the 3D pieces to be combined with the sleeves underneath. The aller on the left front is hand knitted from organic nettle. The second piece is the hem with slits on both sides. There is a belt made of its fabric at the waist. Its closure is with the front center button. The piece connects to the upper body with buttons to lengthen the jacket. The third piece is the arms. The vest turns into a jacket when it is combined with the arm sleeve in the body. There are hand-knitted belt details from organic nettle yarn at the ends of the sleeves. The piece sewn between the arms at one end is fastened with a button on the front. The 4th piece is a hand-knitted hoodie from organic nettle yarn. The piece can be attached and removed under the collar of the jacket with the help of buttons.

6. CONCLUSIONS

In the design of this product, whose starting point is sustainability, completely organic fabrics, yarns and accessories were used. It is aimed to reduce the need-based purchasing action with the option of adding or removing different parts according to the user. A removable hood detail has been added to the product, which is designed as a vest. With this modular design, which transforms into itself and offers various style alternatives, a seasonal and timeless women's clothing product is designed that adapts to different weather conditions and occasions. These functional ready to wear women’s design using ecological textile materials; it is considered for the production of garments such as vests, coats and overcoats.

ACKNOWLEDGMENT

We would like to thank one of our managers Günseli Aksoy Oral, Bahise Kurt, and Ayşegül İlkentapar for their support of this study.

REFERENCES

[1] https://cloudinstitute.org/blog/2011/3/8/what-is-sustainability.html. “What is Sustainability”. Available: 28/03/2022.

[2] https://www.epa.gov/sustainability/learn-about-sustainability#what. “Learn about Sustainability”. Available: 28/03/2022.

[3] ISI. (2019). “Sustainability and the Role of Envision”. [Online]. Available: https://slideplayer.com/slide/17775943/. Accessed: 28.03.2022.

[4] J. Morelli. Environmental Sustainability: A Definition for Environmental Professionals. Journal of Environmental Sustainability, Vol: 1(1), Article 2. pp. 1-10. 2011.

[5] B. Moldan, S. Janousková, T. Hak. How To Understand And Measure Environmental Sustainability: Indicators And Targets. Ecological Indicators, Vol:17. pp. 4-13. 2012.

[6] S. Baumgartner and M. F. Quaas. What Is Sustainability Economics. Ecological Economics, Volume 69, Issue 3. pp. 445-450. 2010.

[7] D. Tüm Cebeci. The Use Of Bamboo Fiber In Baby Clothing From The Point Of Sustainability And Life-Cycle Processes.Ulakbilge, 41. pp. 703-710. 2019.

[8] Y. Özbey. Isırgan Otu Lifiyle Elde Edilmiş Tekstillerde Görsellik. Marmara Üniversitesi-Güzel Sanatlar Enstitüsü-Tekstil Anasanat Dalı. Yüksek Lisans Tezi. 2013.

[9] A.K. Ayan, Ö. Çalışkan ve C. Çırak. Isırgan Otu (Urtica spp.)’nun Ekonomik Önemi ve Tarımı. OMÜ Zir. Fak. Dergisi, 21(3). pp. 357-363. 2006.

[10] M. Kurban. Isırgan Otu Lifinden Üretilen Kumaşların Ön Terbiye İşlemlerinin Araştırılması. Pamukkale Üniversitesi-Fen Bilimleri Enstitüsü. Yüksek Lisans Tezi. 2012.

[11] https://tr.doashop.com/blogs/news/neden-organik-pamuk. “Neden Organik Pamuk?”. Available: 28.03.2022.

[12] https://www.textilegence.com/kuresel-organik-pamuk-uretimi-artti/. “Küresel Organik Pamuk Üretimi %31 Arttı”. Available: 28.03.2022.

[13] A. Molla. Giysi Tasarımı Aşamalarının İncelenmesi ve Hazır Giyim İşletmelerindeki Tasarımcı Performansının Değerlendirilmesi. Selçuk Üniversitesi-Sosyal Bilimler Enstitüsü-Giyim Endüstrisi ve Giyim Sanatları Eğitimi Ana Bilim Dalı. Yüksek Lisans Tezi. 2007.

[14] https://www.pointsofmeasure.com/tutorials-education/the-design-process-in-9-simple-steps. “The Design Process in 9 Simple Steps”. Available: 31/03/2022.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EVALUATING AVAILABILITY CHARACTERISTICS OF KNITTED USED FOR INTERIOR DESIGN

LUTIC Liliana

"Gh. Asachi" University, Faculty of Textile Leather and Industrial Management, Knitting and Ready – Made Clothing Department, 29 Dimitrie Mangeron Street, 700050, Iasi, România

Corresponding author: Lutic Liliana, E-mail: llutic@tex.tuiasi.ro

Abstract: *Technical knitted are successfully used in manufacturing mattresses, upholstery and interior decoration. This is due to the extremely varied design of the knitted, the structural diversity, the raw materials of a remarkable variety (including the ecological and biodegradable ones), durability, particular versatility and improved performances during use. These aspects lead to beneficiaries' satisfaction during both the visual and tactile analysis of the products as well as their use. Establishing a correlation between the requirements of the beneficiaries, the functions and representative quality characteristics, in relation to the usage of the product, is the basis of the creation and design activity, finalized with the elaboration of the product and process documentation. Evaluating the product's quality level has as a starting point, the use of standardized methods for measuring / estimating the representative quality characteristics, in order to determine the degree of influence these characteristics have on the product behavior during use. This leads to the possibility of choosing the optimal variants, which best reflects the wishes of the beneficiaries. In the case of knitted intended for mattresses, upholstery and interior decoration, availability characteristics (durability, maintaing shape, appearance, color and size) can be considered a priority.*
In this sense, the paper presents the evaluation methods for resistance and deformation of technical knitwear, under the action of uniaxial and multiaxial mechanical stresses (tearing resistance and elongation, piercing resistance and deformation arrow). These characteristics highlight the durability of the products and their ability to maintain their original shape, appearance and dimensions over time.

Key words: *quality, availability, mattress, decorations, evaluation, characteristics.*

1. GENERAL CONSIDERATIONS

Knitted fabrics ensure the manufacture of a great diversity of products used in all compartments of human activity. This is due to the many advantages offered:

- diversity of presentation forms;
- reduced specific mass compared to other textile materials;
- creating knitted structures that combine the characteristics of woven fabrics (resistance to mechanical stress, reduced extensibility), with those specific for knitted (spatial modelling capacity, voluminousness, possibilities for extended diversification, pleasant touch, etc);
- use of a large range of yarns with superior features;
- performance of knitting technologies;
- possibility of directing the knitting process in order to insure the quality characteristics demanded by the beneficiaries;

- high economic efficiency.

Speciality literature classifies knitted products in 12 branches: Agrotech, Buildtech, Clothtech, Hometech, Geotech, Medtech, Protech, Sporttech, Mobiltech, Indutech, Packtech, Oekotech [1, 2].

2. TECHINCAL KNITTED USED FOR INTERIOR DECORATIONS

2.1 Beneficiary requirements for the products used in interior design (Hometech)

The technical knitted used in mattress manufacturing, upholstery articles and interior decorations (Hometech branch) is characterized by an extermly varied design, structural diversivity, raw materials with remarkable variety, including the ecological and biodegradable ones, durability and versatility. These aspects lead to gaining user satisfaction during both the visual and tactile analysis of the products as well as improved performance during their use.

Beneficiary requirements for products used in interior design can be [3]:

- Constructive - ergonomic requirements regarding insurance of dimensional correspondence, fibrous composition, structure, mass;
- Aesthetic requirements for surface appearance, type of material, colour or chromatic combination, novelty degree, seams appearance, etc;
- Requirements for insurance of thermal and psychosensorial comfort, flexibility, extensibility and elasticity;
- Ecological requirements for health protection, harmful substances content, flammability, biodegradation capacity in the environment;
- Availability requirements: durability, preservation of shape, dimensions, appearance, colours and elasticity;
- Maintanence requirements regarding for efficient cleaning ability, resistance to dirt, remedy and reconditioning, decontamination ability, etc.

Technical solutions that made possible satisfying these requirements were aimed at:

- ✓ producing integrated knitted with "quilted" finish, whose thickness is obtained by inserting filling yarn between the two layers of stratified knitted fabrics;
- ✓ creating stratified Jacquard structure with voluminous filling yarns, fixed between the two layers of the knitted by connection points; the effect consists of increasing the elastic rebound capacity after compression forces exerted during use are stopped;
- ✓ using natural fibres with an ability to absorb and wick away moisture, good air circulation and temperature regulating capacity (offers warm or cool sensation according to the outside temperature);
- ✓ using synthetic fibres obtained through performant technologies that offer the possibility to create voluminous structures with a touch specific to natural fibers;
- ✓ processing yarns with a high mechanical stress endurance;
- ✓ using filament yarns and structures resistant to pilling;
- ✓ producing knitted structures with high resistance against homogenous and heterogeneous friction;
- ✓ using yarns and knitted structures with high endurance for cyclical stress (pull – return, repeated bending and compression);
- ✓ using yarns and a finishing technologies that ensure a fast and efficient cleaning;
- ✓ sing advanced technologies to produce materials resistant to dirt and moisture;
- ✓ using yarns and a finishing technologies that ensure a fast and efficient cleaning.

2.2. Knitted used for interior designs.

Integrated knitted fabrics are complex multilayer type structures. The yarns processed in manufacturing the two layers of integrated knitted must have characteristics specific for esthetics, comfort, protection and durability, while the filling yarns serve the purpose of thermal isolation and elastic rebound after compression.

In this paper, the study of knitted behaviour aimed for mattresses, covers and interior decorations was performed for five variants of integrated knitted fabrics, with jacquard structure, manufactured from different types of yarns. The knitted was subjected to:

- unidirectional traction loads until tearing, measuring resistance and tear elongation;
- multiaxial deformation loads, measuring the piercing resistance and the deformation arrow [4].

The characteristics of the five variants of integrated knitwear under study are presented in Table 1.

Table 1: *Characteristics of integrated knitted variants*

Knitted variant	**Structure**	**Prime material**			**Filling yarns sequen-ce**	**Thick-ness [mm]**	**Weight [g/m²]**	**Special characteristics**
		Front yarns	**Back yarns**	**Filling yarns**				
V 1	**Irregular jacquard**	PES Nm 18/1	PES 150 den	PES 600 den	1/4	1,59	245	Special esthetic look by using yarns of different sheen High termal comfort
V2	**Double relief rib jacquard**	PES Nm 18/1	PES 150 den	PA 1250 dtex	1/3	2,48	350	Special esthetic look by using yarns of different sheen High termal comfort
V 3	**Double relief rib jacquard**	Bamboo viscose Nm 20/1	PES 150 den	PES 1200 den	1/4	2,49	250	High termal comfort achieved through ecologicall fibers
V 4	**Double relief rib jacquard**	Bamboo viscose Nm 20/1	PES 150 den	PES 600 den	1/4	3,15	264	High termal comfort achieved through ecologicall fibers
V 5	**Irregular jacquard**	PES 52% PES+ Viscose 48% Nm 20/1	PES 150 den	PES 1200 den	1/2	2,68	342	Superior comfort and ecological charcateristics

2. EVALUATING AVAILABILITY CHARACTERISTICS

3.1. Evaluating availability of the knitted

The integrated knitted fabrics can be used as outer layer for producing mattresses, furniture upholstery and interior decorations (covers, coverlets), etc. As such, it is necessary that the knitted be characterised by:

- ❖ high spatial shaping ability;
- ❖ increased resistance to different types of loads;
- ❖ good rebound ability by returning to initial shape and size when usage mechanical loads are ceased;
- ❖ proper adhesion strength to contact layers.

Evaluating product quality implies the establishment of representative characteristics in relation to their destination and the application of standardized testing methods, in order to choose the optimal variants. Static mechanical loads (tearing elongation and resistance, piercing resistance, ripping) and dynamic loads (shock resistance), non destructive or distructive, are commonly encountered during use. To assess the availability of integrated knitted used in mattresses, upholstery and interior decoration (covers, coverlets, etc.) these characteristics were considered as representative: durability for unidirectional loards for stretching to tearing and multidirectiona loadsl to piercing. Tear elongation and piercing resistance influence the product's behavior during use and largely determine its availability function. Testing the behavior of the five intergrated knitted variants under tear-elongation mechanical loads was performed in three directions of strain: longitudinal direction (stitch columns), transverse (stitch rows) and a diagonal direction, forming a 45-degree angle with the vertical axis [4, 5].

The average values obtained are summarized in Table 2.

Table 2: *Resistance values for the analysed knitted variants*

Knitted variant	Tearing resistance R_T [daN]			Tearing elongation ε [%]			Piercing resistance R_P [daN]	Deformation arrow [mm]
	Şir Col	Rând Row	Diagonal	Şir Col	Rând Row	Diagonal		
V 4	57,8	60,0	57,0	84	40,0	41,0	84,5	1,7
V 5	59,4	61,9	58,1	82	42,0	43,0	86,0	1,8
V 1	54,6	67,0	54,0	105	55,0	70,0	80,5	1,8
V 3	41,2	46,4	34,8	92	55,0	95,0	74,8	2,7
V 6	56,7	68,0	56,4	79,0	39,0	42,0	87,5	1,5

Comparative analysis of tearing resistance for the six variants of knitted are suggestively illustrated in figures 1 – 4.

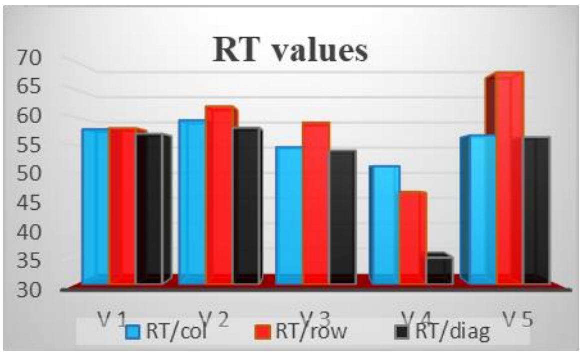


Fig. 1 *Comparative analysis of tearing resistance variation on the three stress directions for the knitted variants tested*

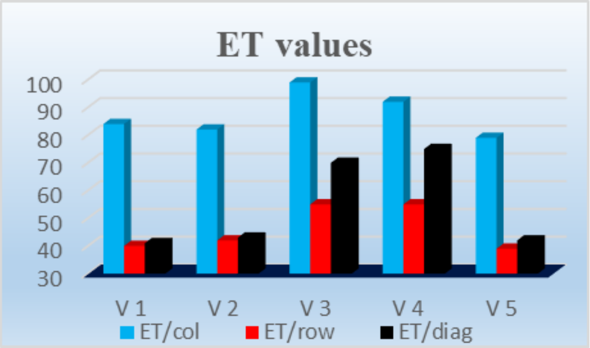


Fig. 2 *Comparative analysis of tearing elongation variation on the three stress directions, for the knitted variants tested*

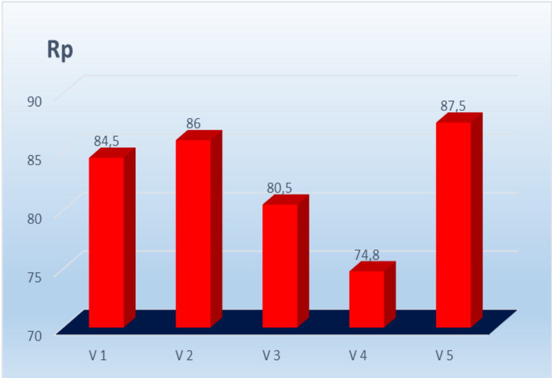


Fig. 3: *Comparative analysis for piercing resistance for all three knitted fabrics models*

Fig. 4: *Comparative analysis for arrow deformation for all three knitted fabrics models*

3.2. Conclusions regarding knitted behavious for elongation and piercing demands

- ❖ Tearing resistance values, on the three strain directions, are not significantly influenced by the thickness, or the mass of the knitted, but only by the raw material processed, the linear density of the filling yarns processed, and the number of connection points between the two layers of integrated knitted;
- ❖ Knitted variants made of PES yarns, on both front and back (V1, V2, V5) have the highest values of tear-elongation and piercing resistance;
- ❖ The highest tear-elongation resistance values (over 58 daN), on the transverse direction (stitch rows), were recorded in five of the knitted variants analysed. This is explained by the distribution of forces both on the stitch elements (needle loops and jack loops) and on the filling yarns, inserted between the two layers of the knitted;
- ❖ The lowest tear resistance values for the three stress directions, were recorded in the V4 variant that contains bamboo viscose yarns on the front and the lowest filling yarns count. Even if the V1 variant has the same filling yarns count, the fact that it is made on the front with PES yarns compensates for this;
- ❖ The lowest resistance values were registered in variant V4; this is explained by the lowest count of filling yarns (600 den) and their lowest insertion ratio (1/4);
- ❖ The lowest numbers for tear-elongation were recorded on the transverse direction (of the stitch columns), and the highest values of elongation were recorded in the longitudinal direction (of the stitch rows);
- ❖ The lowest numbers in tear-elongation and the deformation arrow were recorded in the V5, V2 knitted variants, for which the insert ratio of filling threads is higher (1/2, 1/3 respectively);

❖ In regard to the availability characteristics, **the tearing and piercing resistances can be associated with the ability of the product to maintain its integrity**, to the destructive loads exerted during use. **Elongations (deformations) can be associated with shape stability.** As such, it can be considered that:

  - ❖ The best variants, with superior behaviours in use (minimal risks of losing their initial characteristics over time) are the variants V1, V2, V5;
  - ❖ The most unfavorable variants (with the highest risk of deformation) are the V3, V4 variants.

4. CONCLUSIONS

Technical knitted fabrics used to manufacture mattresses, upholstery and interior decoration are characterized by: varied design, structural diversity, a wide spectrum of raw materials, durability, versatility and high performance during use. For the evaluation of the availability of integrated technical knitted, there were considered as representative, in regards to their destination, measurements of resistances for tear elongation and piercing (using the textile dynamometer). Resistance to tearing and piercing can be associated with the ability of the product to maintain its integrity against destructive loads that may occur during use. Elongation and deformation arrow may be associated with the stability of the shape, appearance and dimensions of the product. The evaluation resulted in the following conclusions:

- ❖ In what concerns the availability characteristics, the best variants of integrated knitted with superior behaviours during use (minimal risks of losing their initial characteristics over time) are:
  - Knit fabrics made of PES yarn (on the front, back and as filling yarns) (variants V1, V2);
  - Knitted made of yarn blends with 52% PES, 8% viscose (variant V5).
- ❖ The least favourable variants of the five analyzed (with the highest risk of deformation) are knitted manufactured with bamboo-viscose yarns on the front and PES yarns on the back and filling (variants V3, V4).

REFERENCES

[1] L. Lutic, "*Concepts Regarding the Quality of the Knitted Used in Mattress Production*", 14th Romanian Textiles and Leather Conference, Sinaia, 6-8 September 2012, pp. 320 – 327.

[2] L. Lutic, A. Pandelea, "*Knitted Structures Used in Mattress Manufacturin*", 46th International Congress IFKT, Sinaia, 6-8 September 2012, pp. 805 – 812.

[3] L. Lutic, "*Asigurarea calității în tricotaje - confecții*", Ed. Performantica, ISBN ISBN 978-606-685-856-4, Iaşi, 2022

[4] L. Lutic, "*Metrologie aplicată în Textile - Pielărie*", Ed. Performantica, ISBN 978-606-685-256-2, Iaşi, 2016

[5] ***, *SR EN 14976/2006*. Materiale textile. Material pentru saltele. Specificaţii şi metode de încercare

[6] ***, *SR EN ISO 13935-1/2002*. Materiale textile. Proprietăţi privind rezistenţa la tracţiune a cusăturilor ţesăturilor/tricoturilor şi articolelor textile.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ESTIMATION OF QUALITY LEVEL BASED ON QUALITY INDICATORS

PUSTIANU Monica, POPA Alexandru, BARBU Ionel, FOGORASI Magdalena, BUCEVSCHI Adina

Aurel Vlaicu University, Faculty of Engineering, AIITT Department, Revoluției,77, 310130, Arad, Romania, E-Mail: pustianumonica@yahoo.com

Corresponding author: Barbu, Ionel, E-mail: ionelbarbu@yahoo.com

Abstract: *Calimetry is a vast field of research, with applications in the textile field. It deals with both compliance and comparative measurements.This paper presents a comparative study of quality estimation based on integral indicators, two variants of fabrics made of a mixture of threads of 45% cotton and 55% polyester, intended for outerwear. For determining the integral indicators, an additive calculation method was used, based on synthetic indicators of the groups of characteristics (structural, mechanical, functional).By comparing the values of the integral (complex) indicators obtained for the two fabric variants, we could evaluate the best variant that corresponds to its destination in terms of the structural, mechanical and functional solutions adopted.To determine the integral indicators, an additive calculation method was used, based on synthetic indicators of the characteristics groups (structural, mechanical, functional).Synthetic indicators are the indicators of the subgroups and groups of characteristics and are obtained by following the steps below: determination of the degree of importance of the representative characteristic, adoption of the scale of assessment, reporting to the same assessment scale, determination of the value of synthetic quality indicators. Integral indicators calculated by statistical-mathematical analysis, express the level of product quality. They can be calculated both by methods based on synthetic indicators of feature groups and by methods based on simple indicators, using additive or multiplicative calculation methods.*

Key words: *Calimetry, integral and synthetic indicators, quality level of fabrics.*

1. INTRODUCTION

Calimetry is an interdisciplinary science dealing with the study of quality level estimation using technical, analytical or sociological measurement methods and resulting in the calculation of quality indicators.[1]

The measurement methods are applied on samples extracted by sampling, from batches of raw materials, semi-finished products, finished products, etc.

The estimation of the quality level is based on the statistical processing and interpretation of the data obtained from the evaluation of the quality characteristics.[2], [3], [4],[6].

Integral (complex) indicators calculated by statistical-mathematical analysis, express the level of product quality. They can be calculated both by methods based on synthetic indicators of feature groups and by methods based on simple indicators, using additive or multiplicative calculation methods.[1]

By comparing the integral indicators, it can be estimated for the best variant in terms of the solutions adopted.

2. RESULTS AND DISCUSSIONS

For this study, two variants of 45% cotton and 55% polyester yarn blend fabrics were used, with the same structure, but with other adopted values of structural, mechanical and functional characteristics, intended for outerwear.

To determine the integral indicators, an additive calculation method was used, based on synthetic indicators of the characteristics groups (structural, mechanical, functional).

Synthetic indicators are the indicators of the subgroups and groups of characteristics and are obtained by following the steps below:

- Determination of the degree of importance of the representative characteristic,
- Adoption of the scale of assessment,
- Reporting to the same assessment scale,
- Determination of the value of synthetic quality indicators.

2.1 Determination of the degree of importance of the representative characteristic

Determination of a synthetic indicator is based on a series of quality characteristics and requires their hierarchy through the coefficient of importance [1],[5].

For this study, the following groups of quality characteristics were adopted according to the destination of the article, presented in Table 1.

Table 1. *Adopted quality characteristics*

No.	Structural characteristics	Mechanical characteristics	Functional characteristics
1.	fabric width – l [cm]	Breaking load in warp- Su [kg f]	Wrinkle recovery angle to warp [0]
2.	specific mass – M [g / m]	Weft breaking load -Sb [kg f]	Wrinkle recovery angle in the weft [^{0}]
3.	Density in the warp – Du [yarns / 10 cm]	Elongation at break in the warp- Au [mm]	Humidity [%]
4.	Weft density – Db [yarn / 10 cm]	Elongation at break in the weft- Au [mm]	Wash fastness [notes]
5.		Resistance to splice [N]	Ironing fastness [Notes]
6.			Crocking fastness [notes]
7.			Fastness to perspiration [notes]

Tissue samples were taken and the following intervals of variation of the values of each characteristic were obtained. The preferred direction of variation of these characteristics (ascending ↑ or descending ↓) presented in Table 2 was also established.

Table 2. *Intervals and variation of the characteristics adopted*

No.	Characteristics groups	Characteristic	Value variation of the values	Preferably sense of variation
1.	Structural characteristics	fabric width - l [cm]	147-156	↑
		specific mass - M [g / m]	350 - 400	↓
		Warp setting - Du [yarn / 10 cm]	150-220	↓
		weft spacing - Db [yarn / 10 cm]	150-220	↓
2.	Mechanical characteristics	Warp breaking load Su [kg f]	50-100	↑
		Weft breaking load Sb [kg f]	40-100	↑
		elongation at break in the warp [mm]	10-50	↑
		elongation at break in the weft Au [mm]	10-50	↑
		Resistance to splice [N]	25-50	↑
3.	Functional characteristics	Wrinkle recovery angle to warp [0]	90-180	↑
		Wrinkle recovery angle to weft [^{0}]	90-180	↑
		Humidity [%]	1-10	↑
		Wash fastness [notes]	1-5	↑
		Ironing fastness [Notes]	1-5	↑
		Crocking fastness [notes]	1-5	↑
		Fastness to perspiration [notes]	1-5	↑

Measures were carried out on the two variants of fabrics and the values obtained for the characteristics are shown in Table 3.

Table 3. *Values of the characteristics obtained for each variant of fabric*

No.	Characteristics groups	Characteristic	Variant V1	Variant V2
1.	Structural characteristics	fabric width - l [cm]	149	152
		specific mass - M [g / m]	387	360
		Warp setting - Du [yarn / 10 cm]	205	196
		weft spacing - Db [yarn / 10 cm]	201	180
2.	Mechanical characteristics	Breaking load in warp Su [kg f]	89	60
		Weft breaking load Sb [kg f]	85	45
		Elongation at break in the warp Au [mm]	39	23
		Elongation at break in the weft Au [mm]	37	20
		Resistance to splice [N]	26	30
3.	Functional characteristics	Wrinkle recovery angle to warp [0]	154	140

		Wrinkle recovery angle in the weft [^{0}]	158	130
		Humidity [%]	3,5	5,5
		Wash fastness [notes]	5/5/5	4/4/4
		Ironing fastness [Notes]	5/5	4/4
		Crocking fastness [notes]	5/5	4/4
		Fastness to perspiration [notes]	5/5/5	4/4

The matrix method was used for calculating the importance coefficients of characteristics. The square matrices built with the chosen characteristics are presented in Tables 4,5,6.

Table 4. *The square matrix for structural characteristics*

Ci / Cj	C1 (l)	C2 (M)	C3 (Du)	C4 (Db)	$\sum_i n_{ij}$
C1 (l)	1	0	1	0	2
C2 (M)	1	1	1	1	4
C3 (Du)	0	0	1	1	2
C4 (Db)	1	0	1	1	3
$\sum_j n_{ij}$	3	1	4	3	$\sum_i\sum_j n_{ij} = 11$

Table 5*. The square matrix for Mechanical characteristics*

Ci / Cj	C1 (Su)	C2 (Sb)	C3 (Au)	C4 (Ab)	C5 (Rs)	$\sum_i n_{ij}$
C1 (Su)	1	1	0	0	1	3
C2 (Sb)	0	1	0	0	1	2
C3 (Au)	1	1	1	1	1	5
C4 (Ab)	1	1	0	1	1	4
C5 (Rs)	0	0	0	0	1	1
$\sum_j n_{ij}$	3	4	1	2	5	$\sum_i\sum_j n_{ij} = 15$

Table 6. *The square matrix for Functional characteristics*

Ci / Cj	C1 (Șu)	C2 (Șb)	C3 (U)	C4 (Rs)	C5 (Rc)	C6 (Rt)	C7 (Rf)	$\sum_i n_{ij}$
C1 (Șu)	1	0	1	1	1	1	1	6
C2 (Șb)	1	1	1	1	1	1	1	7
C3 (U)	0	0	1	1	1	1	1	5
C4 (Rs)	0	0	0	1	0	0	0	1
C5 (Rc)	0	0	0	1	1	0	0	2
C6 (Rt)	0	0	0	1	1	1	0	3
C7 (Rf)	0	0	0	1	1	1	1	4
$\sum_j n_{ij}$	2	1	3	7	6	5	4	$\sum_i\sum_j n_{ij} = 28$

Values of importance coefficients obtained with Equation 1, are presented in Table 7.

$$\alpha_i = \frac{\sum_i n_{ij}}{\sum_i \sum_j n_{ij}} \quad \textbf{(1)}$$

Table 7. *Calculated importance coefficients*

No.	Characteristics groups	Importance coefficient α_i	Values	Hierarchy of characteristics
1.	Structural characteristics	α1	0.27	C3>C1≥C4>C2
		α2	0.09	
		α3	0.36	
		α4	0.27	
2.	Mechanical characteristics	α1	0.2	C5>C2>C1>C4>C3
		α2	0.26	
		α3	0.06	
		α4	0.13	
		α5	0.33	
3.	Functional characteristics	α1	0.071	C4>C5>C6>C7>C3>C1>C2
		α2	0.035	
		α3	0.107	
		α4	0.25	
		α5	0.214	
		α6	0.17	
		α7	0.14	

From the analysis and comparison of the values of the importance coefficients, these characteristics can be ranked and it is clear which is the most important characteristic for each group of characteristics.

2.2. Adopt the scale of assessment of quality characteristics and reporting to the same assessment scale of all the characteristics adopted,

The values were reported on a scale of (0-10) and the following values presented in Table 8 were obtained.

Table 8. *Nj scores given to the characteristics adopted on the scale (0-10), for each fabric variant*

No.	Characteristics groups	Characteristic	Score n_j	Variant V1	Variant V2
1.	Structural characteristics	fabric width - l [cm]	n_1	2.22	5.55
		specific mass - M [g / m]	n_2	2.6	8
		Density in the warp - Du [yarns / 10 cm]	n_3	2.14	3.4
		Weft density - Db [yarn / 10 cm]	n_4	2.71	5.71
2.	Mechanical characteristics	Breaking load in warp Su [kg f]	n_1	7.8	2
		Weft breaking load Sb [kg f]	n_2	7.5	0.83
		Elongation at break in the warp Au [mm]	n_3	7.25	3.25
		Elongation at break in the weft Au [mm]	n_4	6.75	2.5

		Resistance to splice [N]	n_5	0.4	2
3.	Functional characteristics	Wrinkle recovery angle to warp [0]	n_1	7.1	5.5
		Wrinkle recovery angle in the weft [^{0}]	n_2	7.5	4.4
		Humidity [%]	n_3	2.7	5
		Wash fastness [notes]	n_4	10	7.5
		Ironing fastness [Notes]	n_5	10	7.5
		Crocking fastness [notes]	n_6	10	7.5
		Fastness to perspiration [notes]	n_7	10	7.5

2.3. The calculation of the synthetic indicators of the adopted characteristics was made with the relationship:

$$I_c = \frac{N_p}{N_{p\,max}} \quad \textbf{(2)}$$

Where:
N_P - The average score obtained for the quality features adopted
N_{pmax} - The maximum score for the scoring system

$$N_p = \sum_i \alpha_i \cdot n_i \quad \textbf{(3)}$$

Where:
α_i- the values of the coefficients of importance of the characteristics
n_i – the score granted to the quality characteristics adopted

The values of the mean scores and the values of the synthetic indicators calculated are shown in Table 9.

Table 9. *Average score values and values of synthetic indicators calculated*

No.	Characteristics groups	Variants	Average score	Max score	Synthetic indicator
1.	Structural characteristics	V1	2.32	10	I_{c1} =0.232
		V2	4.97	10	I_{c2} = 0.497
2.	Mechanical characteristics	V1	4.94	10	I_{c1} = 0.494
		V2	1.79	10	I_{c2} = 0.179
3.	Functional characteristics	V1	8.794	10	I_{c1} = 0.879
		V2	6.879	10	I_{c1} = 0.687

For the calculation of the integral indicators, the additive method was used based on the synthetic indicators, of the characteristics groups, which involves in addition to these indicators and the application of a calculation relationship containing these indicators and the level of importance of each synthetic indicator. That is why the level of importance for these indicators has been established by the matrix method.

The square matrices built with these synthetic indicators are shown in Table 10.

Table 10. *Quadratic matrix for synthetic indicators*

Cj \ Ci	C1 (Structural characteristics indicator)	C2 (Mechanical characteristics indicator)	C3 (Functional characteristics indicator)	$\sum_i n_{ij}$
C1 (Structural characteristics indicator)	1	0	0	1
C2 (Mechanical characteristics indicator)	1	1	1	3
C3 (Functional characteristics indicator)	1	0	1	2
$\sum_j n_{ij}$	3	1	2	$\sum_i \sum_j n_{ij} = 6$

Values of importance coefficients obtained with Equation 4, are presented in Table 11

$$\alpha_i = \frac{\sum_i n_{ij}}{\sum_i \sum_j n_{ij}} \quad \textbf{(4)}$$

Table 11. *Importance coefficients of the calculated synthetic indicators*

No.	Synthetic indicator	Synthetic indicator values		Importance coefficient α_i	Values
		Variant V1	Variant V2		
1.	Structural characteristics indicator	0.232	0.497	α1	0.5
2.	Mechanical characteristics indicator	0.494	0.179	α2	0.16
3.	Functional characteristics indicator	0.879	0.687	α3	0.33

The following relationship was used for calculating the integral indicator (5) Aad the values obtained are shown in Table 12.

$$N_I = \sum_i \alpha_i \cdot N_i \quad \textbf{(5)}$$

Where:

N_I - the level of the integral indicator
α_i - the values of the importance coefficients of the synthetic indicator

N_i - Synthetic indicator level

Table 12. *The values of the integral indicators obtained by the additive method*

No.	**Variant**	**Integral indicators**
1.	V1	0.485
2.	V2	0.502

3. CONCLUSIONS

Comprehensive product quality indicators can express the level of quality of these products

By comparing the values of the integral (complex) indicators obtained for the two fabric variants, it results that the V2 variant corresponds better to its destination in terms of the structural, mechanical and functional solutions adopted.

REFERENCES

[1] “*Handbook of Textile Engineering*”, AGIR Publishing House Bucharest, 2004.

[2] A. Florea A “*Product Quality Control”* Iaşi, Gh. Asachi Publishing House, 2001.

[3] L. Lutic, “*Evaluation of the yarn quality characteristics through synthetic indicators”*, Bulletin of the Polytechnic Institute Iași, LVI (LX), 2, 2010.

Theory of traveling-wave optical laser,” Phys. Rev., vol. 134, pp. A635–A646, Dec. 1965.

[4] E. Moisescu, “*Technical Quality Control- Knit wear”,* Iaşi, Gh. Asachi Publishing House, 2000.

[5] M. Pustianu, E. Airinei, A. Popa, and A. Bucevschi A, “*Comparative study on different types of knit products using synthetic indicators*”, Annals of the University of Oradea, Fascicle of textiles, leatherwork, XIX(2) 85-89, 2018.

[6] T.Iqbal, N.Khan, “*Export Performance a Vital Indicator for Measuring Industry Competitiveness: Evidence from Pakistan Textile and Clothing Industry*”, Life Science Journal-Acta Zhengzhou University Overseas Edition, vol.9, no.4, pag.3816-3822, 2012.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ESTIMATING mg CO_2 GENERATED FROM A COTTON FABRIC DEGRADATION

SÁNCHEZ-MARTINEZ Ainhoa[1], BELDA-ANAYA Raquel[1], BONET-ARACIL Marilés[1], CAPABLANCA Lucía[1] GISBERT-PAYÁ Jaime[1]

[1] Universitat Politècnica de València, Departamento de Ingeniería Textil y Papelera, Plaza Ferrándiz y Carbonell s/n, 03801 Alcoi, Spain, maboar@txp.upv.es

Corresponding author: Bonet-Aracil, Marilés, E-mail: maboar@txp.upv.es

Abstract: *Nowadays, concern about sustainability is a fact. Textile industry is considered as one of the most pollutants. There is an increase interest in quantifying the pollution generated by textiles. The chemicals and water used by textile industry are considerable. However, water consumption and wastewater are not the only drawback form textile sector. Greenhouse gases are important pollutants as well. It is necessary to measure pollution, in order to design and apply mecanisms to reduce the one generated from textiles, it is also important to improve product stewardship and control the value chain.*

This article establishes a method to evaluate the accelerated biodegradability by burial in compost of textile materials. In our experiment, a respirometric technique has been used to estimate the production of CO_2 through the comparison of results between the textiles to be analyzed against a reference product, which corresponded to a microcrystalline cellulose, and the ecosystem itself, without fibers. This test has allowed adjusting the reactions for reagent consumption volumes within an acceptable range. The results obtained have made it possible to validate the analysis method, since the process shows sufficient sensitivity to obtain significant differences between the analyzed samples which are microcrystalline cellulose and a sample from cotton fabric.

Key words: *Biodegradability, cellulose, greenhouse gas, sustainability, environment, fiber*

1. INTRODUCTION

The main environmental problems caused by the textile industry are usually related to high energy consumption, high amount of water consumption, the formation of wastewater, the use of chemical products, CO_2 emissions and solid waste. Textiles are responsible for 10% of global carbon emissions [1,2]

As for solid waste, it is the current model of textile production and preparation and its high consumption that leads to the formation of large quantities, since only 20% of textile waste, worldwide, is recycled or reused; while the remaining 80% is deposited in landfills or incinerated. This produces a great loss of energy and raw materials, as well as contamination of soils and marine ecosystems.

Solid waste can be generally classified according to its origin into three main types:

1. Post-industrial waste: those produced in manufacturing;
2. Pre-consumer waste: substandard or unsold items;
3. Post-consumer waste: generated by consumers.

But, in addition, they can be classified according to their raw material, in biodegradable waste (natural fibers or biopolymers) or non-biodegradable (synthetic polymers). Synthetic waste that is not recovered or recycled takes 100 to 1,000 years to degrade and ends up as microplastics, usually as a result of photodegradation, in small fragments. Microplastics, around five millimeters in size, accumulate above all in the sea, but also in the terrestrial environment [3].

This causes, therefore, contaminated farmland and, consequently, contamination of the food that is grown; as well as marine pollution, since agricultural products end up in local streams, rivers and groundwater, which will transport these residues to the sea.

With all this, some larger plastics cause death by suffocation or choking in marine animals that ingest them without realizing it. But the real problem is microplastics, which alter the quality of water, which are absorbed by plants and animals and, finally, reach the human food chain through the food that is consumed. [4,5]

The presence of these compounds continues to grow, affecting marine life, and therefore the entire planetary ecosystem, becoming a public health problem. [6]. For this reason, the textile sector is moving towards products that follow the bases of the circular economy in order to obtain products that are more durable, recyclable and easier to reuse or repair, as well as the greater use of biodegradable materials, in order to obtain greater sustainability in the sector.

Biodegradation occurs due to the action of enzymes from natural microbes (bacteria, fungi, and algae) resulting in a reduced molar mass of macromolecules that make up the biodegradable material. The biodegradation process can be divided into:

- 1) primary degradation
- 2) final degradation.

During primary degradation, the material undergoes weight loss, fragmentation, molecular weight reduction, and degrades into soluble, low molecular weight compounds. Final biodegradation or mineralization leads to the conversion of low molecular weight compounds (from primary degradation) into water (under aerobic conditions), CH_4 (under anaerobic conditions), CO_2 and/or cellular biomass, when it is a compostable material.

The degree of biodegradation or mineralization is defined as the conversion of organic carbon to CO_2. This depends on the properties of the polymer, as well as various abiotic and biotic factors.

For example, in compost and soil, where the higher temperature is available for degradation reactions, the rate of biodegradation is higher. Similarly, the concentration and diversity of microbial communities are higher in soil and compost that support higher rates of biodegradation. In aquatic systems, microenvironments have been shown to have a profound impact on the degradation of biodegradable plastics. Therefore, to efficiently capture the complexity of aquatic environments, the testing methodology must take into account all habitats (supralittoral, eulittoral, sublittoral benthic, deep-sea benthic, pelagic, and sediment) along with stress factors. abiotic (pH, salinity, temperature, UV etc.) and the microbial communities that influence degradation. Other factors that affect the biodegradation of materials include salinity, moisture, the presence of oxygen, pH, and UV radiation.

Therefore, this article aims to establish a work methodology to assess the degree of biodegradation of textile materials, in a compost environment at accelerated ageing. In this paper we compare results from a microcrystalline cellulose with results from cotton fabric. The ecosystem for burial is made of compost and perlite, and the amount of CO2 is from the ecosystem is also taken into consideration.

2. MATERIALS AND METHODS

2.1 Materials

In this study, a glass container with a hermetic closure with a capacity of 2.5 L is used, which will contain perlite and universal cultivation soil, both acquired from Batlle, distilled water and a 100 % cotton fabric 115 g/m^2 sample to be evaluated. Microcristalline cellulose was used as control.

Biodegradability assessment is performed with potassium hydroxide (KOH) solution, barium chloride ($BaCl_2$) solution, hydrochloric acid (HCl) solution and phenolphthalein as indactor. All solutions were prepared with distilled water.

2.2 Methods

This test was conducted according to the methodology described by Miniyasami et al [7] and Modelli et al [8]. Three bottles were prepared as shown in figure 1. Every bottle has the same composition except the material subjected to the biodegradation. One was prepared with, perlite, soil, perlite, and water, placing a glass with 40 mL KOH on the top. The second one was prepared with microcrystalline cellulose in the middle of the soil and the third one with the cotton fabric to test. Every sample was tested twice and the average value was offered as the test result showed in this paper.

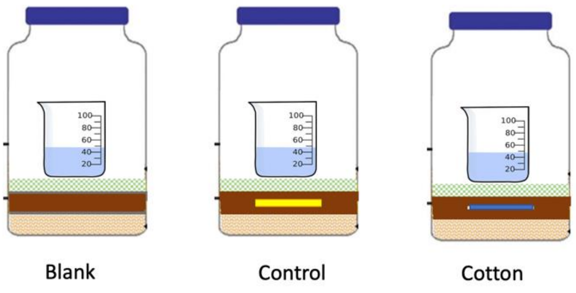


***Fig. 1**: Samples prepared for the burial test.*

Twice a week for 50 days, the beaker containing KOH is removed and a new one is inserted, the container is hermetically sealed again to maintain the ecosystem created inside. Then, an exces of mL of $BaCl_2$ are introduced into the KOH beaker that has captured the generated CO_2, to convert soluble K_2CO_3 into insoluble $BaCO_3$, and it is allowed to stand for 10 min so that all the precipitate forms are placed at the bottom of the glass. This process can be expressed as the chemical reaction (1):

$$2KOH + CO_2 \rightarrow K_2CO_3 \text{ (soluble)} + H_2O \qquad \textbf{(1)}$$

Afterwards, 10 mL of the solution are extracted without taking precipitate and introduced into a clean beaker, magnetic stirring is applied, 2 drops of phenolphthalein are added as indicator and the titration is carried out by dropping HCl from a burette, previously prepared, until the color of the solution returns to the initial one, according to the chemical reaction (2).

$$K_2CO_3 + BaCl_2 \rightarrow 2KCl + BaCO_3 \text{ (Precipitate)} \qquad \textbf{(2)}$$

The volume in mL of HCl consumed is noted, and then the mg of CO_2 determined according to the equation 1:

$$\text{mg } CO_2 \text{ sample} = \text{mg } CO_2 \text{ test} - \text{mg } CO_2 \text{ blank} \quad \textbf{(3)}$$

where:

- Sample = Fabric to analyse
- Test = bottle with soil, perlite and the fabric
- Blank = bottle with soil and perlite

Substracting the CO_2 from the blank allows to obtain results from the fabric or the sample buried, without including the CO_2 due to the soil nor the perlite.

3. RESULTS

Generally, the biodegradation process of a polymeric material is divided into two steps, initially the depolymerization or rupture of the polymeric chain is generated, and later the mineralization is obtained [8,9]. During the biodegradation, CO_2 is generated. Test conducted in our study allowed to measure its production. Figure 2 shows the behavior of both microcrystalline cellulose and cotton fabric. Apparently, both samples show similar behavior. As cotton is mainly comprised of cellulose, such similarity was expected. Cotton fabric is generating slightly lower quantities of CO_2 in comparison to microcrystalline cellulose.

Once results are analysed concisely, it can be clearly observed that during the first 10 days the CO2 generation is quite similar although, once the test has been conduted for more than 10 days, there is a change in tendency, and CO_2 generated from cotton is not increasing as fast as the CO_2 from microcristallyne cellulose. This can be since, cotton has cellulose but some other components which are not being degradated by soil burial at the same speed as cellulose.

It is also noticeable, there are some slight fluctuations in the results which can also be observed for both samples. This can be due to the fact that every measurement was conducted on Thuesday and Friday weekdays, what implies every 3 or 4 days, but it can also be due to some fluctuations on the temperature of the heater which are accelaerating or reducing the speed of the sample degradation.

In order to determine the final degradation of the process, the test should have been conducted until the CO_2 produced from the fabric is equal to cero what would imply the CO_2 is solely due to the blank composition, and there is no more influence of the fiber, nor the cellulose tested as reference. Some authors [7] stated that the test must be conducted for at least 180 days to get the final degradation of cellulose used as reference.

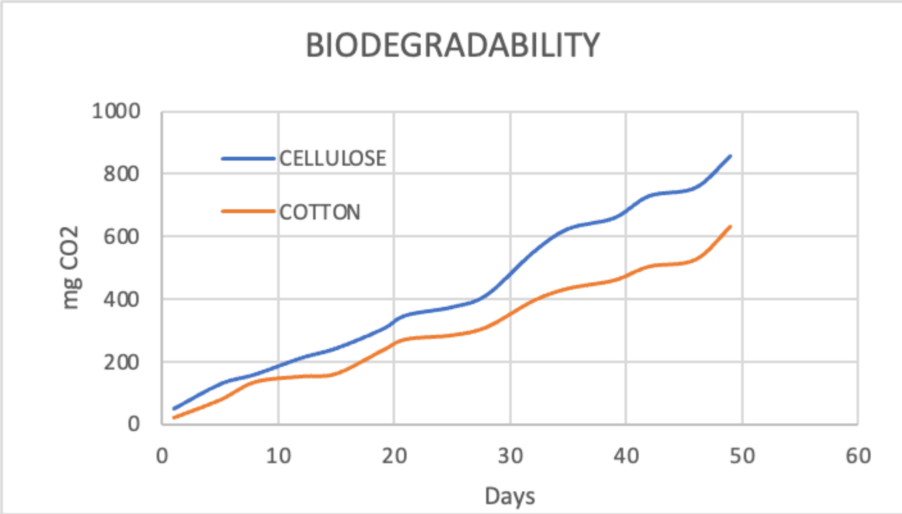


Fig. 2*: Biodegradability of cotton fabric.*

4. CONCLUSIONS

According to the suggested procedure, we have demonstrated it is possible to obtain results which are sensitive enough to estimate the CO_2 produced from the degradation of fabrics buried in soil. Althoug at first sight it would be easy to state that cotton generated lower quantity of CO_2 gas than cellulose, this cannot be affirmed as we don´t know the total amount of this gas generated by every tested samples. This test allows to stablish comparisons with some reference materials such as the microcristallyne cellulose used in our study, and it will allow to compare the biodegradability of different materials.

Furhter studies must be conducted with different materials and stablishing comparisons between the quantity of CO_2 generated. Considering the speed of degradation can be different from different samples, comparisons must be conducted not only for the same period of time, but for the final degradation of the tested sample. This will allow to determine the total quantity of CO_2 generated per gram of fiber and stablish compmarisons between fibers.

ACKNOWLEDGEMENTS

Authors want to acknowledge the contribution of the Students during 2021/2022 course in the Master of textile engineering at UPV, concisely to Alejabdro Mira, Marina Munar and Claudia Martínez for some of their results on the measurements for the second cotton fabric.

REFERENCES

[1] BREWER, Mark K. Slow fashion in a fast fashion world: Promoting sustainability and responsibility. Laws, 2019, vol. 8, no 4, p. 24.

[2] VIRTA, Laura; RÄISÄNEN, Riikka. Three futures scenarios of policy instruments for sustainable textile production and consumption as portrayed in the Finnish news media. Sustainability, 2021, vol. 13, no 2, p. 594.

[3]Koszewska, M. (2018). Circular economy—Challenges for the textile and clothing industry. Autex Research Journal, 18(4), pp. 337-347.

[4] Greenpeace (2021), “Plásticos en los océanos. Datos, comparativas e impactos” < http://archivoes.greenpeace.org/espana/Global/espana/2016/report/plasticos/plasticos_en_los_oceanos_LR.pdf > [visited: 04-02-2022]

[5] aclima (2018), “Microplásticos, problema ambiental de primer orden” < https://aclima.eus/microplasticos-problema-ambiental-de-primer-orden/ > [visited: 04-02-2022]

[6] Muniyasamy, Sudhakar; Patnaik, Asis. Biodegradable Behavior of Waste Wool and Their Recycled Polyester Preforms in Aqueous and Soil Conditions. Journal of Renewable Materials, 2021, vol. 9, no 10, pp 1661.

[7] Acharya, S., Rumi, S. S., Hu, Y., & Abidi, N. (2021). Microfibers from synthetic textiles as a major source of microplastics in the environment: A review. Textile Research Journal, 91(17-18), 2136-2156.

[8] Modelli, Alberto; Calcagno, Barbara; Scandola, Mariastella. Kinetics of aerobic polymer degradation in soil by means of the ASTM D 5988-96 standard method. Journal of environmental polymer degradation, 1999, vol. 7, no 2, pp. 109-116.

[9] Calmon, A., Dusserre-Bresson, L., Bellon-Maurel, V., Feuilloley, P., & Silvestre, F. (2000). An automated test for measuring polymer biodegradation. Chemosphere, 41(5), pp. 645-651.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

TEXTILE ENERGY STORAGE DEVICES – BATTERIES

STROE Cristina Elena[1], AILENI Raluca Maria[1], SÂRBU Teodor[1]

[1]National R&D Institute for Textiles and Leather, 16 Lucretiu Patrascanu Street, Bucharest 030508, Romania
E-Mail: office@incdtp.ro

Corresponding author: Stroe, Cristina Elena, E-mail: cristina.stroe@incdtp.ro

Abstract: *We are in the age of digital technologies, and the continuous growing demand for wearable and portable smart devices leads us to replace the conventional energy storage devices necessary for power supply with new ones that fully meet the needs of consumers by meeting specific conditions: be flexible, adaptable to deformation, have a long service life, be light, thin, sometimes invisible and with adaptable shapes and small dimensions. In addition, ensuring safety, wearing comfort and the use of non-toxic and eco-friendly materials are other current concerns that pave the way for further successful implementation of these devices. Among the energy storage technologies, batteries are the oldest, most common, and widely accessible form of storage. Technology and materials have evolved, so we have the most varied and sustainable resources for the manufacture of innovative batteries that meet all the requirements mentioned above.*
In this regard, this paper briefly presents a new possibility for the realization of energy storage devices, namely using textile materials. Thus, the aspects related to the component materials, the design features, and some technologies for the construction of textile-based batteries are approached. Several research teams addressed this matter, developing either fibre-shaped batteries or, more complex, fabric-based alternatives. Also, the encountered technical difficulties in developing such devices are discussed.

Keywords*: wearable technology, energy storage, textile battery, deformability, design strategy*

1. INTRODUCTION

The battery industry is changing very fast given the rapid progress of new designs, production methods and modified chemistries. Also, the miniaturization and digitalization of consumer electronic products are two directions that contribute to changing the design and performance of these batteries.

The growing need for batteries in the digital age of laptops, smartphones, tablets, smart electronics, electronic textiles, etc. will drive the global consumer battery market to reach $50 billion by 2025 [1]. As the wearable electronics market expands and traditional battery technologies struggle to achieve flexibility, foldability, stretchability, thinness and lightweight properties, new energy storage solutions with innovative and modern form factors that can meet these criteria are needed [2]. In this regard, important steps have been taken in the development of functional energy storage textiles, for truly wearable and portable smart devices. Thus, textile fibre-shaped batteries are one step closer to this goal and have excellent new features that can enhance their applicability.

As structural deformability is being one of the most important demands for these new batteries, there are two general approaches to introduce it into batteries:

- replacing intrinsically stiff materials by soft and bendable compounds;
- processing of the stiff materials into structures that are flexible [3].

2. TYPES OF TEXTILE BATTERIES

A battery is a device that can store chemical energy and convert it through a series of electrochemical reactions into electricity. In general, the architecture of a battery is made up of several elements, such as two electrodes (anode and cathode), each with a current collector, that sits on opposite ends of the battery, and a separator between them. While these items are common to all batteries, the difference lies in the choice of constituent materials [4].

Two approaches are considered for the construction of a textile battery, namely:
(1) the one-dimensional (1D) approach, in which all battery materials are stacked into a single fibre, yarn, or cable (fibrous structure);
(2) the two-dimensional (2D) approach, in which the available textiles (woven, knitted, nonwoven) are incorporated with active materials (planar structure) [4].

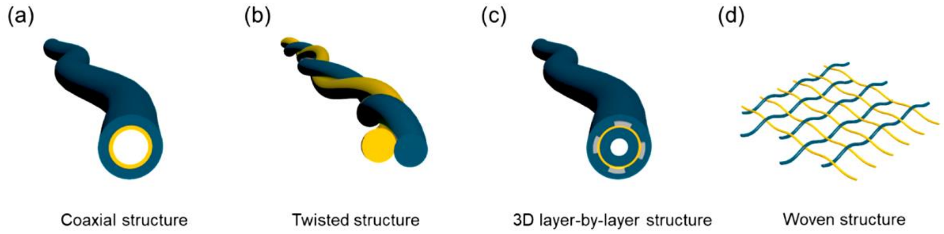


Fig. 1: Schematics of batteries structures made of textile materials: (a–c) 1D electronic fibres and (d) 2D electronic textiles [5]

2.1 Fibrous structure-based battery

Fibrous materials (fibres, filaments, yarns) represent a promising option to manufacture batteries attributing to their superstructure with large surface area, lightweight, good flexibility, cost-effectiveness, and the ability to sustain complex deformations. In addition, their potential for mass production and in many different forms (solid, hollow, core-shell, or hierarchically porous structure) due to the various textile technologies makes them suitable for building batteries [6].

When designing a fibrous battery should be considered that the essential components of these batteries (electrodes, electrolytes, and separators) and their structures to be compatible.

Since the electrodes are being the core elements in a battery, they should possess the intrinsic ability to bend, the most important factor, therefore ideal materials need to be chosen. So far, several materials and structures have been studied for the manufacture of electrodes, such as metal wire-based electrodes, carbon fibre-based electrodes, carbon nanotube fibre-based electrodes, graphene fibre-based electrodes or film-based electrodes (e.g carbon nanotube sheets) [7]. Although carbon materials have outstanding electrical and mechanical properties, the production of CNT fibres is extremely expensive, and often requires using expensive technologies [8].

The electrolyte is the element that separates the electrodes. Electrolyte performance has a direct impact on the working temperature, safety, cyclability, and cell capacity of the battery [9]. To improve the performance of a battery, a large number of electrolytes have been developed, primarily categorized as liquid-based electrolytes and solid electrolytes.

Liquid electrolytes can be further classified into nonaqueous electrolytes (carbonate esters and ethers) and aqueous electrolytes. The non-aqueous electrolytes hold many advantages like high ionic conductivity, low viscosity, high stability, and relatively low cost, but they often pose potential safety hazards resulting from electrolyte leakage and flammability [10]. Instead, the aqueous types are non-flammable and attractive for batteries with high power density. They possess highly ionic conductivity and are also low-cost. But they face some major problems by affecting the metal electrode by corrosion, passivation, hydrogen evolution, and dendrite formation, they have limited water thermodynamic electrochemical window and their performance at low temperatures is limited by the freezing point [11].

Solid-state electrolytes can be divided into polymer-based (organic) electrolytes and inorganic electrolytes. Among them, gel-polymer type (GPE) is a more desirable electrolyte formed by incorporating an organic liquid electrolyte in a polymer matrix. It is safe, has high thermal stability, and low volatile nature [12]. It benefits from a better ionic conductivity than that of solid-polymer (SPE) types and is very close to the values observed for liquid electrolytes. The most common polymers used to prepare GPEs are polyacrylonitrile (PAN), polymethylmethacrylate (PMMA), polyvinylchloride (PVC), and polyvinylidene fluoride (PVDF) [13]. One of the significant drawbacks of GPEs is insufficient mechanical strength, due to the lack of rigidity in their matrix, which limits their application [12]. Besides, when the incorporation of fillers is achieved, a new class of electrolytes arises, the composite-polymer electrolytes (CPE) [9].

The first battery made into a fibre shape was the lithium-ion battery (LIB), because of its easy fabrication. But the low energy density limited its real applications [14]. In addition, until now numerous other fibre-shaped batteries have been also developed, according to the main materials used for making the electrodes: zinc-ion battery (ZIB), zinc-air battery (ZAB), lithium-air battery (LAB) (table 1).

Table 1: Different types of fibrous batteries

Battery type	**Shape**	**Anode**	**Cathode**	**Electrolyte**	**Voltage**	**Cycle life**	**Ref.**
LIB	twisted	$Li_4Ti_5O_{12}$ (LTO)-composite coated onto a steel-filled polyester conductive thread (SPCT)	$LiFePO_4$ (LFP)-composite coated SPCT	LiPF6 and polyethylene oxide (PEO) solid-state electrolyte	~ 2.3 V	>30000 bend-release cycles	[8]
ZIB	coaxial	Zn wire	MnO2 coated carbon wire	GO flakes–embedded PVA hydrogel	~ 90 mV	>1000 charging/ recharging cycles and >500 twisting cycles	[15]
ZAB	spring	Zn wire spring	Teflon plate covered with aligned and cross-stacked CNT sheet	PVA-PEO-KOH hydrogel electrolyte	1.0 V	30 discharge/ charge cycles and 100 bending cycles	[16]
LAB	coaxial	Li wire	Aligned CNT sheet	Gel electrolyte	2.45 V	100 cycles	[17]

2.2 Fabric-based batteries

To develop fabric-based batteries different approaches have been used:

a) stitching a few fibre-shaped batteries into a piece of existing fabric;
b) fabricating loosely woven - knitted fabrics with fibre-shaped battery units [18].
c) using printing technology to add a proper layer with demanded properties to a textile layer, woven or knitted;
d) coating fabrics that are stacked together layer by layer.

By integrating multiple fibre batteries in fabric structures, an increased storage capacity will be obtained, thus providing a long working time for future wearable electronics [19]. Realizing soft woven/knitted energy textiles is still challenging due to the generally large diameter of the battery fibres with complex layered structures, as well as the increased mechanical modulus, affecting further their processability [18].

Printing technologies are much more appropriate to produce batteries including textile substrates, because of many advantages: design freedom, a wide variety of materials, textile breathability and flexibility, ultra-thin, lightweight, environmental safety and low cost. There are two most common printed battery designs: stack or sandwich, and coplanar or parallel (two electrodes placed in a side-by-side arrangement) architectures. Also, two chemistries are very used for the manufacturing of printed batteries: lithium-ion and zinc–manganese dioxide chemistries [20].

Further are exemplified some approaches to manufacture fabric-based batteries, which are based on unusual types of electrolytes that support the production and storage of energy.

Sweat activated fabric-based battery

Recently, Gang Xiao et al. developed a cotton-yarn-based sweat-activated battery (CYSAB) with a three-segment structure, in which carbon-black-modified, pristine yarn and Zn foil-wrapped segments were prepared to serve as the cathode, salt bridge, and anode, respectively. This type of battery can be rapidly activated upon electrolyte absorption. The ion concentration, the infiltrated electrolyte volume, and evaporation rate are three key factors that influence its performance.

The CYSABs were woven into fabrics and connected in series and parallel configurations to produce an energy supplying headband, which was activated by the sweat eliminated during physical activity to power light-emitting diode headlights. Electricity generation from the CYSAB greatly relies on the wicking of the electrolyte solution into capillary channels between the fibres and the migration of ions in the aqueous environment. Thus, it is demonstrated the ability to use these batteries in health monitoring [21].

Bacteria activated fabric-based battery

Bio-based batteries can be developed by using enzymes or microorganisms to scavenge biochemical energy from the wearers' body fluids such as sweat, saliva, blood, and tears. This type of biological battery can be the most suitable power source for wearable-health monitoring systems [22]. This approach was recently studied by a research team at the State University of New York-Binghamton. They developed an entirely textile-based, bacteria-powered biobattery that could one day be integrated into wearable electronics. It was used a single-layer fabric comprised of 92% polyester and 8% spandex. The structure of the battery consisted of the anode and cathode placed in a single reaction chamber with no separating membrane. The single-chamber was formed by screen printing an anodic paste (PEDOT:PSS) on one side of the fabric and then a cathodic paste (PEDOT:PSS modified silver oxide) on the other side while controlling the pastes' penetration into the material. The anodic reaction chambers were engineered to have electronic conducting paths, and microfluidic reactors for the bacterial cells and the silver oxide/silver were used as coupled solid-state oxidant cathodes [22].

Fruit-based textile battery

Fruit-based gel electrolytes are a promising approach to produce batteries because natural fruits contain abundant ionic content. By using citric acid extracted from citrus juices and mixing it with gelatine or starch, flexible, transparent and environmentally friendly gel electrolytes can be obtained. These electrolytes can be sandwiched between metallic fabric-based electrodes to create energy storage devices [23] [24].

Compared with planar batteries, the designing and fabrication of fibre-shaped batteries (FBs) encounters some problems (Fig. 2). Mainly, the FBs devices should avoid the short-circuiting and leakage of the electrolytes, in the processes of work and deformation. The safety, convenience, and durability of FBs are important directions for their practical applications in the future [25].

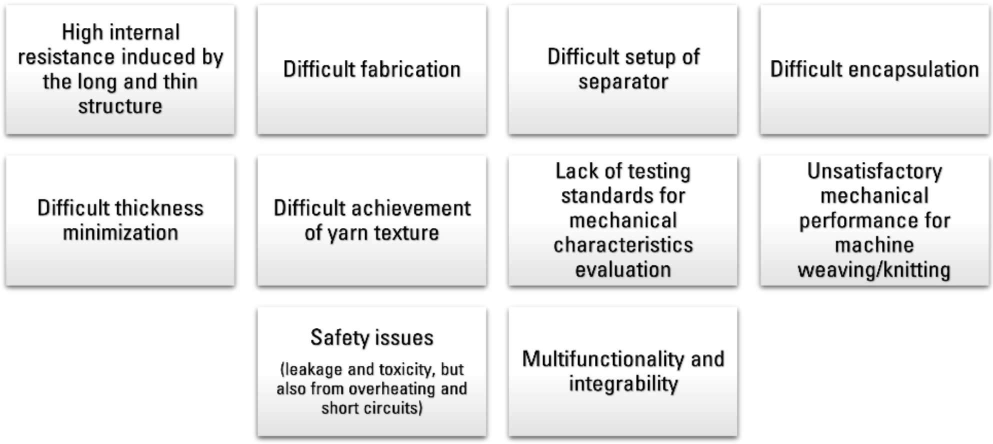


Fig. 2: The technical difficulties encountered by the 1D textile-based batteries for future wearable applications [18]

3. CONCLUSIONS

Wearable devices are used both for personal and work-related purposes in many different industries like healthcare, sport and fitness, fashion, security, retail, construction, logistics and transportation, etc. because of the multiple advantages that they bring: health monitorization, stimulation to have an active life, safety, data storage, information and so on.

We need efficient fabrication strategies for the storage energy technology to obtain functional and smart wearable devices for a better user experience and with improved performances on many different levels: mechanical properties (flexibility, bendability, rollability, stretchability, foldability, etc.), high rate/cycle capability, thickness, durability over time, stability and biocompatibility, interactivity, adaptability and aesthetic design.

ACKNOWLEDGEMENTS

This work is funded by the MCID (Romania) through the National Project "Electroconductive composite textiles based on 3D polymeric matrices for sensory systems for monitoring and attenuation of electromagnetic waves (3D ELECTROTEX)" [PN 19 17 01 01].

REFERENCES

[1] StrategyR, "Consumer Batteries-World Market Report," USA, 2020.

[2] X. He, "Flexible, Printed and Thin Film Batteries 2020-2030: Technologies, Markets and Players," IDTechEx, 2020.

[3] L. A. Wehner et al., "Multifunctional Batteries: Flexible, Transient, and Transparent," *ACS Cent. Sci.*, vol. 7, no. 2, p. 231–244, 2021.

[4] N. S. Hudak, "Water-based textile batteries-Mitre Technical Report," MITRE Corporation, 2019.

[5] M. Kang and T. Kim, "Recent Advances in Fiber-Shaped Electronic Devices for Wearable Applications," *Appl. Sci.*, vol. 11, no. 13, p. 6131, 2021.

[6] Y. Gao et al., "Fibrous Materials for Flexible Li–S Battery," *Adv. Energy Mat.*, vol. 11, no. 15, 2020

[7] W. Ma et al., "Smart fibers for energy conversion and storage," *Chem. Soc. Rev.*, vol. 50, no. 12, p. 7009–7061, 2021.

[8] H. Qu, X. Lu and M. Skorobogatiy, "All-solid flexible fiber-shaped lithium ion batteries," Cornell Univeristy, arXiv:1801.04850 [physics.app-ph], 2018.

[9] B. Maia et al., "Designing Versatile Polymers for Lithium-Ion Battery Applications: A Review," *Polymers*, vol. 14, no. 403, 2020.

[10] C. Zhao et al., "Flexible Na batteries," *InfoMat*, vol. 2, no. 1, pp. 126-138, 2019.

[11] A.G. Olabi et al., "Metal-Air Batteries—A Review," *Energies*, vol. 14, no. 7373, 2021.

[12] A. Naskar et al., "Polymer-Ceramic Composite Electrolyte for Li-Ion Batteries," in *Materials Science and Materials Engineering*, Elsevier, 2021.

[13] E. Bekaert et al., "Chapter One - Electrolytes for Li- and Na-Ion Batteries: Concepts, Candidates, and the Role of Nanotechnology," in *Emerging Nanotechnologies in Rechargeable Energy Storage Systems*, Elsevier, 2017, pp. 1-43.

[14] L. Ye et al., "Recent advances in flexible fiber-shaped metal-air batteries," *Energy Storage Mater.*, vol. 28, pp. 364-374, 2020.

[15] X. Xiao et al., "An ultrathin rechargeable solid-state zinc ion fiber battery for electronic textiles," *Sci. Adv.*, vol. 7, no. 49, 2021.

[16] Y. Xu et al., "Flexible, Stretchable, and Rechargeable Fiber-Shaped Zinc-Air Battery Based on Cross-Stacked Carbon Nanotube Sheets," *Angew. Chem. Int. Ed.*, vol. 54, no. 51, p. 15390–15394, 2015.

[17] Y. Zhang et al., "High-Performance Lithium-Air Battery with a Coaxial-Fiber Architecture," *Angew. Chem. Int. Ed.*, vol. 55, no. 14, p. 4487–4491, 2016.

[18] F. Mo et al., "An overview of fiber-shaped batteries with a focus on multifunctionality, scalability, and technical difficulties," *Adv. Mater.*, vol. 32, no. 5, 2019.

[19] Y. H. Zhu et al., "Flexible 1D Batteries: Recent Progress and Prospects," *Adv. Mater.*, vol. 32, no. 5, 2019.

[20] A. Ali et al., "Fabric based printed-distributed battery for wearable e-textiles: a review" *Sci. Technol. Adv. Mater.*, vol. 22, no. 1, pp. 772-793, 2021.

[21] G. Xiao et al., "A weavable and scalable cotton-yarn-based battery activated by human sweat for textile electronics," *Adv. Sci.*, vol. 9, no. 7, 2022.

[22] S. Pang et al., "Flexible and Stretchable Biobatteries: Monolithic Integration of Membrane-Free Microbial Fuel Cells in a Single Textile Layer," *Adv. Energy Mater.*, vol. 8, no. 7, 2017.

[23] S. Gellner, A. Schwarz-Pfeiffer and E. Nannen, "Textile-Based Battery Using a Biodegradable Gel-Electrolyte," *Proceedings*, vol. 68, no. 17, 2021.

[24] Z. Wang et al., "Fully transient stretchable fruit-based battery as safe and environmentally friendly power source for wearable electronics," *EcoMat*, 3:e12073, 2021.

[25] Y. Zhang et al, "Electronic fibers and textiles: Recent progress and perspective," *iScience*, vol. 24, 102716, 2021.

STUDY ON THE TREATMENT OF TEXTILE MATERIALS FOR THE MANUFACTURE OF MATTRESS COVERS

ŞUTEU Marius Darius[1], BOHM Gabriella[1], DOBLE Liliana[1]

[1]University of Oradea, Faculty of Energy Engineering and Industrial Management, Department Textiles, Leather and Industrial Management, 410058, Oradea, România, E-Mail: suteu_marius@yahoo.com

Corresponding author: ŞUTEU Marius Darius, E-mail: suteu_marius@yahoo.com

Abstract: *Changes in the rules for flammability testing have emphasized from the foam used in the contents of mattresses, to their covers, so the prevalence of these additives in current mattress covers is a very important unknown. In the present work, the materials for making two mattress covers (a mattress cover for domestic use and a mattress cover for hotel regime) were treated and tested in order to obtain basic information about the chemical treatment of fibers from the new mattress covers. The constituent components of the two mattress covers were each undersampled by cutting each layer then, it was passed to the collection of samples in small, labeled bags. Each sample was sampled over its entire layer depth, with section areas of about 1 - 2cm. This paper highlights the difference in finishing treatments, depending on the areas of use of knitted materials, intended for mattress covers. Thus, in addition to the differences between the solutions that apply to these materials, we can also see that those intended for domestic use are passed through different surface treatments, compared to those intended for the hotel industry, which require an immersion treatment, in order to obtain that load with 100% to 150% solution. The apparent omission of mattress covers from the criteria for chemical-free mattress certifications suggests that improvements are needed in terms of mattress labelling and also correct consumer education.*

Key words: *mattress cover, fiber, household, short term rental.*

1. INTRODUCTION

The inclusion of flame-resistant fibres in mattresses is driven by the California and US flammability regulations, despite the fact that their use in products poses a potential health risk [1]. Changes in california furniture flammability testing rules have shifted the focus from foam to their covers [2], so the prevalence of these additives in current mattress covers is an important unknown. "Certi-PUR-US" is an industry-based certification program that designates that foam products are free of heavy metals, PBDE, TDCPP or TCEP ("Tris") flame retardant, as well as numerous flame retardant additives [3], [4].

Consumers may think that certiPUR-US certified mattresses have undergone rigorous testing and do not contain hazardous substances.

Flame retardants in the components of the mattress without foam must be labelled if they are for young children or infants [5]. In this respect, it is not clear whether substances such as fiberglass (being considered a hazardous substance) are considered a flame-retardant chemical using current guidelines [6], [7].

However, certification and testing do not seem to include mattress covers [8].

2. EXPERIMENTAL PART

In the present work, the materials for making two mattress covers (a mattress cover for domestic use and a mattress cover for hotel regime) were treated and tested in order to obtain basic information about the chemical treatment of fibers from the new mattress covers.

The constituent components of the two mattress covers were each undersampled by cutting each layer then proceeded to collect the samples in small labeled bags. Each sample was sampled over its entire layer depth, with section areas of about 1 - 2cm.

Sample preparation and analysis were carried out using a standard internal operating procedure for the analysis of the fibrous content of the materials in the two mattress covers.

All samples were made with a Microscope Motic Fig. 1.

Fig. 1*: Microscope Motic*

Table 1: *Mattress cover for domestic*

Treatment	Likroll
Supplements	Clean&Fresh
Recipe	Citric Acid 0.2% Elastofin STO501 1.4% Sanitezed TH15-14 0.5%, Temp:150°C
Request width	229-231 cm
Request weight	204-212 gr/m^2
Composition	100%Polyester
Color	Natural, Ciment

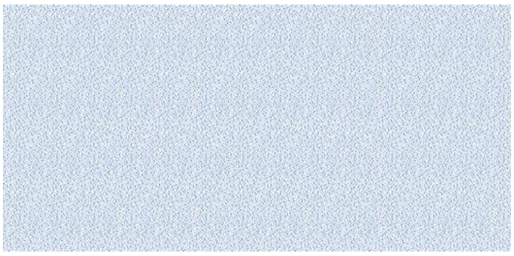


Fig. 1*: Treated material for home pouch (mattress)*

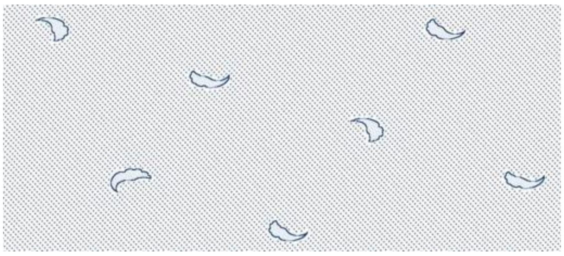


Fig. 2*: Material treated for short term rental cover (mattress)*

The main components of each mattress cover tested and their observed compositions are summarised in Table 1 and Table 2. The different component parts as a result of the finishing treatments of the two mattress covers, for home use - which were mixtures of: JASMINE AbioFlame 14%, citric acid / pick-up 100% control poids/weight controle, Temp:130^{0}C, compared to the covers intended for the hotel industry - which have in their component: AbioFlame JASMINE 14% noer no citric acid / pick-up 100% control poids/weight control, Temp:130°C, are different and require immersion treatment, to get that load with 100% to 150% solution.

Table 2: *Mattress cover for hotel regime*

Treatment	PADDER FR + LIKROLL – COATING FR (on back)
Supplements	Abioflame Polyester
Recipe	AbioFlame JASMINE 14% NO softener NO citric acid / pick-up 100% controle poids/weight controle, Temp:130°C
Request width	229-231 cm
Request weight	267-278 gr/m^2
Composition	100%Polyester
Color	Natural, Mimosa

3. CONCLUSIONS

This paper highlights the difference in finishing treatments, depending on the areas of use of knitted materials, intended for mattress covers. Thus, in addition to the differences between the solutions that apply to these materials, we can also see that those intended for domestic use are passed through different surface treatments, compared to those intended for the hotel industry, which require an immersion treatment, in order to obtain that load with 100% to 150% solution.

Although flame-resistant fibers are used in mattress covers to comply with flammability regulations, their compositions are uncertain on labels that can only describe the foam content in the architectural structure of the mattress.

The apparent omission of mattress covers from the criteria for chemical-free mattress certifications suggests that improvements are needed in terms of mattress labelling and also correct consumer education.

REFERENCES

[1] Stapleton H.M., Klosterhaus S., Keller A., Ferguson P.L., van Bergen S., Cooper E., Webster T.F., Blum A. Identification of Flame Retardants in Polyurethane Foam Collected from Baby Products. Environ. Sci. Technol. 2011;45:5323–5331. doi: 10.1021/es2007462.

[2] BHGS (California Bureau of Household Goods and Services) Technical Bulletin 117-Residential Upholstered Furniture Standard Fact Sheet. [accessed on 08 aprilie 2022]; Available online:. https://bhgs.dca.ca.gov/industry/tb_117_faq_sheet.pdf.

[3] AFPF (Alliance for Flexible Polyurethane Foam Inc.) CertiPur-US Technical Guidelines for Molded Foam. 20 November 2020. [accessed on 08 aprilie 2022]. Available online: https://certipur.us/technical-guidelines.

[4] Petreas M., Gill R., Takaku-Pugh S., Lytle E., Parry E., Wang M., Quinn J., Park J.-S. Rapid methodology to screen flame retardants in upholstered furniture for compliance with new California labeling law (SB 1019) Chemosphere. 2016; 152:353–359. doi: 10.1016/j.chemosphere. 2016.02.102.

[5] SFDE (San Francisco Department of the Environment) FAQ for Retailers Selling Upholstered Home Furniture in San Francisco, Including Information about Flame Retardant

Chemicals. 2018. (accessed on 08 aprilie 2022). Available online: https://sfenvironment.org/sites/default/files/fliers/files/sfe_th_flame_retardants_faq_for_retailers.pdf

[6] BHGS AB 2998 Frequently Asked Questions. (accessed on 08 aprilie 2022); 2019 Available online: https://bhgs.dca.ca.gov/forms_pubs/ab2998_faq.pdf.

[7] ISPA (International Sleep Products Association) Survey of FR Fibers and Materials Used by Mattress Producers to Meet Federal Flammability Standards. (accessed on 08 aprilie 2022); 2020 Available online: https://bhgs.dca.ca.gov/forms_pubs/20200131_frsurveyreport.pdf

[8] Fiberglass and Other Flame-Resistant Fibers in Mattress Covers Jeff Wagner, Jefferson Fowles, Tracy Barreau Int J Environ Res Public Health. 2022 Feb; 19(3): 1695. Published online 2022 Feb 1. doi: 10.3390/ijerph19031695 PMCID: PMC8835476

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

FORMULATION AND OPTIMIZATION OF CLAY-BASED DISPERSION FOR TEXTILES FUNCTIONALIZATION

TANASESCU Elena-Cornelia[1,2], LITE Mihaela-Cristina[1,2], SANDULACHE Irina-Mariana[1], SECAREANU Lucia-Oana[1,3] IORDACHE Ovidiu[1], CONSTANTINESCU Roxana[1]

[1] National Research and Development Institute for Textiles and Leather – INCDTP, 030508, Bucharest, Romania, E-mail: office@incdtp.ro

[2] University Politehnica of Bucharest, Faculty of Applied Chemistry and Materials Science, 1-7 Gheorghe Polizu, 011061, Bucharest, Romania, E-mail: secretariat@chimie.upb.ro

[3] Gheorghe Asachi" Technical University of Iasi-Romania, Faculty of Industrial Design and Business Management, 59A Prof. D. Mangeron Blvd., 700050, Iasi, Romania, E-mail: secretariat@chimie.upb.ro

Corresponding author: Tanasescu Elena-Cornelia, E-mail: cornelia.tanasescu@incdtp.ro

Abstract: *One of the main factors for diseases transmission is represented by textile materials and an example for textiles that can support bacterial growth is met in hospitals where patients contaminate their cloths and bed covers by bacterial shedding. Thus, there is a need to improve the quality of people's lives by intensive research to develop antimicrobial textiles. Because of the way we live and the environment we live in there is a need for multifunctional textiles with antimicrobial properties. Efficient antimicrobial solutions can be plants derived chemicals and clays. This paper is a part of a Eureka project. The main objective of the project is to develop multi-functional antimicrobial textile materials to prevent bacteria spreading and to create an antimicrobial shield for human body. The work was carried out through 2 steps. The first step consisted of making 4 variants (different in terms of constituent components) and using 3 types of equipment to prepare these 4 variants. The selection of the method for obtaining the most suitable dispersions was made by evaluating the stability over time and by evaluating by molecular absorption spectrophotometry in UV-VIS (on the wavelength range: 200–800 nm). The second step to obtain a stable and physico-chemically and pharmacologically adequate dispersion was to prepare 8 dispersion variants according to the method selected in step I. The evaluation of the obtained dispersions was performed by microbiological methods (inoculation with two strains: Escherichia coli and Staphylococcus aureus), measurements of Zeta potential and by evaluation of the antioxidant character.*

Key words: *antibacterial textiles, nano clays, plant extracts, blue clay.*

1. INTRODUCTION

Textiles can provide a substrate for the development of different populations of microorganisms, especially in conditions of adequate humidity and temperature, in contact with the human body. With increasing attention to hygiene, many investigations have been carried out to make textiles with antimicrobial properties. As many antimicrobial agents are avoided due to possible side effects, a promising alternative is to use inorganic nanoparticles and their nanocomposites.

Chemical finishing of textiles involves the use of chemicals that can perform various functions. They can be applied in the form of aqueous solutions or emulsions, by a variety of methods. Of course, all these treatments also highlight the need to assess and ensure their ecological character [1]. In addition, any antibacterial treatment performed on a textile material, in addition to being effective against micro-organisms, must not be toxic to the user or to the environment [2].

The development of nanotechnologies brings, in the field of textile functionalization, a wide range of new application possibilities [3].

They can be used by:

• introduction of functional nanomaterials in artificial/synthetic fibers, in the synthesis process combining the original characteristics of the fiber with the functionality induced by nanomaterials.

• covering the surface of fibers or textiles with functional nanomaterials, resulting in functional textiles with a higher added value.

• spinning polymers by electrospinning to produce nanometric fibers, which lead to textiles with improved or new characteristics, with multiple applications [4, 5].

The work is part of a project aimed at developing antimicrobial textiles to prevent the spread of bacteria and to create an antimicrobial shield for the human body. The innovation consists in the use of bio-active compounds incorporated in different forms: in blue clay or micro-encapsulated, for the functionalization of textile materials.

2. MATERIALS AND METHODS

The components of the dispersions prepared are blue clay from Râciu (S.C. ROMCOS IMPEX S.R.L.), plant extract (Propolis, *Aloe Vera*, *Calendula officinalis*, and *Plantago major*), Kaolinite CAS 1318-74-7, Halloysite nanoclay CAS 1332-58-7, dimethyl sulfoxide (DMSO) (CAS 67-68-5), and distilled water. To optimize the preparation method, 3 types of stirring equipment have been used: ultrasound bath from Elma, thermostatic water bath equipped with stirring system from mrc, mechanical stirrer from VWR. The stability of the dispersions has been evaluated by measuring their Zeta potential, using the Zetasizer Nano ZS (Malvern Instruments Ltd., Worcestershire, UK). The microbiological methods for establishing the most effective antimicrobial dispersions involved the inoculation with two strains: *Escherichia coli* ATCC 10536 and *Staphylococcus aureus* ATCC 6538 from Scharlau. The antioxidant activity assessment has been performed through TEAC method (Trolox Equivalent Antioxidant Capacity), using the Merck reagents and the UV-VIS Spectrometer Lambda 950 from Perkin Elmer.

In the first step, the preparation method has been optimised, by combining the components into 4 aqueous dispersion versions and using the 3 types of stirring equipment: ultrasound bath, thermostatic water bath equipped with stirring system, and mechanical stirrer. The selection of the optime method for mixing the dispersions was accomplished by observing the dispersions visual aspect over time: initial visual assessment, after 24 hours, and after 48 hours.

In the second step, the 4 dispersion versions have been prepared in 2 concentrations (0,1% and 0,3%) and characterized by measuring the Zeta potential and evaluating the antioxidant and antimicrobial activity.

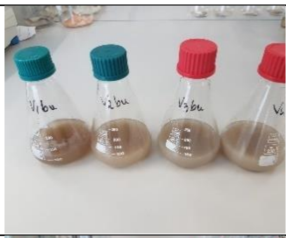
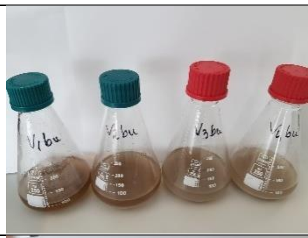
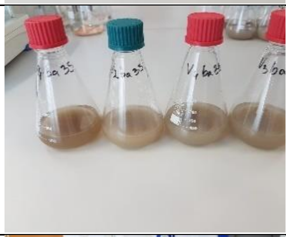
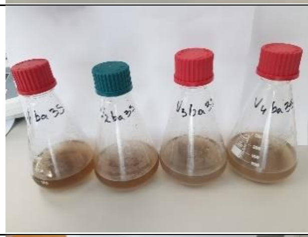
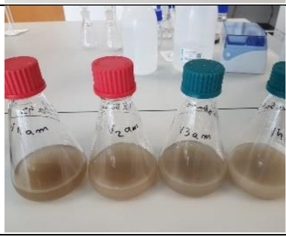
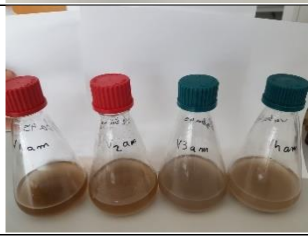
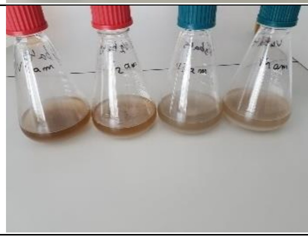
3. RESULTS AND DISCUSSIONS

Table 1 shows the components of the prepared dispersions and table 2 presents their visual aspects, initially, after 24 hours and after 48 hours from stirring the mixed components for 2 hours, at room temperature.

***Table 1:** Components of the prepared dispersions*

Version 1 (**V1-1**)	0,1% (w/w) Plant extract	0,1% (w/w) Blue clay from Râciu	-	10% (v/v) DMSO
Version 2 (**V2-1**)			0,1% (w/w) Kaolinite	
Version 3 (**V3-1**)			0,1% (w/w) Halloysite nanoclay	
Version 4 (**V4-1**)			0,1% (w/w) Kaolinite 0,1% (w/w) Halloysite nanoclay	
Version 1 (**V1-3**)	0,3% (w/w) Plant extract	0,3% (w/w) Blue clay from Râciu	-	
Version 2 (**V2-3**)			0,1% (w/w) Kaolinite	
Version 3 (**V3-3**)			0,1% (w/w) Halloysite nanoclay	
Version 4 (**V4-3**)			0,1% (w/w) Kaolinite 0,1% (w/w) Halloysite nanoclay	

***Table 2** Visual aspects, initially, after 24 hours and after 48 hours from stirring the mixed components*

	Initial	After 24 h	After 48 h
Ultrasound bath			
Thermostatic water bath equipped with stirring system			
Mechanical stirrer			

After observing the dispersions for 48 hours, the formation of the sediments deposited on the bottom of the flasks were observed in the case of water bath equipment and mechanical stirrer. The most homogenous dispersions were formed when using the ultrasound bath. This stirring method is the most suitable for cracking the aglomerations of the powders and dissolving the plant extracts, resulting into homogenous and stable in time dispersions.

3.1. Zeta potential measurements

To measure the zeta potential, 300 μL dispersion was added, by pipetting, to 20 mL of distilled water, along with 50 μL of 0.9% NaCl solution and the resulting suspension was subjected to analysis. The mean values of the zeta potential measured are listed in table 3 and illustrated in figure 1.

Table 3 *Zeta potential values obtained for the prepared dispersions*

Conc.	Sample version	Zeta potential (mV)
0,1%	V1	-29,3 ± 1,670
	V2	-35,4 ± 3,610
	V3	-32,9 ±1,640
	V4	-34,8 ± 0,945
0, 3%	V1	-21,6 ± 0,551
	V2	-24,2 ± 0,874
	V3	-25,3 ± 0,115
	V4	-26,8 ± 0,907

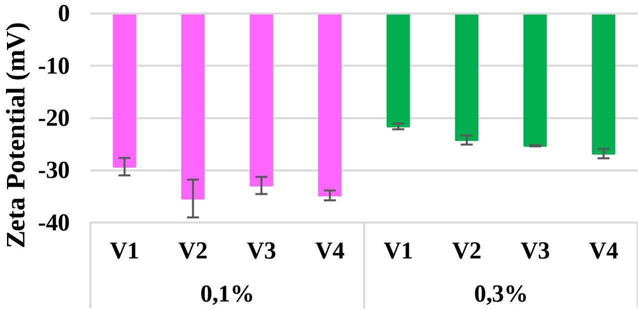


Fig. 1 *Graphic illustration of the zeta potential of the dispersions*

A dispersion is considered stable when the absolute value of the zeta potential is higher than 20 mV. Considering this criterion, all dispersions analysed are stable. However, when comparing the mean values of the zeta potential between the two concentrations, a higher stability of the dispersions with 0,1 % concentration is noticed.

3.2. Antibacterial activity

The antibacterial tests were performed in a 1:1 ratio with the microbial inoculum. Fresh cultures were obtained from each strain, by growing in nutrient broth Nutrient Agar, at 37°C, 48h, this representing the stock culture. For testing, two decimal dilutions of paraffin oil (10^{-2}) were prepared from each culture and the cell concentration in the inoculum used was $1,2 \times 10^5$ CFU/mL (Colony Forming Units) for *Staphylococcus aureus* and $1,5 \times 10^5$ CFU/mL for *Escherichia coli*. The percentage of the microorganism reduction is calculated using the following formula:

$$R = \frac{C_t - T_t}{C_t} X 100\% \quad \textbf{(1)}$$

where: R – represents the percentage of antibacterial activity.
C_t – represents the average number of bacteria obtained from the control sample, after an incubation of 18 h to 24 h.
T_t – represents the number of bacteria obtained from the antibacterial effect sample after an incubation of 18 hours to 24 hours.

Table 4 *Antibacterial results for the dispersions prepared with **0,1%** concentration*

Sample	***Staphylococcus aureus ATCC 6538***			***Escherichia coli ATCC 11229***		
	Result	**R%**	**Log_{10} red.**	**Result**	**R%**	**Log_{10} red.**
Inoculum concentration	$T_0=1,2x10^5$ CFU/mL	-	-	$T_0=1,5x10^5$CFU/mL	-	-
V1	$T_0=1,2x10^5$ CFU/mL $T_{24}= 8,9x10^1$ CFU/mL	99,93	3,13	$T_0=1,5x10^5$CFU/mL $T_{24}= 1,5x10^2$ CFU/mL	99,90	3,00
V2	$T0=1,2x10^5$ CFU/mL $T_{24}=2,1x10^2$ CFU/mL	99,83	2,76	$T_0=1,5x10^5$CFU/mL $T_{24}=2,4x10^2$ CFU/mL	99,84	2,80
V3	$T_0=1,2x10^5$CFU/mL $T_{24}= 4,5x10^1$ CFU/mL	99,96	3,43	$T_0=1,5x10^5$CFU/mL $T_{24}= 1,1x10^2$ CFU/mL	99,93	3,13
V4	$T_0=1,2x10^5$ CFU/mL $T_{24}= 1,9x10^2$ CFU/mL	99,84	2,80	$T_0=1,5x10^5$ CFU/mL $T_{24}= 2,9x10^2$ CFU/mL	99,81	2,71

Table 5 *Antibacterial results for the dispersions prepared with* ***0,3%*** *concentration*

Sample	***Staphylococcus aureus ATCC 6538***			***Escherichia coli ATCC 11229***		
	Result	**R%**	**Log_{10} red.**	**Result**	**R%**	**Log_{10} red.**
Inoculum concentration	T_0=1,2x10^5 CFU/mL	-	-	T_0=1,5x10^5CFU/mL	-	-
V1	T_0=1,2x10^5 CFU/mL T_{24}= 3,5x103 CFU/mL	97,08	1,54	T_0=1,5x10^5 CFU/mL T_{24}= 5,2x10^3 CFU/mL	96,53	1,46
V2	T_0=1,2x10^5 CFU/mL T24=2,2x103 CFU/mL	97,17	1,74	T_0=1,5x10^5CFU/mL T_{24}=7,4x10^3CFU/mL	95,07	1,31
V3	T_0=1,2x10^5CFU/mL T24= 1,7x10^3 CFU/mL	98,58	1,85	T_0=1,5x10^5CFU/mL T_{24}= 4,3x10^3CFU/mL	97,13	1,54
V4	T_0=1,2x10^5 CFU/mL T24= 2,8x10^3CFU/mL	97,67	1,63	T_0=1,5x10^5 CFU/mL T_{24}= 2,1x10^3CFU/mL	98,96	1,85

All samples tested present antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. However, the percentage of the microorganism reduction was higher when the blue clay and plant extract concentration was 0,1%.

3.3. Antioxidant activity

The dispersions analyzed in terms of antioxidant activity are those with 0,1% concentration. The TEAC method is based on spectrophotometric monitoring of the color change and absorbance of the cationic radical 2,2-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) - $ABTS^+$.

The discoloration of the solution is related with the percentage of inhibition of the long-life radical $ABTS^+$. Radical inhibition is calculated in relation to the reactivity of Trolox used.

Firstly, a calibration curve was constructed, at 734 nm. Figure 2 shows (a) the calibration curve and (b) the dependence of the degree of inhibition of the $ABTS^+$ radical on the Trolox concentration.

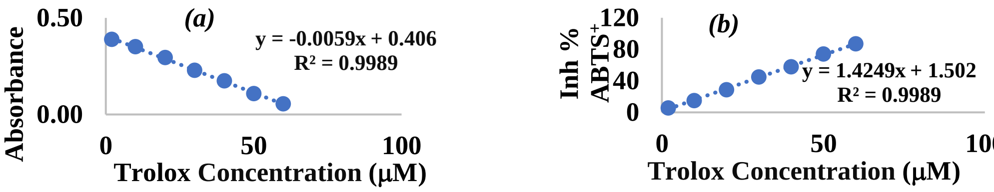


Fig. 2 *(a) Calibration curve of Trolox reagent, (b) Dependence of the degree of inhibition of the $ABTS^+$ radical on the Trolox concentration.*

To determine the antioxidant activity, the absorbance of the samples is measured on the calibration curve performed. The ABTS + radical capture activity is calculated as follows:

$$Inh\ ABTS^+(\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad \textbf{(2)}$$

where:

$A_{control}$ – represents the absorbance of the $ABTS^+$ radical distilled water.
A_{sample} – represents the absorbance of the radical $ABTS^+$ sample extract/standard Trolox.

Using the equation y = 1.4249x + 1.502, the antioxidant activity expressed in Trolox equivalent can be evaluated. The results obtained are presented in Table 6.

Table 6. *Results of antioxidant activity of the dispersions with 0,1% concentration.*

Sample	Absorbance	Inh % ABTS	Trolox equivalent (μM)
Control	0,4251	-	-
V1	0,1461	65,6	45.0
V2	0,0245	94,2	65.1
V3	0,0113	97,3	67.3
V4	0,3557	16,3	10.4

The dispersions with the highest values of antioxidant activity (the highest percentage of inhibition of the $ABTS^+$ radical) are the dispersions V2 and V3 (with 0,1% concentration of blue clay and plant extract), with inhibition percentages above 90%. Dispersion V1 presents. Also, a relative high antioxidant activity, with an inhibition percentage of 65,5%. V4 has a low antioxidant activity, with an inhibition percentage of 16.3%.

5. CONCLUSIONS

In the presented paper, 4 dispersion versions were prepared by 3 stirring methods (water bath, ultrasonic bath, and mechanical agitation). Following the visual observations, ultrasonic bath was selected as the stirring method. The concentration of the bioactive compounds was varied (0,1% and 0,3% (w/w) blue clay and plant extract) and the concentration of the other components was kept constant to 0,1% (w/w), resulting 8 dispersion versions. Their stability was further evaluated *via* zeta potential measurement, showing a relative higher stability for dispersions prepared with 0,1% concentration. The antibacterial tests against *Staphylococcus aureus* and *Escherichia coli* revealed the same trend. When assessing the antioxidant character, except for V4, all the other dispersion versions presented antioxidant activity, with inhibition percentages of the $ABTS^+$ radical between 65,5% and 97,3%. Following the tests presented, V1 and V3 (with 0,1% blue clay and plant extracts) were selected to be incorporated in textiles. This work is still in progress.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian Ministry of Research and Innovation CCCDI-UEFISCDI, project no. PN-III-P3-3.5-EUK-2017-02-0084, within PNCDI III. The publication of the paper is funded by the Ministry of Research and Innovation within Program 1 - Development of the national RD system, Subprogram 1.2 - Institutional Performance - RDI excellence funding projects, contract no. 4PFE/2021.

REFERENCES

[1] Uddin F., Environmental Concerns in Antimicrobial Finishing of Textiles, International Journal of Textile Science, vol. 3, nr. 1A, 2014, p. 15-20.

[2] Santos Morais D., Guedes R. M, Ascensão Lopes M., Antimicrobial Approaches for Textiles: From Research to Market, Materials, 9, 498, 2016.

[3] Almeida L., Functionalisation of Textiles - Future Perspectives, 2015, din https://www.technicaltextile.net/ articles/functionalisation-of-textiles-3174.

[4] Birzu Maria, Procese de hidrofobizare a materialelor textile: Caracteristici fizico-chimice si modelare statistico-matematica, Teza de doctorat, Academia Romana, 2017.

[5] Ibrahim N. A., Eid B.M., El-Batal H., A novel approach for adding smart functionalities to cellulosic fabrics, Carbohydrate Polymers, 87, 2012, p. 744– 751.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

TEXTILE STRUCTURES WITH ANTI-INFLAMMATORY PROPERTIES FOR THE TREATMENT OF BURN INJURIES

Emilia Visileanu[1], Alexandra Ene[2], Razvan Scarlat[3], Alina Vladu[4], Stelian Sergiu Maier[5]

[1,2,3,4]The National Research and Developement Institute for Textile and Leather, 16, Lucretiu Patrascanu street, sector 3, Bucharest, Romania

[5]Sanimed International Impex SRL ,2A, Road Bucharest-Giurgiu, Calugareni, Romania

Corresponding author: Visileanu Emilia, E-mail: e.visileanu@incdtp.ro

Abstract: *The development of multilayer medical devices with composite characteristics, usable for basic medical interventions on superficial burns involves an interfacing layer with the lesion that is non-adherent, biologically inert and microporous and the outer layer acts as a carrier, insulator and protector of the underlying layers, being elastic, resistant and submicro-porous (to block the physical access of microorganisms to the lesion). These layers were made by classical and nonconventional textile technologies (weaving and nonwovens technology) using natural fibers (100% cotton, 100% bamboo) and artificial fibers (100% lenpur) with contemt of active substances (chitosan, Zn). Biocompatibility tests performed by two standardized methods, namely the MTT cell viability test and the LDH cell integrity test planned to identify and quantify the possible harmful effect of the presence of textile samples on cells culture. Evaluation of the antimicrobial activity is performed in order to establish the safety of the biomedical use of the materials, or verification of the efficiency of their use in infection control and decontamination processesn. Evaluation of the antimicrobial activity of the samples was performed by determining the logarithmic and percentage reduction of some microbial populations. For testing, the following standardized strains were used: Staphylococcus aureus ATCC 6538, Escherichia coli ATCC 8739 and Candida albicans ATCC 10231. The textile structures that provided the most effective antibacterial effect were those incorporating chitosan and Tencel fibres, which provided percentage reductions in Escherichia coli (Gram-negative bacteria) populations of about 76%, lower than those against Staphylococcus aureus (Gram-positive bacteria) of 90%.*

Key words: active substances, infection, tissue, biocompatible, antimicrobial, decontamination.

1. INTRODUCTION

Severely burned skin stops to fulfill its natural role of protection and barrier and promotes a dramatic increase in water loss and can become a gateway for bacterial invasion. It seems that the activation of a proinflammatory cascade after a burn plays an important role in the development of a subsequent immune dysfunction, bacterial translocation in the intestine, susceptibility to sepsis and multiple organ failure [1]. A local response to a burn involves not only direct tissue coagulation, but also tissue conversion, a process in which damaged cells, rather than recovering, progress to cell death, extending the depth and severity of the initial lesion. The systemic response to burns is caused by the loss of the skin barrier and the release of vasoactive mediators from the wound and subsequent infection. When the size of the burn exceeds about 25% of the body surface, interstitial edema develops in organs and soft tissues, mainly as a side effect of a combination of mediators released by wounds and hypoproteinemia [2]. Thermal damage cause a massive release of proinflammatory cytokines, chemical mediators including histamine, complement, arachidonic acid, coagulation cascade products, and oxygen free radicals, which increase vascular permeability leading to hypovolemia and acute kidney failure. This can be complicated by systemic inflammatory response syndrome and marked immune suppression. Subsequent wound infection and bacterial translocation from the gastrointestinal tract promote sepsis. This adds to the final common path to multi-organ failure and death [3].

2. MATERIALS AND METHOD

The development of multilayer medical devices with composite characteristics, usable for basic medical interventions on superficial burns with thermal origin (flame and melts) occurred on anatomical regions protected by clothes (so except face and eyes) involves textile structures with such characteristics that ensure antimicrobial and analgesics effects, as well as fluid management in the injured region, through local transfer processes (sorption/ desorption in porous media) [4].

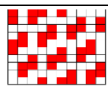
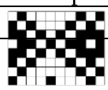
The interfacing layer with the lesion must be non-adherent, biologically inert and microporous and the outer layer acts as a carrier, insulator and protector of the underlying layers, being elastic, resistant and submicro-porous (to block the physical access of microorganisms to the lesion). These layers were made by classical and nonconventional textile technologies (weaving and nonwovens technology) using natural fibers (100% cotton, 100% bamboo) and artificial fibers (100% Lenpur) with contemt of active substances (chitosan, Zn). Biocompatibility tests performed by two standardized methods, namely the MTT cell viability test and the LDH cell integrity test planned to identify and quantify the possible harmful effect of the presence of textile samples on cells culture [5]. To consider that a particular sample is biocompatible, the optical density values for MTT tests must be higher than those of the LDH quantification test (in other words, a sample is biocompatible if the number of viable, metabolically active cells is greater than the number of dead cells).

Evaluation of the antimicrobial activity is performed in order to establish the safety of the biomedical use of the materials, or verification of the efficiency of their use in infection control and decontamination processes [6]. Evaluation of the antimicrobial activity of the samples was performed by determining the logarithmic and percentage reduction of some microbial populations. For testing, the following standardized strains were used: *Staphylococcus aureus* ATCC 6538, *Escherichia coli* ATCC 8739 and *Candida albicans* ATCC 10231.

3. RESULTS

5 variants of woven fabrics and 3 variants of nonwoven fabrics were made. The main design parameters are shown in table 1 and 2.

Table 1: *The main design parameters for woven fabrics*

Woven fabric codification	Design parameters					Pattern
	Yarn type		Yarn count		Weft set [yarns/10 cm]	
	Warp	Weft	Warp	Weft		
BZNT1	100% cotton	80% cotton/ 20% fibres with ZnO	Nm 50/2	Nm 68/2	240	 Derivated patterns
BBT1	100% cotton	100% bamboo	Nm 50/2	Nm 34/1	250	

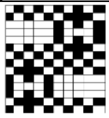
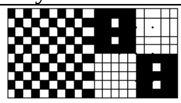
BLT1	100% cotton	100% Lenpur	Nm 50/2	Nm 34/1	200	Honeycomb weave 1
BAT1	100% cotton	100% Tencel	Nm 50/2	130 dtex	350	 Honeycomb weave 2
BBT2	100% cotton	100% cotton	Nm 50/2	Nm 60/2	255	 Combined patterns

***Table 2:** The main design parameters for nonwoven fabrics*

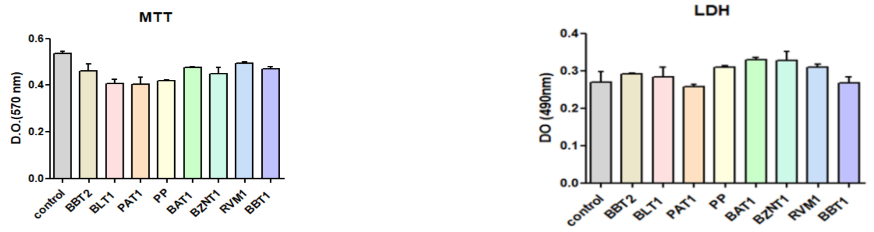
Parameter	Variant		
	C1	C2	C3
Yarn type	100% chitosan	50/50 chitosan/viscose	20/80 chitosan/viscose
Weight, g/mp	108.16	54.68	43.12
Thickness, mm	1.38	0.3	0.23
Breaking strength lengthwise/crosswise, N	35.39/ 44.07	33.37/ 45.64	57.42/ 70.70
Elongation at break, lengthwise/crosswise, %	54.37/ 45.37	33.05/ 43.34	29.19/ 44.2
Tear resistance, lengthwise/crosswise, N	9.1/ 9.11	4.29/ 4.43	6.96/ 7.49
Absorption capacity, %	92	308	198
pH	8.2	8.3	8.2

3.1 Evaluation of biocompatibility

Fig. 1 shows the results of the MTT and LDH tests applied to the textile samples subjected to characterization. Fig. 2 comparatively compares the results of quantifying the optical density of samples subjected to MTT and LDH tests, and fig. 3 is dedicated to samples with chitosan content.

***Fig. 1:** The result of biocompatibility tests applied to textile samples*

After 72 hours of cultivation, the proliferation of co-cultivated L929 cells in the presence of textile samples was similar to the proliferation of the control sample (L929 cells, unstimulated). The cytotoxicity of the samples was investigated by the LDH test to quantify the level of LDH enzyme released into the culture environment from dead cells. No statistically significant differences were found between LDH levels compared to the control sample.



a. b.

Fig. 2: *Comparative value of optical densities*

a. b.

Fig. 3*: Comparative value of optical densities*

The samples BAT1 and BZNT1 showed a higher degree of cytotoxicity, according to the LDH test (Fig. 2.b). In the case of textile samples including chitosan, there was an increase in cell proliferation (Fig. 3). According to the comparative determinations MTT and LDH, variant C3 showed the highest biocompatibility, similar to that of the cells in the control sample, unstimulated.

3.2 Evaluation of antimicrobial activity

Evaluation of the antimicrobial activity of the samples was performed by determining the logarithmic and percentage reduction of *Staphylococcus aureus*, *Escherichia coli* and *Candida albicans* microbial populations.

The diagrams presented in fig. 4 indicate the values obtained for the 2 parameters in relation to the *Staphylococcus aureus* (Gram-positive bacteria). For the tested variants, logarithmic reductions between 0.26 and 0.87 were obtained. The variants of textile structures that ensure the most effective antibacterial effect are those that include chitosan, along with the 100% cotton sample (BBT2). The presence of Tencel fiber combined with chitosan fiber amplifies the antibacterial effect of the blending, ensuring percentage reductions of the *S. aureus* population close to 90%, a value considered as a reference in inhibiting bacterial cultures.

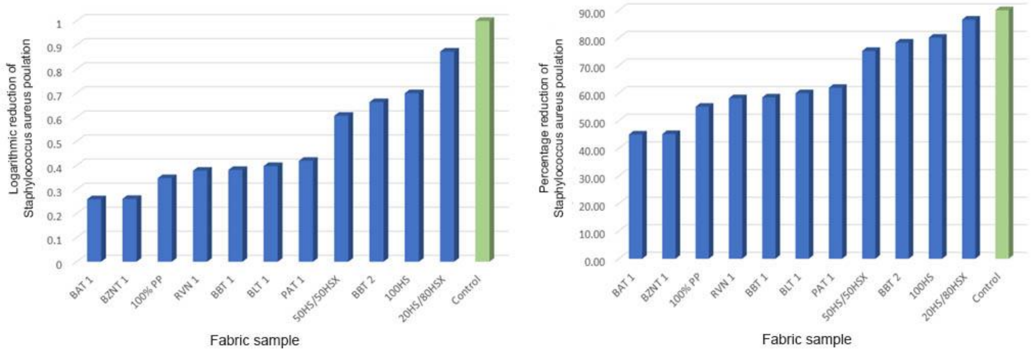


Fig. 4: *Logarithmic and percentage reduction of the Staphylococcus aureus population*

The diagrams presented in fig. 4 indicate the values obtained for the 2 parameters in relation to *Escherichia coli* bacteria (Gram-negative bacteria). Logarithmic reductions between 0.25 and 0.63 were obtained. The textile samples that provide the most effective antibacterial effect are those that include chitosan, along with Tencel fibers, which provide a percentage reduction in the *Escherichia coli* (Gram-negative bacteria) population of about 76%, but lower than those against *Staphylococcus aureus* (Gram-positive bacteria).

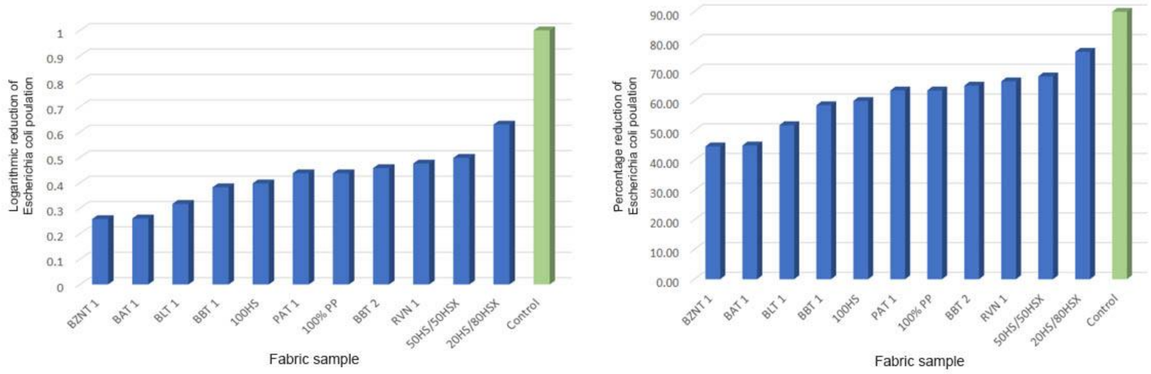


Fig. 5*: Logarithmic and percentage reduction of the Escherichia coli population*

In fig. 6 este prezentata expresia grafica a valorilor obtinute pentru cei doi parametrii in raport cu

Bacteria. Reducerile logaritmice obtinute sunt cuprinse intre 0,33 si 0,66, iar reducerile procentuale intre 53 si 78 %. Si in cazul inhibarii dezvoltarii *Candida albicans*, varianta BZNT1 este ceea mai eficienta in reducerea populatiilor fungice.

The diagrams presented in fig. 6 indicate the values obtained for the 2 parameters in relation to bacteria. The logarithmic reductions obtained are between 0.33 and 0.66, and the percentage reductions between 53 and 78%. In the case of inhibiting the development of Candida albicans, the BZNT1 variant is the most effective in reducing fungal populations, as well.

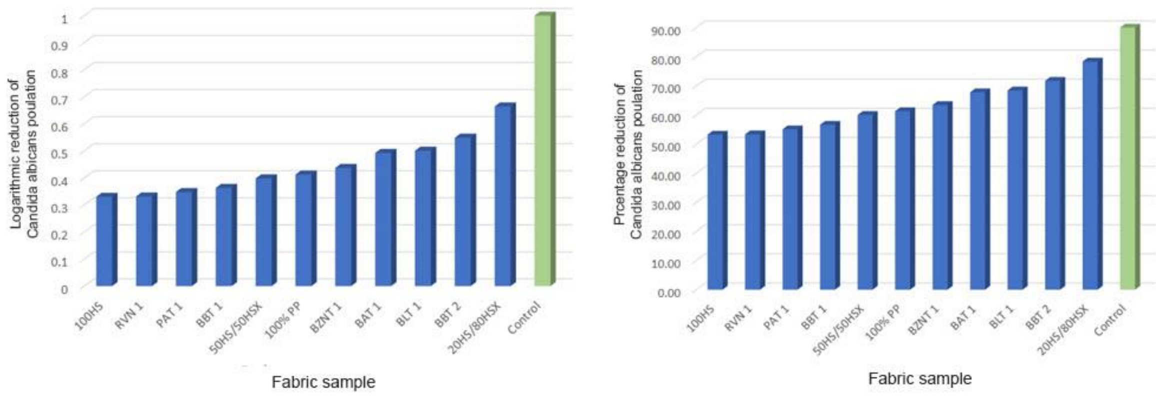


Fig. 6: *Logarithmic and percentage reduction of the Candida albicans population*

4. CONCLUSIONS

- The variant of nonwoven fabric made of 20% chitosan/ 80% viscose recorded the highest biocompatibility similar to that of the cells in the control sample, unstimulated. This fabric also obtained the best results in antimicrobial tests, being qualified for the interfacing with the injury due to burns of the multilayer structure.

- Woven fabrics variants BAT1 and BZNT1 showed a higher degree of cytotoxicity, these qualifying for the outer layer with the role of carrier, insulator and protector of the underlying layers of the multilayer structure.

- Although the antimicrobial activity of all textile samples is moderate, the final biomedical application of textiles should be considered. Because they are intended to be used as medical devices (hemostatic support), their antimicrobial properties are only needed until systemic antibiotic treatment is in action (about. 4-5 hours after application). Percentage microbial reductions of over 50% are considered optimal for the targeted application.

ACKNOWLEDGEMENTS

This research is carried out within the project: Innovative medical device for emergency and operational medicine ”CELLMATRIX, PN-III-P2-2.1-PED-2019.

REFERENCES

[1] D. K. Macintire, T. L. Bellhorn, “*Bacterial translocation: Clinical implications and prevention”*, in Vet Clin North Am Small Anim Pract. 2002;32(5):1165–78, [PubMed] [Google Scholar].

[2] B. R. Sharma, D. Harish, V. P. Singh, S. Bangar, “*Septicemia as a cause of death in burns: an autopsy study*”, Burns. 2006 Aug;32(5):545–9, [PubMed] [Google Scholar].

[3] Z. Pengju, Z. Bingwen, L. Yih-Cherng, H. *Canhua, “Burns & Trauma*”, Volume 9, 2021, tkaa047, https://doi.org/10.1093/burnst/tkaa047.

[4] W. W. Monafo, “*Then and now: 50 years of burn treatment”*, Burns. 1992;18(Suppl 2): S7–10, [PubMed] [Google Scholar].

[5] B. N. Saida, A. Ferjeni, N. Benhadjtaher, K. Monastiri, J. Boukadida, “*Clonality of clinical methicillin-resistant* Staphylococcus epidermidis *isolates in a neonatal intensive care unit*”, Pathol Biol (Paris) 2006; 54(6):337–42, [PubMed] [Google Scholar].

[6] Z. Daoud, C. Moubareck, N. Hakime, F. Doucet-Populaire, “*Extended spectrum beta-lactamase producing Enterobacteriaceae”* in Lebanese ICU patients: Epidemiology and patterns of resistance, J Gen Appl Microbiol, 2006;52(3):169–78. [PubMed] [Google Scholar].

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

LEATHER FINISHING PRODUCTS WITH APPLICATIONS IN CREATIVE INDUSTRIES AND CULTURAL HERITAGE

NICULESCU Olga

National Research and Development Institute for Textiles and Leather – Division Leather and Footwear Research Institute, Ion Minulescu Street, no. 93, Sector 3, Bucharest, Romania, icpi@icpi.ro

Corresponding author: Niculescu Olga, E-mail: o_niculescu@yahoo.com

Abstract: *From prehistoric times to the present day, pigments have been used in cave paintings, decorations, clothing, writing, fine arts and more. Blue is the color most often considered the symbol of spirituality. Cobalt blue is a mixed oxide of cobalt and aluminum and one of the most important blue pigments used in painting. It was used a lot by Van Gogh and Renoir. Heritage objects from museums, libraries and archives are sensitive to the quality of the microclimatic conditions in storage and exhibition areas. Inadequate environmental conditions may alter the aesthetic, use and material quality of art works and reduce their lifetime. The quality of pigment pastes used in the production of finishing films for semi-processed leather influences some of the physico-mechanical, technological, aesthetic properties of the finished products. Pigment pastes were obtained based on cobalt blue oxide, polymeric binder, lauryl alcohol ethoxylated with 7 moles of ethylene oxide (biodegradable), waxes and plasticizers and were characterized by physical-chemical, microscopic, rheological and thermal analyses. Pigment pastes were used in combination with film forming polymers (acrylic and polyurethane) with high resistance to light and aging for finishing natural leather with applications in creative industries (bookbinding, office items, paintings on leather) and cultural heritage.*

Key words: *natural leather, pigment pastes, creative industries, cultural heritage*

1. INTRODUCTION

Pigments are organic or inorganic chemical compounds which constitute the dye base for coatings. Pigments used in leather finishing must have certain characteristics, among which the most important are: fastness to light, resistance to weathering and high temperatures, bright and vivid color, high coating power, high dispersion degree, compatibility with the other components of coating dyes. (1)

In leather finishing operations there are restrictions regarding the use of heavy metals in pigment pastes, ethoxylated alkylphenols, formaldehyde and other toxic crosslinking agents. (2)

Ecological and Toxicological Association of Dyes and Organic Pigment Manufactures (ETAD) has set limits for heavy metal content in water-soluble dyes (for cobalt the permissible limit is 500 ppm). (3) SG, "The Test Mark for Low Pollutant Leather Products", includes the limits for heavy metal content in leather products (for cobalt the permissible limit is 4.0 ppm). (4)

Recipes are proposed to obtain stable pastes with aqueous dispersion medium using the components: cobalt blue oxide, acrylic resin as dispersion medium for pigments, light and ageing resistant vegetable oils as plasticizers (poppy seed oil), natural and artificial wax emulsions (beeswax, lanolin and stearin, the last obtained by splitting of natural fats) and completely biodegradable non-ionic emulsifier - lauryl alcohol ethoxylated with 7 moles of ethylene oxide – as dispersing agent. Pigment pastes were used in combination with film forming polymers (acrylic and polyurethane) with high resistance to light and aging for finishing natural leather with applications in creative industries (bookbinding, office items, paintings on leather, albums) and cultural heritage.(5-8)

2. EXPERIMENTAL

2.1. Materials

• Cobalt blue (Pebeo, France), is a mixed oxide of cobalt and aluminum ($CoO \cdot Al_2O_3$) - 95%, particle size – 3 ± 120µm.

• Acrylic binder Bindex Brillant (Pebeo, France), homogenous emulsion, dry substance – 30,24 %, density – 1.965 g/cm^3, pH – 6.5, Hoppler viscosity – 4.000 cP.

• Poppy oil (Pebeo, Franţa), total fatty matters – 99%, viscosity Ford coupe Φ 6 – 23 s, saponification index – 290 mg KOH/g, acidity index – 3 mg KOH/g, iodine index – 138g 100/g oil.

• Ricin oil (SC Happynatura SRL, Bucharest), total fats – 64%, Ford cup viscosity Φ 6 – 57 s, saponification index – 14 mg KOH/g, acidity index– 9 mg KOH/g, iodine index – 92g 100/g oil.

• Nonionic emulsifier – lauric alcohol etoxilated with 7 mols ethylene oxide (SC Elton Corporation SA, Bucharest), density at 40^{0}C – 0.950 g/cm^3, pH (10%) solution – 7-8.

• Wax emulsion AGE 7 (ICPI), dry substance – 12%, pH (10% solution) – 7.0.

• Blue pigment paste, viscous and homogenous fluid, dry substance – 30-32%, pH (10% solution) – 6.5-8.0, ash – 23-25%.

• Roda-cryl 87 (Triderma, Germany), acrylic binder for ground coat (marked AC87), dry substance – 38.92%, pH (10% solution) – 6.0, Ford cup viscosity Φ4 – 14.5, density – 1.036 g/cm^3.

• Roda-Pur 5011 (Triderma, Germany), polyurethane dispersion (marked PU5011), dry substance – 40%, pH (10% solution) – 5.5, Ford cup viscosity Φ4 – 7, density – 1.053 g/cm^3.

• Roda lacquer 93 (Triderma, Germany), nitrocellulose emulsion (marked LAC93), dry substance –15%, pH (10% solution) – 5.5, Ford cup viscosity Φ4 – 125, flash point – 82°C.

• The nappa bovine leathers, mineral tanned and wet finished by retanning, fatliquoring and dyeing (1.0-1.2 mm thick, dyed blue) (INCDTP – Division ICPI Bucharest, Romania).
`

2.2. Methods

• Attenuated Total Reflectance Fourier transform infrared spectroscopy (ATR-FTIR) measurements were run with a Jasco instrument (model 4200), in the following conditions: wavenumber range – 600-4000 cm^{-1}; data pitch – 0.964233 cm^{-1}; data points – 3610: apperture setting – 7.1 mm; scanning speed – 2 mm/s; number of scans – 30; resolution – 4 cm^{-1}.

• Simultaneous Thermal Analysis of TG with DTA mode (ΔT) and DSC (mW) were run with a Perkin-Elmer instrument (model STA 6000); themperature: 25-950^{0}C, heating rate 10° C/min.

• Optical microscopy images were captured using a Leica stereomicroscope S8AP0 model with optic fiber cold light source, L2, with three levels of intensity, and magnification 20X.

• Rheological behaviour was determined using Haake VT 550 rotational viscometer, equipped with MV1 sensor system for average viscosities and RheoWin Thermo Fischer software.

• Physical-mechanical characteristics of finished leather assortments were determined according to the following standards: fastness to light (1-8 ranking) – SR EN ISO 105-B02:2003; dry and wet abrasion (1-5 ranking) – SR EN ISO 11640:2002.

• Finished leathers were artificially aged and tested according to ISO 17228/2006 standard.

2.3. Obtaining of pigment pastes

The pigment pastes based on cobalt blue oxide (PBC) were obtained by the following operations:

- mixing powder pigment with vegetable oil emulsion (poppy seed oil) and non-ionic emulsifier;

▪ 25-30% cobalt blue oxid, 8-10% vegetable oil emulsified with 0.8-1.0% non-ionic emulsifier – polyehtoxylated lauryl alcohol (reported to the amount of oil);

- mixing the intermediate product with the acrylic binder (Bindex Acrylic), AGE 7 wax emulsion (made from beeswax, lanolin and triethanolamine monostearate), lauryl alcohol ethoxylate with 7 moles of ethylene oxide and water;

▪ 35-40% acrylic resin in which the pigment is dispersed, 1-2% wax emulsion, 8-10% fully biodegradable non-ionic emulsifier and water;

▪ The disperse system is subjected to mechanical stirring (60-80 rot/min), at 25-30^{0}C, for 3-4 h.

The composition of new pigment pastes are given in Table 1.

Table 1. *The composition of new pigment pastes (PBC and M)*

New pigment paste composition	Quantity (%)- PBC	Quantity (%)- PBC-M
Cobalt blue oxide	25-30	25-30
Polyacrylic binder	35-40	35-40
Ethoxilated lauric alcohol	8-10	8-10
Poppy oil	8-10	-
Ricin oil	-	8-10
Wax emulsion	1-2	1-2
Water	8-23	8-23

2.4. Obtaining the Finishing Film on Glass Plate

Finishing compositions were prepared containing: 100 g/L new pigment paste (PBC) ; 30 g/L wax emulsion (AGE 7); 300 g/L acrylic binder (AC87); 570 g/L water. With these dispersions, finishing films were obtained by deposition on glass plate and dried on air.

2.5. Framework technology for dry finishing of bovine leathers

Framework technology for dry finishing of bovine leathers, with blue pigment paste is presented in Table 2.

Table 2. *Framework technology for dry finishing of bovine leathers*

Operation	Composition of dispersion/Method of application
Applying base coat	50-100 g/L pigment paste, 30 g/L wax emulsion, 300 g/L acrylic dispersion, 570-620 g/L water. Application by spraying (2 applications)
Intermediate pressing	In hydraulic press using mirror plate; parameters: T=50-60oC; P=50-100 atm.
Applying base coat	Spraying (2-3 applications)
Applying top coat (fixing)	Emulsion/dispersion with the following composition: 700 g/L aqueous polyurethane dispersion (PU5011) or nitrocellulose emulsion (LAC93), 300 g/L water. Application by spraying (2 applications)
Final pressing	In hydraulic press using mirror plate, parameters: T=70-80oC; P=50-100 atm.

The samples vere marked: PBC –FP (witch contains poppy oil/ fixing with polyurethane dispersion, PBC –FN (witch contains poppy oil/ fixing with nitrocellulose emulsion), PBC-M-FP (witch contains ricin oil/ fixing with polyurethane dispersion) and PBC-M-FN (witch contains ricin oil/ fixing with nitrocellulose emulsion).

2.6. Testing artificially aged finished Leather

Mechanical characteristics of finished natural grain Nappa leather assortments in the same variants but artificially aged were determined. The following abbreviations were used:

- IT1 – leather aged at 50^0C for 7 days;
- IL – leather aged with artificial light (Xenotest) for 7 days.

3. RESULTS

3.1. Characterization of Pigment Pastes by physical-chemical analyses

Physical-chemical characteristics are presented in the Table 3.

Table 3. *Physical-chemical characteristics of pigment pastes*

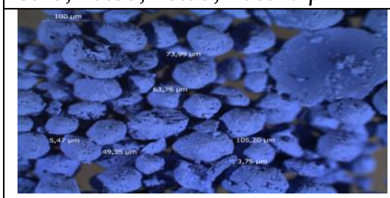
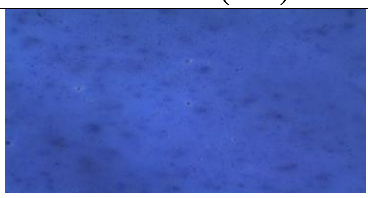
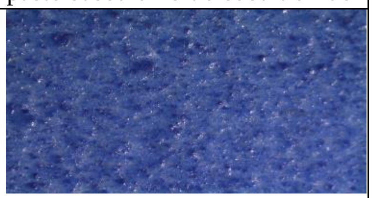
Characteristics /samples	Pigment paste - PBC	Pigment paste - PBC-M
Dry substance, %	30.67-31.87	30.12-31.75
pH 10% solution	6.5-6.8	6.5-6.8
Ash, %	23.42-25.25	23.80-24.86

The new pigment pastes are viscous and homogeneous fluids and dry substance content indicates that they are more concentrated pastes. They are stable over time, without sediments of phase separation and have the characteristics of concentrated pastes.

3.2. Analysis of pigment pastes and leather finished with pigment paste by optical microscopy

Table 4 illustrates optical images of blue cobalt oxide powder and particle sizes, of pigment paste based on blue cobalt oxide (PBC), as well as the image of leather finished with pigment paste.

Table 4. *Optical images at 20X of the particle sizes of pigment powders, the pigment paste (PBC) and the leather finished with pigment paste*

<table>
<tr><th>Particle sizes of pigment powders: 3.75; 49.35; 73.99; 105.20 µm</th><th>Pigment paste based on blue cobalt oxide (PBC)</th><th>Leather finished with pigment paste based on blue cobalt oxide</th></tr>
<tr><td>
</td><td></td><td></td></tr>
</table>

Images indicate an acircular geometry of particles, with agglomerate sizes ranging between 3.75 and 105.20 µm for the initial powder.

The resulting shades can be used to paint leather in a modern style.

3.3. Characterization of Pigment Pastes by FT-IR

The new pigment pastes, dried on the glass plate, were analyzed by ATR-FTIR and spectra are shown in Figure 1.

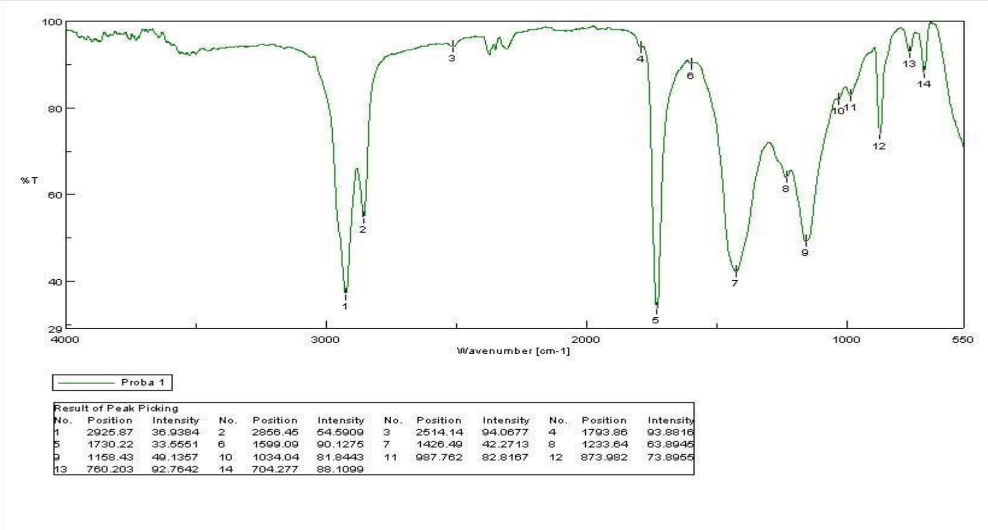


Figure 1. *ATR-FTIR spectrum for pigment pastes (PBC)*

The spectra of films obtained from the pigment pastes show characteristic bands of acrylic polymers: between 2925 and 2856, 1500 and 1426 and approximately 760 cm^{-1} assigned to asymmetric and symmetric stretching and deformation vibrations of CH_3 and CH_2 groups, an intense band at $\approx$1730 cm^{-1} typical for acrylates (the stretch of the ester carbonyl groups) and 1200-1000 cm^{-1} assigned to ether groups.

3.4. Characterization of coating films by thermal analysis

Figure 2 a and b presents TG and DTA curves for finishing films obtained by depositing on glass and drying, for the new pigment paste (PBC).

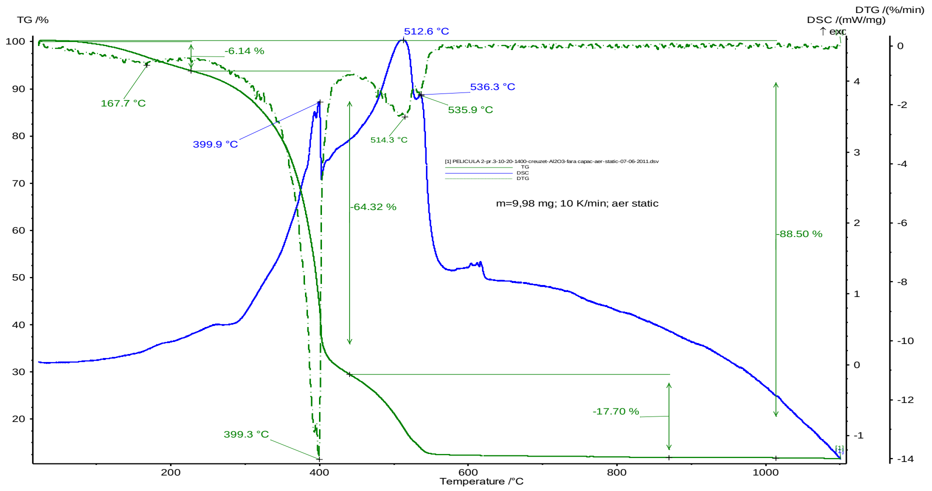


Figure 2. *TG and DTA diagram for the finishing film for the PBC*

For finishing film containing new pigment paste, the temperature interval for mass loss is 0-514°C. Mass loss is 6.14% in the temperature interval 0-167.7°C, 64.32% in the temperature interval 167.7- 399.3°C, and in the temperature interval 399.3-514.3°C, mass loss is 17.70%. Total degradation of the finishing film (88.50 %) occurs at the temperature of 514°C.

The specific thermal degradation parameters show that finishing film containing new pigment paste (PBC) has a very good thermal stability.

3.5. Rheological behaviour of pigment pastes

Rheograms obtained for pigment pastes PBC, containing blue cobalt oxide, when increasing (sus) and decreasing (jos) shear rates are shown in Figure 3.

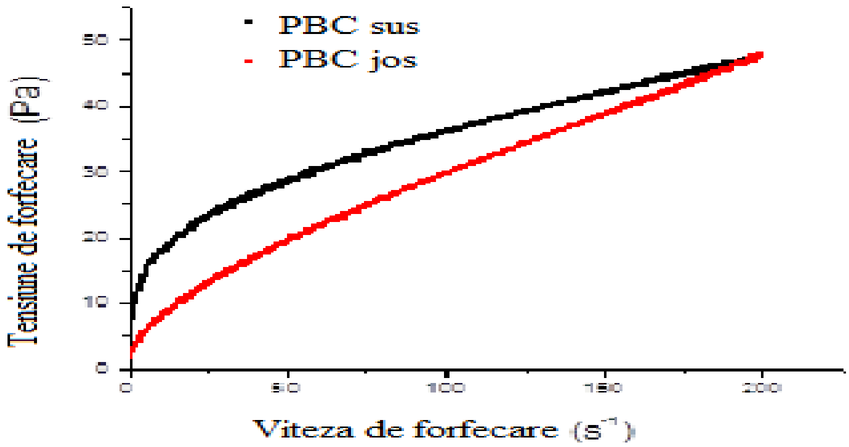


Figure 3. *Rheograms of pastes PBC when increasing (sus) and decreasing (jos) shear rates*

Parameters obtained by modelling rheograms in Figure 3 using the Cross model, both whenincreasing and decreasing shear rates, are presented in Table 5.

Table 5. *Parameters obtained by modelling rheograms in figure 3 with the Cross model*

System	η_0 (Pa.s)	η_∞ (Pa.s)	1/C (s^{-1})	m
PBC up	4.18 ± 0.05	0.040 ± 0.010	2.14 ± 0.08	0.65 ± 0.01
PBC down	6.42 ± 0,50	0.158 ± 0.002	0.08 ± 0.03	0.53 ± 0.01

They were modeled with Cross four parameters model, which has the advantage of providing information on system viscosity for the entire shear rates range, where η_0 and η_∞ are the limit values of the apparent viscosity at low and high shear rates, respectively, when the viscosity asymptotically approaches a constant value, C – adjustable parameter with dimension of time called Cross time constant and m – dimensionless adjustable parameter representing the dependence of viscosity on shear rate, called Cross velocity constant. The value indicates 1/C the shear rate at which pseudoplastic behavior begins. (9)

Rheograms show that the pastes have a pseudoplastic behaviour, flow starting at lower shear stress of 2-5 Pa.s. Rheograms obtained by increasing and decreasing shear rates do not overlap, but show a hysteresis loop, that is the pastes (PBC) are thixotropic.

Thixotropic behavior is desirable, fluidity increasing under the action of shear stress, facilitating the application and restoring original viscosity after application prevent dripping.

Hysteresis loop area is a measure of thixotropy. (10)

3.6. Characterization by mechanical methods of finished leathers

After the application of artificial aging treatments, the physical-mechanical characteristics were determined, using the same standards as for the non-aged ones. Variation of the physical-mechanical characteristics for finished natural grain napa leather samples marked: PBC-FP, PBC-FN, PBC-M- FP, PBC-M-FN, aged using IT1 and IL methods (M) is shown in Table 6.

Table 6: *Physical-mechanical characteristics of bovine hides into natural grain nappa*

Samples	M	PBC-FP	PBC-FN	PBC-M- FP	PBC- M-FN	SR EN ISO
Tear Resistance (N/mm^2)	IT1	44.5	44.1	43.8	42.7	SR EN ISO 3377:2012
Resistance to dry friction (mark)	IT1	5/4	5/3-4	5/3	5/2	SR EN ISO 11640:2002
Resistance to wet friction (mark)	IT1	4/4-5	4/4	4/3	4/2	SR EN ISO 11640:2002
Fastness to light (1-8 ranking)	IL	8	7-8	7-8	7	SR EN ISO 105-B02:2003

Leather finished using the prepared pigment pastes and polyurethane binder (of final dressing) have the higher notes for fastness to light after artificial ageing, IL (8 on a scale of 1 to 8), and that finished with nitrocellulose dressing have the note 7 or between 7 and 8. Poppy seed oil, used as plasticizer, improve resistance to yellowing of coating films.

4. CONCLUSION

• Pigment pastes are concentrated pastes with pH of 1/10 solution of 6.5-8.0, with good coating power, more or less pseudoplastic and thixotropic rheological behavior and contributions of elastic and viscous components dependent on pigment and binder used. The spectra of films obtained from the pigment pastes show characteristic bands of acrylic polymers.

• The specific thermal degradation parameters show that finishing film containing new pigment paste has a very good thermal stability.

• The highest resistance to light after aging under the influence of artificial light has the leathers finished with polyurethane dressing in comparison with those finished with nitrocellulose dressing. Poppy seed oil, used as plasticizer, improve resistance to yellowing of coating films.

• Pigment pastes were used in combination with film forming polymers (acrylic and polyurethane) with high resistance to light and aging for finishing natural leather with applications in creative industries (bookbinding, office items, albums, paintings on leather) and cultural heritage.

ACKNOWLEDGEMENTS

This research was funded by the Romanian Ministry of Research and Digitalization, CCCDI - UEFISCDI, Nucleus Program, TEX-PEL-VISION 2022, 4N/8.02.2019, project number PN 19 17 01 02_ CREATIV_PIEL, and PNCDI III - Program 1 – Development of the national RD system, Subprogram 1.2-Institutional Performance-RDI excellence funding projects, Contract no. 4PFE/ 2022.

REFERENCES

[1] Gh. Chiriţă, M., Chiriţă, (1999), Chemistry and technology of leather (in Romanian), vol. I and II, Gh. Asachi Press, Iaşi.

[2] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

[3] Ecological and Toxicological Association of Dyes and Organic Pigment Manufactures (ETAD).

[4] SG, “The Test Mark for Low Pollutant Leather Products”.

[5] O., Niculescu, A., Manta, Patent RO A/00533/2019, Inorganic pigment pastes for natural leather finishing.

[6] O., Niculescu, Z., Moldovan, M., Leca, C., Chelaru, Alexandrescu, L., Aboul-Enein, H. Y., Characteristics of natural leather finished with some ecofriendly mixtures of polymeric aqueous dispersions, J. Polymer Eng., 2015, 35(6), p.463-470.

[7] O., Niculescu, C., Gaidau, E., Badea, L., Miu, D., Gurau, D., Simion, (2020), *Special effect finish for bookbinding leather*, Proceedings of ICAMS 2020, p. 231-236.

[8] M., Lucretia, V., Bratulescu, C., Gaidau, V., Bocu, O., Niculescu, Natural leather for the patrimony book binding and the procedure for its development, Patent RO A/ 122098/2008.

[9] Cross, M.M., Rheology of non-newtonian fluids: A new flow equation for pseudoplastic systems, J. Colloid Sci., 1965, 20, 417.

[10] Schramm, G., A Practical Approach to Rheology and Rheometry,2nd ed., Gebrueder HAAKE GmbH, Karlsruhe, 2000.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

INNOVATIVE CLEANER LEATHER PRODUCTION PROCESS AND ENVIRONMENTAL PROTECTION

Dr. S. Rajamani

Chairman-Asian International Union of Environment (AIUE) Commission, Chennai - 600 028, India, E-mail: dr.s.rajamani@gmail.com

Abstract : *Environmental challenges in treatment and disposal of tannery effluent with high salinity, stringent environmental regulations including Total Dissolved Solids (TDS), etc. resulted in development of new appropriate cleaner production process to reduce the volume of water usage, pollutional discharges, segregation of streams such as saline soak liquor, spent chrome liquor enable to adopt advanced aerobic oxidation process, membrane system, recovery of chromium, purified salt and water for reuse.*

The achievements of the innovative cleaner production and effluent treatment are : (i) Reduction in water usage in soaking process from 6000-8000 liters to less than 3000 liters/ton of hides, (ii) Segregation of high saline streams from soaking operations and spent chrome liquor for separate treatment and recovery of quality salt, chromium in form of cake/powder, (iii) Conversion of physiochemical treatment into biological treatment with reduced chemical usage and sludge generation by about 70% and (iv) Advanced oxidation treatment using ozone for achieving COD, colour and turbidity.

Viable cleaner production and sustainable treatment technologies had been engineered and are being implemented in a major leather cluster with more than 200 new tanneries, a Common Effluent Treatment Plant. This would become a biggest leather cluster development during this century in World Leather Sector.

Key Words: *Segregation, Soaking, Effluent, Chrome Recovery, Advanced Oxidation, Ozone Treatment.*

1. INTRODUCTION

The treatment and disposal of tannery effluent with high salinity and Total Dissolved Solids (TDS) is a major challenge in most of the land locked tannery clusters. This resulted in development of appropriate cleaner production process to reduce the volume of water usage and pollution discharges. The segregation of streams such as saline soak liquor, spent chrome liquor enable to adopt advanced aerobic oxidation process, membrane system, recovery of quality chromium in the form of cake/powder, purified salt (sodium chloride) and water for reuse [1].

The merits of the developed cleaner production and effluent treatment are : (i) Reduction in water usage in soaking process from 7000 liters to less than 3000 liters/ton of hides, (ii) Segregation of high saline streams from soaking operations and spent chrome liquor for separate treatment and recovery of quality salt, chromium in form of cake/powder, water for reuse under ZLD concept, (iii) Upgradation of physiochemical treatment into biological treatment process with reduction in chemical usage to reduce sludge generation by 60-70%, (iv) Advanced oxidation treatment using ozone for achieving COD reduction, colour and turbidity removal to the required level in the composite effluent and (v) Integration of treated tannery effluent with treated domestic sewage for achieving TDS norms and use of the entire treated effluent for irrigation.

Viable cleaner production and sustainable treatment technologies had been engineered and are being implemented in a Mega Leather Cluster (MLC) with more than 200 new tanneries, a Common Effluent Treatment Plant (CETP) of 20 MLD in modules. This would likely be the biggest leather cluster with adoption of new and innovative cleaner productions by all the cluster member tanneries and first of its kind in World Leather Sector.

1.1.Viable Cleaner Technology for Reduction of TDS at Source

The raw hides & skins available in the market for leather tanning contains 30-50% of salt (Sodium Chloride) on total weight basis. These hides & skins are taken for soaking operations without proper salt dusting. The volume of water usage is 6000-8000 liters per ton of hides and TDS concentration ranges from 40000 to 60000mg/l. The entire soak liquor is mixed with other sectional streams and discharged as a composite stream and the TDS level is in the range of 20000-25000mg/l. This high TDS level in the effluent affects the performance of biological treatment system and inability to achieve discharge parameters particularly TDS which is being enforced in many Indian States and other countries as well.

In order to meet the challenges in achieving the environmental regulations and to improve the in effluent treatment system with recovery of quality chemicals, salt and water for reuse the following cleaner productions have been developed for implementation.

- Improved mechanism for desalting of skins by using simple system such as DODECA by tanneries at source and centralized mechanical desalting of hides by adopting proven equipments which are portable as well.
- Sulphide reduced liming process by the use of suitable enzymes to extent feasible for reduction of Sulphide load by 60-70% in the effluent.
- Safe and sustainable disposal of waste fleshing by conversion into fertilizer, composting by using with dewatered bio-sludge and other degradable organic matter.
- Segregation of Chrome stream and adoption of improved Common Chrome Recovery System (CCRS) and recovery of Chromium in the form of cake. The supernatant also further processed and converted into reusable chemical and quality water.
- Reduction in sludge generation by biological treatment with minimum chemical usage, anaerobic digestion of sludge with bio-energy generation and conversion into composting.

1.2. Segregation of Streams in individual Tanneries

All the individual tanneries in addition to the adoption of suitable cleaner productions, the streams are segregated as follows for separate treatment.

- Saline soak liquor from pre-soaking, main soaking and washing.
- Spent chrome liquor from chrome tanning operations.
- All other streams starting from liming, deliming, washing and all remaining wet finishing operations are collected as a composite stream.

The concept of the innovative cleaner production process in cluster of tanneries, improved chrome recovery system, sustainable TDS management and disposal of treated effluent is shown in figure-1.

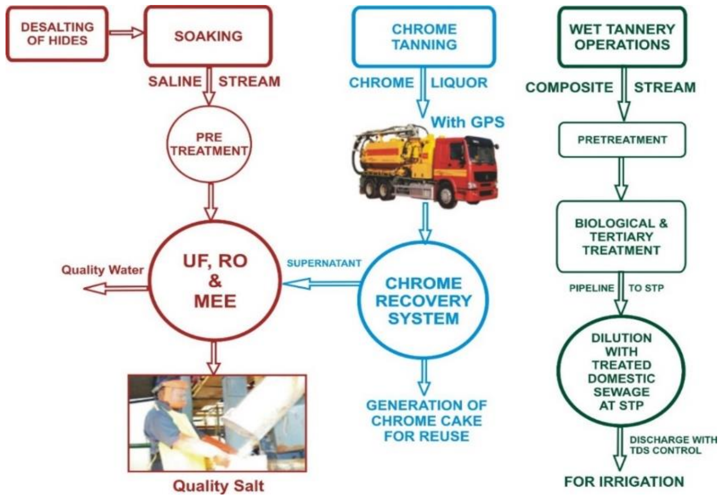


***Fig 1**: Innovative Cleaner Production for Sustainable Treatment with TDS Control*

1.3. Saline Soak Liquor

Saline Soak Liquor is generated from the three stage operations of namely (i) Pre or Dirt soaking (soaking I), (ii) Main soaking (soaking II) and (iii) Wash after main soaking (soaking III). During the conventional three stages of soaking using pits and paddles more than 6-8m3 of effluent is discharged per ton of raw material process. By the use of drums for soaking after viable desalting and cleaner production process, the volume of water usage and effluent discharge is reduced to less than 4m3/ton of raw hides and skins.

The saline soak effluent from each tannery is discharged into the exclusive conveyance system to CETP for separate treatment under ZLD concept with recovery of quality water and reusable salt [2]. The treated saline stream is partly reused in pickling / soaking and balance is evaporated for generation of reusable salt (mainly sodium chloride) and water. The salt is having more than 99% purity and has got market demand for industrial and other uses in land locked areas. The overall TDS level in the other composited stream is reduced by about 60% (i.e. from more than 20000mg/l to less than 10000mg/l). Due to this reduction, the environmental authorities permit the sustainable option of mixing the treated composite effluent with treated domestic sewage available near the tannery cluster and enable meet all the discharge parameters including TDS.

1.4. Manual / Mechanical Desalting Process

The tanneries processing salted goat, sheep, cow & buff calf skins in small scale can adopt desalting frames and rotary drums. DODECA wooden frames can be adopted for small size skins weighing upto 4-5kgs. For medium size hides weighing upto 10kg can be desalted using rotary drums with perforated holes.

Majority of tanneries in the cluster are in small & medium scale, they are not having the capability and land space to have mechanical desalting system required for big size hides. Hence, it is necessary to adopt mechanical desalting as a centralized facility. It is proposed to provide two centralized desalting facility for a capacity of about 80-100 tons per day during the first phase implementation. The desalting process, clarification of the dusted salt solution, reuse in pickling, etc. are shown in following process flow diagram.

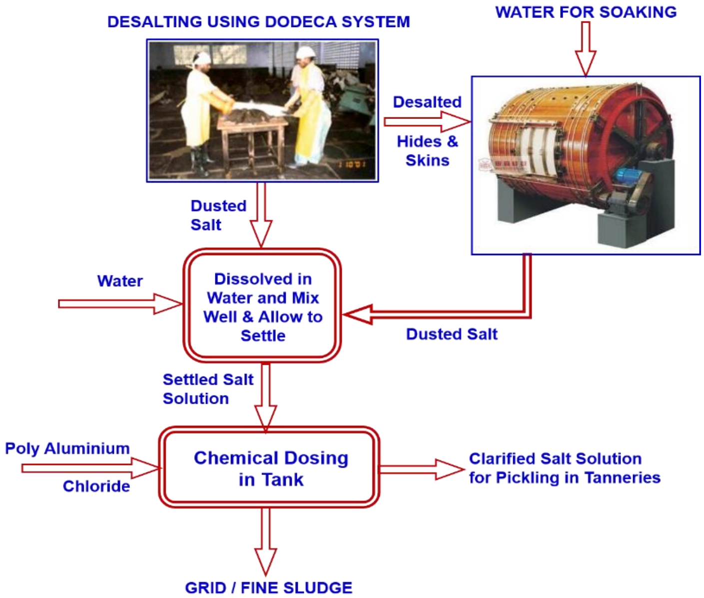


Fig.-2: *Desalting Process and TDS Management*

The salt collected from desalting process would contain grit and organic ingredients. This can be clarified by adding 200 liters of water for 20kg dusted of salt and grit will settle in bottom of the tank. The supernatant can be collected in a separate tank and added with Poly Aluminium Chloride (PAC) dosing. The suspended and organic settleable matter settles in the bottom as a sludge. This can be disposed in the sludge dewatering system installed in individual tanneries. The clarified supernatant which contains 7-8% salt solution can be used for pickling by adding required balance salt, sulphuric acid and water. The desalting process would reduce the TDS content in the saline soak liquor from the range of 40000-50000 to 20000-30000mg/l [5].

1.5. Improved Chrome Recovery System

The effluent discharge from chrome tanning operation is about 4-6% of total volume of wastewater from chrome tanneries. Conventionally, the tanneries provide individual chrome recovery system by using MgO (Magnesium Oxide) as alkali and the recovered chrome slurry is regenerated as Basic Chromium Sulphate (BCS) by mixing with Sulphuric Acid (H_2SO_4). BCS is in the form of liquid is reused in the tanning process [3, 4]. In this conventional process, there are limitation and management and reuse of Chromium. The discharge of entire supernatant from chrome system with high TDS (25000-40000mg/l), Chlorides (8000-15000mg/l), Sulphate (4000-8000mg/l), etc. to the CETP along with other streams results in increase of overall TDS in composite stream, constraints in adopting biological treatment system particularly anaerobic system achieving TDS level in the treated effluent is not feasible.

The concept of the improved CCRS (i) Collection of spent chrome liquor from individual tanneries through tankers fitted with GPS, (ii) Screening, pretreatment, separation of Chromium as a slurry in the reactor by using suitable alkali, (iii) Dewatering of chrome slurry using Chamber Filter Press and recovery of Chromium in the form of cake and (iv) The supernatant with high TDS of more than 30000mg/l is taken for further treatment integrated with saline soak stream treatment system for recovery of quality salt and water by adopting membrane system.

2. CENTRALIZED FACILITIES FOR SUSTAINABLE SOLID WASTE MANAGEMENT

The tanneries during beam house operation generate large amount of fleshing. It is estimated 20-30kg of fleshing generated during the process of 1000kg of hides & skins. Only part of fleshing is taken for commercial process and about 50% of fleshing mainly from skins and small hides are becoming waste. The waste fleshings are proposed to be disposed by adopting the following options: (i) Conversion into composting using other organic degradable waste and bio-sludge, (ii) Conversion into biological liquefaction and feed to anaerobic reactor for bio-energy generation and bio-sludge, (iii) Mixing with dewatered bio-sludge from digester and converting into bio-fertilizer.

The centralized solid waste management comprises of biological liquefaction of fleshings, anaerobic digestion, composting, etc [6]. A separate RCC industrial type building in an area of 500m2 within the CETP in a land space of 1200m2 is proposed to be implemented for solid waste management in the CETP area during the Phase-1.

3. COMPOSTING AND GENERATION OF BIO-FERTILIZER

It is estimated that about 5-10 tons of partly dewatered bio-degradable sludge would be generated from soak liquor treatment, composite treatment and anaerobic digester [7]. This bio-degradable sludge can be processed further by adding waste fleshing and degradable organic waste available in the local area. The ratio of the mix would be generally 1:1:1 and the composting process would take about 15-20 days. Proper bio-seeding generated from STP / bio-spray would be periodically applied for accelerating the composting process.

4. RESULTS AND DISCUSSION

- Improved desalting using DODECA mechanism removes the salt content from 60% to 30% on weight basis.
- Modified and improved soaking process reduces the water usage and effluent discharge from the level of 600-800% to 300-400%.
- Improved chrome recovery system generates chromium in the form of cake / powder.
- Entire supernatant is further process and recovered in the form of quality salt and water for reuse.
- Segregation & treatment of saline soak liquor under ZLD system generates quality water and salt.
- TDS level in the composite stream reduced from about 20000mg/l to less than 10000mg/l.
- Improved cleaner production and segregated treatment enable to comply the environmental regulations and discharge norms.
- Scope for replicability in many tannery clusters.

5. CONCLUSION

This unique and sustainable technological developments in cleaner production and effluent treatment will reduce the level of TDS in the effluent discharge by 50%, hazardous category sludge generation by 60% and meets the environmental norms [8,9]. Based on the pilot scale development, commercial scale systems are being implemented in Effluent Treatment Plants (ETPs) and CETPs in India and other countries.

ACKNOWLEDGMENT

Contributions of Department for Promotion of Industry and Internal Trade (DPIIT)-Govt. of India, Indian Leather Technology Association (ILTA), IAFLI, UNIDO, National Mission for Clean Ganga (NMCG), National Green Tribunal (NGT), Mega Leather Cluster (MLC)-Kanpur, Schoolnet India Limited, Asian International Union Environment (AIUE) Commission, Asian International Forum and others commission members from various countries, AMECON & TNO Netherlands, Central Leather Research Institute (CSIR-CLRI), European Union including Italy, Spain, The Netherlands and other Countries such as China, Japan, Romania, Turkey, Taiwan and Russian Federation, New Zealand are acknowledged. Leather Industry Associations and Common Effluent Treatment Plants (CETP) specifically Pallavaram, Dindigul, Madhavaram, Kanpur, Banthar, Unnao CETPs in India are acknowledged.

REFERENCES

[1]. S. Rajamani (2014), *Growth of Leather Sector and Recent Environmental Development in Asian Countries*, Paper presented in 10th Asian International Conference on Leather Science & Technology, Okayama, Japan.

[2]. S.Rajamani (2020), *Sustainable ZLD System by Adopting Centralized Treatment of Segregated Streams for Recovery of Reusable Quality Chemical, Salt & Water – First of its kind in India & Asia* – Article published in Leather News India Journal.

[3]. Jakov Buljan - UNIDO, S. Rajamani (1996), *"Technology Package - A system for recovery and reuse of chromium from spent tanning liquor using magnesium oxide and sulphuric acid"* – TECHPACK / UNIDO / RePO / 1.

[4]. J.E Schaapman, S. Rajamani, S.N. Gupta, R.B Mitra and H.H.A Pelckmans, (1990) *"Cleaner Technology in the Leather Industry - Chrome recovery and Reuse"*. Paper presented in Water Pollutional Control Federation 63rd Annual Conference, Washington DC, USA.

[5]. Jakov Buljan, G. Reich, J. Ludvik (1997) *"Mass Balance in Leather Processing"*. Paper presented in IULTCS Congress, London, UK.

[6]. J.S.A Langerwerf, S. Rajamani, T. Ramasami, K.V Raghavan, J.W Van Groenestijn, A. Mulder (1995), *"Implementation and Dissemination of the Results of the TNO-CLRI Co-operation Programme"*. Paper presented in XXIII IULTCS Congress, Friedrichshafen, Germany.

[7]. Suthanthararajan, S. Rajamani, Chitra Kalyanaraman, B. Umamaheswari, E.Ravindranath - *Anaerobic Digestion of sludge from highly saline wastewater streams from tanneries with special Anaerobic Sludge Digester with Liquid Separator (ASDLS) System and generation of Bio-energy* - Paper presented in the 2001 IULTCS Congress held at Cape Town, South Africa.

[8]. S.Rajamani (2018), *Sustainable Environmental Technologies Integrated with Cleaner Production – Recent developments in World Leather Sector* – Paper presented in XIVth International Scientific-Practical Conference, Ulan-Ude, Russia.

[9]. S.Rajamani (2016), *Innovative Environmental Technologies including Water Recovery for Reuse from Tannery and Industrial Wastewater - Indian and Asian Scenario*, Paper presented in 6th International Conference on Advanced Materials and Systems (ICAMS 2016), Bucharest, Romania.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

TRIALS ON SYNTHESIS OF SYNTANS FROM VARIOUS MONOMERS AND DETERMINATION OF THEIR TANNING PERFORMANCES

YILMAZ Onur[1,*], OZGUNAY Hasan[1,*], ONEM Ersin[1], BASARAN Bahri[1], YORGANCIOGLU Ali[1]

[1] Ege University, Engineering Faculty, Leather Engineering Department, 35100, Bornova-Izmir, Turkey

Corresponding authors: Yilmaz Onur, onur.yilmaz@ege.edu.tr; Ozgunay, Hasan, hasan.ozgunay@ege.edu.tr

Abstract: *The present study report on the attempts of synthesis of synthetic tanning agents based on different starting materials of phenol, urea, salicylic acid, resorcinol, dihydroxydiphenyl sulfone via condensation with formaldehyde. After many trials, best results were obtained from phenol-formaldehyde, phenol-urea-formaldehyde and dihydroxydiphenyl sulfone-formaldehyde systems. It was shown that the experiments with other starting materials need further investigations and more detailed studies for controlled reactions to obtain usable resins. The pH values and dry matter contents of the successful resins obtained from reactions were determined and the structural analysis was done by FTIR. Then the produced syntans were used as solo tanning agents for the tanning of pickled sheep skins. The results showed that all the leathers tanned with the synthesized syntans had shrinkage temperatures over 70 °C. Moreover, the filling coefficients of the produced syntans, the physical properties of the leathers in terms of tensile strength, percentage of elongation and tear strength were investigated. The produced syntans gave very white and/or light beiege colors with a good filling effect and plain grain structure.*

Key words: *Leather, Tanning, Synthetic Tannin, Syntan, Resin*

1. INTRODUCTION

Tanning, which is the basic process of leather production, is one of the first production processes of human being [1]. Tanning can simply be defined as the process of converting the organic leather raw material, which is putrescible by bacterial activities, into an impurtescible and stable material [2]. Approximately 80-85% of the leathers produced in the world are tanned with basic chromium-sulphate compounds [3-4]. Chrome-tanned leathers are particularly characterized by their lightness and high tensile strength. This is due to the fact that chromium forms crosslinks between polypeptide chains by making coordination bonds with acidic amino acid side groups in skin collagen [5]. This cross-linking causes significant increases in the physical and mechanical properties of chrome-tanned leathers and can increase the wet thermal resistance of leathers up to 100 °C. Besides all these advantages of chrome, it also has some negative features. However, the main disadvantage of chrome tanning is generation of liquid and solid wastes containing chromium (a heavy metal that has negative effects on human health and the environment) at the end of the process, since the consumption of chrome tanning materials is 60-70% [5]. For these reasons, due to the increasing environmental pressure and the support given to environmental production in recent years, chrome tanning has become controversial. So, the studies on minimizing the use of chromium, increasing its consumption, recycling it or using alternative tanning agents have come to the fore. Demands for leather products such as chrome-free or metal-free have started to increase in the sector, and this has gradually increased the importance of alternative tanning agents. The production of metal-free leather, which has started to develop in the European market in recent years and is expected to increase worldwide in the coming years, has gained importance.

Considering the current technologies in the production of this type of leather, it is seen that aldehyde, vegetable tannins and syntans come to the fore as tanning agents. Among them, aldehydes are limited to use alone because they do not have a sufficient filling effect on the leather and may have harmful effects on human health. Vegetable tannins, on the other hand, have been used for many years, but they cannot be used for every leather type and are preferred for certain product groups, since they coarsen the grain, have low light fastness, and give leathers in light and dark brown color tones. However, syntans are increasing in use in the production of metal-free leathers, as they can be used as substitutes for vegetable tannins in a wider range of products, and because they provide leather with lighter color tones and relatively higher light fastness. Synthetic tannins or syntans have been used in the leather industry for many years [6-10]. The first phenolic syntan was obtained by Stiasny in 1911 by condensation of phenol with formaldehyde and sulfonation with sulfuric acid. In addition, the first comprehensive information on the production and use of synthetic tannins was reported by Wolesenksy and Stanley [11-15].

Due to the increasing environmental awareness in recent years, the importance of alternative tanning agents to chrome tanning materials, which are the most used tanning agents, is gradually increasing. For this reason, the use of both vegetable tanning and synthetic and polymeric tanning agents has increased and R&D studies in this field have been accelerated [16].

From this point of view, in our study many trials were carried out on the synthesis of synthetic tannins via condensation with formaldehyde, using different starting monomers such as phenol, urea, resorcinol, salicylic acid, dihydroxydiphenic sulfone. It is aimed to reveal the production of synthetic tannins containing different starting materials in detail and comparatively with an academic approach. In addition, synthesized syntans were used as solo tanning agents in tanning process, then their tanning performances and their effect on the leather properties were examined.

2. MATERIALS and METHODS

2.1 Materials

For the synthesis of syntans Phenol (Ph, TEKKİM, %85), Urea (Merck, %99), Salicylic acid (SA, Merck, %99), Resorcinol (Rc, Merck, %99), Dihydroxydiphenyl sulfone (DHDPS, Merck, %98) and Formaldehyde (FA, TEKKİM, %37) were used as different starting monomers. Sulfuric acid (TEKKİM, 95-98%) was used as catalyst and sulfonation agent in the reactions. The neutralization and pH adjustment of the syntan solutions was done by 1M NaOH (TEKKİM, 98%) solution. The polymerization reactions took place in 2 necked 250-1000 mL glass balloons equipped with a condenser. Heating and mixing procedures was done in glycerin bath by using a Heidolph magnetic stirrer. For tanning trials Metis type pickled sheep skins were used.

2.2. Methods

2.2.1 Syntheses of syntans

In the study many trials on the condensation of phenol, salicylic acid, recorsinol, phenol-urea, dihydroxydiphenyl sulfone with formaldehyde were performed. Table 1 shows the details of all polymerization reactions performed. For condensation, first novalac type reactions were performed (F1-F3). The water solubility of the final resins was found to be low, thus, all the other condensation trials were carried out using nerodol type reactions for all monomers.

In the trials mol ratios of the starting materials and reaction temperatures were varied. After all trials, salicylic acid-formadehyde and recorsinol-formaldehyde based condensation did not give any soluble final resins. For these trials further detailed investigations were found to be necessary. On the otherhand successful condensation reactions were obtained for phenol-formaldehyde, dihydroxydiphenyl sulfone-formaldehyde and phenol-urea-formaldehyde resins. From each group one resin gave the optimal results were re-produced in larger scale (Table 4) and used for the leather application as solo tanning agent.

As an example for the synthesis of syntans; 23,5 g phenol and 28,4 g H_2SO_4 were mixed at 90 °C over night for sulfonation. Next morning the system was cooled down, 5.6 g of water was added and 15,2g formaldehyde was dropped in the reaction for 90 min. Afterwards, the reaction temperature was raised to 75 °C and kept 3h for the completion of condensation. At the end the reaction the system was cooled down to room temperature and pH was adjusted between 5,0-6,0 with 1M NaOH solution. The final solutions were used directly in tanning process.

Table 1. *Polymerization trials on syntan synthesis using different starting monomers*

Code	Ph (mol)	SA (mol)	RS (mol)	DHDPS (mol)	Urea (mol)	H_2SO_4 (mol)	FA (mol)	Reax. Temp (°C)	Final Solid content (%)
F1	0,50	-	-	-	-	0,50	0,29	40	32
F2	0,50	-	-	-	-	0,24	0,29	40	30
F3	0,50	-	-	-	-	0,30	0,40	40	45
F4	0,10	-	-	-	-	0,10	0,08	70	49
F5	0,25	-	-	-	-	0,28	0,1375	35	44
F6	0,25	-	-	-	-	0,28	0,1375	40	39
F7	0,25	-	-	-	-	0,28	0,1875	40	52
F8	0,25	-	-	-	-	0,28	0,23	35	55
S1	-	0,250	-	-	-	0,002	0,1875	75	X
S2	-	0,0625	-	-	-	0,07	0,04687	70	14
S3	-	0,125	-	-	-	0,14	0,094	70	X
S4	-	0,125	-	-	-	X	0,094	80	X
R1	-	-	0,20	-	-	1 drop	0,1060	70	X
R2	-	-	0,25	-	-	0,14	0,1875	120	X
R3	-	-	0,25	-	-	0,28	0,1875	90	X
R4	-	-	0,25	-	-	0,20	0,1875	50	X
D1	-	-	-	0,25	-	0,28	0,1375	70	41
D2	-	-	-	0,25	-	0,28	0,1875	70	39
F-U1	0,50	-	-	-	0,45	0,50	0,50	70	X
F-U2	0,50	-	-	-	0,40	0,50	0,50	70	X
F-U3	0,50	-	-	-	0,33	0,50	0,50	70	43
F-U4	0,50	-	-	-	0,25	0,50	0,50	70	45

2.2.2. Tanning application

For the preparation to the tanning process the pickled sheep skins were first depickled followed by acidic sammying and degreasing procedures. The tanning procedure was given in Table

2. After tanning process, the leathers were rested for a week, shaved and then a conventional retanning/lubrication process was applied (Table 3). After the wet processes completed the leathers were dried, mill drummed and toogled.

Table 1. *The recipe where the produced syntans were used as solo tanning agent*

Process	Amount (%)	Chemical	Temperature (°C)	Duration (min.)	pH
Pickle&tanning	70	Water	30	10	-
	10*	Syntan	-	60	-
	1,5	Synthetic fatliquoring agent	-	30	-
	10*	Syntan	-	60	-
	5*	Syntan	-	60	-
Fixation	1	Formic acid	38	90	3.5
Washing	100	Water	25	5	-

*based on dry content of the syntan solution

Table 3. *The recipe of the retanning and fatliquoring process applied to tanned leathers*

Process	Amount* (%)	Chemical	Temperature (°C)	Duration (min.)	pH
Neutralization	200	Su	35	5	-
	2	Neutral syntan	35	60	4,5-5,0
Retanning	2	Amphoteric polymer	-	45	-
Fatliquoring	9	Combined fatliquoring agent	45	60	-
Fixation	1,5	Formic acid	-	120	3,8-4,0
Ø					
Washing	100	Water	25	10	-

*based on shaved weight

2.2.3 Characterization of synthesized resins

The structural characterization of the synthesized resins was carried out by FTIR spectroscopy using Perkin Elmer Spectrum-100 model FTIR-ATR spectrometer. For this purpose, dried samples were scanned within the range of 4500 – 600 cm^{-1}. Other physical properties of the resins such as pH (pH meter) and dry matter (gravimetrically) were also measured.

2.2.4 Determination of Physical Properties of the Leathers

After completing the tanning processes, the shrinkage temperatures of tanned leathers were determined according to standard method of IUP 16 [17]. Filling coefficiency of the leathers were determined by measuring the thickness of the leathers before and after tanning process. The physical properties such as tensile strength, percentage of elongation, tear strength were tested according to TS EN ISO 3376 and TS EN ISO 3377-2 standard test methods [18,19].

3. RESULTS and DISCUSSIONS

3.1 Synthesis of the syntans

As explained in the method section three selected syntans gave successful results were produced relatively in higher amount (300g). The resin types, molar ratios of the starting monomers, their final pH and solid content were given in Table 4. All the resins were obtained coagulum free, dark reddish-brown colored solutions.

Tablo 2. *The selected syntans synthesized in higher scale and their properties*

Syntan no	Content	Molar ratios	pH	Solid content (wt%)
1	Phenol-Formaldehyde (PF)	1 / 0,75	5,0	45
2	Phenol-Urea-Formaldehyde (PUF)	1 / 0,5 / 1	5,3	48
3	Dihydroxydiphenyl sulfone -Formaldehyde (DF)	1 / 0,75	5,6	42

3.2 FTIR analysis

Structural analysis of synthesized synthetic tannins was done by FTIR. The Spectra of large scale produced syntan samples are given in Figure 1 and detailed analysis of the spectra are given in Table 5. When the spectra of the synthetic tannin samples are examined, the –NH stretching vibration of urea-containing syntan is at 3375 cm^{-1}, the phenolic –OH absorption band was around 3280 cm^{-1} as a wide peak, the C=O and N–H bands of the urea groups were observed at 1723 cm^{-1}. Absorption peaks of aromatic C=C vibrational stretch belonging to phenol and dihydroxydiphenyl sulfone groups were observed at 1590 and 1431 cm^{-1}, aliphatic –CH stretching at 1501 and 1110 cm^{-1}, C-O stretching at 1645 cm^{-1}. The results show that synthetic tannins were successfully synthesized.

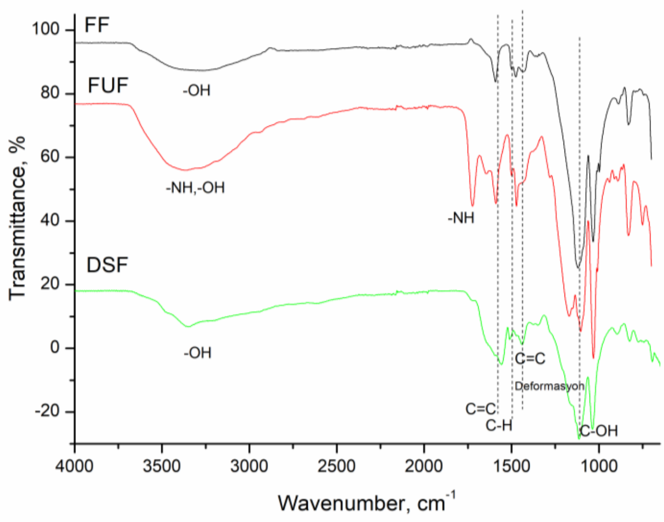


Fig. 1. *IR spectra of phenol, formaldehyde and synthesized phenolic syntan samples*

Table 3. *IR absorption bands of synthetic tannin samples and related absorption groups*

Wavenumber, (cm^{-1})	Relevant group absorption
3375	-NH stretching
3280	-OH stretching
1723	-C=O stretching
1645	-NH stretching
1590	C=C aromatic ring
1558	C=C aromatic ring
1431	C-H aliphatic
1432	C = C, CH_2- benzene ring veiled with methylene groups
1110	C-O stretching
1030	C-O stretching of -CH_2OH groups

3.3. Leather properties

The synthesized syntans were used successfully in the tanning process without any problems. It was observed that the consumption of syntans was very good at the end of tanning process. It was also observed that the leathers obtained were full-handed, light-colored and had smooth-grain. The leather images taken at the end of the tanning and after drying were shown in Figure 2.

In Table 6 the other leather properties obtained from physical tests were summarized. During the tanning process with synthetic tannins, it was observed that the bath was clean at the end of tanning process indicating that the consumption of the synthetic tannins by the leathers was high. As can be seen from the results given in the Table 6, an increase was observed in the average thickness of all leathers after tanning. The filling coefficiency of the syntans were found to be 21,41%, 25,40% and 42,74% for phenol-formaldehyde resins, phenol-urea-formaldehyde and dihydroxydiphenyl sulfone-based synthetic tannins, respectively. The results showed that the thickness of the leathers increased significantly after tanning, and the highest increase was obtained with dihydroxydiphenyl sulfone based synthetic tannins.

Fig. 2. *Leather images taken at the end of tanning process and after drying (From left to right: Leathers tanned with Phenol-FA, Phenol-Urea-Formaldehyde, Dihydroxydiphenylsulfone-Formaldehyde)*

The shrinkage temperature values of the leathers were shown also in Table 6. According to the results, the highest shrinkage temperature of 74 °C was observed for leathers tanned with phenol-formaldehyde resin. This was followed by dihydroxydiphenol sulfone at 72 °C and phenol-urea-formaldehyde resin at 70 °C. The results showed that all the synthesized syntans had good tanning ability.

When the mechanical properties were evaluated it was observed that highest values of tensile strength, elongation percentage and tear strength were in the order of dihydroxydiphenylsulfone-formaldehyde, phenol-urea-formaldehyde and phenol-formaldehyde, respectively.

Table 6. *Leather properties*

Reçine No	Filling coefficiency (%)	Shrinkage temperature (°C)	Tensile strength (N/mm^2)	Elongation percentage (%)	Tear strength (N/mm)
1	21,41	74	9,44	53,01	26,12
2	25,40	70	14,38	60,10	40,48
3	42,74	72	16,06	87,81	79,36

4. CONCLUSION

In the study, synthetic tannin syntheses were carried out, which includes the condensation reactions of different starting materials such as phenol, phenol-urea, resorcinol, salicylic acid and dihydroxydiphenyl sulfone with formaldehyde. Among these, successful results were obtained from phenol-formaldehyde, phenol-urea formaldehyde and dihydroxydiphenyl sulfon-formaldehyde-based samples. It has been observed that trials with other starting materials require further and detailed laboratory studies. However, resin production of phenol, phenol-urea, dihydroxydiphenyl sulfone with formaldehyde have been carried out successfully. The obtained resins were then used in the tanning process as solo tanning agents, and shrinkage temperatures of 70°C and above were obtained in all trials. It has been observed that leathers tanned with synthetic tannins gave leathers with white and light beige color tones with high fullness and smooth grain. It was also observed that phenol-formaldehyde resins had high tanning ability, but gave tighter and relatively low elasticity leathers, while the leathers tanned with dihydroxydiphenyl sulfone-formaldehyde resin had higher flexibility and fullness.

Acknowledgement: This work was supported by Ege University Scientific Research Projects Coordination Unit. Project Number: 17-MÜH-004

5. REFERENCES

[1] M. Kite, and R. Thomson, "*Conservation of Leather and Related Materials*", UK:Elsevier, 2007.

[2] A. D. Covington, "*Tanning Chemistry, the Science of Leather*" Cambridge: The Royal Society of Chemistry Publishing, 2009.

[3] M.A. Eid, E.H.A. Nashy, E.A. El-Ashkar, K.A. Eid, E.H. Borai, "*Speciation of Chromium İons İn Tanning Effluents And Subsequent Determination Of Cr(VI)*", Journal of the American Leather Chemists Association, vol. 97, pp. 451, 2002.

[4] C. Hauber and H.P. Germann, "*Investigation On A Possible Formation And Avoidance Of Chromate İn Leather*", World Leather, October, pp. 73-80, 1999.

[5] K.J. Srearam and T. Ramasami, "*Sustaining Tanning Process Through Conservation, Recovery And Better Utilization Of Chromium*", J. Resources Conservation and Recycling, vol. 38, pp. 185-212, 2003.

[6] J. Ammenn, "*100 Years of Syntans How Chemistry Enabled İncreasing Performance On Leather*", XXXII. Congress of IULTCS, İstanbul-Turkey, 29-31 May, 2013.

[7] J. Ammenn, C. Huebsch, E. Schilling, B. Dannheim, "*Chemistry of Syntans And Their İnfluence On The Leather Quality*", Journal of The American Leather Chemists Association, Vol. 110 (11), pp. 349-354, 2015.

[8] E.N. Daniel, C. Stamford, "*Preparation of Sulfonated Phenolic Resins*", US Patent No: 2.621.164. 1952.

[9] Y. Dikmelik, "*Deri Teknolojisi*", İzmir: Sepici Kültür Hizmeti Yayınları, 2013.

[10] J., Miglarese, "*Manufacture of Syntans From Vanillin And Leather Tanned Therewith*", Us Patent No: 2.564.022, 1951.

[11] A. Stanley, L. Livingston, J.M. Kelly, N.J. Belford, "*Condensates of Sulfonated Formaldehyde-Mexed Phenols Condensates With Formaldehyde And A Phenol*", Us Patent No:3.442.859, 1969.

[12] E. Wolesensky, "Investigation of Synthetic Tanning Material, Technologic Papers of the Bureau of Standards", No.302, Government printing office, Washington. 1925.

[13] E. Wolesensky, "*Action of Sodium Sulphate In Synthetic Tanning Materials, Technologic Papers of the Bureau of Standards*", No.317, Government printing office, Washington, 1926a.

[14] E. Wolesensky, "*Analysis of Synthetic Tanning Materials, Technologic Papers of the Bureau of Standards*", No.316, Government printing office, Washington, 1926b.

[15] E. Wolesensky, "*Behavior of Synthetic Tanning Materials, Toward Hide Substance Technologic Papers of the Bureau of Standards*", No.309, Government printing office, Washington, 1926c.

[16] Y.Z. Wang, J.B. Li, Z.H. Shan, "*A novel synthesized melamine compound for leather making*", Journal of the American Leather Chemists Association, vol. 101, pp. 38-42, 2017.

[17] IUP 16, Leather Physical and Mechanical Tests, "Determination of Shrinkage Temperature up to 100 degrees", 2002.

[18] TS EN ISO 3376, Leather - Physical and Mechanical Tests - Determination of Tensile Strength and Percentage Extension, 2012.IUP 8, "Measurement of tear load – double edge tear", JSLTC, vol. 84, pp. 327-329, 2000.

[19] TS EN ISO 3377-2, Leather - Physical and Mechanical Tests - Determination of Tear Load Part 2: Double Edge Tear, 2016.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

BRIEF CONSIDERATIONS ON THE ENVIRONMENTAL ISSUES IN THE TEXTILE INDUSTRY AND THE RELEVANT EUROPEAN LEGISLATION IN THIS FIELD

DOCIU Maria-Ariana[1], GHERGHEL Sabina[2]

[1] Bihor Bar Association, George Enescu Street, no. 1, 410034, Oradea, Bihor, Romania, E-Mail: dociuariana@gmail.com

[2] University of Oradea, Energy Engineering and Industrial Management Faculty, Department of Textile-Leather and Industrial Management, B. Ştefănescu Delavrancea Street, no. 4, 410058, Oradea, Bihor, Romania, E-Mail: gherghelsabina@yahoo.com

Corresponding author: Dociu, Maria-Ariana, dociuariana@gmail.com

Abstract: *In the modern society, environmental protection is a widespread, but still a sensitive topic. The textile industry is one that still generates environmental problems, starting from the production of raw materials used to make various products to the stage when some textiles become waste. This paper outlines the main environmental issues in the textile industry in the European Union, as well as the measures taken by the European authorities to implement the Waste Framework Directive, which sets the basic concepts of the waste management. Regarding the environmental issues, several aspects have been identified, such as the water problem from the double perspective of the huge quantity being used in the production of different textile items and the pollution generated, the gas emissions problem and also the waste problem. All of these issues are being connected, as the more items are produced, more water is used and ultimately, going through all the stages, a larger amount of waste is produced. This is the reason why, at the European level, the authorities are trying to implement a circular economy model in the textile industry. The main goal of the Waste Framework Directive is to reduce the quantity of waste, including the one that comes from the textile industry, by following a five-step plan, including prevention, re-use, recycling, recovery and disposal.*

Key words: *water, gas emissions, waste, recycling, circular economy.*

1. INTRODUCTION

The textile industry is one of the most important and largest industries in the world, providing the society the so-needed textiles in many aspects of our lives and also numerous jobs. Despite the existing positive facts, there is also a significant negative side, because of the significant environmental issues that are connected to the textile production and consumption, regarding the use of resources, water, chemicals and also the resulted waste.

2. MAIN ENVIRONMENTAL ISSUES

According to the official dates, Europeans consume on average 26 kg of textiles per person per year [1] and, on the other hand, approximately 11 kg of textiles is the amount being discarded by each person per year. Even though the COVID-19 health crisis has affected the textile industry economy, resulted in the decrease by 9% of the textiles turnover, as a whole [2], it still had the fourth highest impact on the environment and climate change from a global life cycle perspective.

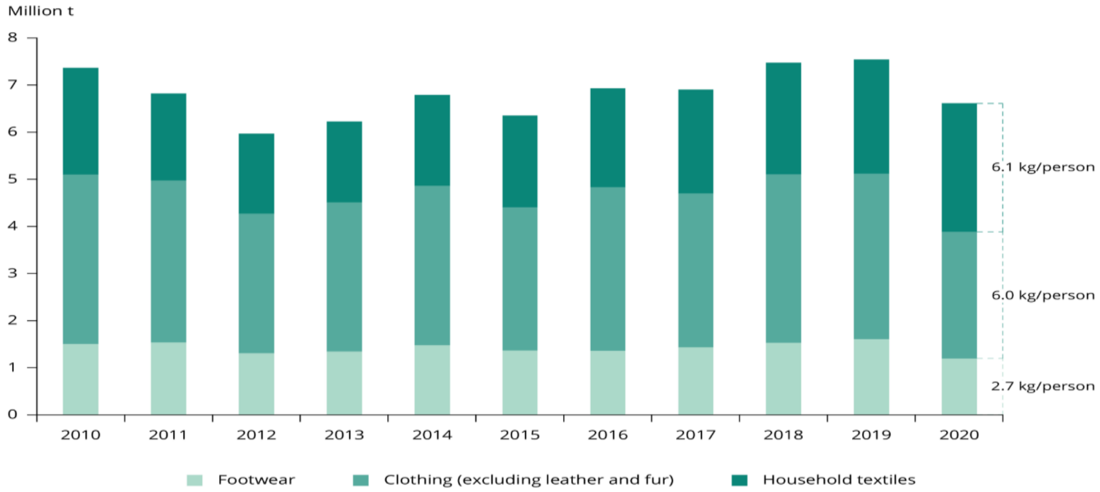


***Fig. 1**: EU-27 estimated consumption of clothing, footwear and household textiles (excluding fur and leather clothing) for the period 2010-2020 (million tonnes and kilograms per person)* [2]

2.1. The use of water and water pollution

In the field of the textile industry, one of the well-known environmental issues is the use of water. For example, it has been estimated that the at the global level, this industry uses almost 80 billion cubic metres of water per year [3], and just for the making of a single cotton t-shirt there are needed 2,700 metres of fresh water, which is the amount that a person would drink in 2,5 years. Another relevant example showing the great amount of water used in the textile industry is that in order to produce only 1 kg of fabric, there are normally necessary 200 litres of water [4], which implies the processes of washing, bleaching, dyeing and cleaning the items. Although there are large amounts of water that are used, another worrying situation arises, consisting in the pollution that occurs when the untreated water is discharged into the environment.

A lot of water is used in the process of washing the synthetic fibers, a process which generates pollution, being estimated that 0,5 million tons of microfibers are released in a year into the ocean. Studies have shown that approximately 8% of the European microplastics that are found in the oceans come from synthetic textiles [5]. Usually, microplastics that come from textiles have a fiber shape, which is why they are called microfibers. Even though there are textiles that are not synthetic, these items can also be considered as a source of water pollution, due to the fact that they shed microfibers as well. Studies also take into consideration the fact that nowadays fast fashion has an important role in the use of water and consequently in the release of microfibers in the environment, as the items contain high levels of synthetic fibers. Moreover, it has been shown that the first machine washes are the ones that generate the greatest release of microfibers, which is another argument from which it is quite clear that the products produced in fast fashion are quite dangerous for the environment, as they are not being used for a long period of time [5].

Another problem can be encountered in the process of the production of raw materials and converting them into fibres, that also means the use not only of the water, but also of pesticides and other chemicals. Chemicals are commonly used in the textile industry, starting from the phase of growing raw materials, such as cotton, and then in the process of dyeing and different treatments [6].

2.2. Air pollution

10% of the global greenhouse gas emissions is caused only by the fashion industry, even more than the international flights and maritime shipping together. Official dates show that in 2017, textile purchases in the European Union generated approximately 654 kg of CO2 emissions per person**.** Improving the way cotton and polyester (these being the mainly fabrics used) are produced could have a huge impact on the reducing of the emissions.

In 2015, it was estimated that over 706 billion kilograms of greenhouse gas were released in polyester production in textile industry [6], as polyester is made from oil and processing the raw material requires a lot of energy. In the case of the cotton, the use of the fertilizer releases nitrous oxide, which is a greenhouse gas with 300 times more warming power than CO2.

2.3. Textile waste

Another modern problem, which is very spread nowadays due to the great number of textiles that people buy and the existence of the fast fashion phenomenon, is the fact that the unused or unwanted items are being thrown away and not recycled or re-used. This generates huge amounts of textile waste, and the impact is felt especially in the so called third countries, where the waste is being sent. For example, recently, in February 2022, the Romanian Customs stopped a transport of 15 tons of textile waste, meaning clothes that were in an advanced state of degradation and were classified as hazardous waste.

Last year, border guards from the western and southern borders of Romania, together with customs workers and representatives of the National Environmental Guard, discovered on a container and 10 trucks, the total amount of 186,409 kilograms of waste, consisting of textiles, aluminium, polystyrene, glass, rubber and plastic, which were to be imported into Romania, without complying with legal provisions.

2. MAIN SOLUTIONS TO THE ENVIRONMENTAL PROBLEMS IN THE EUROPEAN UNION

The first step in trying to solve the shown environmental problems it is represented by the awareness that these problems really exist and that the environment is seriously affected, a fact that should be in the attention of the society and of the governing bodies of the states and of the European Union.

For example, regarding the problem of the microfibers released in the environment, it has been shown that this is a very complex issue, whose solution would require more knowledge on the release mechanisms and the impact on the environment. As this is a constantly evolving process, the European Union has considered putting into practice some policies in order to minimise the release of microfibers from textiles. In 2018, the European strategy for plastics has been adopted and it contained provisions for reducing microplastic pollution. Also, the European Commission implemented the so-called REACH regulation (number 1907/2006), whose aim is to improve the protection of the environment with the help of four processes regarding chemicals, which are the registration, evaluation, authorisation and restriction of chemicals [7]. This topic is also brought into attention in the EU economy action plan, in which textiles and plastics are among the key value chains.

Regarding the use of chemicals, one of the solutions would be reducing the need for them, especially in the process of producing the denim, as it often uses dyes and other chemical-based substances in order to create the final product [8]. Consequently, companies have taken into consideration replacing dyes with digital printing, having a positive effect on both the use of water and reducing waste. Another solution would be the existence of dyes that do not contain hazardous chemicals or the use of lasers instead of chemicals, which were put into practice by some manufacturers [8].

As for the textile waste, there are a few solutions found even in the Waste Framework Directive, but it has to be mentioned that these solutions that are specified below can be the key to solve not only the problem of the waste, but can be linked to the other aspects shown above. For example, it has been shown that mechanically recycled polyester generates 70 percent less emissions than virgin polyester [6], and this would also imply reducing textile waste.

The achieving of the goal of reducing the environmental and climate impacts of the textile industry strongly requires a systemic change towards circularity, a fact which presupposes effective policies related to materials and design, production and distribution, use and reuse, collection and recycling in this industry.

3. THE CIRCULAR ECONOMY MODEL. WASTE FRAMEWORK DIRECTIVE.

The success of the circular economy model depends a lot on the policies and regulations regarding the quality and safety requirements of a certain item, from the very beginning of its production. The main goal is that of a longer use of the product, even its reuse or recycling.

Because it produces more than 2,5 billion tons of waste every year, the European Union aims to create a model named the circular economy [9], so the legislation in this subject plays a fundamental role. The main idea is to reach an extended life cycle of the product.

The shift towards circular business models is therefore essential, and there are a number of steps that need to be followed in order to achieve this. First of all, is important ensuring an increased period of use and reuse of the product. Also, the process of choosing the most adequate and eco-friendly materials, that could lead to the durability and longevity of the product. The whole process implies reducing waste to a minimum and also the diminution of the annual greenhouse gas emissions.

In order to accomplish the move to a circular economy, the European Union has included the principles for waste management and other aspects regarding a five-steps waste hierarchy, such as prevention, re-use, recycling, recovery and disposal, in the Waste Framework Directive, number 2018/851, which modifies the 2008/98/EC Directive on waste.

The targets which are settled by the Waste Framework Directive for municipal waste are the following [10]:

- preparing for an increase a minimum of 55% by weight of recycling and reuse of municipal waste by 2025;

- preparing for an increase a minimum of 60% by weight of recycling and reuse of municipal waste by 2030;

- preparing for an increase a minimum of 65% by weight of recycling and reuse of municipal waste by 2035.

The fundamental measures that need to be put into practice as soon as possible are the waste prevention and re-use of the items, which will have the immediate effect of reducing the total annual greenhouse gas emissions generated by the productions of materials. In order to achieve the waste prevention goal, the authorities could consider, as shown in the article 9 of the Directive, the promotion and support of the sustainable production and consumption models; encouraging the design, manufacturing and use of products that are resource-efficient, durable (including in terms of life span and absence of planned obsolescence), reparable, re-usable and upgradable; targeting products containing critical raw materials to prevent that those materials become waste; encouraging the re-use of products and the setting up of systems promoting repair and re-use activities, including in particular textiles.

Regarding the hazardous waste, as the one mentioned above that was about to enter Romania, the Directive provides not only an additional labelling, but also the record keeping, monitoring and control obligations from the waste production to the final disposal or recovery. On the other hand, it also bans the mixing of hazardous waste with the non-hazardous one.

4. TEXTILE RECYCLING IN ROMANIA

Romania is one of the countries in which the recycling rate is low, of only 13,7% in 2020 [11]. A series of factors have been identified [12] for this low rate, including the insufficient implementation of the separate collective service and the lack of the necessary infrastructure for the recycling process. In Romania, as in other European countries, there is a significant number of textile waste, which results not only from the degradation of some items, but from the idea that some clothes are no longer considered modern or trendy. Consequently, people usually throw and consider these items as household waste, although they could be recycled. Textile recycling is not a very known and spread process in Romania, though it would be an important part of the circular economy business model.

The top 10 European countries in which recycling clothes is very popular are Ireland, Germany, the Netherlands, France, Spain, Poland, Italy, Denmark, Sweden and Czechia. Romania ranks 19th in the European Union [13]. The Waste Framework Directive sets the obligation for all member states, including Romania, to set up separate collection for textiles by 1 January 2025.

5. CONCLUSIONS

Although the textile industry raises some environmental issues, they are not irreparable ones, being in an interdependent relation, which implies that the solutions to fix them are mainly common.

Prolonged use of textiles, reuse or recycling could be the key to solving many of the problems identified, leading to the use of smaller amounts of water and, consequently, a lower level of pollution and leading to lower gas emissions and it might also handle the waste issue. Of course, in order to be put into practice, these solutions must be made aware by the authorities to the society, through legal regulations in this field, which is the purpose of the European Waste Framework Directive, and the Member States must achieve the goals via their own laws.

REFERENCES

[1] European Environment Agency. (updated on 2021, Mar 09). Textiles in Europe´s circular economy. [Online]. Available: https://www.eea.europa.eu/publications/textiles-in-europes-circular-economy/textiles-in-europe-s-circular-economy

[2] European Environment Agency. (updated on 2022, Feb 10). Textiles and the environment: the role of design in Europe´s circular economy. [Online]. Available: https://www.eea.europa.eu/publications/textiles-and-the-environment-the/textiles-and-the-environment-the

[3] European Parliament. (updated on 2021, Mar 03). The impact of textile production and waste on the environment (infographic). [Online]. Available: https://www.europarl.europa.eu/news/en/headlines/society/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographic

[4] Inconvenient truth: fashion is one of the most polluting industries of the world. [Online]. Available: https://www.greenofchange.com/textile-pollution

[5] European Environment Agency. (2022, Feb 10). Microplastics from textiles: towards a circular economy for textiles in Europe. [Online]. Available: https://www.eea.europa.eu/publications/microplastics-from-textiles-towards-a

[6] Four ways brands can reduce climate impact. (2021, Dec 10) [Online]. Available: https://www.commonobjective.co/article/can-fashion-stop-climate-change

[7] European Commission. [Online]. Available: https://ec.europa.eu/environment/chemicals/reach/reach_en.htm

[8] K. Tsai. (2019, Feb 07). More sustainable use of chemicals in the textile industry. [Online]. Available: https://www.transparency-one.com/sustainable-chemicals-textile-industry/

[9] European Parliament. (updated on 2021, Mar 03). Circular economy: definition, importance and benefits. [Online]. Available: https://www.europarl.europa.eu/news/en/headlines/priorities/circular-economy/20151201STO05603/circular-economy-definition-importance-and-benefits

[10] S. Botha. C. Tommencioni Pisapia. (2021, Aug 24) The EU imposes separate textiles waste collection by 2025. [Online]. Available:

https://knowledge-hub.circle-lab.com/circularnorway/article/8909?n=The-EU-imposes-separate-textiles-waste-collection-by-2025

[11] Eurostat. (2022, Mar 29) Recycling rate of municipal waste. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/t2020_rt120/default/table?lang=en

[12] EUR-Lex. European Commission. (2018, Sep 24). The early warning report for Romania. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018SC0423

[13] Romania Journal. (2021, Feb 2). The top 10 EU countries for recycling clothes. [Online]. Available: https://www.romaniajournal.ro/society-people/social/the-top-10-eu-countries-for-recycling-clothes-hows-romania-ranking/

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

COMMUNICATION AND EXPRESSION OF PERSONALITY THROUGH CLOTHING

UROŠEVIĆ Snežana[1], VUKOVIĆ Milovan[2], UROŠEVIĆ Igor[3]

[1, 2]University of Belgrade, Technical Faculty in Bor, Vojske Jugoslavije 12, Bor, Serbia
E-Mail:mvukovic@tfbor.bg.ac.rs

[3]Student of the Faculty of Architecture, University of Belgrade, Bulevar kralja Aleksandra 73/II,
E-Mail: igor.urosevic66@gmail.com

Corresponding author: Urošević Snežana, surosevic@tfbor.bg.ac.rs

Abstract: *In the world of business, behavior and appearance are equally important; namely, a person represents his institution (organization) with both personality and clothing - to dress in a recognizably good style means to prepare oneself for success. Clothes emphasize the personality, they should to reflect the occupation, status, individuality of the wearer. They send certain messages. Every suit and the way someone dresses says a lot about that person. Today, business behavior and business attire are more important, because the behavior and appearance of managers and employees as a whole strongly influence the reputation and business success of each company. Also, one of the functions of clothing is to achieve a sense of spiritual balance. Clothing and fashion enable the multiplication of several personalities in one person. With the help of clothes, certain shortcomings of a person can be compensated and covered, and in that way, a certain spiritual and psychological balance is achieved. The social status of a person can be successfully shown through the dressing. This paper studies clothing as a type of communication and shows how one can communicate with clothing. Communication with clothes is effective when it is in accordance with the accompanying circumstances and the person wearing it. Fashion and clothing act as a way of communicating identity. The paper will also analyze fashion as a cultural phenomenon, but as a form of communication that provides an opportunity for an individual to get closer and identify with a person who dominates in a certain time and space.*

Key words: *Business communication, non-verbal communication, clothing, business clothing, fashion, expression of personality.*

1. INTRODUCTION

Good physical appearance in the business world opens many doors because it is of great importance when creating the first impression of a person [1]. It is known that people tend to create stereotypical notions about other people based on their appearance, clothing, and behavior in public. The appearance of each individual emits a large amount of information about certain aspects of their personality [2].

In the world of business, behavior and appearance are equally important; namely, a person represents his institution (organization) with both personality and clothing - to dress in a recognizably good style means to prepare oneself for success. Clothes emphasize the personality, the clothes should be with a complete appearance, to reflect the occupation, status, individuality. They send certain messages with the clothes that people wear. Every suit and the way someone dresses says a lot about that person [3].

Today, business behavior and business attire are more important, because the behavior and appearance of managers and employees as a whole strongly influence the reputation and business success of each company. Also, one of the functions of clothing is to achieve a sense of spiritual balance [4].

Clothing and fashion enable the multiplication of several personalities in one person [5]. With the help of clothes, certain shortcomings of a person can be compensated and covered, and in that way, a certain spiritual and psychological balance is achieved [6].

The social status of a person can be successfully shown through the clothing. Clothing can show a person's status through many different things, for example, through the colors of clothes, their price, and even though the material from which the clothes are made, that is, through their quality. Clothing, in a way, is a kind of visual signature of a person. The business look also reflects the attitude towards work, which means that it is equally important for the employee and the organization.

This paper studies clothing as a type of communication and shows how one can communicate with clothing. Communication with clothes is effective when it is in accordance with the accompanying circumstances and the person wearing them. Fashion and clothing act as a way of communicating identity [7,8]. The paper will also analyze fashion as a cultural phenomenon, but as a form of communication that provides an opportunity for an individual to get closer and identify with a person who dominates in a certain time and space.

2. FORMS OF BUSINESS COMMUNICATION

Organizational communication is close to understanding a business culture that varies from company to company. General, national and organizational culture have the greatest influence on the creation of business culture. Cvetanović believes that business culture consists of business morale, business behavior and appearance, business communication and public relations [9]. Pavlović, on the other hand, classifies organizational culture, communication, conflict resolution and national culture as elements of business culture [10].

Business communication is considered to be oral or written contact between business partners, which is carried out in order to disrupt business activities. Business communication requires mastering a whole set of skills, and refers to communication between organizations and within the organization [11]. Research shows that the strategic orientation of business is the continuous improvement of business skills and enables the achievement of business results.

If the use/non-use of words is taken as a criterion for the division of forms of communication, ie the use of a symbolic system for creating a message, then business communication is divided into verbal and non-verbal (Figure 1). Verbal communication has two forms - oral and written (printed).

Non-verbal communication is defined as wordless communication and includes visible characteristics such as eyes, facial expressions, touch and tone of voice, clothing, posture, and spatial distance between persons communicating. Nonverbal communication is the process of using behavior without using words [12]. Non-verbal communication takes place in different ways. Body language is manifested mainly through special body movements, ie through gestures, facial expressions and posture. Of great importance is the way people use space, attitude towards time, as well as the style of clothing [3,13, 14].

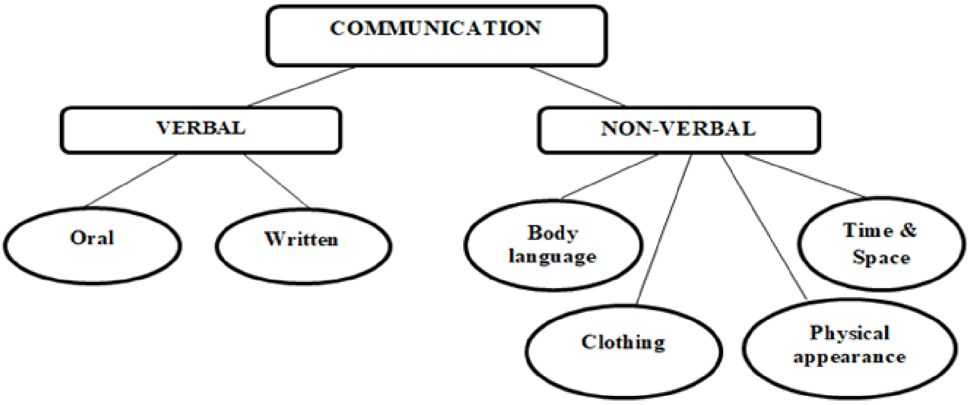


Fig. 1: *Ways of communication [15]*

3. CULTURE OF BUSINESS BEHAVIOR AND CLOTHING

Realizing the importance of employee behavior for success, today many companies around the world are trying to standardize the behavior of their employees. By standardizing business behavior, an organization shows how much it cares about doing a good job. Thus, business behavior is not left to the individual, rather his upbringing and assessment of the situation. Good business manners thus become a recognizable style of organization, which creates a very favorable impression in business contacts.

We express business behavior by the way we behave, how we address people in communication, how we look, how we treat colleagues, customers, users of our services and the rest of the population. By our behavior, we express the personality, but also the organization in which we work. According to us and our behavior, people usually conclude about our organization. Today, business behavior is increasingly considered a condition for business success.

Physical appearance is very important when creating a first impression of a person. It is known that people tend to create stereotypical notions about other people based on their appearance, clothing and behavior in public. The appearance of each individual emits a large amount of information about certain aspects of his personality. However, the way we dress, groom and nurture, the way we sit or stand, the tone and color of our voice, posture, etc., are all essential elements for a good appearance.

Dressing varies from country to country, depending on tradition, customs and climatic conditions. However, there are also standard forms of clothing that are used on certain occasions. Good behavior and clothing starts with the little things and is recognized by the little things. It starts with the look of the clothes and everything that is available to our senses and perception in the first contact. Most often, this first contact predetermines the later relationship between people. The foundation of business and personal culture is orderliness, or cleanliness. Good looks in the business world open many doors. What applies to the body also applies to the suit. The first rule is cleanliness and tidiness, and maintenance is a daily task. Clothing should be appropriate for the age, season and occasion in which it is worn [1]. In the business world, employees of special managers need to stick to a formal style of dress.

Business people need to pay a lot of attention to their appearance. This applies to almost all aspects of nonverbal communication. Non-verbal communication plays a significant role in public speaking. Personal style, ie physical appearance is the first component that can be seen in employees and managers. Research has shown that appearance has a great influence on the general impression.

The criteria that define a good appearance also depend on the culture [16].

4. EXPRESSING PERSONALITY THROUGH CLOTHING

Although at the beginning it seemed that the clothes were used exclusively for practical purposes, to protect the body from the weather, today we can say with certainty that the clothes gained additional meaning. Our clothing is now seen as an instrument of nonverbal communication [17,18,19]. We can also say that today fashion is an instrument of non-verbal communication. We see this language of clothes everywhere, e.g. blue "identifies" boys, or pink, on the other hand, identifies girls. Also, uniforms are identified with certain occupations, so immediately think of a police officer or officer. Through these examples, we can see that clothes speak to us before a single word is said. However, there are more subtle signs that clothing conveys, which may be more difficult to read or interpret immediately. In general, clothing and fashion have the ability to reflect the identity of the wearer.

Clothing will create a certain image of the user. We often use our clothes but also other fashion accessories as a medium for expressing ourselves and conveying the social message through a symbolic instrument. A message conveyed through symbolic instruments may be related to other characteristics. For example, wearing expensive brands is associated with wealth. So, we can see that the function of clothing has changed slightly, because now it can and will be related to attitudes, character, values, social status or status [20].There is no doubt that the dress code is one of the forms of communication, and, therefore, it is a misconception that it endangers individuality - personal identity. The dress code is, in fact, a professional and even civilizational standard.

As in speech, the meaning of any garment depends on the circumstances, because the garment is not spoken "in vain" but in a certain place and at a certain time. Every change in the situation changes its meaning. On the other hand, just as it is easy to recognize people who speak clearly, with dignity and security in everyday life, so it is easy to recognize the way clothes are worn, which is as important as the clothes themselves. With the same care with which the aesthetics of a garment is assessed, the question should be considered in terms of whether a certain suit suits the person wearing it. Starting from aesthetic criteria, it is not only important that the clothes appear in a certain place and at a certain time, but also that a certain person wears them. Apart from age and gender, all the psychophysical characteristics of the person wearing it have a decisive role in judging the choice of clothes.

The appearance of each individual emits a large amount of information about certain aspects of his personality that can be true or false. Occupation, origin, taste, opinion, sexual desires and current mood can be unambiguously expressed through clothing [3]. Clothes emphasize the personality, they should be with a complete appearance, to reflect the occupation, status, individuality. Good taste in clothing means the right choice of clothes, shoes, jewelry and other accessories, but of course it should be tailored for every occasion. Clothing is not just a way of dressing, it is an external characteristic and feature of a person who appears in public [4]. Business attire implies respect for certain unwritten rules, to be elegant and unobtrusive, to emphasize and preserve authority, and not to act rigid or too nonchalant, to be in line with fashion trends, but not fashionable, because it is a bit frivolous [5].

All business people and those who come into contact with customers must act elegantly and authoritatively in the first place. Behavior and appearance are also important at work, because a person represents his company with his personality and clothes [21]. That is why all the details must be designed and carefully selected. The rules related to business attire are color harmony, simplicity, inconspicuousness, moderation unrelated to fashion trends. The business style of dressing will mainly depend on where you work and what the dress policy of that house is. Only respecting the rules guarantees success in business, a good impression on partners and a strong image of the company [13,14].

"Suit does not make a man" is a well-known saying, which we use every time we are disappointed in a man when we, at first glance, thought he was pleasant and honest. Experiments can be seen on social networks in which people treat beggars in a bad way, while decently dressed people are treated with a lot of respect and esteem. If someone wears a clean suit and is nicely dressed, we immediately think that he is honest, and vice versa. From this, people's reaction indicates that the suit affects the first impression we leave on others and others on us. If we are clean and decent, we open the possibility for establishing communication, while other qualities such as communication skills, professionalism and morality come on only later [22].

Considering the connection between personality and clothing, personality and fashion, it can be concluded that clothing is used more to convey social meanings than to express personal emotions and moods [23]. Fashion helps a person a lot in expression, because a person can communicate with other people through various signs, for example, through clothes. The suit primarily indicates social status or class, ethnic, urban, rural and other affiliation. Fashion can also have a compensatory role. When a person wants to be psychologically affirmed, but cannot do so through his activities and values, he does so through fashion.

Today, fashion is also present at work, so we cannot imagine a bank clerk who is not pleasantly dressed, a manager who is not in a suit or a presenter who does not captivate with make-up and beautiful clothes. Fashion accompanies employees not only at work but also in their free time, so that fashion fully participates in creating identity. In the end, it should be said that fashion helps in self-affirmation and self-expression of a person.

5. CONCLUSIONS

Communication is very important in all professions. Communication is established between the employee and the client, the superior and subordinate in the company, the media and the public, etc. Communication that involves a transaction, whether it is material goods, information or knowledge, is called business communication. Nonverbal communication plays a significant role in public speaking. Personal style, ie physical appearance is the first component that can be seen in employees and managers, and therefore business people must pay a lot of attention to their appearance. Appearance refers to clothes, neat dress or neglect. Although it is known that "a suit does not make a man, but a suit in any case makes them look more attractive." Physical appearance is very important when creating a first impression of a person. It is known that people tend to create stereotypical notions about other people based on their appearance, dress and behavior in public. Clothes emphasize the personality, they should be with a complete appearance, to reflect the occupation, status, individuality. Clothing is not just a way of dressing, it is an external characteristic and feature of a person who appears in public. Fashion helps a person a lot in expression, because a person can communicate with other people through various signs, such as clothes.

ACKNOWLEDGEMENTS

The paper was prepared with the financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia, within the funding of scientific research work at the University of Belgrade, Technical Faculty in Bor, according to the contract number 451-03-68 /2022-14 /200131.

REFERENCES

[1] V. Stefanović, B. Vojnović, S. Urošević, *„Menadžment ljudskih resursa-Strategije i kontraverze",* Institut za ekonomiku poljoprivrede, Beograd, 2012.

[2] A. Vuković and M. Vuković, *"Kultura poslovne komunikacije"*, Nauka, Beograd, 2010.

[3] M. Ranisavljev-Kocareva, *„Moda i komunikacija",* Tekstilna industrija, 2009, Vol. 57, No 4-6, pp. 27-29.

[4] J. Efremov, M. Kertakova, V. Dimitrijeva-Kuzmanovska, "*Expression of personality through dressing",* Tekstilna industrija, 2001, Vol. 69, No 1, pp. 28-35.

[5] K.J. Pine, "Mind What You Wear: The Psychology of Fashion", Kindle, 2014.

[6] D. Crane, *"Fashion and it's social agenda's: class, gender and identity in clothing",* University of Chicago Press, 2001.

[7] B. Malcolm, *„Fashion as communication",* NY- London: Routledge, 2007.

[8] E. Castaldo Lundén, *„Exploring Fashion as Communication: The Search for a new fashion history against the grain",* "Popular Communication", 2020. Vol. 18, No 4, 249-258.

[9] V. Cvetanović, *„Kultura poslovnog komuniciranja".* Beograd: Obeležja, 1999.

[10] N. Pavlović, *"Poslovna kultura i etika".* Vrnjačka Banja, Fakultet za hotelijerstvo i turizam, 2016.

[11] A. Vuković, M. Vuković, S. Urošević, I. Mladenović-Ranisavljević, *"Upravljanje komunikacijama u kriznim situacijama u preduzećima odevne i tekstilne industrije".* Tekstilna industrija, 2021. 69(3), 10-17.

[12] Y.R. Lamichhane,*"Non-verbal skills: Unavoidable in communication",* Repositioning The Journal of Business and Hospitality, 2016, 1, 91-98.

[13] M.Vuković, S. Urošević, A.Vuković, *"Neverbalna komunikacija i stvaranje ličnog i profesionalnog identiteta preko odevanja".* Tekstilna industrija, 2021, Vol. 59, No 2, 27-32.

[14] S. Urošević, B. Pejčić, *"Uticaj poslovnog ponašanja i odevanja na uspeh u poslu".* Tekstilna industrija, 2014, 62(1), 39-46.

[15] S. Možina, M. Tavčar, A. Kneževič, *"Poslovno komuniciranje".* Maribor: Obzorja, 1998.

[16] S. Borovac Zekan, K. Gabrić, *"Neverbalna komunikacija kao alat uvjeravanja u javnom nastupu".* Zbornik radova Veleučilišta u Šibeniku, 2021, 15(3-4), 143-158.

[17] M. R. Gozalova, M. G. Gazilov, O.V. Kobeleva, M. I. Seredina, E. S. Loseva,*"Non-verbal communication in the modern world".* Mediterranean Journal of Social Sciences, 2016, 7(4), 553-553.

[18] R. C. Dinică, 2014, *"Non-verbal communication-indispensable complement of oral and written communication".* Procedia-Social and behavioral sciences, 137, 105-111.

[19] T. Todorovič, T. Toporišič, A.P. Čuden, "Clothes and Costumes as Form of Nonverbal Communication", Tekstilec, 2014, Vol. 57, No 4.

[20] A. Goedhart, *"Non-verbal communication skills of clothing".* Erasmus University Rotterdam, 2020.

[21] A. Lukač-Zoranić,*"Kultura i jezik u poslovnoj komunikaciji",* Ekonomski izazovi, 2013, Vol. 2, No 3, 161-169.

[22] I. Lj. Stojanović Prelević, *"Poslovna komunikacija i etika",* Filozofski fakultet u Nišu, 2018.

[23] Dž. Fisk, "*Popularna kultura", Beograd,* Clio, 2001.

CONTENTS

	TEXTILES FUNCTIONALIZATION	**LITE Mihaela-Cristina[1,2], SANDULACHE Irina-Mariana[1], SECAREANU Lucia-Oana[1,3] IORDACHE Ovidiu[1], CONSTANTINESCU Roxana[1]**	Development Institute for Textiles and Leather – INCDTP, 030508, Bucharest, Romania [2] University Politehnica of Bucharest, Faculty of Applied Chemistry and Materials Science, 1-7 Gheorghe Polizu, 011061, Bucharest, Romania [3] Gheorghe Asachi" Technical University of Iasi-Romania, Faculty of Industrial Design and Business Management, 59A Prof. D. Mangeron Blvd., 700050, Iasi, Romania	
11	**TEXTILE STRUCTURES WITH ANTI-INFLAMMATORY PROPERTIES FOR THE TREATMENT OF BURN INJURIES**	**Emilia Visileanu[1], Alexandra Ene[2], Razvan Scarlat[3], Alina Vladu[4], Stelian Sergiu Maier[5]**	[1,2,3,4]The National Research and Developement Institute for Textile and Leather, 16, Lucretiu Patrascanu street, sector 3, Bucharest, Romania [5]Sanimed International Impex SRL ,2A,	**81**

			Textile-Leather and Industrial Management, B. Ştefănescu Delavrancea street, no. 4410058, Oradea, Bihor, Romania	
16	**COMMUNICATION AND EXPRESSION OF PERSONALITY THROUGH CLOTHING**	**UROŠEVIĆ Snežana[1], VUKOVIĆ Milovan[2], UROŠEVIĆ Igor[3]**	[1, 2]University of Belgrade, Technical Faculty in Bor, Vojske Jugoslavije 12, Bor, Serbia [3]Student of the Faculty of Architecture, University of Belgrade, Bulevar kralja Aleksandra 73/II	**115**

***The editors take no responsibility of the results, opinions and conclusion expressed in the published papers*.**