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Sumar

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Evaluation and calculation model for heat transfer equilibrium through clothing articles

IONUT DULGHERIU
IRINA IONESCU
DORIN IONESI
ALINA DRAGOMIR

REZUMAT – ABSTRACT

Model de evaluare şi de calcul al echilibrului schimbului termic prin îmbrăcăminte

Izolarea termică a organismului, prin intermediul îmbrăcămintei, are drept scop obţinerea unor regimuri de temperatură care să permită dezvoltarea diverselor procese ale acestuia, în limitele confortului. Prin intermediul îmbrăcămintei se creează un echilibru termic între cantitatea de căldură produsă în organism şi cea cedată spre exterior. Deplasarea căldurii în interiorul acesteia are loc, ca în orice mediu, numai la diferenţe de temperatură corespunzătoare diferitelor stări ale corpului şi diferitelor condiţii meteorologice. În lucrare, sunt prezentate, pe lângă câteva date generale privind producerea energiei în organism şi aspecte referitoare la conexiunea dintre fluxul de căldură şi unele tipuri de structuri vestimentare pentru femei. Având în vedere aceste afirmaţii, în cele ce urmează, autorii prezintă o metodologie de apreciere a indicatorilor care influenţează starea de confort şi dacă se ţine seamă de faptul că organismul uman este o sursă permanentă de energie, explicaţiile vor fi făcute prin prisma principiilor din termodinamică, specifice transferului de căldură şi masă.

Cuvinte cheie: *izolare termică, indicatori de confort, transfer de caldură*

Evaluation and calculation model for heat transfer equilibrium through clothing articles

The thermal isolation of the body through clothing articles aims to obtain thermal regions that allow the development of various processes thereof, within the limits of comfort. Using the clothing articles a terminal equilibrium between the produced and yielded quantity of heat is created. The heat transfer occurs only if the body temperature and the outside temperature are different. In the paper are presented, in addition to some general information regarding the production of energy into the body, aspects of the connection between heat flow and some types of women clothing structures. This paper aims to present a method for assessing the indicators that influence the state of comfort, and taking into account that the human body is a constant source of energy, explanations shall be made through the principles of thermodynamics that are applied for heat and mass transfer.

Key words: *thermal insulation, comfort indicators, heat transfer*

GENERAL ASPECTS

The clothing articles created and tested were designed closely related with the average temperature that corresponds to laboratory conditions and requirements. This is an essential factor because both humidity and speed of air movement could generate weaken or strengthen action of the clothing articles.

The existences of some differences between the temperatures that correspond to different states of the body represent the condition for heat passing through clothing structures. By changing the structure of the clothing system the value of temperature difference is modified. The heat exchange generated by the body, as a process of release from heated particles inside the body to less heated particles from exterior environment, is based on general laws of heat transfer that are known in thermodynamics and physics [1].

The basal metabolism shall be expressed more accurately by the amount of heat lost per area unit and time and varies according to sex and age. If the developed area of the body is considered equal to 1.8 m^2 the unit heat flux q is equal to 43 kcal/m^{2}h. Taking into account that only 0.56 of unitary heat flux q crosses the clothing system for an average skin temperature of 33 °C and an exterior temperature of 21 °C the global heat transfer coefficient required is 2 kcal/m^{2}h °C [2].

It is important to note that the ratio of intake, consumption and loss of energy, called energy balance can be assessed by direct and indirect calorimetry. These two ways of assessing the energy balance provides indications of the intensity of energy exchanges between the organism and the environment.

The most eloquent example for direct calorimetry is the one that outlining the body heat, knowing its weight, specific heat and temperature difference. The indirect calorimetry is addressed to the caloric content of ingested food or to the necessary oxygen amount required for their oxidation. In this case it is necessary to know the consumption of food principles over a period of 24 hours [3].

In the conditions of the fundamental law of dynamics, the total amount of heat produced in the body is the sum of the quantity of heat Q lost in dry clothes; the amount of heat that is lost through evaporation of the epidermis and the amount of heat converted into mechanical work L, and can be written as:

$$U = Q + E + L \ \text{[kcal/h]} \quad (1)$$

To obtain a uniform heat flux, it is necessary to divide this value by the average area of the body held F, and results:

$$q' = \frac{Q + L + E}{F} = U/F = q + l + e \ \text{[kcal/m}^2 \cdot \text{h]} \quad (2)$$

In this case q is the heat flux crossing the clothing unit, and is converted into mechanical energy. The parameter "e" is the energy lost through evaporation of sweat.

It approximates, $l = 0.2\,q'\,e = 0.24\,q'$ and then the balance of heat exchange:

$$0{,}56\,q' = q = K\,(t_1 - t_e) \ \text{[kcal/m}^2 \cdot \text{h]} \quad (3)$$

This fundamental relation highlights the fact that at a certain amount of heat flow, the structure of clothing must be designed in order to ensure a certain amount of total heat transfer coefficient K, taking into account the temperature gradient created by the temperature difference between the surface, the body and the environment [4]. The structure of the clothing system must be chosen that not only can take heat from the surface of the body, but also the amount of moisture released by the skin in a variety of different tasks, which may have values from 1 to 50 grams, reported to the surface of one square meter, within one hour.

Given these statements, in what follows, the authors present a method for assessing the indicators that influence the state of comfort, and taking into account that the human body is a constant source of energy, explanations shall be made through the principles of thermodynamics that are applied for heat and mass transfer [5].

Therefore, the clothing system has not only a quasi-physiologic character but also the task of protecting the body from the negative influences of the environment and weather, as well as to correct the outward appearance of human, constantly subjected to changing conceptions of ethics and fashion of the time. It is noted the multifunctional character of clothing systems, which is an ensemble whose parts are structurally and functionally related.

These factors influence each other mutually and continuously into an almost total interdependence. In the relation body – clothes – environment, human material needs are satisfied, correlated with the anthropometric, physiological and hygienic needs. Thereby, typical for the characterisation of functional properties turns to be the complex of various characteristics, such as the isolation degree of human related to physical environment and the character of the exterior conformation. In addition to these requirements it is necessary to satisfy the material needs, which generally include the value of presentation, functionality and durability. In the whole clothing system the isolation is mainly given by the air layer that is found between the fibres or between the layers of the textile products. A comparison between the thermal conductivity of different materials for clothing products shows that almost no difference appears, so it is not possible to draw up conclusions for practice, especially if the structural parameters are similar.

The layer of air that surrounds the human body is the decisive parameter that influences the comfort and the orientation of heat flows. The area found between the skin and the clothing system is called microclimate. This area is actually the main region of mutual takeover of loads with continuous action for the transport of heat, carbon dioxide and other body emissions. There may be present stagnant air masses, but may occur eddy currents. As the product is composed by layers of material and air, there is a levelling out of the indoor climate, avoiding the greenhouse climate. Measurements by temperature and humidity in the microclimate as well as between the different layers of the product showed that the layer has a decisive influence on the structure and permeability by the gradual change in temperature and humidity [6, 7]. By this a full range of product climate, which sets microclimate and human comfort is realized. The current scientific knowledge base is available to any fabric and is essentially independent from the practical standpoint of fibres.

It can be noticed an essential additional feature in synthetic materials. These materials are capable, based on their hydrophilic character to transport the moisture of the surface, especially in liquid phase. This property is particularly accentuated if the synthetic materials are found in knitted products.

When a clothing article is designed, taking into account the qualities of fibres, the intended use must be considered and the optimal structure and parameters must be respected. Consequently remarkable research is undertaken to obtain textile articles that are enjoyable, healthy skin tolerated, easy to maintain and in accordance with age of the wearer clothing articles. One of the main aspects of this complex problem is to establish on the scientific basis of the optimum characteristics that must be fulfilled by the clothing articles in order to suit to the desired purpose. As results from those presented below, the experiment was extended for women clothing structures, consisting in jacket with three options for the base material and blouse with two different fibre contents. It is highlighted the heat flow value accepted by the clothing structure which can be compared with specific energy levels of the human body.

EVALUATION AND CALCULATION MODEL

Ensuring normal body temperature is achieved by thermo genetic heat-producing processes and thermolytic heat loss process. Those two types of processes are in a permanent dynamic balance, provided by the action of biological factors of control of the production and loss of heat. The quantity of heat produced by the body in a certain period of time is equal to the quantity of heat lost by various ways in the same time period. A large part of this amount of heat is lost through clothing.

Table 1

BASAL METABOLIC VALUES BY SEX AND AGE GROUP			
No. crt.	**Age (years)**	**Basal metabolism (kcal/m^2·h)**	
		Men	**Women**
1	14 – 16	46.0	43.0
2	16 – 18	43.0	40.0
3	18 – 20	41.0	38.0
4	20 – 30	39.5	37.0
5	30 – 40	39.5	36.5
6	40 – 50	38.5	36.0
7	50 – 60	37.5	35.0
8	60 – 70	36.5	34.0
9	70 - 80	35.5	34.0

The heat source in this case is the human body and clothing system represents the protective liner which facilitates the transfer of heat to the environment. The amount of heat produced in the body shall be assessed generally bowing from the fixing of metabolism in various forms: basal, energetic and total.

Taking into account that it is a complex form of heat transfer, the expression of basal metabolism is the amount of heat lost per unit area in time unit and differs according to sex and age, as shown in table 1.

The thermal calculations of clothing systems are based on the consideration that basal energy expenditure of a subject is averaging 40 [kcal/m^{2}h or W/m^2, 1163].

The calculus of the total heat transfer coefficient starts from the uniform heat flux q relationship:

$$q = U/F \;\; [\text{kcal/m}^2\text{h}] \;\; \text{or} \;\; [\text{W/m}^2] \qquad (4)$$

where U represents the heat generated in the body, equal with the amount of heat transferred at the same time.

This quantity of heat corresponds to the total metabolism (basal + energetic). Table 2 presents some values that can be taken in specific calculations of heat exchange balance. This value can be calculated using the relation:

$$U = 60\, K_c \;\; [\text{kcal/h}] \text{ or } [\text{W}] \qquad (5)$$

where:

K_c represents the energetic consumption expressed in (kcal/min) or (W/min);

F – the developed area of the body that is calculated by the relation of DuBois;

$$F = 0{,}007184\, G^{0{,}425}\, l_c^{0{,}725} \;\; [\text{m}^2] \qquad (6)$$

where:

G represents the body mass [kg];

l_c – body height [cm].

The heat lost through clothing systems as superficial heat flux q is calculated with:

$$q' = q - I - e \;\; [\text{kcal/m}^2\text{h}] \qquad (7)$$

Table 2

VALUES OF TOTAL METABOLISM		
No. crt.	**Status condition of the subject**	**Yielded heat U (kcal/h)**
1	During sleep	40
2	Seated	50
3	Easy Work	75
4	Light work	100
5	Average labor	150
6	Go at a walk	180
7	Hard work	300
8	Maximum effort	660

where:

I represents the amount of heat converted into mechanical work which is calculated by the relation:

$$I = 0{,}20\, q \qquad (8)$$

e – the amount of heat lost by evaporation which is calculated by the relation:

$$e = 0{,}24\, q \qquad (9)$$

So:

$$q' = q - 0{,}20\, q - 0{,}24\, q = 0{,}56\, q \qquad (10)$$

By knowing the uniform heat flux that crosses the clothing systems, total coefficient K of thermal transfer that is imposed to the clothing system can be determined.

$$K = \frac{q'}{t_p - t_e} \;\; [\text{kcal/m}^2\,\text{h}\,°\text{C}] \qquad (11)$$

where t_p represents the temperature of the skin, which in terms of ensuring the comfort condition is considered to be equal to the value of 33 °C ; t_e – the ambient temperature (°C).

It can be determined the amount of heat index I and the thermal efficiency index value N, based on the following relations (optimally correspond to I = 1 and N = 1):

$$I = 0.15\, \frac{t_p - t_c}{N} - \frac{5.7}{\alpha} \qquad (12)$$

$$N = 0.78\, U/100 \qquad (13)$$

where α represents the coefficient of thermal conductivity transfer or individual thermal transfer coefficient that can be calculated with the relation:

$$\alpha = \alpha_c - \alpha_r \qquad (14)$$

Convection coefficient:

$$\alpha_c = 11{,}2\, \sqrt{v} \qquad (15)$$

where v represents the speed of air movement which is adopted depending on the season: v_v = 1 m/s (summer); v_{pt} = 2–3 m/s (spring – autumn); v_i = 5 m/s (winter).

The radiation coefficient:

$$\alpha_r = 0.215\,(T_e/100)^3 \;\; [\text{kcal/m}^2\,\text{h}\,°\text{C}] \qquad (16)$$

where $T_e = 273.2 + t_e$ [K].

For outdoor temperature t_e conventional three values are adopted for each destination. To calculate the imposed thermal resistance of the clothing structure, the following relation must be applied:

$$R = 0.175\ I \ \ [\text{kcal/m}^2\,\text{h}\,°\text{C}] \qquad (17)$$

Based on this relation the physical characteristics of the clothing system are adopted taking into account the thermal resistance of the clothing system R_{SV}:

$$R_{SV} = \frac{\delta}{\lambda} + \frac{1}{\alpha} \qquad (18)$$

where: $\frac{1}{\alpha}$ represents the surface thermal resistance with a small share that can be neglected.

Therefore $R_{SV} = \delta / \lambda$, from where can be established also the overall value of the conductivity coefficient $\lambda = \delta_{tot} / R$.

Maintaining a constant body temperature in all climatic conditions and human activity is the primary function of clothing, according to the climate differences, activity and body and is achieved by varying the proportions between the physical properties of clothing in order to create conditions as constant as possible.

If laboratory measurements of the degree of ventilation (air permeability, the inner circulation of air between the body, clothing and environment), absorption capacity, retention and disposal of moisture (hygroscopic, hydrophilic), research methods, measurement units, recording instruments are generally known for objective determination of thermal insulation performance it was necessary to create a unit that must underpin the clothing standardization.

This measurement unit expresses the capacity of the clothing article or of the entire clothing system formed form from several layers of clothing articles (lingerie, coat and suit) of retaining the heat produced by the human body. The measurement unit has been named "CLO" and corresponds to a clothing structure that at a temperature of 21°C and at a relative humidity smaller or equal with 50% produces a maximum feel of comfort to a health adult person.

The feeling of maximum comfort corresponds to a state of inactivity, when the average surface body temperature is 33°C and both heat and thermal efficiency index have values equal to the unity value. Also the wind speed must be close to zero (v = 0.1 to 0.15 m/s), which implies reference values for surface heat exchange or conductivity coefficient, with the value of reference 7.15 kcal/m^2 h °C.

In these conditions the "CLO" unit corresponds to a value of 0.18 m^2 h °C/kcal, has as correspondent the "thermal ohm" (T-Ω) which is expressed by °Cm^2/W and represents the thermal resistance that requests an energy of 1W/m^2.

$$1\ \text{“T-}\Omega\text{”} \ldots\ 1\ \text{m}^2\ °\text{C/W} = 1.163\ [\text{m}^2\text{h}°\text{C/kcal}] \qquad (19)$$

$$1\ \text{“CLO”} = 0.18\ \text{m}^2\text{h}°\text{C/kcal} \qquad (20)$$

$$1\ \text{“T-}\Omega\text{”} = \text{”CLO”} = 6.45\ \text{“CLO”} \qquad (21)$$

Another unit of thermal insulation is "Tog" which is equal to 0.645 "CLO" and is approximately the isolation value provided by light summer clothing articles. Taking into account the above statements, the "CLO" or thermal resistance reference R_0 is determined as follows:

First it is estimated that the thermal comfort sensation is ensured in terms of metabolism:

$$U/F_m = 50 \ \ [\text{kcal/m}^2\text{h}] \qquad (22)$$

where:

U is the quantity of heat from the body (kcal/h);

F_m – the average size of the body developed equal to 1.8 m^2.

If the coefficient of thermal conductivity is in such conditions α_0 = 7.15 kcal/m^2 h °C, then the surface thermal resistance of reference is:

$$R_{po} = 1/\alpha_0 = 0.14\ [\text{m}^2\text{h}\,°\text{C/kcal}] \qquad (23)$$

The amount of heat flow q_0 that passes through the body surface in inactivity state, represents about 75% of the U/F_m, namely 38 kcal/m^{2}h. The remaining 25% or 12 kcal/m^{2}h corresponds to a loss of heat and mass.

Based on the relationships of heat flow definition:

$$q_0 = \frac{\Delta t_0}{R_0 + R_{p0}} \ \ [\text{kcal/m}^2\text{h}] \qquad (24)$$

$$\Delta t_0 = 33 - 21 = 12\ [°\text{C}] \qquad (25)$$

$$R_{p0}\,\frac{1}{\alpha_0} = 0.14 \ \ [\text{m}^2\text{h}\,°\text{C/kcal}] \qquad (26)$$

$$R_0 = \Delta t_0 / q_0 - R_{p0} = 0.175\ \text{m}^2\text{h}\,°\text{C/kcal} \approx$$
$$\approx 0.18\ [\text{m}^2\text{h}\,°\text{C/kcal}] \qquad (27)$$

If it is considered the thermal resistance R of a clothing system and is compared with the thermal resistance R_0 of a normalized variant the insulation capacitive index should be calculated $I = R/R_0$, that clearly expresses the conditional insulation of the clothing systems. If for the subject clothed in a light summer clothing system this index value is 1, for the warm winter clothing ensemble the value is exceeding 4. Also it is considered that the thermal efficiency index is the ratio of heat flux q and heat flow data q_0, namely $N = q/q_0$.

As the value of N is larger, the human subject is further from normal conditions and the body feels more the sensation of cold, so the fighting against the atmospheric conditions is more intense.

As can be seen this measurement unit could be determined on a scientific criteria. It is a reference unit and based on it, it is estimated that in standard atmospheric conditions, for temperature and air speed, the same body requires a clothing system of:

- 0.5 "CLO" – for hard physical work;
- 2 "CLO" – for light physical work;
- 6 "CLO" – for rest.

Depending of the body heat released, of the temperature or wind speed changes in the environment, it appears the need to change the number of “CLO” of the clothing system. It is very important; therefore, that in addition to the information necessary for sizing the products provided by anthropometric standards (SA) and branch technical standards (STR) to be transmitted the information related to the way of proper microclimate is created.

This implies the knowledge of the whole evolution of the product, from the choice of the structure, and the characteristics of the base, secondary and auxiliary materials, production technology and the comfort parameter limits.

Researches concerning the comfort of women clothing products, as well as other groups of carriers, have a certain theoretical and practical interest, aiming at studying and solving problems related to the transfer of heat and moisture through different clothing ensembles. The experiments were performed under laboratory conditions and under variable conditions of intensity of the activity of the specific parameters of the body and of the environment.

The present research is based on the comfort requirements, conditioned by the thermo genesis and thermolysis phenomenon and on the of self-regulation mechanisms of the body. It is aimed to achieve the agreement between the structural and functional requirements and characteristics of the whole adopted clothing system. Such a study is, at the same time, an instrument for the rational use of textile materials, offering also to the designers and technologists an overview of the scientific criteria for clothing standardization.

As shown in the tests performed on women clothing systems and from conducted calculations the determined heat flux values and very similar to the normal limits both in rest and in activity condition. To balance the heat flux a uniform heat flux of 70–100 kcal/m^{2}h is required.

Taking into account that 56% of this value passes through the body maximum heat releasing area, that is covered with clothing articles, then the values included in the charts for the three types of clothing structures made in two variants, correspond to both rational selection of materials assortments and clothing systems.

In relation to the standard clothing structure a standard value of the heat flux and the maximum and minimum values have been established. The standard product and the standard clothing system were determined in principle as:

- Product and clothing systems based on wool or wool type materials:
  - high thermal resistance;
  - high resistance to vapour passage;
  - high resistance to air flow.
- Product and clothing systems based on cotton or cotton type materials:
  - low thermal resistance;
  - low resistance to the passage of vapours;
  - low resistance to airflow.

These values correspond to a certain group of materials, and may be easily influenced by the particularities of the control sample. It must be specified that for the women jacket, although the research has been conducted on a large number of materials, the products that are made from 100% wool (250 and 163 articles) and from 100% cotton (“Cenei” article) and from 100% linen (“Alin” article) have been considered as control samples.

For laboratory and wear conditions, this fact is illustrated in table 3 and an overall numeric analysis can be done by analyzing figures 1, 2 and 3. From these figures we can observe very narrow limits of heat flux *q* expressed in kcal/m^{2}h, with values between 29 and 40 for laboratory conditions and 53 and 85 for conditions imposed on garment made of wool or wool type, values between 45 and 56 for laboratory conditions and 72 and 111 for cotton or cotton type materials and 51 and 55 for the laboratory conditions and 90–105 for linen and linen type materials. Also it could be noted a slight increase of the heat flow value for clothing articles made from 100% cotton (“Fledru” article). The framing into the standard limits from Table 1 is justified by energy consumption and metabolism studies.

A detailed analysis is provided by the graphs for all the studied clothing systems related to both I and II variants. The balance of heat exchange can be seen in the tests carried out with clothing worn structures, or similar, made with the same basic materials groups. The relationship between the physiological characteristics of the body and comfort properties is determined when the thermoregulation has an insignificant value.

The veracity of calculus related to the thermal insulation of proposed clothing systems corresponds to the situation in which they are carried out based on the knowledge of total metabolism (basal metabolism plus energy metabolism) and taking into account taking into account the thermal influence exerted on it by the external environment under the condition that feeling of comfort, which is accepted at an average skin temperature of 33°C, to be ensured.

CONCLUSIONS

The analysis of graphics representation of the thermal low reveals that all the clothing systems present similar behaviour in both laboratory and given conditions. These studies confirm that if the global thermal transfer value is calculated depending on the clothing system characteristics or of body state condition they must correspond to the metabolism conditions without thermoregulation request.

This statement is confirmed by the biological point of view because under normal circumstances, all of the energy produced in the organism into a period of 24 hours should also be eliminated, as a result of a continuous process for maintenance of vital functions into the body. The limits for the heat flow values, obtained as a result of extensive research undertaken,

Table 3

HEAT FLOW LIMIT VALUES				
Clothing structure	Variant	Limitations	Heat flux imposed on the body q, kcal/m^2·h	
			Laboratory	Given conditions
Wool type	I – weaving made from cotton and PES (a,b)	Minimum Standard Maximum	28.93 37.843 40	52.46 77.18 84.121
	II – weaving made from cotton 100% (c,d)	Minimum Standard Maximum	30.8244 41.0532 43.5888	57.245 87.664 96.677
Cotton type	I – weaving made from cotton and PES (a,b)	Minimum Standard Maximum	44.2488 48.6024 56.784	71.178 83.16 110.388
	II – weaving made from cotton 100% (c,d)	Minimum Standard Maximum	48.7596 54.0996 64.446	83.6232 100.662 143.532
Linen type	I – weaving made from PES (a,b)	Minimum Standard Maximum	50.65 50.95 55.147	89.352 90.293 104.34
	II – weaving made from cotton 100%(c,d)	Minimum Standard Maximum	53.041 53.041 62.532	97.213 97.213 134.37

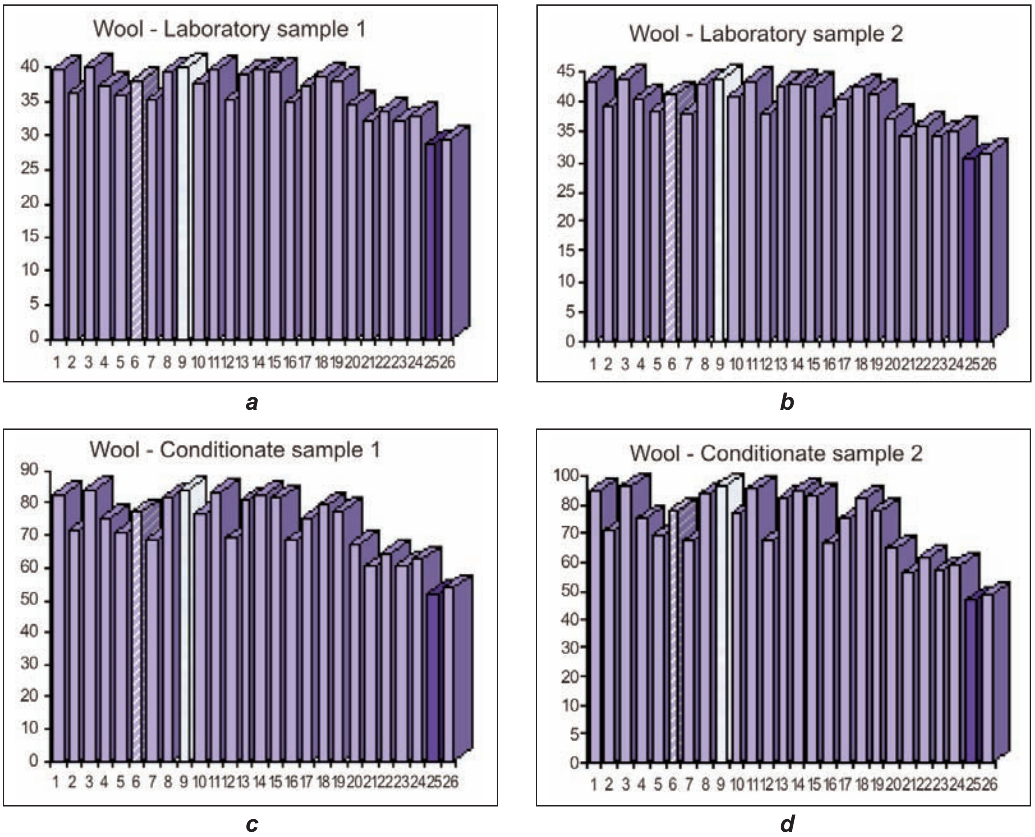

Fig. 1. Heat flow impose for wool and wool type materials

are confirmed by the values presented in table 1 and by the graphs illustrated in figures 1, 2 and 3.

These graphics show the specific values for the state condition, therefore the conditions for heat exchange equilibrium are fulfilled.

The clothing system is an intermediate with an important role in ensuring the equilibrium. Due to the fact that the body temperature is different from that of the environment there will not be a thermodynamic equilibrium between the body and the environment.

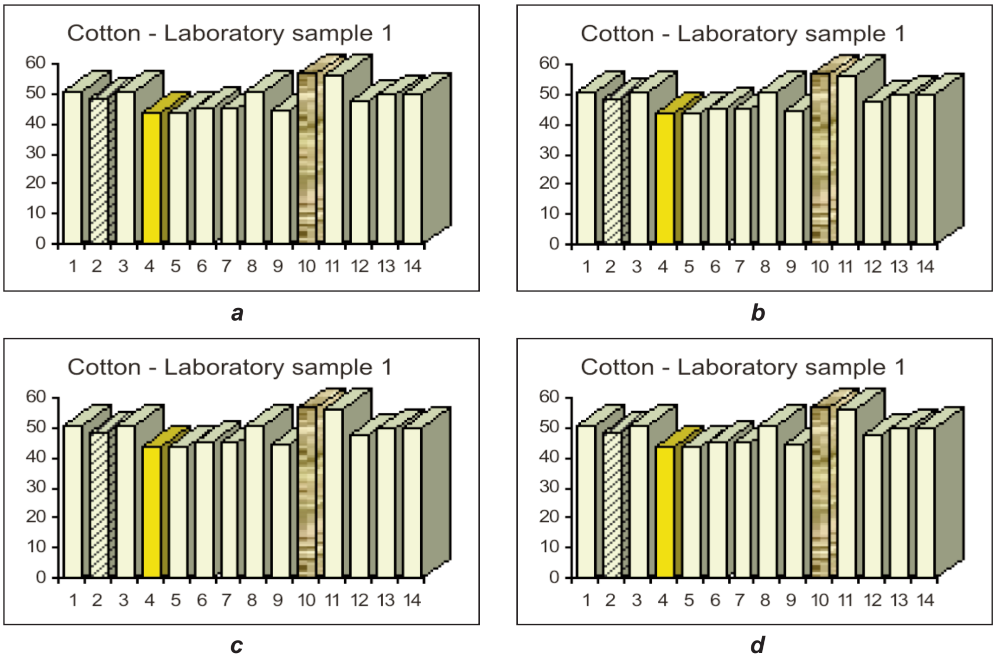

Fig. 2. Heat flow impose for cotton and cotton type materials

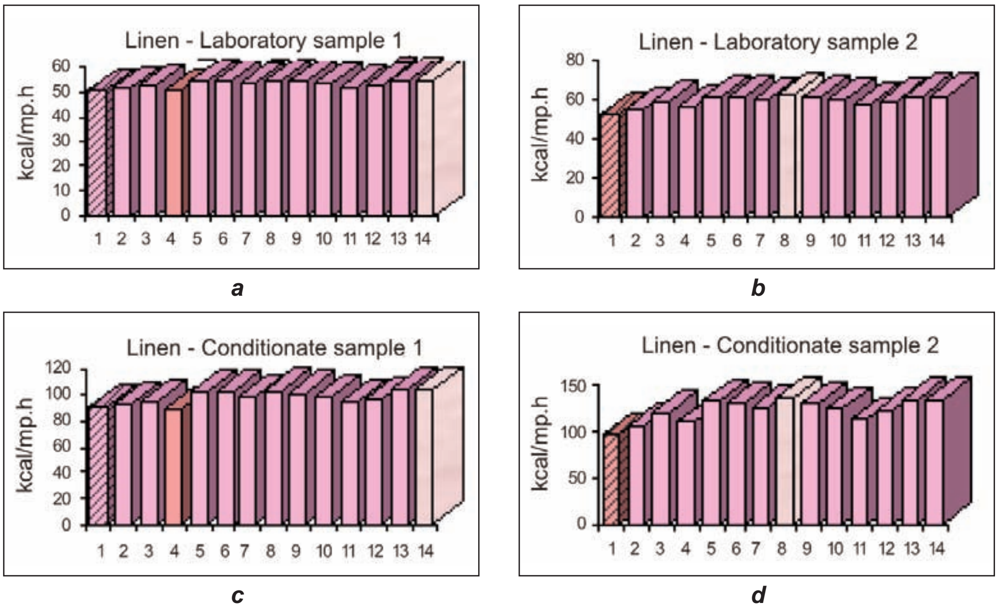

Fig. 3. Heat flow impose for linen and linen type materials

It should be noted that a human subject in thermal neutrality point (28–30°C, undressed) presents between the core and skin temperature a difference of 4 Celsius degrees. If the ambient temperature is rising, the skin temperature is also rising.

The knowledge of the temperature variation on the body surface t_i allows adequate thermal calculations, taking into account that the unit value of the heat flux q_i is different.

- t_c = 17°C – for wool or wool type materials;
- t_c = 21°C – for cotton, cotton type, linen and linen type materials.

The research has been extended to the clothing articles for adults, with recourse to the structuring of the clothing systems designed in report with the production technology and the materials particularities. As shown in the tests conducted on adult clothing structures and the associated calculations for heat flow, the values are included in the boundaries, very close to normal in both resting conditions and in practice behaviour.

It can be noted that the clothing systems that include blouses made from cotton and polyester require lower values for the heat flow. This aspect is justified by the lower values of the thermal conductivity of these materials.

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Authors:

Dr. eng. Dulgheriu Ionut
Dr. eng. Ionesi Dorin
Dr. eng. Irina Ionescu
Dr. eng. Alina Dragomir
„Ghe. Asachi” Technical University
Faculty for Textiles-Leather, 28,
D. Mangeron Bd, 700050 Iasi – Romania

Corresponding author:

Dr. eng. Dulgheriu Ionut
e-mail: idulgheriu@tex.tuiasi.ro

Digital printing of blue-printed textile exhibits replicas

LARA PLAJH
ALENKA PAVKO ČUDEN
PETRA FORTE TAVČER
BRIGITA TOMŠIČ
KLARA KOSTANJŠEK
BRANKO NERAL
SIMONA JEVŠNIK

REZUMAT – ABSTRACT

Imprimarea digitală a reproducerilor de exponate textile

Numeroase surse furnizează dovezi ale textilelor decorative prin păstrarea și vopsirea acestora, una dintre tehnici fiind reproducerea. Din păcate, părți ale materialelor textile sunt supuse influențelor externe; prin urmare, doar câteva exponate textile s-au păstrat. Pentru a înțelege și a conserva patrimoniul cultural, este foarte important să se examineze eșantioane reprezentative ale exponatelor textile existente prin utilizarea metodelor nedistructive. Acest studiu prezintă rezultatele măsurării proprietăților fizico-textile ale reproducerilor textile. Am analizat compoziția materialului, tipurile de țesere, desimea țesăturii, sensul torsiunii, grosimea țesăturii, diametrul fiului și masa per unitatea de suprafață. În plus, au fost efectuate analize legate de caracteristicile de culoare ale exponatelor textile reproduse. Rezultatele ambelor analize au servit la crearea unor reproduceri calitative ale exponatelor textile produse prin tehnica de imprimare digitală modernă cu coloranți reactivi. Pe baza rezultatelor obținute utilizând măsurători fizico-textile, cele mai adecvate materiale textile moderne au fost selectate, iar pe baza rezultatelor obținute din caracteristicile de culoare, au fost alese cele mai potrivite culori pentru imprimarea digitală. Materialele imprimate rezultate au fost reevaluate, iar reproducerile s-au dovedit a fi suficient de similare cu originalul. Reproducerile textilelor imprimate sunt destinate activității muzeelor în scop expozițional, pentru producerea unor piese lipsă sau a textilelor întregi, în scop folcloric, precum și pentru comercializarea de suveniruri de înaltă calitate, și pentru producția de îmbrăcăminte destinată vânzării și a textilelor de casă cu elemente ale patrimoniului cultural.

Cuvinte-cheie: reproducere, patrimoniu cultural, caracteristici fizico-textile, caracteristici de culoare, reproduceri

Digital printing of blue-printed textile exhibits replicas

Numerous sources provide evidence of decorating textiles by reserving and dyeing, one of the techniques being blue-printing. Unfortunately, textile material´s fragment are subject to external influences; therefore, only a few textile exhibits have been preserved. In order to understand and preserve cultural heritage, it is very important to examine the representative samples of existing textile exhibits by using non-destructive methods. This study presents the results of measuring textile-physical properties of blue-printed textiles. We analysed material composition, weaving types, fabric density, twist direction, fabric thickness, yarn diameter and mass per unit area. Furthermore, analyses were conducted of colour characteristics regarding blue-printed textile exhibits. The results of both analyses served for the creation of qualitative replicas of blue-printed textile exhibits produced with the technique of modern digital printing with reactive dyes. Based on the results obtained using textile-physical measurements, the most suitable modern textile materials were selected and based on the results obtained from colour characteristics, the most suitable colours for digital printing were chosen. The resulting prints were re-evaluated, whereby the replicas were proved to sufficiently correspond to the original. The replicas of blue printed textiles are intended for museums for their exhibition needs, the making of missing pieces or entire textiles, for folklore purposes, as well as for the marketing of high-quality souvenirs, and the production of marketable clothes and home textiles with the elements of cultural heritage.

Keywords: blue-printing, cultural heritage, textile-physical characteristics, colour characteristics, replicas

Cultural heritage represents the evidence and sources of human history and culture, irrespective of their origin, development and preservation, and related cultural goods that must be protected due to their irreplaceability. The concept of the cultural heritage hides the initial components that indicate its many-sided effects, i.e. designing, educating, protecting, worshipping, and residing [1]. Therefore, cultural heritage is a process associated with human activities and corresponding timeframes, i.e. interpretation of cultural heritage within a contemporary industrial world [2–4]. Each nation has its own cultural heritage that extends to various areas, including the field of textiles. Through traditional arts, each generation adds their gift of creativity to tradition, the sense of what is beautiful, symbolic and qualitative [5].

There are numerous written and imagery sources providing evidence for decorating textiles with reserving and dyeing, including blue-printing, which is supposed to be one of the oldest decorative techniques, as was already known in India, Tibet, China, Java and Africa several centuries BC [1]. Moreover, a number of sources acknowledge the popularity of blue-coloured and blue-printed textiles in Europe in the 19th century [6–10].

Blue-printing is one of the oldest methods for fabric patterning that was most commonly handmade, using printing blocks (wooden, metal or combined), with which a colourless resist paste was applied onto the patterns of an undyed fabric. Before printing, the fabric would be pre-treated with starch and calendered to provide a flat surface upon which the resist print would form a more perfect protective cover. After printing, the goods would be thoroughly dried to consolidate the resistance barrier. The ground would then be dyed by dipping the fabric into indigo or woad vat as many times as required in order to produce the desired depth of blue. The protective action of the resist paste would be partly due to its oxidising properties, which would have the effect of throwing the indigo out of the solution before it could reach the fibres. The process is completed by oxidation of the indigo or woad and washing to remove thickener, surface dye and chemicals [11]. The reserved patterns retain the basic colour (white), while the rest of the fabric is dyed with the bath colour [12]. The oldest specimen of negative blue-printing so far discovered is the sample of starry and dotted patterns on a child's tunic from Egypt and dates back to the 4th and 5th century AD [13]. There are several theories describing when, how, where from and in what manner the blue-printed fabric came to Europe for the first time; nevertheless, all these theories are unanimous in the fact that these goods come from the eastern countries. In Slovenia, blue-printing was used in the 19th century and was most likely brought to the Slovenian territory from Germany, the Czech Republic and Slovakia [14, 15]. As white and light clothes got dirty very quickly, the blue colour was practical in this respect as well, whereas the pattern enriched the fabric and made it more attractive. Versions of positive blue-printing on a light basis are known as well; however, this is rather an exception than a rule [14].

The development of Slovenian blue-printing art was similar to those in other parts of the world and related to the demand and consumption of blue-coloured textiles. Most of the sources indicate that the larger consumers of this textile in the 19th century were peasant women who used this textile for clothes and internal design [8, 14, 15]. The first visual sources of blue-printed textiles are depictions showing peasant costumes, aprons, skirts, and vests. The most popular were striped, checked, dotted, and flowered patterns. From 1830–1845, blue-printing was also very popular amongst the rural population [15]. In the second half of the 19th century, clothes in blue, red and green tones with printed floral patterns, stripes, dots and squares were in fashion. In the period between the two wars and after the World War II, two-way blue-printed aprons were popular also in cities as accessories to the work clothes of housewives. At the end of the 19th century, a blue-coloured fabric was used for work wear. Furthermore, particularly richer families preferred to have blue-printed bed covers with floral patterns [14, 15]. The blue-coloured fabric was later used for the hardening of working and festive clothing as well as head coverings [14].

There are many preserved blue-printing models bearing evidence of widespread usage of blue-printing, as well as a scarce collection of textile exhibits. The latter can be found in two Slovenian museums, i.e. the Slovene Ethnographic Museum (Slovenian: Slovenski etnografski muzej) in Ljubljana and the Škofja Loka Museum (Slovenian: Loški muzej) in Škofja Loka.

The purpose of this study was to analyse the textile-physical characteristics of Slovenian blue-printed textile exhibits with non-destructive methods, and to analyse their colour tones and present the possibilities of producing replicas using a modern digital printing technique which would be the fastest, cheapest and the most effective method of changing an idea into a final product [16]. The replicas are earmarked for exhibition needs, the creation of missing exhibit pieces or entire textiles. They would also be used for folklore purposes and for the marketing of high-quality souvenirs, or for the marketing of clothes and home textiles with the containing elements of cultural heritage. The study of a small representative piece of an existing blue-printed textile is a valuable source for getting an overall view of that period, at the same time enabling further interdisciplinary research.

MATERIAL AND METHODS

Textile museum exhibits

This article presents the results of textile-physical measurements and the measurements of colour characteristics for eight blue-printed textile exhibits from the Slovene Ethnographic Museum in Ljubljana (table 1). The study did not additionally strain or damage the exhibits. Most of the research methods were non-destructive, with the exception of the method for determining the material composition. The fibres used in this analysis were obtained at the already damaged spots (holes, edges). The measuring conditions were constant, the measurements being conducted indoors during daylight.

The exhibit EM 3131 is a textile sampler (w = 87 cm, l = 115 cm). There are 16 different pattern fields with white and light-blue geometrical and stylised plant patterns on a dark-blue fabric. The pattern fields are demarcated on all sides having a border with a repetitive plant motif. The sampler is rimmed with a yellow ribbon which suggests that it was also used as a tablecloth. The model is in good condition. The year 1832 is handwritten in the corner and this is probably the year of the samples origin.

The exhibit EM 3132 is a textile sampler (w = 87 cm, l = 90 cm). There are 16 different pattern fields with yellow geometrical and stylised plant patterns on a dark-blue fabric. The pattern fields are demarcated on all sides with dotted lines. The sampler is rimmed with a cream-coloured ribbon, implying that it was also used as a tablecloth. The sampler was manufactured in the first half of the 19th century.

The exhibit EM 9321 (w = 21 cm, l = 26.5 cm) is a remnant of a blue-coloured fabric printed with stylised flowers. The aprons made of such a fabric were still being worn around the year 1940.

Table 1

BLUE-PRINTED TEXTILE EXHIBITS AND INVENTORY NUMBERS			
 EM 3131	 EM 3132	 EM 9321	 EM 13689
 EM 13690	 EM 13691	 EM 13695	 EM 18519

The exhibit EM 13689 (l = 49 cm) is a blouse with a white stylised floral pattern. This item is poorly preserved, torn and incomplete. The clothing was made around the year 1930 and was used as a festive holiday afternoon blouse; however, around 1950, it was worn as work clothing.
The exhibit EM 13690 (l = 47 cm) is women's work clothing made of a blue-coloured fabric with geometrical patterns. The clothing was manufactured around the year 1930 and was still worn in the 1950s.
The exhibit EM 13691 (l = 47 cm) is clothing made of a blue-coloured fabric that has a ribbon with a white pattern sewed in on the front and on the cuffs as ornamental. The item is poorly preserved. The blouse was manufactured around the year 1930 and was used as festive holiday afternoon clothing. Around 1950, it was worn as work clothing.
The exhibit EM 13695 (w = 16 cm, l = 97 cm) is a remnant of the lower part of a blue-coloured skirt with white patterns.
The exhibit EM 18519 (w = 21 cm, l = 43 cm) is a remnant of a blue-coloured fabric with white patterns. The item is poorly preserved and torn in many places. It was manufactured around the year 1930. This fabric was used for women's clothing.

Printing fabric

A 100% cotton fabric in plain weave, manufactured in Tekstina d. d., Ajdovščina (SI), was used for the digital printing of blue patterns. The fabric was industrially desized, scoured and bleached. The fabric was chosen on the basis of the analysis of the above mentioned blue-printed museum exhibits, with the aim of being as close as possible to the characteristics of the latter.

Methods

The textile-physical analyses included the determination of the material composition of exhibits (performed with an optical microscope Olympus CX21 Olympus, USA), the determination of the type of weave (standards ISO 3572:1976 and ISO 9354: 1989), fabric density (standard SIST EN 1049-2: 1999; ISO 7211-2:1984 modified), twist direction (defined by means of close-up images of the yarn taken with a 65.560 Novex Euromex (NL) stereo microscope with a CMEX 5000 digital camera in accordance with the standard SIST EN ISO 2061:2010 fabric thickness (conducted on a Mitutoyo (J) instrument for measuring thickness at the specific pressure of 20 cN/cm^2 in accordance with the standard SIST EN ISO 5084:1996), yarn diameter (conducted with a monocular magnifier) and mass per unit area (standard ISO 3801:1977). The measuring points where each fabric was the more preserved were defined on the basis of a subjective assessment, this being in the middle part of the exhibit fabric.
Analyses the colour characteristics of blue-printed textile exhibits were also conducted. The measuring points for the more intense colours were defined on the basis of a subjective assessment. These points were at those areas that were least exposed to physical wear (rubbing, light), i.e. on hidden edges, under the collar or inside the decorative fold. Each individual measurement of the reflection automatically included 20 measurements and the measurements of each textile exhibit were conducted at 5 different measuring points. The colour reflections were measured with a Spectrocam 75RE spectrophotometer Spectrostar BV (NL). The reflection measurements were performed within the wavelength range 380 nm to 750 nm, with the surface exposure 3.5*4 mm, measuring aperture 1.5*2 mm, geometry of measuring 45° and with present gloss (gloss trap in closed position). On the basis of the measured reflection values, the CIE tristimulus values XYZ were calculated using Spectrocam 2.05 Spectrostar BV (NL) software in accordance with the standard ISO 13655:1996, as were the CIE chromaticity yxz values, colour values L*,a*,b*,C*,h CIELAB 1976 and colour difference

dE*. The colour differences, dE*, were calculated with Microsoft Excel and in accordance with the CIE recommendations and guidelines.
Firstly, the L*a*b* colour values of museum exhibits were measured, then the average values were calculated and converted into CMYK values, which finally represented the basic point for digital printing.

Printing process

After capturing textile exhibits and their samples, digitalization with CAD/CAM software was conducted. For artistic analysis and reproduction of primary samples of blue-printed exhibits, Adobe (USA) software was used. Graphic files which contained the basis of patterns and their rapports were created for digital printing. The printing was conducted on a large-format digital printer TX2-1600 Mimaki (J) with Jettex R inks of the manufacturer DyStar (D). The cotton fabric was impregnated with a 150 g/mL migrating agent, 40 g/L soda ash, 20 g/L anti-reduction agent, 150 g/L urea, 10 g/L de-aerating agent. On the basis of the colour analyses conducted on the blue-printed museum exhibits, L*a*b* values were obtained, which were afterwards rounded up and then with the RIP-compatible software Texprint 11 Ergosoft (CH) converted into the CMYK values. After the first test prints, the colour values were corrected and the samples were printed with 100, 200 and 300% of ink applications. The printing was followed by 10-minutes of normal steaming in saturated steam at T = 103 °C at normal air pressure within a DHE 20675 laboratory steamer Werner Mathis (CH). Additional treatments were carried out after the fixation: rinsing in cold water, rinsing in hot water (T = 70 °C), rinsing in boiling water (until the dye stoped bleeding), boiling soaping (3 L of water, 1.5 g/L after-clearing agent, T = 98 °C, t = 15 min), rinsing with boiling water, rinsing with hot water and rinsing with cold water. The fabric was then left to air-dry at room temperature.
Finally, the colorimetric measurements were repeated on the printed samples with a Spectrocam 75RE Spectrostar BV (NL) Spectrophotometer in accordance with the above described procedure.

RESULTS AND DISCUSSION

The results of the textile-physical measurements of the blue-printed textile exhibits from the Slovene Ethnographic Museum in Ljubljana, which included the determination of yarn type, type of weave, coiling type, yarn diameter, fabric density, fabric thickness and mass per unit area, are presented in table 2. On the basis of comparisons and calculations, the cotton fabric was selected, which is suitable for digital printing with reactive dyes produced by a Slovenian manufacturer present on the market (table 3).
The average yarn diameter of the textile exhibits (tab. 2) in the warp direction is 0.26 mm and in the weft direction 0.25 mm, whereby the exhibit EM 18519 had the thinnest warp yarn (0.20 mm) and the exhibits EM 13690 and 13691 had the thickest warp yarn (0.29). The same characteristics are also reflected from the analysis of the weft. The average number of threads of textile exhibits is 27.10 in the warp direction and 25.75 in the weft direction. Fabric density is within the range from 21.6 (EM 9321 and 13689) to 35.8 (EM 3131) number of threads/cm in the warp direction and to 31.2 (EM 3131) number of threads/cm in the weft direction. Analysis of the fabric thicknesses of the textile exhibits showed that the average fabric thickness is 0.38 mm and ranges from 0.285 (EM 3131) to 0.458 mm (EM 13690), being particularly affected by yarn diameter of warp and weft. The described properties of individual parameters are also reflected in the mass per unit area,

Table 2

MEASUREMENT RESULTS REGARDING THE INDIVIDUAL PARAMETERS AND CHARACTERISTICS OF BLUE-PRINTED TEXTILE EXHIBITS AND THEIR AVERAGE VALUE

Exhibit number	Yarn type	Weaving type	Twist direction		Yarn diameter (mm)		Fabric density (number of threads/cm)		Fabric thickness (mm)	Mass per unit area (g/m^2)
			Wa*	We*	Wa	We	Wa	We		
EM 3131	Cotton	Linen	Z	Z	0.22	0.21	35.8	31.2	0.285	104.6
EM 3132	Cotton	Linen	Z	Z	0.23	0.24	31.4	30.0	0.300	104.6
EM 9321	Cotton	Linen	Z	Z	0.27	0.27	21.6	21.6	0.396	115.2
EM 13689	Cotton	Linen	Z	Z	0.27	0.27	21.6	21.6	0.396	115.2
EM 13690	Cotton	Linen	Z	Z	0.29	0.28	24.4	24.4	0.458	**
EM 13691	Cotton	Linen	Z	Z	0.29	0.28	24.4	24.0	0.443	**
EM 13695	Cotton	Linen	Z	Z	0.28	0.28	24.4	24.0	0.440	**
EM 18519	Cotton	Linen	Z	Z	0.20	0.20	33.2	29.2	0.300	**
Average	Cotton	Linen	Z	Z	0.26	0.25	27.10	25.75	0.380	109.90

Used abbreviations:
**Wa – warp, *We – weft*
*** The surface mass of textile exhibits was not determined due to the lining that could not be removed without damaging the exhibit.*

Table 3

CHARACTERISTIC OF USED TEXTILE SUBSTRATE FOR DIGITAL PRINTING	
Parameter	Fabric
Producer	Tekstina d. d. Ajdovščina (SI)
Product:	Fabric for outerwear
Yarn type:	100% cotton
Weaving type:	linen
Twist direction Warp: Weft:	 Z Z
Yarn diameter Warp: Weft:	 0.15 mm 0.15 mm
Density Warp: Weft:	 56 threads/cm 30 threads/cm
Fabric thickness:	0.285 mm
Mass per unit area:	112 g/m^2
Colour characteristics (CIE D65/10):	L* = 93.38 C* = 2.38 h = 252.48
Whiteness degree:	WI_{CIE} = 94.29

which is 109.90 g/m^2 on average. It should be noted that in order to protect the textile exhibits only exhibits EM 3131, 3132, 9321 and 13689 were analysed as other exhibits would be damaged by analysis. The analysis of the results of textile-physical characteristics of the textile exhibits was the basis for the selected fabric for the digital printing of replicas. The selected fabric had properties that are closest to the average value of the textile exhibits.

The colour characteristics of blue-printed museum exhibits are presented in figure 1, and table 4.

From the reflexion curves (fig. 1a) of the measured textile exhibits from SEM Ljubliana we can conclude that the curves are harmonious, with no interaction which would signal the presence of metamerism. Based on the observed facts we can conclude that dyes used for dyeing the blue-printed textile exhibits have the same chemical properties, which confirms the assumptions [14]. Amongst the curves, the curve of exhibit EM 13691 stands out (fuzzy peak at 42 nm, strong rising in the wavelength of the red light), which can be attributed to non-equality and damaged areas caused by exposure to light and abrasion. We could also see monotony in the curves of exhibits EM 3131 and 3132, without distinct peaks.

Presentation of colour values in the CIELAB diagram (figure 1b) reveals further differences. It is clearly evident that the textile exhibits extend over three colour areas. Exhibits EM 3131 and 3132 are located in the fourth quadrant of the CIE space (area of blue-red colour), while the remaining exhibits are located in the third quadrant (area of blue colour). Thus, exhibits EM 9321, 13689 and 13695 form one group that is closer to the colour values of –b* axis (with a higher proportion of blue) and exhibits EM 13690, 13691 and 18519 form another group which is more distant from the –b* axis.

The analysis of colour characteristics (table 4) shows that textile exhibits EM 3131 and 3132 differ from the values of other exhibits. Their average values for brightness L* are 15.51 units, whilst for the other exhibits they amount to 25.90 units. Discrepancy also occurs during average chromaticity C*, amounting to 5.67 units for exhibits EM 3131 and 3132 and 16.54 for other exhibits. The described differences are also reflected in the varying angle of hue (h) so the average hue for exhibits EM 3131 and 3132 is 283.41 and for the rest of the exhibits the average hue is 267.04 units. In further research we focused on EM 9321, 13689 and 13695 due to the small colour differences whilst other textile exhibits were excluded.

Measured and rounded L*a*b* values were converted into CMYK colour values with the help of the Adobe program equipment and RIP software Texprint 11 Ergosoft (CH). This was followed by digital printing and re-evaluation of the colour characteristics where it was shown that the colour differences between

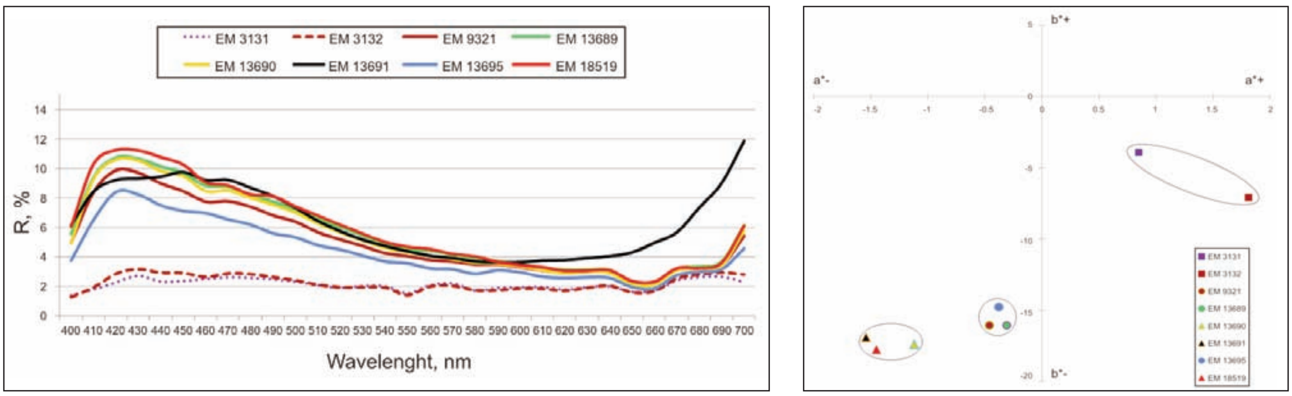

Fig. 1. Reflectance curves (a) and positions in CIELAB diagram (b) of blue-printed museum exhibits

Table 4

COLOUR CHARACTERISTICS OF BLUE-PRINTED TEXTILE EXHIBITS FROM SEM LJUBLJANA					
Exhibit number	***CIELAB 1976 colour characteristic (D65/10)***				
	L*	***a****	***b****	***C****	***h***
EM 3131	15.58	0.85	– 3.91	4.02	282.51
EM 3132	15.44	1.81	– 7.09	7.31	284.30
EM 9321	25.21	– 0.46	– 16.08	16.09	268.35
EM 13689	26.83	– 0.31	– 16.07	16.07	268.94
EM 13690	26.13	– 1.12	– 17.42	17.46	266.27
EM 13691	26.82	– 1.54	– 16.91	16.99	264.84
EM 13695	23.22	– 0.38	– 14.77	14.78	268.50
EM 18519	27.19	– 1.45	– 17.78	17.84	265.32

originals and prints are unacceptable. The CMYK colours values were corrected due to the subjective optical perception of colour differences and subsequently, in order to better correspond to the actual colour of textile exhibits. In most cases, C (cyan), Y (yellow) and K (black) decreased, whereas M (magenta) increased. The samples with selected CMYK colour values were printed in three different printing modes, with 100, 200 and 300% ink application. The measurements of colour values were repeated on the fixed and treated prints and then compared with all existing exhibits. The results are shown in table 5.

From the results shown in tab. 5 we can generally conclude that a higher quantity of the deposited ink does not contribute to lowering the value of L * and also does not change significantly during saturation (chromaticity) and is within the limits of 0.49 (EM 13689) and 3.12 (EM13695) . There is a difference in angle diversity in the digital print of exhibit EM 9321, which increases with the amount of quantity of the ink to 4.22°, whilst the EM 13689 and 13695 reduces to 1.92° and 2.52° accordingly. Colour differences between digital prints and textile exhibits increase with the amount of the used dye to 2.52 (EM 9321) and 0.92 (EM 13689). The exception occurs in comparing digital print $DP_{EM13695}$ and textile exhibit EM 13695, where dE * falls to 2.31 units. The best colour-comparable print was obtained in sample $DP_{EM13689}$, with colour values C = 76, M = 84, Y = 39, K = 32 at a 100% ink application.

According to the standard DIN 5033-7:1983, the visual estimation of the colour distinction is determined as very clear (3.0–6.0). The final print does not completely correspond to the colour of the blue-printed textile exhibits. A better congruence amongst the replicas and the original could be achieved with further research, different pre-treatments and inks,

Table 5

COLOUR DIFFERENCES AMONG DIGITAL PRINTS AND MUSEUM TEXTILE EXHIBITS					
Printing mode (%)	**Digital print**				**Textile exhibit**
		L*	**C***	**h**	**dE* CIELAB (D65/10)**
100	DP_{EM9321}	32.42	17.43	269.04	7.33
200		31.71	17.32	269.16	6.62
300		33.19	20.30	273.26	9.14
100	$DP_{EM13689}$	29.25	13.59	265.47	3.59
200		30.05	13.24	263.55	4.51
300		29.94	13.73	263.78	4.09
100	$DP_{EM13695}$	33.28	20.33	272.27	11.54
200		33.36	19.97	271.32	11.42
300		32.13	17.21	269.75	9.24

printing using printers from other manufacturers and under other printing conditions. It is also assumed that the colour differences could be reduced to a weak (0.5–1.5) or even very weak (0.2–0.5) visual estimation of the colour distinction if further research of corrections was conducted and the corrections were made of the input components that define the colour in digital print (CMYK values).

CONCLUSIONS

The aim of this article was to present the possibility of producing blue-print replicas with modern digital printing techniques. These replicas can be made for museums, folklore or marketing purposes. Museums can use the replicas for exhibition needs and for the creation of missing pieces of the existing blue-printed textiles or replicas of entire clothes and textiles as the interiors as many museums do not possess them. Good replicas enable the production of high-quality souvenirs (museum or art shops) and of everyday clothes and textiles with the elements of cultural heritage. This article presented the methods for analysing the textile-physical characteristics and the results that enable the selection of modern textile materials available on the market. It also presented the colorimetric measurement procedures that serve for selecting of the more suitable CMYK colour values for digital printing or for further analyses of the obtained results and comparisons with the original. The results show that with the suggested approach and methods, satisfactory replicas can be produced. Furthermore, possible non-destructive methods are indicated when examining textile exhibits, as is the production of replicas on the basis of obtained results. The presented method enables the creation of new modern textiles through which the Slovenian cultural heritage could be incorporated into contemporary production and could thus influence the economic development of the textile and clothing industry [18]. Moreover, the latter would promote the sustainable development and increase the quality of life, together with the identification and education potential of the cultural heritage.

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Authors:

Chief of works LARA PLAJH
Platon d. o. o., Brunšvik 17b, 2327 Rače, Slovenia

Assoc. Prof. dr. ALENKA PAVKO ČUDEN
Prof. dr. PETRA FORTE TAVČER
Assist. Prof. dr. BRIGITA TOMŠIČ
KLARA KOSTANJŠEK
University of Ljubljana
Faculty of Natural Sciences end Engineering
Department of Textiles
Snežniška Street 5, Ljubljana

Assoc. Prof. dr. BRANKO NERAL
University of Maribor
Faculty of Mechanical Engineering
Design and Textile Materials
Smetanova Street 17, Maribor

Assoc. Prof. dr. SIMONA JEVŠNIK
Istanbul Technical University
Textile Technologies and Design Faculty
Inönü Caddesi, No: 65, Gümüşsuyu (34437)
Beyoğlu, Istanbul, Turkey
e-mail: lara.plajh@gmail.com

Study on the thermal property of highly porous nonwoven fabrics

GUOCHENG ZHU
DANA KREMENAKOVA
YAN WANG
JIRI MILITKY
RAJESH MISHRA

REZUMAT – ABSTRACT

Studiu asupra proprietăților termice ale nețesutelor cu porozitate mare

În general, proprietatea termică a textilelor este evaluată fără a se lua în considerare transferul de căldură prin convecție și radiație, dar transferul de căldură prin nețesute poate include conducția prin fibre solide, conducția prin aerul aflat în spațiile dintre fibre, convecția liberă și radiațiile datorită structurii lor unice. Prin urmare, scopul acestei lucrări este de a investiga efectul structurii asupra properietății termice a nețesutelor, precum și raportul dintre transferul de căldură prin conducție, convecție și radiație și transferul total de căldură. Nețesutele cu parametri diferiți în ceea ce privește desimea, grosimea, porozitatea și dimensiunea porilor au fost supuse preparării cu ajutorul unei mașini de cardat și al unei mașini de perforat cu ace. Proprietățile termice ale fibrelor și ale nețesutelor au fost măsurate cu ajutorul instrumentului Alambeta, care permite măsurarea rapidă a proprietăților termice, atât în starea de echilibru, cât și în regim staționar. S-au observat câteva rezultate interesante în această lucrare. Odată cu creșterea gradului de porozitate și a dimensiunii porilor, transferul de căldură prin radiație a dus la creșterea transferului de căldură total, care poate fi reprezentat prin conductivitate termică efectivă. Între timp, raportul căldurii prin radiație a ajuns până la 50% din transferul de căldură total în anumite circumstanțe. Grosimea nu a arătat un efect evident asupra conducției de căldură și asupra radiației termice atunci când porozitatea materialului nețesut a fost menținută constantă. A fost raportată proprietatea termică a nețesutelor cu porozitate mare (> 95%) și a fost studiată relația dintre dimensiunea porilor și conductivitatea termică efectivă a nețesutelor.

Cuvinte-cheie: *conductivitate termică, nețesut, porozitate, dimensiunea porilor, Alambeta*

Study on the thermal property of highly porous nonwoven fabrics

Generally, the thermal property of textiles is predicted without considering convective and radiative heat transfer, but heat transfer through nonwoven fabrics may include conduction through solid fibers, conduction through air in the interfiber spaces, free convection, and radiation due to its unique structure. Therefore, the purpose of this work is to investigate the effect of structure on the thermal property of nonwoven fabrics, as well as the ratios of conductive, convective, and radiative heat transfer to the total heat transfer. Nonwoven fabrics with different parameters in terms of density, thickness, porosity and pore size were prepared by carding machine and needle-punching machine. The thermal properties of fibers and nonwoven fabrics were measured by Alambeta instrument, which enables the quick measurement of both steady-state and transient-state thermal properties. Some interesting results were observed in this work. With the increase of porosity and pore size, the increased radiative heat transfer led to the increase of total heat transfer, which can be represented by effective thermal conductivity. Meanwhile, the ratio of heat radiation reached up to 50% to the total heat transfer in some circumstances. The thickness did not show an obvious effect on the heat conduction and heat radiation when the porosity of the nonwoven fabric was kept as a constant. The thermal property of nonwoven fabrics with high porosity (>95%) was reported, and the relationship between pore size and effective thermal conductivity of nonwoven fabrics were studied.

Key-words: thermal conductivity; nonwoven fabric; porosity; pore size; Alambeta

In nonwoven fabrics, pores of all geometrical shapes are possibly formed and the pore sizes could be in a larger scope due to the random arrangement of fibers. Thereby, heat transfer through nonwoven fabrics may in general be represented by several mechanisms: conduction through solid fibers, conduction through air in the interfiber spaces, free convection, and radiation[1]. Despite the fact that there are several mechanisms operative in the transfer of heat through nonwovens, the phenomenon can be quantified by an effective thermal conductivity for the nonwoven.

In theoretical work, the most widely used model for predicting effective thermal conductivity was proposed by Bogaty [2], who took the textiles as a fiber-air mixture and assumed that the air is stagnant. In Bogaty's model, the volume fraction of each material and the orientation of fibers are needed. Due to the difficulty of determining fiber's orientation, Bogaty's model was simplified by Militky [3], who assumed the fibers were arranged in both series and parallel structures. He also proposed that the average value from these two kinds of structures was the effective thermal conductivity of textiles. These two models had good agreements with the experimental results in some cases. Other concepts for describing the heat conduction through textiles were either based on thermal resistance network or differentiation [4–7], which needs over simplification of the structures of fibrous materials. In addition, for some materials with complicated physical structures, these models are not appropriate.

The heat convection in textiles is often ignored due to its complexity. But the natural convection could exist when the temperature difference on both sides of textiles and the pore size of textiles is big enough.

Two techniques were used for determining the heat radiation, one is called direct method, which is based on the study of the interaction between the fiber and radiation by the resolution of the Maxwell equations. The resolution was done with the Mie theory and made it possible to obtain radiative properties of a single fiber. The radiative properties of the medium were given by averaging the properties of a fiber over size and orientation distributions within the medium [8, 9]. The second method is an inverse method based on the inversion of the radiative transfer equation starting from measurements of reflection and transmission [10, 11]. Methods of determining heat radiation were reported in literatures, but they require determination of the scattering parameter and emissivity of the hot and cold side boundaries. These parameters are beyond the scope of this paper, and we will address them, for the materials reported here in a future paper.

In this work, the thermal conductivity of nonwoven fabrics with various parameters including areal density, porosity and thickness was evaluated to investigate the effect of structure on the thermal property. Components of thermal conductivity, convection, and radiation were also estimated.

METHODOLOGY

Materials and measurements

The polyester hollow fiber, supplied by the Sinopec Yizheng Chemical Fibre Company Limited (Suzhou of China), was used to prepare nonwoven fabrics in a carding machine and a needle-punching machine. The nonwoven fabrics were conditioned in a constant temperature and constant humidity box for 24 hours before measurements.

The thermal conductivity of fiber was evaluated in some previously reported research [12] by measuring the thermal conductivity of composites including fibers and polymer. In this work, a bundle of hollow fibers were put into PEO solution in which the air bubbles were removed by a vacuum pump. After drying, the thermal conductivity of composite were measured, and the thermal conductivity of fiber could be calculated.

The thermal conductivity of composites and nonwoven fabrics were measured by an Alambeta instrument, which enables quick measurements of both steady-state and transient-state thermal properties. The temperature difference between the upper and bottom heating plates which were directly in contact with the both sides of nonwoven fabric was constant (10°C or 40°C), and then the instrument directly measured the stationary heat flow density and the sample thickness under a pressure of 200 Pa or 1000 Pa [13]. At last, the values of thermal conductivity, and thermal resistance were determined accordingly. In this work, the measurement of thermal conductivity was at room temperature with 65 % humidity, 10°C temperature difference on the both sides of fabrics under a pressure of 200 Pa. The average values of five repeated measurements were adopted.

Determination of the characteristic of fiber

Fiber geometric characteristic and density

The profile of the hollow fiber was observed by a scanning electron microscope with an accelerating voltage of 30 kV. Samples were sputter-coated with a thin layer of gold by electro deposition to make the surfaces conductive and reduce charging before analyzing. The hollow fiber was taken as a cylinder. It was found that the fiber diameter was around 45 ± 5 μm, and the diameter of hollow core was 22 ± 3 μm (figure 1).

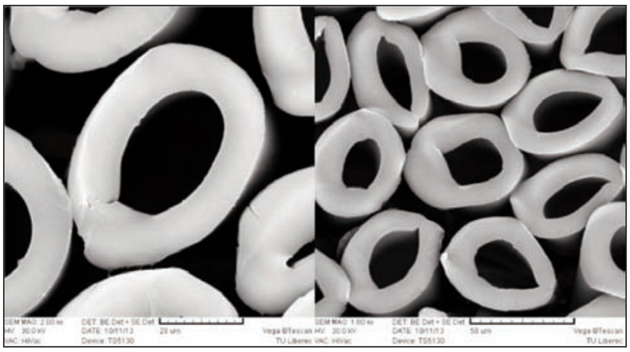

Fig. 1. Image of hollow fibers

The air volume content in the hollow fiber could be determined by using image processing analysis by Matlab. Firstly, the SEM images of fibers were imported into Matlab, the SEM images were converted into binary images, and then the hollow area and the fiber area were extracted (as shown in figure 2). Lastly, an in-house Matlab code was developed to calculate the area ratio of fiber material and the hollow part to the total area. The mathematical expressions are given by,

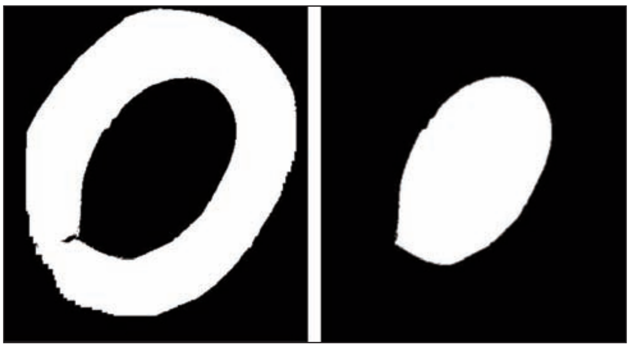

Fig. 2. Binary images of hollow fiber

$$\varepsilon_f = A_f / A_t \quad (1.a)$$

$$\varepsilon_h = A_h / A_t \quad (1.b)$$

$$\varepsilon = \varepsilon_h / \varepsilon_f \quad (1.c)$$

where ε_f is the ratio of fiber area to total area in the figure 2, ε_h is the ratio of hollow area to total area in the figure 2, ε is the porosity of hollow fiber, A_f, A_h, and A_t are the areas of the fiber cross-section, the cross-section of the hollow core and the total area of the figure 2, respectively. The air volume content in hollow fiber was 27 ± 8% based on the above method.

The hollow fiber density was 1034 kg/m^3 which was calculated from the following equation,

$$\rho_h = \frac{n \cdot m}{\pi r^2 l \cdot n} \quad (2)$$

where ρ_h is the density of the hollow fiber (kg/m^3), n represents the number of fibers, m represents the mass of a single fiber (kg), r is the diameter of hollow diameter (m), l represents the length of a single fiber (m). The density of fiber material, ρ_f, can be easily obtained by equation,

$$\rho_f = \frac{\rho_h}{1 - \varepsilon} \quad (3)$$

Fiber thermal conductivity

It is very difficult to measure the thermal conductivity of a single fiber due to its fine diameter. Therefore, one widely used method [12] for evaluating the thermal conductivity of fiber is to measure the thermal conductivity of the composite specimen including a bundle of the fibers, and then the thermal conductivity of the fiber can be calculated. On the other hand, numerous analytical models for predicting the effective thermal conductivity of composites were developed in recent years. The numerical results were in good agreements with experimental results [3, 14–16]. In this work, the thermal conductivity of PEO was 84.7 × 10^{-3} W/(m·K), the effective thermal conductivity of the composite, 3.12% fiber and 96.88% PEO in volume, was 86.6 × 10^{-3} W/(m·K). According to Equation (8), the thermal conductivity of fiber was 119.2 × 10^{-3} W/(m·K).

Determination of the characteristics of nonwoven fabrics

For nonwoven fabrics, pores of all geometrical shapes are possible due to the random arrangement of fibers (as shown in figure 3). And there is no doubt that the pore size and the pore shape have important influence in convective heat transfer. We assumed that the pores in nonwoven fabric are evenly distributed cylinders. And then, the mean effective pore diameter in the nonwoven fabrics is given by Verschoor's Equation [17],

$$D = \frac{\pi d}{4(1 - \varepsilon_n)} \quad (4)$$

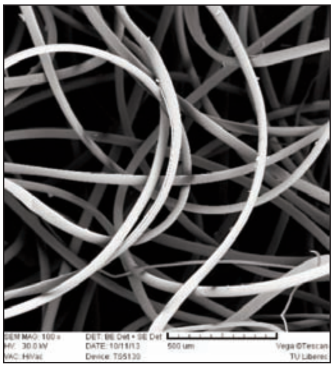

Fig. 3. Image of nonwoven fabric

where D is the mean effective pore diameter, d is the mean fiber diameter, ε_n is the mean porosity of the nonwoven fabric. The porosity of nonwoven fabric is given by,

$$\varepsilon_n = \left(1 - \frac{\rho_n}{\rho_h}\right) \times 100\% \quad (5)$$

where ρ_n and ρ_h are the densities of the nonwoven fabric and the hollow fiber, respectively.

RESULTS AND DISCUSSIONS

Theoretical analysis of conduction, convection, and radiation

The effective thermal conductivity of the nonwoven fabric K_{eff} is given by

$$K_{eff} = \frac{Q_{cond} + Q_{conv} + Q_{rad}}{A \Delta t} \quad (6)$$

Or

$$K_{eff} = k_{cond} + k_{conv} + k_{rad} \quad (7)$$

where Q_{cond}, Q_{conv}, and Q_{rad} are the heat flow through nonwoven fabrics by conduction, convection, and radiation, respectively, A is the area where heat flow went through, Δt is the temperature gradient on the both sides of the nonwoven fabric, k_{cond} is the conductivity of the nonwoven fabric due to conduction, k_{conv} is the conductivity of the nonwoven fabric due to convection, and k_{rad} is the conductivity of the nonwoven fabric due to radiation.

Thermal conductivity k_{cond} in this work can be obtained by applying the Militky's model, which is given by [3],

$$k_{cond} = \frac{k_f V_f + k_a V_a}{2} + \frac{k_f k_a}{2(k_f V_a + k_a V_f)} \quad (8)$$

where k_f and k_a are the thermal conductivities of the fiber and the air, respectively; V_f and V_a are volume fractions of the fiber and the air, respectively. The first term of the right side of this equation describes an ideal model of a textile construction whose fibers are totally parallel to the flow of the heat. The second term describes an ideal model of a textile construction whose fibers are totally in series to the heat flow.

We assumed that the pores inside the nonwoven fabric are cylinders, the conductivity of the nonwoven fabric due to convection k_{conv} can be obtained by [18],

$$k_{cond} = \begin{cases} k_a & \frac{g\beta\Delta TL^3}{\upsilon^2}\mathrm{Pr} < 1700 \quad (9.1) \\ 0.059k_a\left[\frac{g\beta\Delta TL^3}{\upsilon^2}\mathrm{Pr}\right]^{2/5} & 1700 < \frac{g\beta\Delta TL^3}{\upsilon^2}\mathrm{Pr} < 7000 \quad (9.2) \\ 0.212k_a\left[\frac{g\beta\Delta TL^3}{\upsilon^2}\mathrm{Pr}\right]^{1/4} & 7000 < \frac{g\beta\Delta TL^3}{\upsilon^2}\mathrm{Pr} < 3.2\times10^5 \quad (9.3) \\ 0.059k_a\left[\frac{g\beta\Delta TL^3}{\upsilon^2}\mathrm{Pr}\right]^{1/3} & \frac{g\beta\Delta TL^3}{\upsilon^2}\mathrm{Pr} > 3.2\times10^5 \quad (9.4) \end{cases}$$

where c and n are constants, which can be obtained from literatures [18], k_a is the thermal conductivity of the air, g is the gravitational acceleration, β is the coefficient of volume expansion, ΔT is the temperature gradient of both sides of the nonwoven fabric, L is the characteristic length of the pore in nonwoven fabric, υ is the kinematic viscosity of the air. $Pr = (\mu C_p / k_a)$ is the Prandtl number, μ is the dynamic viscosity of air, C_p is the specific heat capacity of air, and k is the thermal conductivity of air. The Equation (9.1) describes the case with no convective heat transfer.

And the conductivity of the nonwoven due to radiation, k_{rad}, can be obtained by [19],

$$k_{rad} = \frac{16\sigma T_m^3}{3\beta_R} \quad (10)$$

where σ is the Stefan-Boltzmann constant, $\sigma = 5.669 \times 10^{-8}$ W/m^2·K^4, T_m is the mean temperature in the nonwoven fabric, and β_R is the Rosseland average extinction coefficient. In this work, the k_{rad} was estimated by Equation (7) due to the parameter β_R which is beyond the scope of this paper. k_{eff} can be obtained experimentally. The experimental results are shown in table 1.

The relationship between the density and porosity

The density or the porosity of the nonwoven fabric is an important parameter to characterize thermal properties. Obviously, the density of nonwoven fabric is inversely proportional to the porosity of the nonwoven fabric according to Equation (5), and the correlation between them was given in figure 4. Meanwhile, the densities of nonwoven fabrics were in a more wide range with respect to the porosities of nonwoven fabrics.

Effect of porosity on thermal property

According to the theoretical analysis, the convective heat transfer can be ignored due to the critical value is much less than 1700 (Equation 9.1). Therefore, if only the conduction mechanism was considered, effective thermal conductivity of nonwoven fabric should decrease continually with the decreasing density or

Table 1

SAMPLE PARAMETERS VS. THERMAL PROPERTY OF NONWOVEN FABRICS

Thickness (mm)	Porosity (%)	Pore diameter (mm)	K_{eff} (W/(m·K))	k_{con} (W/(m·K))	k_{rad} (W/(m·K))
6.25±0.04	97.87±0.026	1.66±0.02	48.3±1.1	27.21	21.09
6.9±0.04	97.87±0.026	1.66±0.02	48.1±0.9	27.22	20.88
7.59±0.05	95.32±0.022	0.76±0.012	46.2±1.1	28.1	18.1
	96.12±0.021	0.91±0.013	47.5±0.8	27.87	19.63
	97.07±0.023	1.21±0.017	47.8±1.2	27.5	20.3
	97.87±0.026	1.66±0.02	49±1.3	27.21	21.79
	98.35±0.021	2.14±0.022	53.2±1.3	27.17	26.03
	98.83±0.025	3.01±0.028	54.4±1.1	27	27.4
8.01±0.05	97.87±0.026	1.66±0.02	48.7±0.8	27.21	21.49
8.53±0.07	96.99±0.023	1.17±0.016	47.9±1.2	27.71	20.19
	97.32±0.027	1.32±0.019	47.9±1.3	27.53	20.37
	97.64±0.028	1.5±0.018	48.3±1.4	27.34	20.96
	97.87±0.026	1.66±0.02	49.6±1.1	27.23	22.37
	98.07±0.027	1.83±0.023	50.2±1.3	27.1	23.1
	98.16±0.028	1.92±0.027	51.2±1.2	27.05	24.15
	98.30±0.027	2.08±0.029	52.4±1.4	26.96	25.44
	98.33±0.028	2.12±0.03	53.1±1.1	26.89	26.21
9±0.06	97.87±0.026	1.66±0.02	48.9±0.9	27.21	21.69

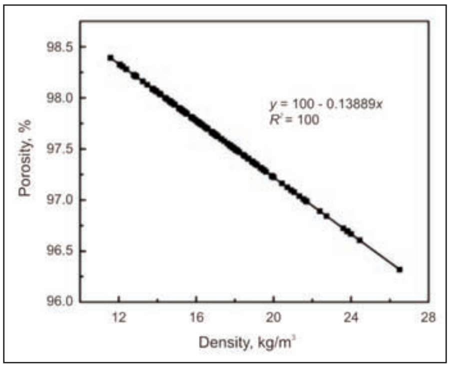

Fig. 4. The relation of density and porosity

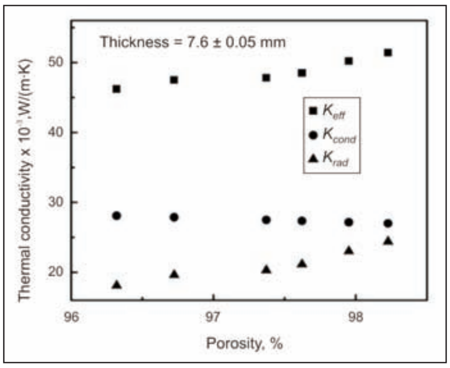

Fig. 5. Effect of porosity on thermal property

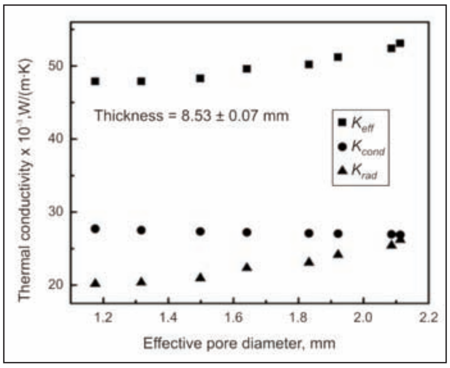

Fig. 6. Effect of effective pore diameter on thermal property

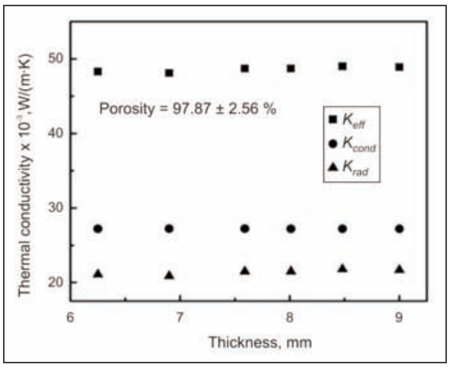

Fig. 7. Effect of thickness on thermal property

porosity. The effective thermal conductivity should finally be close to the conductivity of the air. However, the experiment results showed big differences with the above speculation, which suggested that the heat radiation must contribute appreciably to the apparent thermal conductivity of nonwoven fabrics. Figure 5 shows the effective thermal conductivity of nonwoven fabrics and the contributions of conductive and radiative heat transfer to the total heat transfer. Conductivity heat transfer declined with the increase of porosity due to the very low thermal conductivity of air, but the radiative heat transfer got intensive when the void space inside nonwoven fabric became larger. The effective thermal conductivity of nonwoven fabrics increased as the increase of porosity because the increased contribution from radiation was larger than the loss from heat conduction. Furthermore, the contribution of radiative heat transfer was smaller than the conductive heat transfer to the effective heat transfer.

Effect of effective pore diameter on thermal property

It is well known that the heat radiation through air is much more intensive than through other materials. Therefore, the radiative heat transfer would be more and more intensive with the increase of the pore size inside nonwoven fabric. When keeping the thickness of nonwoven fabrics as constant, the effective thermal conductivity increased with the increase of pore size. The increased effective thermal conductivity is due to the increased radiative heat transfer (as is shown in figure 6). The heat transfer ratio by conduction and radiation were almost the same when the effective pore diameter was bigger than 2 mm.

Effect of thickness on thermal property

If the porosity of nonwoven fabrics were kept constant, the change of thickness had no significant impact on the conductive heat transfer and the radiative heat transfer. If the porosity was kept constant, the nonwoven fabrics could be taken as a homogenous porous material whose thermal conductivity would not be changed as the change of thickness.

CONCLUSIONS

The thermal property of the nonwoven fabric with various structural parameters was investigated in this study, some conclusions can be made based on the results, (1) both the conductive heat transfer and radiative heat transfer contributed to the thermal property of nonwoven fabrics; (2) the effective thermal conductivity of nonwoven fabric increased with the increase of the porosity and the pore size, however, the thickness did not have a significant influence on thermal conductivity of nonwoven fabric; (3) the ratio of radiative heat transfer to total heat transfer increased with the increase of pore size; (4) the ratio of radiative heat transfer was smaller than the ratio of convective heat transfer when the pore size was smaller than 2 mm. Owing to the importance of surrounding conditions and experimental conditions, more experiments with various conditions are still needed in order to understand the heat transfer mechanisms more comprehensively.

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Authors:

Phd. GUOCHENG ZHU
Associate Prof. DANA KREMENAKOVA
Prof. JIRI MILITKY
Phd. YAN WANG
Associate Prof. RAJESH MISHRA
Technical University of Liberec
Faculty of Textile, department of material engineering
Studentská 1402/2, Liberec, Czech Republic
e-mail: gchengzhu@gmail.com; dana.kremenakova@tul.cz; jiri.militky@tul.cz;
yan.wang@tul.cz; rajesh.mishra@tul.cz

A comparison between two types of textile meshes and the intra-abdominal pressure values after rives-stoppa incisional hernia repair

VLAD DENIS CONSTANTIN
BOGDAN SOCEA
ELVIRA NICA
SIMONA BOBIC
ALEXANDRU CARÂP
STELA CARMEN HANGANU
ION PAUN

REZUMAT – ABSTRACT

Comparație între două tipuri de proteze textile și valorile presiunii intra-abdominale după procedeul Rives-Stoppa în cura chirurgicală a eventrațiilor

Cura chirurgicală a herniilor incizionale, mai ales în situația defectelor parietale mari, poate duce la creșterea presiunii intra-abdominale (IAP) sau cauza sindrom de compartiment abdominal (ACS). Societatea Mondială a Sindromului de Compartiment Abdominal identifică repararea herniilor incizionale mari ca factor de risc pentru dezvoltarea unui ACS. Tehnica Rives-Stoppa, o procedură protetică, este considerată de mulți chirurgi standardul in tratamentul herniilor incizionale. Au fost analizate 53 de intervenții chirurgicale folosind polipropilena sau ePTFE. S-a investigat efectul pe care îl au cele două materiale asupra IAP postoperator. S-au luat în calcul scorul Societății Americane a Anesteziștilor (ASA), indicele de masă corporală (BMI) și mărimea defectului parietal. Tipul de material ales, polipropilenă sau ePTFE nu a influențat IAP postoperator în niciuna din situațiile analizate.

Cuvinte cheie: presiune intra-abdominală, hernii incizionale

A comparison between two types of textile meshes and the intra-abdominal pressure values after Rives-Stoppa incisional hernia repair

Repair of incisional hernias, especially for large abdominal wall defects, can cause increases in intra-abdominal pressure (IAP) or cause abdominal compartment syndrome (ACS). The World Society of Abdominal Compartment Syndrome lists massive incisional hernia repair as a risk factor for the development of ACS. Rives-Stoppa repair, a prosthetic procedure, is considered by many surgeons as the gold standard for incisional hernia repair. 53 surgical procedures using polypropylene or ePTFE for repairing were analyzed. The aim of our study was to investigate whether textile material choice influences postoperative IAP values. American Society of Anesthesiology (ASA) score, patient body mass index (BMI) and defect size were considered for the comparison. The choice of material did not influence postoperative IAP values in any of the investigated circumstance.

Key-words: intra-abdominal pressure, incisional hernia

The incidence of incisional hernias after midline laparotomies ranges between 10–20% [1]. Their evolution registers serious complications, such as pain, bowel obstruction, incarceration and strangulation, small bowel fistula [2]. The repair of incisional hernias has results that vary widely. A number of surgical techniques are described and clear consensus is not reached, choice of procedure being influenced by numerous factors, such as surgeon's knowledge and skill, preference for a certain procedure within a surgical center, and availability of textile materials. There is consensus, however, that suture techniques will result in more recurrences, the most important outcome, when compared with procedures that use textile meshes. This result and the recent increase in the number of incisional hernias that are managed by laparoscopic procedures has lead to a drastic increase in the use of prosthetic meshes for incisional hernia repair. One of the recent debates is regarding the best abdominal wall region for the prosthetic mesh placement [3, 4]. However, the Rives-Stoppa procedure, the sub-lay technique, has yielded good results [5, 6] and is considered the current gold standard.

Incisional hernia repair can be associated with a relatively high index of postoperative, short- or long-term, complications. These include wound infection, bowel fistula, seroma, chronic postoperative pain, and recurrence [7]. A short-term postoperative complication is the increase in abdominal pressure and, eventually, the development of abdominal compartment syndrome (ACS) [8]. The updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome [9] list several risk factors for the development of ACS that are in direct relation with incisional hernia repairs. These are: (a) abdominal surgery which results in diminished abdominal wall compliance; furthermore, incisional hernia repair is often accompanied by a degree of adhesiolysis and subsequent bowel wall edema which, in turn, leads to increased intra-abdominal contents, another condition listed as a risk factor;

(b) massive incisional hernia repair is in itself listed as a risk factor for ACS. The guideline does not make any differentiations regarding the choice of surgical procedure of textile mesh.
ACS is a life threatening condition that requires fast intervention, has a very high mortality and is frequently overlooked. It is defined as a sustained intra-abdominal pressure (IAP) higher than 20 mmHg that is associated with new organ dysfunction/failure. Intra-abdominal hypertension (IAH) is defined by a sustained or repeated pathological elevation in IAP higher than 12 mmHg. IAP is the steady-state pressure concealed within the abdominal cavity [9]. Normal IAP is normally below 10 mmHg, with higher values found typically in the critically ill (Intensive Care Unit patients).
The aim of this study is to compare two types of textile materials, polypropylene and expanded polytetrafluoroethylene (ePTFE), placed in the sublay, Rives-Stoppa manner, for the repair of large incisional hernias, in regards to their effect on intra-abdominal pressure values and development of IAH or ACS.

EXPERIMENTAL PART

53 surgical procedures performed for incisional hernias were analysed. Requirements for study inclusion were a large midline abdominal wall defect, primary incisional hernia, and uncomplicated hernias. Large abdominal wall defects were defined as defects with a maximal transverse diameter larger than 7 cm. All surgical procedures were performed in the sublay technique using a ePTFE in 27 cases and a polypropylene mesh in 26 cases. Critically ill patients and patients presenting with other risk factors for developing ACS (as listed in the consensus paper of World Society on Abdominal Compartment Syndrome) were excluded from the study. Patients with a baseline IAP higher than 5 mmHg were also excluded.
Many surgeons consider the Rives-Stoppa procedure the gold standard for the open treatment of incisional hernias (figure 1). It achieves both an anatomic and a prosthetic repair. The anatomical repair restores the structure of the abdominal wall, without bridging, while mesh placement solves the biological defect. The rationale of the procedure exceeds those of the onlay and inlay repairs. The onlay procedures expose the patient to the formation of subcutaneous seromas and mesh infection while inlay techniques exposes the patient to the risk of adhesion formation to surrounding structures. The procedure consists of an anatomical plasty of the posterior lamina of the rectus sheath, implantation of the mesh in the newly formed retromuscular space, and plasty of the linea alba that concludes the repair and separates the mesh from the subcutaneous tissue.
The two synthetic materials used for repair were polypropylene (figure 2) and ePTFE (figure 3). Polypropylene is a polymer discovered by Giulio Nata in 1956. Its repetitive monomer is made of two saturated carbon atoms, one with hydrogen atoms and one with a hydrogen atom and a methyl group. Its molecular weight is 100000 Da. Its resistance is similar to that of iron while only 1/8 of iron's density. It is resistant to biological degradation and relatively

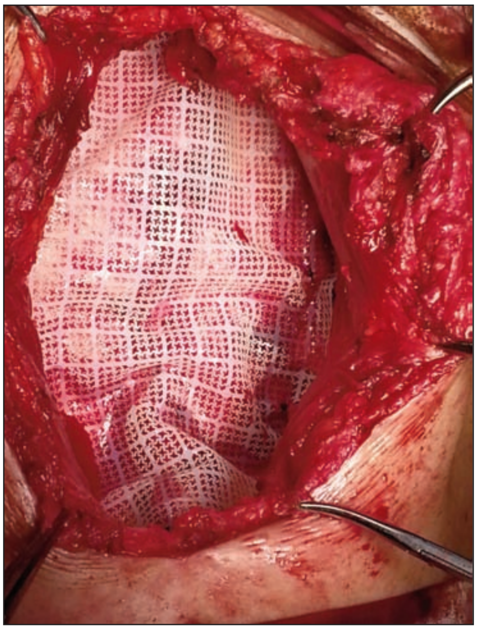
Fig. 1. ePTFE mesh in retro-muscular space, Rives-Stoppa procedure

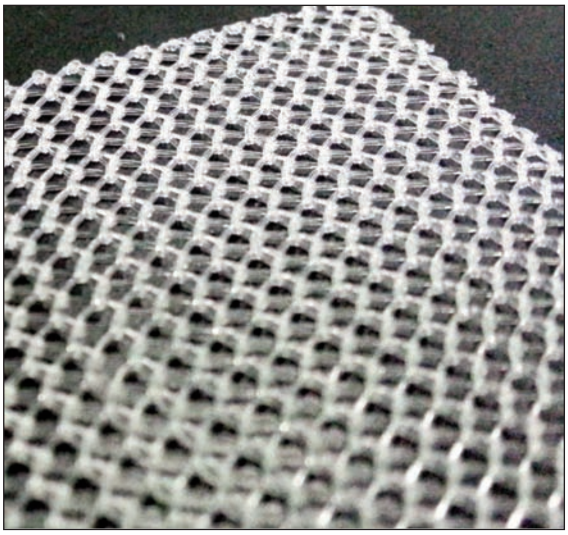
Fig. 2. Polypropylene mesh

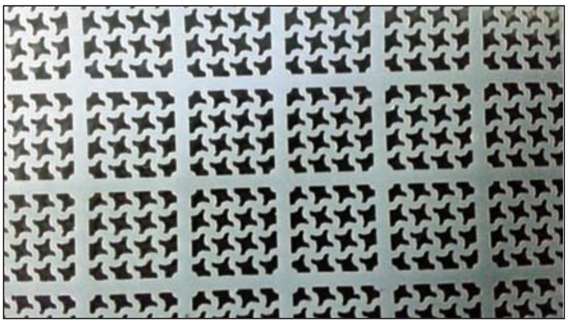
Fig. 3. ePTFE mesh

impermeable to water vapors. It does not suffer from enzyme digestion in vivo. Its structure gives it a very good resistance to high temperatures (up to 168°C), and so, it can be easily sterilized without damaging its properties. Polypropylene is made of a linear series of long and flexible chains. The reduced quantity of catalyzers and additives necessary for polypropylene extraction and production are the main reason for its biocompatibility. The resulting thread is continuous, monofilament, and not absorbable. Its thickness, together with the different weaving patterns, leads to the different types of commercially available meshes. The meshes are woven resulting in vertical and cross-like rows. Pore dimension and wire thickness significantly impact material rigidity, and they influence the degree of scar tissue formation. The mesh used in this study is the Prolene mesh with a thickness of 0,027 cm and a weight of 0,0743 g/cm^3. ePTFE is a completely fluorinated polymer. Also known as Teflon, its using was quickly widespread mainly as a material covering kitchen apparel. Being highly chemically inert with an extremely smooth surface, that does not adhere, it was quickly assimilated into medical practice and studied as a potential biomaterial for surgical use. After several experimental trials ePTFE was introduced in clinical practice in 1972 as a vascular prosthesis used for by-pass surgery. Its widespread use in vascular surgery proved its excellent biological qualities and it began to be used in abdominal wall prosthetic surgery. It is a soft, smooth, microporous material. The microporous aspect is accomplished by small nodules bound together by small fibers. The patches used in this study have an inter-nodal distance of 17 μm. The multidirectional arrangement of the fibers ensures an equally distributed material resistance. Mechanical analyses showed that it retains tensile properties when exposed to acids, bases, heat, organic solvents or bodily fluids.

The methods used for the measurement of the IAP can be direct and indirect. The direct technique represents the estimation of IAP by placing an intraperitoneal catheter. This method, being an invasive one, cannot be used in most clinical cases. Many simple and less invasive indirect methods are most often used in routine clinical practice for IAP estimation. These methods include measurement of pressure in hollow organs of the abdomen or pelvis cavity such as bladder, stomach, intestine, and uterus. Some of the indirect techniques are the measurement of IAP via nasogastric tube and the $PaCO_2$ and $EtCO_2$ gradient that can reflect changes in respiratory function. The intra-bladder technique, using a Foley catheter, has been referred to as the “gold” standard for IAP estimation in the consensus definitions report of the World Society on Abdominal Compartment Syndrome. The intra-bladder pressure measurement can be unreliable in case of low intrinsic bladder compliance (chronic renal failure and anuria), and bladder trauma.

The method used in this study for the determination of the IAP was the Harrahill technique, a manometric technique that is very easy to use. IAP can be obtained in a patient without a pressure transducer connected by using his own urine as transducing medium, first described by nurse Harrahill. One clamps the Foley catheter just above the urine collection bag. The tubing is then held at a position of 30 to 40 cm above the symphysis pubis and the clamp is released. The IAP is indicated by the height (in cm) of the urine column from the pubic bone. The meniscus should show respiratory variations. This rapid estimation of IAP can only be done in case of sufficient urine output. In an oliguric patient 50 ml saline can be injected as priming. It is a cheap method, suitable for resource limited countries. However, care must be taken to ensure that the urinary catheter system used has an air inlet to avoid the generation of erroneously high pressures due to a closed system. If no air-inlet is available the drainage system needs to be disconnected probably increasing the risk of infection. When using this technique a conversion has to be made from cm H_2O to mm Hg and introduces the potential risk for error.

We gathered demographical data, clinical data and measured IAP on all the patients. IAP was measured preoperatively, immediately following skin closure, on postoperative day one and on postoperative day two. These time points will be referred to as T0, T1, T2, and T3 respectively. We analyzed changes in IAP between the two types of meshes and also with increase in size defect, American Society of Anesthesiology (ASA) score and Body Mass Index (BMI).

RESULTS AND DISCUSSIONS

All 53 patients were admitted and operated in our department in the period May 1st 2013 – August 25th 2014. The study population consisted of 37 female patients and 16 male patients, with a mean age of 53 years. 42 patients were from an urban environment and 11 patients were from a rural one. 39 patients had an abdominal wall defect greater than 10 cm and 14 patients had defects ranging from 7 to 10 cm. 28 patients had a BMI greater than 30. The patients were randomly assigned to receive either a polypropylene mesh or a ePTFE mesh. 27 patients received a polypropylene mesh and 26 received ePTFE. IAP was measured using the Harrahill bladder technique using the time points stated earlier. Follow up for the patients continued in our regular institutional fashion but postoperative outcomes and complications other than IAP will not be discussed as they do not make the object of the current research. We compared results for the two types of meshes and correlated them with defect size, ASA score, and size of abdominal wall defect. Results are shown in figures 4 – 7.

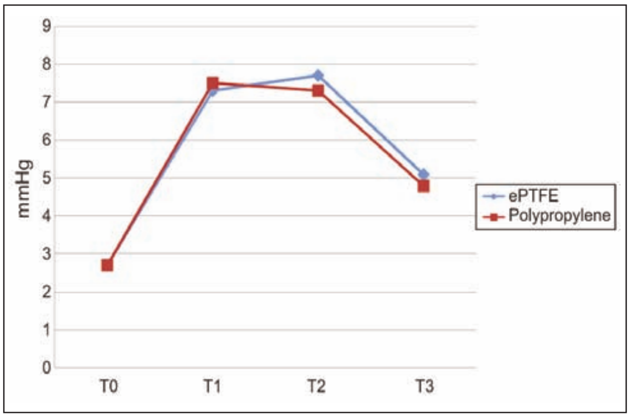

Fig. 4. IAP when comparing the two types of meshes

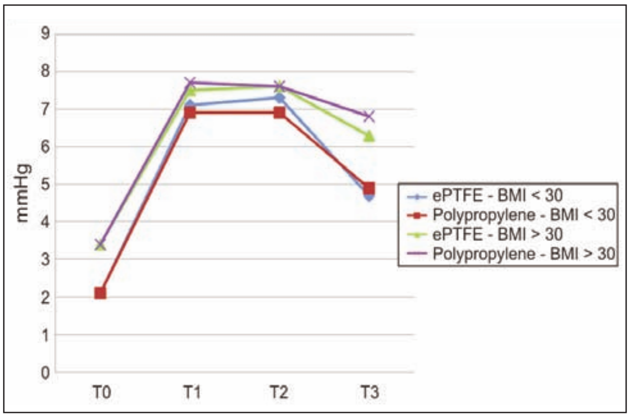

Fig. 6. IAP type of textile material, BMI

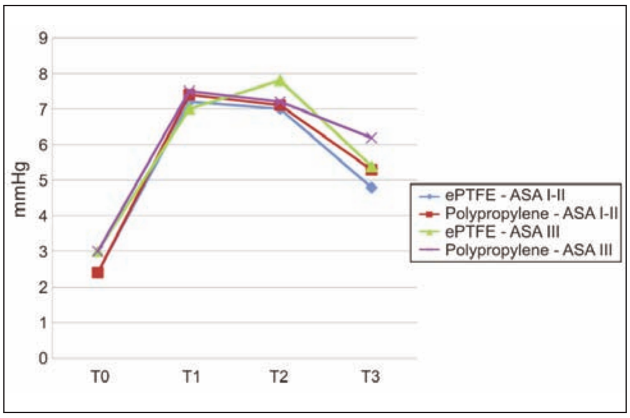

Fig. 5. IAP type of textile material, ASA score

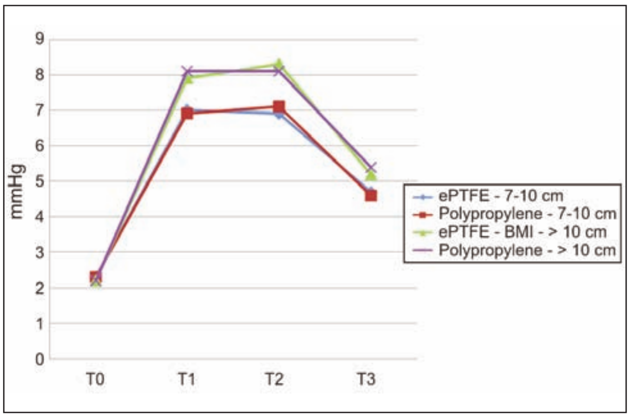

Fig. 7. IAP type of textile material, size of the defect

As can be observed from figure 4 that compares IAP results in the above mentioned time points there is an increase in IAP in the postoperative period that recedes in the second postoperative day (T4). The reduction in visceral edema and increasing compliance of the abdominal wall are possible explanations for this phenomenon. It can also be noted that there are no differences in IAP variations between the two types of materials. Figure 5 compares the IAP curves for patients with different ASA scores. While baseline measurements (T0) show a difference in IAP between ASA I-II and ASA III patients, ASA III patients presenting with slightly higher values, postoperative results yield no statistically significant results. Also the baseline measurement, considering the small population and uneven patient distribution regarding ASA score (17 ASA III patients), prevents us from interpreting the baseline values as significant. Critically ill patients have a higher baseline IAP so it can be inferred that as ASA score increases the IAP should increase as well. Figure 6 compares IAP curves for different patients BMI. Increased BMI is in itself a risk factor for the development of ACS [9]. The curves have the same design but an increase in IAP is observed in both baseline and postoperative measurements. Figure 7 compares curves for different size defects. There is a clear increase in postoperative IAP for patients with defects greater (maximal transverse diameter) than 10 cm.

CONCLUSIONS

No cases of IAH or ACS were observed in the studied population. It can be concluded that elective Rives-Stoppa repair for uncomplicated incisional hernias, for patients with a maximum ASA score of III, using polypropylene or ePTFE is relatively safe regarding IAH or ACS development. It has to mentioned that while defects were large (> 7 cm) no defect had a maximal transverse diameter greater than 15 cm. It can also be noted that no differences were noticed in IAP variation following surgery between the two types of textile materials. Differences did not appear between the two materials regardless of ASA score, patient BMI or size of the defect. Regarding abdominal wall compliance polypropylene and ePTFE have the same postoperative behavior. Even so, IAP variations were recorded. Our strong opinion is that IAP should be measured following the repair of large abdominal wall defects at least for the first 48 hours. If IAP levels continue to increase or show values higher than 12 mmHg further measurements should be done. The World Society of the Abdominal

Compartment Syndrome recommends standardized bladder techniques every 8 hours for patients with risk factors. Polypropylene and ePTFE have a similar behavior when used to repair large incisional hernias in a Rives-Stoppa manner regarding postoperative IAP levels.

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Authors:

Associate prof. dr. VLAD CONSTANTIN
Assistant prof dr.. BOGDAN SOCEA
Prof. dr. ELVIRA NICA
Dr. SIMONA BOBIC
Assistant prof. ALEXANDRU CARÂP
„Carol Davila” University of Medicine and Pharmacy Bucharest
„Sfântul Pantelimon” Emergency Clinical Hospital Bucharest
340-342 Pantelimon street, Bucharest
e-mail: alexandru_carap@hotmail.com; contact@urgentapantelimon.ro

Prof. dr. HANGANU STELA CARMEN
"Gr. T. Popa" University of Medicine and Pharmacy Iasi
Email: carmenhanganu1957@yahoo.com

Associate prof. dr. ION PĂUN
Craiova University of Medicine and Pharmacy
e-mail: dripaun@gmail.com

Water footprint and carbon footprint reduction in textile's waste recycling

GAI-HONG WU
LAI-LI WANG
XUE-MEI DING
XIONG-YING WU
SHU-QIANG LIU
SUNHILDE CUC

REZUMAT – ABSTRACT

Reducerea amprentei de apă și de carbon în reciclarea deșeurilor textile

Reducerea amprentei de apă și de carbon este o preocupare importantă pentru dezvoltarea durabilă a industriei textile globale. Reciclarea deșeurilor textile și de îmbrăcăminte reprezintă una dintre cele mai promițătoare metode de reducere a amprentei de apă și de carbon din lanțul de aprovizionare cu textile și îmbrăcăminte. În această lucrare au fost demonstrate potențialele beneficii ale reciclării deșeurilor textile și de îmbrăcăminte, făcându-se comparație între două tipuri de blugi, unul realizat din fibre de bumbac mixt (70% fibre de bumbac virgin și 30% fibre de bumbac reciclat) și celălalt realizat din fibre de bumbac virgin 100%, în conformitate cu metodologiile referitoare la amprenta de apă și de carbon. Din rezultatele de simulare, s-a constatat că amprenta de apă creată pentru producția unei perechi de blugi din fibre de bumbac mixt a fost cu 26,18% mai mică decât cea utilizată pentru producția de blugi din fibre de bumbac virgin 100%. Amprentele de apă au dus în special la o diminuare a etapelor de producție și de vopsire a fibrelor. S-a observat o reducere mai mică a amprentei de carbon în comparație cu amprenta de apă. Renunțarea la vopsire a contribuit în mare măsură la reducerea amprentei de carbon în producția de blugi realizați din fibre de bumbac mixt.

Cuvinte-cheie: amprentă de apă; amprentă de carbon; reducere; reciclarea deșeurilor textile

Water footprint and carbon footprint reduction in waste textiles recycling

Trimming down of water footprint and carbon footprint is an important concern for sustainable development of the world's textile industry. Recycling of textiles and clothing waste is one of the most promising approaches in minimizing water footprint and carbon footprint in the textiles and clothing supply chain. In this paper, the potential benefits of textiles and clothing waste recycling were demonstrated with a comparison of two kinds of jeans made of mixed cotton fiber (70% virgin cotton fiber and 30% recycled cotton fiber) and 100% virgin cotton fiber according to water footprint and carbon footprint methodologies. From the simulation results, it was noticed that water footprint created in the production of a pair of jeans made of mixed cotton fiber were 26.18% less than that of jeans made of 100% virgin cotton fiber. The water footprints mainly reduced in the phases of fiber production and dyeing. Carbon footprint reduction was less prominent compared to water footprint. Omitting of dyeing contributed largely to the reduction of carbon footprint in the production of jeans made of mixed cotton fiber.

Keywords: water footprint; carbon footprint; reduction; textile waste recycling.

INTRODUCTION

Textiles and clothing are primary needs of human beings. Global population growth and improvements in living standards have caused an increase in consumption of textiles and clothing. For example, the production volume in the world's textile industry in 2011 rose by 6.4% to 85.9 million tonnes [1]. Unlike food products that can be digested after consumption, textiles and clothing become solid waste when they are thrown away after they are worn out or are out of fashion. Besides, industrial production of textiles and clothing also generates large quantities of textiles waste. Therefore, more consumption means more production and more waste.

Textiles and clothing waste comprise 1–5.1% of municipal solid waste compositions in the world regions [2] and have become a universal concern for both developed and developing countries. For example, 4–5% of the municipal solid waste stream is composed of textiles and clothing waste in UK [3], 7% of the Kaikoura landfill in New Zealand [4], 4.95% in US [5] and 1.3% in Beijing, China [6].

Textiles and clothing production and consumption cause environmental impacts such as waste water discharge, greenhouse gases (GHGs) emissions, etc. The increasing quantities of textiles and clothing waste will aggravate the impacts if they are not disposed properly and adequately. Textiles and clothing waste occupy land resource due to the fact that natural degradation of chemical fibers (*e.g.*, polyester fiber, polyurethane fiber) is very difficult. Therefore, textiles and clothing waste recycling will gain many environmental benefits such as conservation of natural resources, reduced fresh water appropriation, waste water discharge, energy consumption, carbon dioxide (CO_2) emissions, and waste going to landfills.

Research on textiles waste recycling is gaining more and more attention in recent years. Woolridge *et al*. [3] compared energy footprint between reuse/recycling of donated textiles and textiles waste made of virgin materials. Upasani *et al*. [7] studied the suitability of the polymer, wherein part of the virgin raw-materials during preparation of polyester was replaced by washed post-consumer polyester, for melt spinning and drawing of polymer into yarn. Altun [8] predicted the waste quantity generated in households and in industrial facilities in Turkey via surveys, factory research and official databases. Muthu et al. [9] investigated carbon footprint reduction in the recycling of textile materials.

In this study, we aim to compare the potential benefits of textiles and clothing waste recycling according to water footprint and carbon footprint methodologies. This article makes an attempt to exemplify reduced fresh water appropriation, waste water discharge and GHGs emissions at different stages in a stated life cycle of a pair of jeans made of mixed cotton fiber, wherein part of virgin cotton fiber is replaced by recycled cotton fiber. Field research and relevant literature were reviewed in order to obtain high quality data to clearly portray this situation.

METHODOLOGY AND MATERIAL

Water footprint methodology

The concept of water footprint, a multi-dimensional indicator measuring water resources appropriation by source and polluted volumes by type of pollution, was first introduced in 2002 [10]. Generally, water footprint has three components: green water footprint, blue water footprint and grey water footprint [11]. The green water footprint refers to the consumption of rainwater that does not become run-off. The blue water footprint refers to the consumption of surface and groundwater resources. The grey water footprint is an indicator of water pollution. It is defined as the volume of fresh water that is required to assimilate the load of pollutants to a given natural background concentrations and existing ambient water quality standards.

For textiles and clothing that are made of natural fibers (*e.g.*, cotton, hemp), water resource is consumed for irrigation and industrial production. Irrigation water includes rainwater, surface water (*e.g.*, river water, lake water) and groundwater. Surface water and groundwater occupy a dominant proportion of water resource appropriation in industrial production of textiles and clothing. Thus, green water footprint (WF_{green}, in l/pc (liter per production cycle)) and blue water footprint (WF_{blue}, in l/pc) are equal to:

$$WF_{green} = RainWarerAppropriation \quad (1)$$

$$WF_{blue} = SurfaceWaterAppropriation + GroundWaterAppropriation \quad (2)$$

Industrial production of textiles and clothing generates large quantities of effluents that contain many pollutants (*e.g.*, salts, total suspended solids, chemical oxygen demand, nutrients and toxic compounds) [12]. Grey water footprint (WF_{grey}, in l/pc) is the indicator of water pollution. It can be calculated with the equation (3):

$$WF_{grey} = \max\left(\frac{L^k}{c^k - c^k_{nat}}\right) \quad (3)$$

where:

WF_{grey} is grey water footprint, L^k (in t/pc) is the load of the pollutant *k* in textiles effluents, c^k (in mg/l) is the concentration of pollutant *k*, c^k_{nat} (in mg/l) is the natural concentration of pollutant *k* in the receiving water body. *max* means WF_{grey} is determined by the most critical pollutant that is associated with the largest pollutant-specific grey water footprint. Generally, c^k is larger than c^k_{nat}.

Carbon footprint methodology

Carbon footprint (*CF*) has become the latest environment terminology to be used frequently in the research fields of global climate change. Product carbon footprint (*PCF*) is a measure of the amount of GHGs emissions through the life cycle of a product. It is often expressed in terms of carbon dioxide equivalent (CO_2e) to shown the global warming effect of the generated GHGs [13]. For a specific product, *PCF* can be calculated with the equation (4):

$$PCF = \sum M_i \times f_i \quad (4)$$

where:

M_i (in mass, such as kg, l, *etc.*) is the quantity of material *i* appropriated for the production of the researched product, f_i (in CO_2 e/mass, such as CO_2e/kg, CO_2e/l, *etc.*) is the emission factor of material *i*.

MATERIALS

Water footprint and carbon footprint methodologies are used to portray reduced fresh water appropriation, effluents discharge and GHGs emissions during the manufacture of jeans made of mixed cotton fiber compared to virgin cotton fiber. The system boundaries were defined starting from cotton cultivation at the farms, then considering the other production phases, finally package of jeans (see figure 1).

In this study, waste cotton fabrics, such as rag, wrong cut patterns, mainly came from the cutting procedure of jeans manufacture. According to factory's practices on yarn spinning with recycled cotton fiber, the qualities of yarn and fabric decrease with the increasing proportion of recycled cotton fiber in the mixed cotton fiber. It is the best combination when the proportion of recycled cotton fiber is 30% considering both the economic benefits and requirements of products (*i.e.*, yarn, fabric and jeans) qualities. Waste cotton fabric in this study had been dyed. Therefore, the new spun yarn with recycled cotton fiber had a specific color and did not need further dyeing and the same applied to the newly woven fabric.

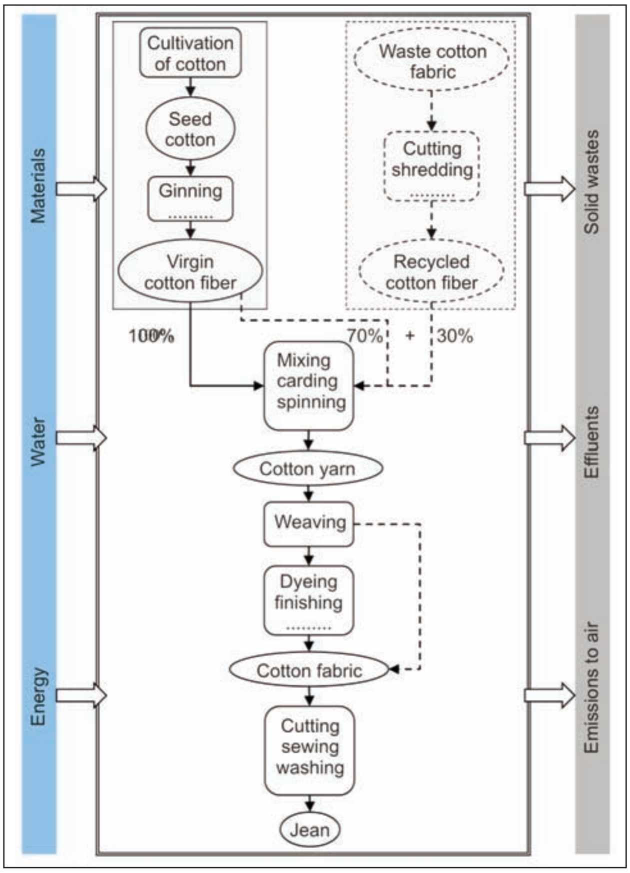

Fig. 1. System boundaries and manufacture processes of jeans

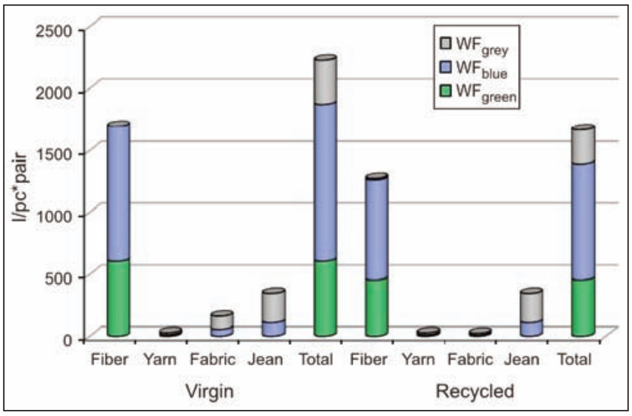

Fig. 2. Water footprints of jeans made of virgin and recycled cotton fibers

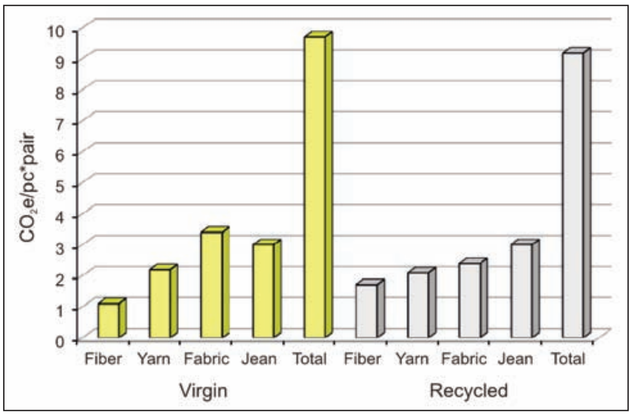

Fig. 3. Carbon footprints of jeans made of virgin and recycled cotton fibers

RESULTS AND DISCUSSION

The functional unit in this research is one pair of jeans. The collected data were divided into two different groups: primary and secondary data. The primary data were collected directly from the companies involved in different phases of production process. Secondary data were extracted from relevant references (reference [14] – [20]). Water footprints and carbon footprints of jeans made of 100% virgin cotton fiber and mixed cotton fiber (*i.e.*, 70% virgin cotton fiber and 30% recycled cotton fiber) were calculated with the collected data according to equation (1)–(4). The results are explained in figure 2 and figure 3.

Figure 2 shows that the total water footprint of a pair of jeans made of mixed cotton fibers is less than that made of 100% virgin cotton fiber, with a reduction of 26.18%. The water footprints reduction mainly occurred in fiber production phase (*i.e.* from cotton cultivation to yarn spinning), then in fabric dyeing phase.

From a global perspective, it is estimated that about 50% of the world's cotton receives irrigation [14]. In one place the crop may be completely dependent on irrigation, and in another, the crop may require only supplemental irrigation with most water coming from rainfall. Whether by rainfall or through irrigation, cotton's share of the global agricultural water footprints is approximately 3% [21]. In this case study, cotton cultivation had large green water footprint and blue water footprint. The replacement of virgin cotton fiber with recycled cotton fiber results in the reduction of water footprint in fiber production phase as recycling of waste cotton fabric to fiber had little water footprint. Dyeing is undoubtedly a fundamentally polluting process. For example, to get the blue color in a pair of jeans, indigo dye is generally applied to the cotton yarn and fabric. Synthetic indigo dyes on the market today are usually sulfur based and are a very enticing choice for those factories trying to cut excess expenses as they are much cheaper [22]. Washing is generally a necessary process to bring particular properties, such as faded look, to jeans. However, it is also a fundamentally polluting process. The materials employed in the washing process of jeans cover glacial acetic acid, ferment powder, soda, phosphate, *etc*. Washing waste water of jeans contains a large amount of suspended solids, dissolved salts, highly fluctuating pH and high COD concentration with poor biodegradability [23]. These two procedures use water extensively. They not only consume large quantity of fresh water, but also emit effluents with high concentrations of chemical pollutants, causing large blue water footprint and grey water footprint. Omitting dyeing is the reason behind water footprint reduction in fabric production using mixed cotton fiber. The two kinds of jeans have equal water footprints in jeans manufacture phase as they undergo the same processes include washing.

From figure 3, it was understood that a pair of jeans made of mixed cotton fiber created less carbon footprint compared to a pair of jeans made of 100% virgin cotton fiber. The carbon footprint reduction mainly occurred in the fabric production phase though the carbon footprint of recycled cotton fiber production was larger than that of virgin cotton fiber production.
For any crop, there exists a process, so called photosynthesis, which converts CO_2 into organic compounds such as sugar by consuming energy from sunlight in the presence of water. Therefore, the carbon footprint is negative in this aspect. However, both respiration and decomposition of the fertilizer in the field emit GHGs. Besides, energy consumption for irrigation, harvesting and post-harvest activities also causes GHGs emissions. Industrial production activities, such as ginning, shredding, are electricity intensive procedures. Thus, the carbon footprint of recycled cotton fiber production is larger than that of virgin cotton fiber.
In dyeing phase, electricity is consumed to motive dyeing machines; coal and natural gas are burned to create heat. Energy (*e.g.*, electricity, coal, natural gas) consumption is a major source of GHGs emissions. Therefore, the carbon footprint of mixed cotton fiber fabric is decreased to some extent though omitting the dyeing procedure.

CONCLUSION

Fresh water appropriation, effluents discharge and GHGs emissions along the textiles and clothing supply chain are three of the most important concerns for the sustainable development of the world's textile industry. Recycling of textiles and clothing waste can not only change solid wastes to new materials, but also minimize water footprints and carbon footprints in the production of textiles and clothing.
This paper presents an analysis of water footprints and carbon footprints reduction in the production of two kinds of jeans. From the results, it was noted that the total water footprint created in the production of a pair of jeans made of mixed cotton fiber were 26.18% less than that of jeans made of 100% virgin cotton fiber. Water footprints mainly reduced in the phases of fiber production and dyeing. From carbon footprint analysis, the reduction was not so prominent compared to water footprint. The fiber production phase of mixed cotton fiber even created larger carbon footprint than that of virgin cotton fiber. Omitting dyeing contributed largely to the reduction of carbon footprint in the production of jeans made of mixed cotton fiber.

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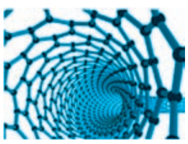
Authors:

GAI-HONG WU[1,2,5], LAI-LI WANG[3], XUE-MEI DING[1,5],
XIONG-YING WU[4,*], SHU-QIANG LIU[2], SUNHILDE CUC[6]

1. Fashion Institute of Design, Donghua University,
Shanghai, 200051, China;
2. Textile Engineering College, Taiyuan University of Technology,
Taiyuan, 030024, China;
3. Fashion College, Zhejiang Sci-Tech University,
Hangzhou, Zhejiang, 310018, China;
4. Shanghai Entry-exit Inspection and Quarantine Bureau,
Shanghai, 200135, China;
5. Key Laboratory of Clothing Design & Technology (Donghua University),
Ministry of Education, Shanghai 200051, China
6. University of Oradea, Department of Textile Engineering
Oradea, Romania

*__Corresponding author:__
XIONG-YING WU
e-mail: wuxy@shciq.gov.cn



Mathematical modeling of water permeability of nonwoven fabrics for geotextiles

ROMULUS BULACU
IOAN FILIP
DANIELA FARIMA
RALUCA MARIA AILENI

REZUMAT – ABSTRACT

Modelarea matematică a permeabilității la apă pentru materialele nețesute utilizate pentru geotextile

Permeabilitatea la apă este una dintre cele mai importante caracteristici funcționale ale geotextilelor, fiind prezentă în mod obligatoriu în fișele pentru orice tip de geotextil. Această caracteristică se regăsește în standarde sub denumirea de "Ge-Te-Flow K". Prin intermediul modelării matematice se poate studia influența parametrilor tehnologici asupra calității. Utilizând graficele 2D și 3D se poate realiza acest obiectiv. În cadrul acestei lucrări se consideră că parametrii tehnologici – densitatea de interțesere și adâncimea de pătrundere a acelor – sunt variabile independente care au o influență majoră asupra calității geotextilelor analizate.

Cuvinte cheie: permeabilitate la apă, modelare matematică, geotextil, grafic 3D.

Mathematical modeling of water permeability of nonwoven fabrics for geotextiles

Water permeability is one of the most important functional characteristics of the geotextiles, being mandatorily marked in the factsheets of any type of trademark geotextile. This feature is found in the standards under the denomination of "Ge-Te-Flow K". The mathematical modeling of the water permeability of geotextiles examines the influence of the technological parameters quality. Using the 3D and 2D graphics, it may achieve this purpose. In this paper it is considered that the technological parameters – interweaving density and depth of penetration – are independent variables which have a huge influence on the quality of the analyzed geotextiles

Key-words: water permeability, mathematical model, geotextile, 3D graphic.

INTRODUCTION

The technical textiles represent the sector of textile industry with the most dynamic evolution. The highest developing rates are recorded in geosynthetic materials, which include geotextiles, geomembranes, geogrids, geocomposites and geocells. According to ASTM D4439-87 [1], a geotextile material is any permeable textile material used for foundations, soil, rocks, earth, or other geotechnical engineering material, like an integral part of a synthetic product, structure or system. Generally, the geosynthetic materials are planar structures obtained from polymers (synthetic fibers) that are used together with stones, rocks, gravel and earth ground works [1, 2, 3]. Like any material manufactured in a controlled way, a geosynthetic material has the advantage of the uniformity of properties over the entire surface and the availability on any emplacement. Due to the reinforcement function of the geosynthetic materials, it brings a considerable improvement to the mechanical properties of the soil. Therefore it allows the building of structures which are difficult or even impossible to be built. The geosynthetic materials with draining or filtering function, allow getting a draining system, without using the sorted granular material. The water permeability is one of the most important functional characteristics of geotextiles that is marked as mandatory in factsheets for any geotextile. The feature is determined by Ge-Te-Flow K Permeameter. The mathematical modeling of the geotextile's water permeability examines the influence of the technological parameters on its quality. The needle-punching process parameters have been correlated to the final properties of the nonwoven fabric by using the multiple regression technique which is shown in detail in [1, 2 and 3]. The needle-punching process parameters have been correlated with the properties of the geotextile, in this case the water permeability [2]. In order to find the influence factors that determine the obtaining of the optimal characteristics of the nonwoven material interwoven for geotextiles, the programming factorial experiments have been used with a program centered composite rotatable with two independent variables. [1, 3, 9].

EXPERIMETAL PART

The determination of the water permeability has been realized according to the standard SR EN ISO 11058:02, using the laboratory equipment for physical-mechanical tests from S.C. Minet S.A. The test conditions were as follows: number of measurements: 5; the surface of samples: 36.1 cm^2; the thickness of samples: 0.311 cm; the water temperature / Rt: 18.5 ºC / 1.037; the difference of the water level assessed: 100.9 mm (94.83 up to –6.105 mm). As dependent variables, the following were measured:

- *V* – index rate of the water flow [mm/s], reported at a temperature of 20 ºC;

• $k_{20°C}$ – index related to a temperature of 20°C [m/s];
• $k_{10°C}$ – index related to a temperature of 10°C [m/s].

The mathematical model is a regression equation, obtained grade II with two variables (equation 1) [5, 6, 7, 8].

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{11}X_{12} + \\ + b_{22}X_{22} + b_{12}X_1X_2. \quad (1)$$

where:

X_1 and X_2 – independent variables or technological parameters representative for the process of interweaving;

X_1 – interweaving density [stitches per/cm^2];

X_2 – depth penetration of the interweaving fibrous layer, [mm].

b_0, b_1, b_2, b_{11}, b_{22}, b_{12} – the coefficients of the regression equation, which by their sign and value show the degree of influence of independent variables on result Y.

The experimental data for the water permeability are shown in table 1 and table 2. It can be noted from table 1 that if the test area is constant, at a value of 36.1 cm^2, the thickness of the nonwoven material is considered the real one, respectively the measured one for each specimen. A more accurate assessment will be carried out for the characteristic if we take into account all data and structural information.

Table 1

EXPERIMENTAL DATA FOR THE WATER PERMEABILITY CHARACTERISTIC

No. exp.	X_1		X_2		V – index determined at 20 °C [m/s]	k – index [meas.] determined at:		Test surface / specimen thickness [cm^2 /cm]
	code	real [imp/cm^2]	code	real [mm]		$k_{20°C}$	$k_{10°C}$	
1	–1	173	–1	10	120.2	9.567 E^{-3}	7.379 E^{-3}	36.1/ 0.398
2	1	187	–1	10	119.1	9.316 E^{-3}	7.185 E^{-3}	36.1 / 0.391
3	–1	173	1	14	107.3	8.155 E^{-3}	6.290 E^{-3}	36.1 / 0.380
4	1	187	1	14	112.0	6.810 E^{-3}	5.252 E^{-3}	36.1 / 0.304
5	–1.414	170	0	12	111.5	8.025 E^{-3}	6.190 E^{-3}	36.1 / 0.360
6	+1.414	190	0	12	106.0	8.264 E^{-3}	6.374 E^{-3}	36.1 / 0.390
7	0	180	–1.414	9	115.5	1.062 E^{-2}	8.194 E^{-3}	36.1 / 0.460
8	0	180	+1.414	15	114.7	6.608 E^{-3}	5.096 E^{-3}	36.1 / 0.288
9	0	180	0	12	120.1	7.471 E^{-3}	5.762 E^{-3}	36.1 / 0.311
10	0	180	0	12	109.6	8.328 E^{-3}	6.423 E^{-3}	36.1 / 0.380
11	0	180	0	12	119.9	7.988 E^{-3}	6.161 E^{-3}	36.1 / 0.333
12	0	180	0	12	113.9	7.516 E^{-3}	5.797 E^{-3}	36.1 / 0.330
13	0	180	0	12	107.1	7.732 E^{-3}	5.963 E^{-3}	36.1 / 0.361

Table 2

TEST CONDITIONS AND OTHER SPECIFIC DATA FOR WATER PERMEABILITY

No. exp.	X_1		X_2		Water temperature / Rt	The difference of water level used in the assessment	
	code	real [imp/cm^2]	code	real [mm]		[mm]	Up to [mm]
1	–1	173	–1	10	18.5 °C / 1.036	101.6	97.22 ... –4.4
2	1	187	–1	10	20.2 °C / 0.996	98.72	99.32 ... 0.5954
3	–1	173	1	14	19 °C / 1.024	96.37	90.98 ... –5.395
4	1	187	1	14	18.2 °C / 1.044	109.2	101.9 ... –7.219
5	–1.414	170	0	12	19 °C / 1.024	108.0	102.5 ... –5.479
6	+1.414	190	0	12	18.9 °C / 1.027	99.17	100.4 ... 1.182
7	0	180	–1.414	9	19.1 °C / 1.021	106.8	100.9 ... –5.936
8	0	180	+1.414	15	18 °C / 1.049	93.67	94.35 ... 0.6867
9	0	180	0	12	18.5 °C / 1.037	100.9	94.83 ... –6.105
10	0	180	0	12	18.8 °C / 1.03	94.04	92.58 ... –1.462
11	0	180	0	12	17.9 °C / 1.052	102.0	101.9 ... –0.04945
12	0	180	0	12	18.5 °C / 1.034	108.5	107.6 ... –0.9229
13	0	180	0	12	20.2 °C / 0.9948	95.45	93.15 ... –2.303

Table 2 highlights other test conditions and other specific data obtained. These are the water temperature / Rt, and the difference of the water level assessed for each of the experiments, out of the 13 that have been carried out.

The velocity variation of the water jet, i.e. of the water flow at the temperature of 20 °C, in dependence on the water head loss "h", is given in table 3. The laboratory equipment used for determination shall display the following – *Flow velocity applying to 20 °C in dependence on the water head loss "h"*.

RESULTS AND DISCUSSIONS

The mathematical modeling of the water permeability of the geotextiles studied

This chapter presents the research carried out relating to the influence of the main parameters of the interweaving process on the property of water permeability of geotextiles made of nonwoven fabrics tests, with a width of 5.4 m.

By carrying out a partial assessment of the data presented in table 1, two mathematical models result, (2) and (3), expressing the relationship between the characteristics of the water permeability measured at two different temperatures of the fluid, and the parameters of the interweaving process, the interweaving density X_1 and the penetration depth of the needles into the fibrous layer X_2, considered in the study.

$$Y_{K20\,°C} = 7.808 - 0.157\,X_1 + 0.491\,X_2 + 0.785\,X_1^2 - 1.369\,X_2^2 - 0.274\,X_1X_2 \quad (2)$$

$$Y_{K10\,°C} = 6.023 - 0.121\,X_1 - 0.925\,X_2 + 0.145\,X_1^2 + 0.326\,X_2^2 - 0.211\,X_1X_2 \quad (3)$$

Table 4 presents the data on testing the significance of the regression equation coefficients by Student test, the values obtained being compared with table value t_{tab} = 2.132 for a probability α = 0.95 and a confidence level μ = 4 degrees of freedom. The final equations after applying the Student Test results are (4) and (5).

$$Y_{K20°Cf} = 7.808 + 0.491X_2 + 0.785X_1^2 - 1.369X_2^2 \quad (4)$$

$$Y_{K10°Cf} = 6.023 - 0.925X_2 + 0.326X_2^2 \quad (5)$$

Also, in table 4, the coordinates of critical points, as well as the values of the multiple correlation coefficients and the multiple determination coefficients are presented.

The final mathematical models (3) and (4) show that a higher influence is determined by the depth of penetration of the needles into the fibrous layer X_2 on both indicators $Y_{K20\,°Cf}$ and $Y_{K10\,°Cf}$. The value of the multiple correlation coefficient of 0.9188 shows that the influence of the depth of penetration of needles into the fibrous layer X_2 upon the analyzed parameter represents a priority, especially by the fact that equation (3) contains only this term, both first and second degree. Tables 5 and 6 show a data related to A [%] deviation for the values measured experimentally, calculated using the final regression equations (3) and (4). In table 5, for the permeability index $Y_{K20\,°C}$ [m/s], there are data obtained for the deviation A, which exceeded the permissible values of ± 10 % . Such a situation is due to the occurrence of phenomena that are specific to anisotropic water flow through the fiber layers. It should be pointed out that these deviations can be even higher, due to the

Table 3

THE VELOCITY VARIATION OF THE WATER JET (WATER FLOW) AT THE TEMPERATURE OF 20 °C

No. exp.	X_1		X_2		The velocity of water jet applied at 20 °C with an influence on the water level loss "h"
	code	real [imp/cm²]	code	real [mm]	
1	–1	173	–1	10	$h = 0.2253 \cdot V_{20} + 0.001587 \cdot V_{20}^2$
2	1	187	–1	10	$h = 0.2074 \cdot V_{20} + 0.001782 \cdot V_{20}^2$
3	–1	173	1	14	$h = 0.2264 \cdot V_{20} + 0.002233 \cdot V_{20}^2$
4	1	187	1	14	$h = 0.2365 \cdot V_{20} + 0.001874 \cdot V_{20}^2$
5	–1.414	170	0	12	$h = 0.2502 \cdot V_{20} + 0.00178 \cdot V_{20}^2$
6	+1.414	190	0	12	$h = 0.2425 \cdot V_{20} + 0.002165 \cdot V_{20}^2$
7	0	180	–1.414	9	$h = 0.2128 \cdot V_{20} + 0.001907 \cdot V_{20}^2$
8	0	180	+1.414	15	$h = 0.1888 \cdot V_{20} + 0.002154 \cdot V_{20}^2$
9	0	180	0	12	$h = 0.2307 \cdot V_{20} + 0.001545 \cdot V_{20}^2$
10	0	180	0	12	$h = 0.2241 \cdot V_{20} + 0.002119 \cdot V_{20}^2$
11	0	180	0	12	$h = 0.2209 \cdot V_{20} + 0.001635 \cdot V_{20}^2$
12	0	180	0	12	$h = 0.2201 \cdot V_{20} + 0.001923 \cdot V_{20}^2$
13	0	180	0	12	$h = 0.2208 \cdot V_{20} + 0.002299 \cdot V_{20}^2$

Table 4

STATISTICAL ASSESSMENT. COORDINATES OF CRITICAL POINTS		
$Y_{K20\ °C}$ or $Y_{K10\ °C}$	Student Test	Critical points. Coefficient of multiple correlation
$Y_{K20\ °C}$ [meas.] (4.21)	Tb_0 = 49.023 – b_0 significant Tb_1 = –1.249 – b_1 insignificant Tb_2 = 3.895 – b_2 significant Tb_{11} = 5.815 – b_{11} significant Tb_{22} = –10.135 – b_{22} significant Tb_{12} = –1.536 – b_{12} insignificant	– Critical point: saddle point with coordinates X_{1cod} = 0.00 thus X_{1real} = 180 [imp/cm^2]. X_{2cod} = 0.179 i.e. X_{2real} = 12.38 [mm] and $Y_{K20\ °C}$ = 7.852 [m/s]. – Coefficient of multiple correlation: 0.6403 – Coefficient of multiple determination: 0.41
Discussions: The index of water permeability $Y_{K20\ °C\ f,}$ at a temperature of 20°C, is influenced by the proportion of 41% by variations in the interweaving density X_1 and depth of penetration of the needles into the fibrous layer X_2, and by 59% due to other parameters.		
$Y_{K10\ °C}$ [meas.] (4.22)	Tb_0 = 49.027 – b_0 significant Tb_1 = –1.251 – b_1 insignificant Tb_2 = –9.528 – b_2 significant Tb_{11} = 1.391 – b_{11} insignificant Tb_{22} = 3.133 – b_{22} significant Tb_{12} = –1.536 – b_{12} insignificant	– Critical point: it doesn't exist – Coefficient of multiple correlation: 0.9188 – Coefficient of multiple determination: 0.8442
Discussions: The index of water permeability $Y_{K10\ °C\ f,}$ at a temperature of 10°C, is influenced by the proportion of 84.42% by variations in the interweaving density X_1 and depth of penetration of the needles into the fibrous layer X_2, and by 15.58 % due to other parameters.		

Table 5

DEVIATION A FOR THE INDEX $Y_{K20\ °C\ F}$ AT A TEMPERATURE OF 20 °C					
No. exp.	**Y_{meas} [meas.]**	**Y_{calc} [meas.]**	**$(Y_{meas}–Y_{calc})^2$ [meas.]^2**	**$(Y_{calc}–Y_{avg})^2$ [meas.]^2**	**A [%]**
1	9.567	6.734	8.023	4.484	29.607
2	9.316	6.734	6.664	3.484	27.71
3	8.155	7.715	0.193	0.498	5.390
4	6.810	7.715	0.820	0.409	13.296
5	8.025	9.379	1.832	0.331	16.867
6	8.264	9.379	1.242	0.664	13.487
7	1.062	4.378	10.997	40.799	12.253
8	6.608	5.765	0.710	0.708	12.753
9	7.471	7.808	0.114	0.000	4.517
10	8.328	7.808	0.270	0.772	6.239
11	7.988	7.808	0.032	0.290	2.248
12	7.516	7.808	0.086	0.004	3.891
13	7.732	7.808	0.006	0.080	0.989

Table 6

DEVIATION A FOR THE INDEX $Y_{K10\ °C\ F}$ AT A TEMPERATURE OF 10 °C					
No. exp.	**Y_{meas} [meas.]**	**Y_{calc} [meas.]**	**$(Y_{meas}–Y_{calc})^2$ [meas.]^2**	**$(Y_{calc}–Y_{avg})^2$ [meas.]^2**	**A [%]**
1	7.379	7.274	0.011	1.137	1.417
2	7.185	7.274	0.008	0.761	1.245
3	6.290	5.424	0.750	0.001	13.771
4	5.252	5.424	0.030	1.125	3.271
5	6.190	6.023	0.028	0.015	2.702
6	6.374	6.023	0.123	0.004	5.510
7	8.194	7.984	0.044	3.539	2.567
8	5.096	5.367	0.073	1.481	5.315
9	5.762	6.023	0.068	0.303	4.526
10	6.423	6.023	0.160	0.012	6.231
11	6.161	6.023	0.019	0.023	2.244
12	5.797	6.023	0.051	0.266	3.894
13	5.963	6.023	0.004	0.122	1.002

phenomena that are specific to fluid flow through the fiber layers, therefore non-homogenous, and thus additional hydrodynamic resistances occur. Therefore, it is estimated that this indicator currently used as a means for assessing the veracity of a mathematical model should be considered in a broader sense. From table 6, the permeability index $Y_{K10\,°C}$ [meas.], it is noted that only one value is outside the allowed range of ±10%. Therefore, equation (4) expresses correctly the characteristic of water permeability at a temperature of 10°C. We find out that the water temperature influences the speed of its passage through a fibrous structure of non-woven interwoven fabric.

Figures 1, 2, 3, 4 and 5 depict graphically the variation of water permeability index $Y_{K20\,°Cf}$ [m/s] at a temperature of 20°C, depending on the two parameters

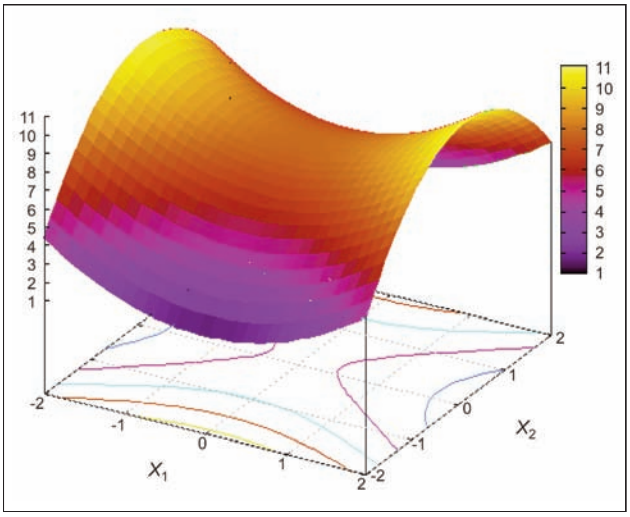


Fig. 1. 3D Graph of water permeability index $Y_{K20\ °C\ f}$

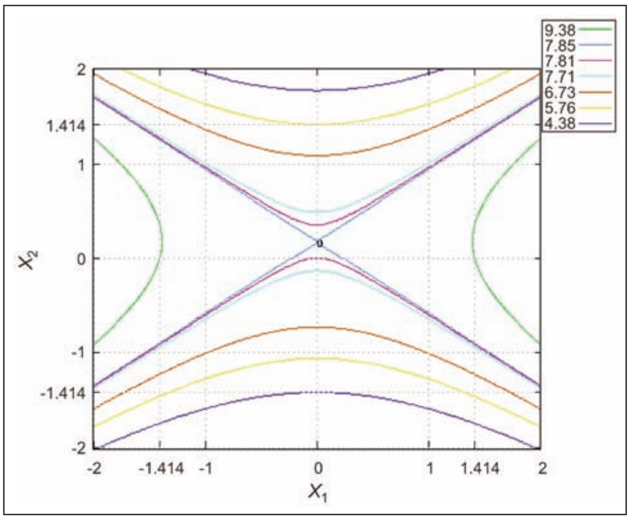


Fig. 2. Isocurves of water permeability index $Y_{K20\ °C\ f}$

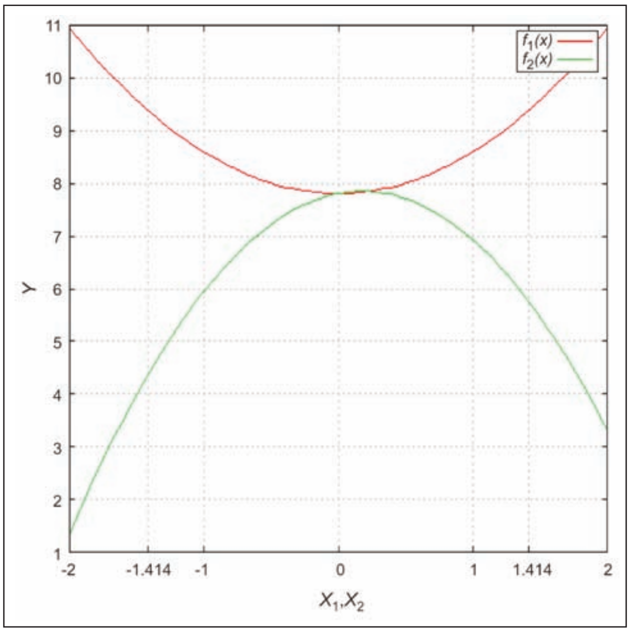


Fig. 3. Graph of water permeability index $Y_{K20\ °C\ f}$ for one parameter, when the second one is constant

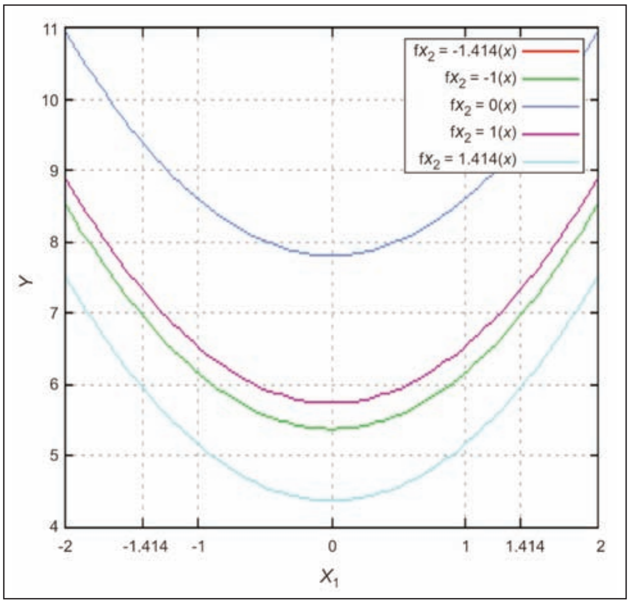


Fig. 4. The influence of X_1 variable on the water permeability index $Y_{K20\ °C\ f}$

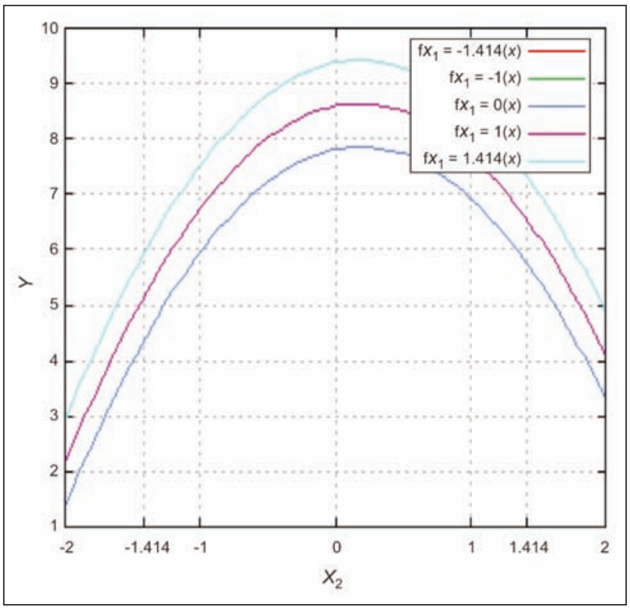


Fig. 5. The influence of X_2 variable on the water permeability index $Y_{K20\ °C\ f}$

X_1 and X_2, by the 3D graph, isocurves, as well as the variation depending on each parameter when the 2nd parameter is constant value in the center of the experimental program, etc.

Figures 6, 7 and 8 depict graphically the variation of water permeability index $Y_{K10\,°C\,f}$ [meas] at a temperature of 10°C, depending on the two parameters X_1 and X_2, by the 3D graph, the variation depending on each parameter when the 2nd parameter is a constant value in the center of the experimental program, etc.

The 3D graph in figure 1, representing a parabolic hyperboloid for translation does not have an extreme point; the situation is indicated by its saddle form,

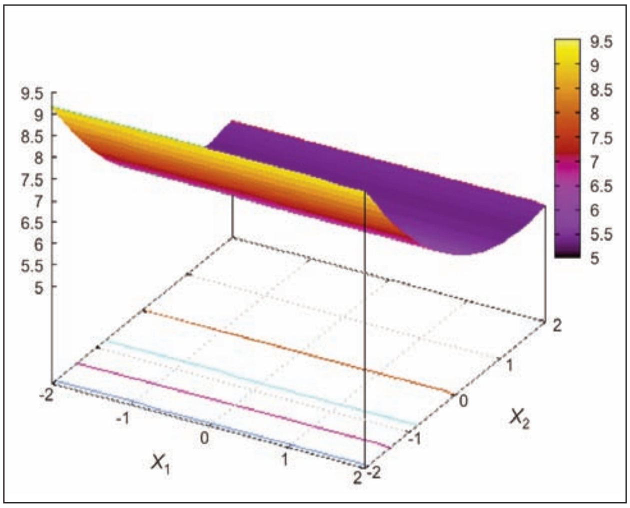


Fig. 6. 3D Graph of water permeability index $Y_{K10\ °C}$

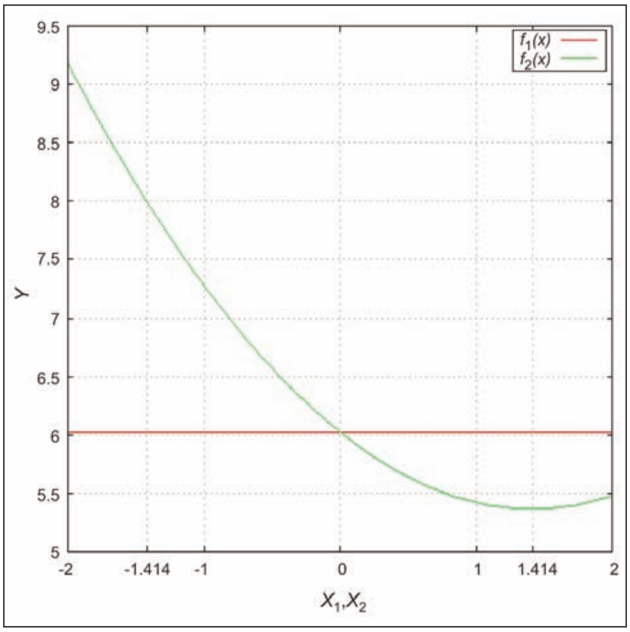


Fig. 7. 3D Graph of isocurves of water permeability index $Y_{K10\ °C\ f}$

shows that the permeability index in case of water at 20°C, has a high value, marked by yellow color in the representation, both negative and positive values of the parameters. The way in which this index must be correlated, speaking as values, to the mechanical properties of the geotextile is obviously by respecting the conclusions above. The value obtained when parameters may vary towards upper limits of the experimental region shall be taken into account. For example, by analyzing the graphs in figures 1, 2, 3, 4 and 5 in order to obtain a material with the desired strength, the permeability index at 20°C shall be comprised between 7.81 and 7.85.

As regards the value of the same index at a water temperature of 10°C, in figures 6, 7 and 8 one may note the same phenomenon, related to obtaining the same values, for the value of mechanical strength of the geotextile. The high value of strength is obtained with the variation towards the positive of the experimental region, while the permeability index shall have, in this case, a low value, i.e. $Y_{k10°C}$ is about 6.

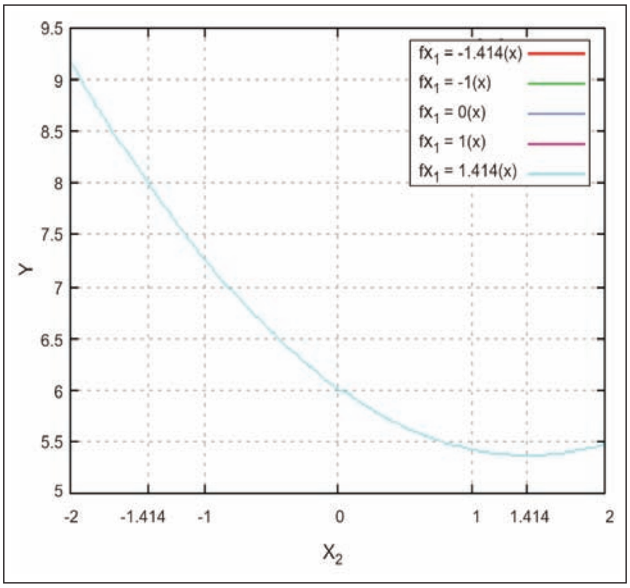


Fig. 8. The influence of X_2 variable on the water permeability index $Y_{K10\ °C\ f}$

CONCLUSIONS

The depth of penetration of the needles into the fibrous layer X_2 is the main parameter that influences the water permeability characteristic due to the fact that, as mentioned above, it is the main technological parameter influencing the geotextile compactness.

The interweaving density X_1 has a reduced influence or has no influence, in case the test is carried out at a water temperature of 10 °C. This could be due to the fact that the fibrous layer is obtained firstly by the superposition of two individual webs from Spinnbau card, after which they are folded in the Thibeau folding machine. In this phase, a large amount of air shall be a component of the prefabricated and the structure has high porosity and thickness.

The disorientation system of the fibers has also an obvious influence in terms of porosity, due to the arrangement of the fibers.

The strengthening by interweaving shall confer consistency and compactness to the fibrous structure, its thickness being at the level of tens of millimeters, and the final product having only few millimeters.

The water temperature, which reproduces approximately what happens during the operation stage, has an influence on the permeability indexes.

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Authors:

ROMULUS BULACU
S.C. Minet S.A. Ramnicu Valcea
DANIELA FARIMA
Technical University “Gheorghe Asachi”, Iasi
IOAN FILIP
S.C. Taparo S.A. Tg. Lapus
RALUCA MARIA AILENI
The National Research & Development Institute for Textiles and Leather
Lucretiu Pătrăşcanu No.16, 030508, Bucharest, Romania

Corresponding author:

DANIELA FARIMA
e-mail: d_farima@yahoo.com

The effects of lubricant amount on sewing needle temperature and tensile properties of Polyester-polyester core-spun thread

ADNAN MAZARI

ANTONIN HAVELKA
ZDENĚK KŮS

REZUMAT – ABSTRACT

Efectul cantității de agent de avivare utilizat asupra temperaturii acelor de cusut și proprietăților de rezistență la rupere ale firului filat cu miez poliester-poliester

În acest articol sunt investigate experimental efectele cantității de agent de avivare asupra temperaturii acului de cusut și proprietăților firului filat cu miez poliester-poliester (PET-PET). În cadrul lucrării sunt utilizate trei tipuri diferite de finețe a firului (40 tex, 60 tex și 80 tex) cu cantitate diferită de agent de avivare (0 până la 7%) pentru coaserea la viteze diferite pe mașini industriale de cusut. Rezultatele cercetării arată că temperatura acului scade pe măsură ce crește cantitatea de agent de avivare, în timp ce proprietățile de rezistență la rupere ale firului scad odată cu creșterea cantității de agent de avivare. Utilizarea agentului de avivare nu reprezintă o metodă economică dacă viteza de coasere este mai mică de 2000 r/min, în timp ce pentru o viteză de coasere de 2500 r/min sau mai mare, cea mai fezabilă regiune de cusut corespunde unei cantități de agent de avivare de 2–4% (regiunea fezabilă pentru cusut este prezentată prin liniile colorate în violet în cadrul graficelor cu contur). Cantitatea mai mare de agent de avivare duce la scăderea temperaturii acului și a tenacității firului. Pentru a obține cea mai mare rezistență la rupere și o viteză maximă de coasere este recomandat să se utilizeze 2–4% din cantitatea de agent de avivare, dar dacă este necesar să se atingă o temperatură mai scăzută a acului de cusut din cauza țesăturilor sintetice, atunci poate fi utilizată o cantitate de peste 3% agent de avivare. Efectul este același pentru toate cele trei tipuri de finețe a firului filat cu miez PET-PET.

Cuvinte-cheie: ac de cusut, temperatura acului, agent de avivare, fir de cusut, pasul cusăturii.

The effects of lubricant amount on sewing needle temperature and tensile properties of Polyester-polyester core-spun thread

In this article, the effects of lubricant amount on sewing needle temperature and tensile properties of polyester-polyester (PET-PET) core-spun thread are experimentally investigated. In this research work, three different thread counts (40 tex, 60 tex and 80 tex) with different lubricant amount (0 to 7%) are used for sewing at different speed of industrial lockstitch machine. The results of the research shows that the needle temperature decreases with increase of lubricant amount, whereas the tensile properties of thread decrease with the increase of lubricant amount. it's not economical to use lubricant if sewing speed is less than 2000 r/min where as for sewing speed of 2500 r/min and higher the most feasible region of sewing is for lubricant amount of 2–4% (feasible region of sewing is shown by purple color lines in contour plots).The higher amount of lubricant decreases the needle temperature and thread tenacity. To obtain highest tensile properties and maximum sewing speed it is recommended to use 2–4% of lubricant amount, but if it's necessary to achieve lower needle temperature due to synthetic fabrics then lubricant amount of more than 3% can be used. The effect is same for all three counts of PET-PET cores-pun thread.

Key-words: Sewing needle, needle temperature, thread lubricant, sewing thread, lockstitch.

In the sewing process, the sewing thread undergoes friction between fabric, guides, tension devices on machine, bobbin thread and the sewing needle. The performance of sewing thread in apparel industry has become extremely important. Every day, thousands of products ranging from shirts to automotive airbags are sewn. Hence, even small improvements may result in significant corporate benefits. Heavy industrial sewing, such as that used in the manufacture of automobile seat cushions, backs and airbags, requires not only high production but also high sewing quality (i.e. good appearance and long-lasting stitches) [1].

Needle heat-up is a major problem on the sewing floor [2]. In recent years, in order to increase production, high-speed sewing has been extensively used. Currently, sewing speeds range from 1000 to 4000 r/min. In heavy industrial sewing, typical sewing speeds range from 700 to 2000 r/min. Depending on the sewing conditions, maximum needle temperatures range from 100°C to 300°C. This high temperature weakens the thread, since thread tensile strength is a function of temperature, resulting in decreased production [2, 13]. In addition, the final stitched thread has 30–40% less strength than the parent thread [3, 14]. As a result of improved understanding of the causes of sewing damage, many technical developments, such as improved needle design [4, 17], fabric finishes [5, 6], thread lubrication and needle coolers [7, 8], have taken place over the years.

Lubricants cause the decrease in friction coefficient of sewing threads and are commonly used in sewing industries [9]. The lubricant improves the surface finish which causes the decrease of friction between yarn and the metal object. Most lubrication is intended to decrease yarn to metal friction. In recent publication,

Table 1

SEWING THREAD USED FOR THE EXPERIMENTS					
Thread type	**Company name / product name**	**Fineness [tex]**	**Twist [t/m]**	**Twist direction [ply/single]**	**Coefficient of friction, μ**
Polyester–polyester core spun	AMANN/Saba C-80	40(20*2)	660	Z/S	0.20
Polyester–polyester core spun	AMANN/Saba C-50	60(30*2)	640	Z/S	0.23
Polyester–polyester core spun	AMANN/Saba C-35	80(40*2)	534	Z/S	0.29

Table 2

FABRIC USED FOR THE EXPERIMENTS					
Fabric type	**Weave**	**Weight**	**Ends/cm**	**Picks/cm**	**Fabric Thickness**
100% cotton Denim	2/1 Twill	257 g/m^2	25	20	0.035 cm

it was reported that the amount of lubricant used have a profound effect on friction [10,12]. Sewing thread lubricant always contains silicon, because silicon provides the heat protection and friction reduction in sewing threads. It is accepted that silicones are poor conductor of heat but good release agent and causes reduction in friction [11].

Due to high strength and durability of PET-PET core-spun thread, it is the most common sewing thread used in apparel industry. High amount of lubricant are applied to decrease friction and needle temperature [9]. In our research we measured the effect of different amount of lubricant on needle temperature, coefficient of friction and breaking tenacity of PET-PET core-spun thread.

Table 3

THREAD TO METAL COEFFICIENT OF FRICTION			
Product name	**AMANN / Saba C-35**	**AMANN / Saba C-50**	**AMANN / Saba C-80**
Thread count	80 tex	60 tex	40 tex
Lubrication amount [%]	μ	μ	μ
0	0.29	0.23	0.2
1.6	0.26	0.21	0.19
2	0.25	0.19	0.17
3	0.21	0.17	0.16
3.5	0.21	0.16	0.15
4	0.2	0.15	0.15
4.5	0.2	0.16	0.15
5	0.19	0.15	0.14
7	0.18	0.15	0.13

EXPERIMENTAL PART

In this research, PET-PET core-spun thread with three different count and eight lubricant amounts (0–7%) are used for the experiment. Silicone lubricated threads are obtained from company AMANN. The properties of sewing thread are shows in table 1. The properties of fabric used for the sewing process are shown in table 2.

Sewing thread friction testing

All sewing thread friction properties are tested before the sewing process. Thread to metal coefficient of friction is measured for all threads with instrument CTT-LH401 (Company Lawson-Hemphill) according to standard ASTM D-3108 for 100m/min and contact angle of 180^o. The friction properties of sewing thread are shown in table 3.

Needle temperature measurement

Inserted thermocouple method is used for measuring the needle temperature during the sewing process. This method shows most precise measurement of needle temperature during the sewing process [12] on industrial lockstitch machine. Conditions for all experiments were kept constant at 26°C and 65% ±2RH. The devices used for the experiments are listed below:

- Lockstitch machine (Brother Company, DD7100-905).
- Thermocouple by Omega (K type 5SC-TT-(K)-36-(36)) for the inserted measurement method.
- Thermocouple by Omega-wireless device and receiver (MWTC-D-K-868).
- Needles (Groz-Becker 100Nm for Saba C-80 and C-60, 110Nm for Saba C-35) R- type.

Needle temperature is measured 5 times each for every thread and the results are shown with standard deviations. Maximum sewing time was 15 seconds for different speeds of sewing process. The stitch length was kept constant at 5 stitches/cm. Results are presented in the next section.

Figure 1 shows the sewing machine setup with thermocouple inside the sewing needle groove.

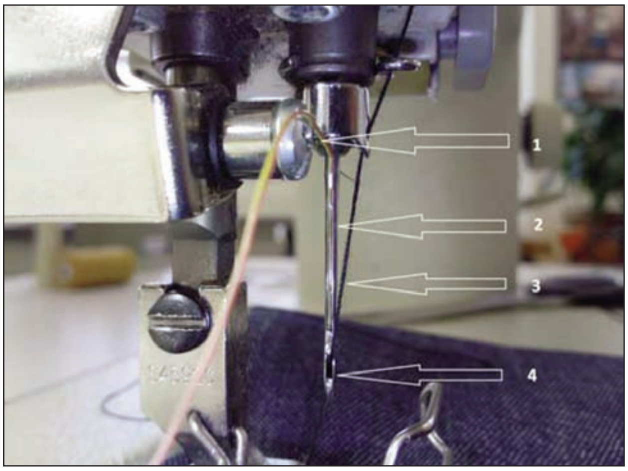

Fig. 1. Needle temperature measurement setup:
1 – Thermocouple wire; 2 – Needle groove;
3 – Sewing thread; 4 – Needle eye

Tensile properties measurement

The breaking tenacity and elongation values of the sewing thread are measured using INSTRON Tensile strength tester according to standard TS245EN ISO 2256.

All sewing threads with different amount of lubricant are tested before sewing and after sewing process, the sewing thread is carefully removed from the seam by cutting the bobbin thread. Each thread is measured 10 times each for all speeds of sewing respectively.

Box-Behnken design

A three-level three factorial Box–Behnken experimental design (constructed using Minitab 16) was used to evaluate the effects of the selected independent variables on the response. The number of experiments required to investigate the previously noted three factors at three levels would be 27. However, this was reduced to 15 by using a Box–Behnken experimental design. The results from this limited number of experiments provided a statistical model, which can help to find the optimum experimental conditions and the relationships between experimental results and parameters.

The significant variables like stitch, speed of sewing, layer of fabric, and the time were chosen as the critical variables and designated as X_1, X_2 and X_3, respectively. The low, middle, and high levels of each variable were designated as −1, 0, and +1, respectively, as shown in table 4 and table 5.

Table 4

FACTORS AND LEVELS CONSIDERED FOR THE EXPERIMENT

Factors	Levels		
	–1	0	1
X_1 = Sewing speed [r/min]	2000	3000	4000
X_2 = Lubricant amount [%]	0	3.5	7
X_3 = Thread count [tex]	40	60	80

Table 5

THE DESIGN OF THE EXPERIMENT

Trial No.	X_1	X_2	X_3
1	–1	–1	0
2	–1	1	0
3	1	–1	0
4	1	1	0
5	–1	0	–1
6	–1	0	1
7	1	0	–1
8	1	0	1
9	0	–1	–1
10	0	–1	1
11	0	1	–1
12	0	1	1
13	0	0	0
14	0	0	0
15	0	0	0

RESULTS AND DISCUSSION

Effect of lubricant amount on Coefficient of friction

The yarn /metal friction is tested on instrument CTT-LH401 (Company Lawson-Hemphill) according to standard ASTM D-3108 for 100 m/min and contact angle of 180°. It is observed that coefficient of friction decreases with the increase in lubricant amount. There is nearly 35% decrease in coefficient of friction when the lubricant amount is 7%. The lubricant improves the surface finish which causes the decrease of friction between yarn and the metal object. Lubrication is intended to decrease yarn to metal friction. In recent publication, it was reported that the amount of lubricant used have a profound effect on friction properties [12, 15]. Sewing thread lubricant always contains silicon, because silicon provides the heat protection and friction reduction in sewing threads. It is accepted that silicones are poor conductor of heat but good release agent and causes reduction in friction [9]. Figure 2 shows the effect of lubricant amount on the friction coefficient of sewing threads.

Effect of lubricant amount on sewing needle temperature

The lubricant causes the reduction in yarn to metal friction (as shown in figure 2). This reduction in friction causes needle temperature to decrease. Figures 3–5 show the needle temperature at different speeds of sewing from 1000 r/min to 4000 r/min. Continuous stitching is performed for 15 seconds with all sewing thread for 5 times respectively.

As shown in figures 3–5, the sewing needle temperature decreases with the higher amount of lubricant.

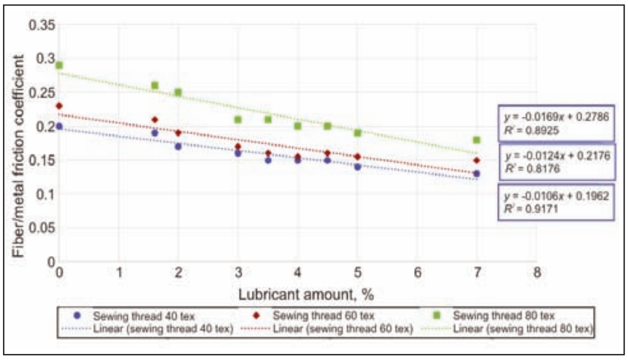

Fig. 2. Effect of lubricant amount on friction coefficient

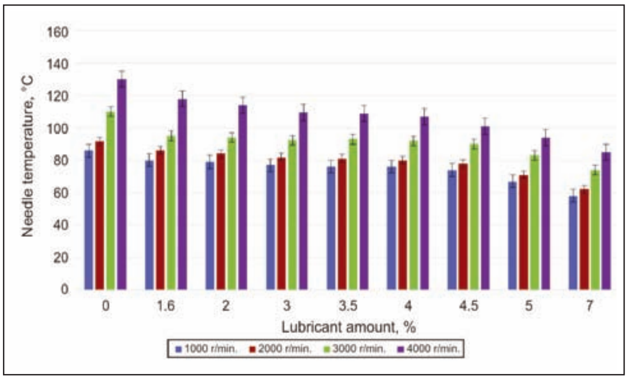

Fig. 3. Needle temperature at different speeds of sewing (40 tex thread with different amount of lubricant)

It is also visible that the sewing needle temperature rises with the increased speed sewing and higher count of sewing thread. Needle temperature decreases linearly with the increase of lubricant amount; there is nearly 30% reduction in needle temperature when lubricant amount is 7% as compared to needle temperature of sewing thread without lubricant. This reduction of needle temperature is very important for heavy industry sewing where sewing speed is higher than 3000 r/min. The use of lubricant decreases the needle temperature and can increase productivity of sewing industries.

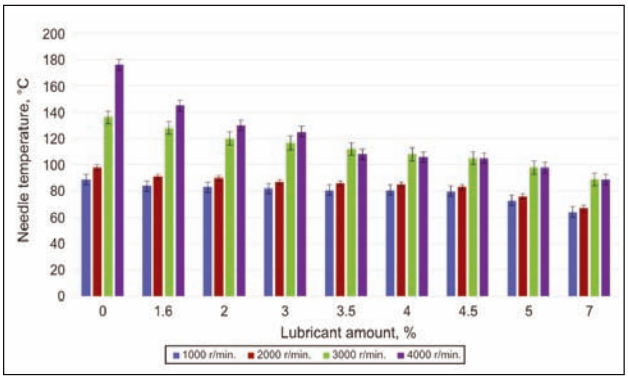

Fig. 4. Needle temperature at different speeds of sewing (60 tex thread with different amount of lubricant)

Effect of lubricant amount on sewing thread breaking tenacity

The most important factor of sewing floor is the tensile properties of sewing threads. In our research we measured the breaking tenacity and elongation at break of the sewing thread using INSTRON Tensile strength tester according to standard TS245EN ISO 2256. All sewing threads with different amount of lubricant are tested before sewing and after sewing process, the stitched thread is carefully removed from the seam by cutting the bobbin thread for tensile testing. Each thread is measured 10 times each for all speeds of sewing respectively. Figure 6 shows the effect of lubricant amount on breaking tenacity of sewing thread before sewing.

It is visible that breaking tenacity decreases with the amount of lubricant. As the lubricant penetrates inside the yarn, it decreases the fiber to fiber friction and makes it slippery for the fibers to hold each other. As shown in figure 6 the breaking tenacity of thread is decreases by nearly 4–7% when the lubricant amount is 7%. There is a linear decrease in breaking tenacity of thread for all thread counts with increase of lubricant amount.

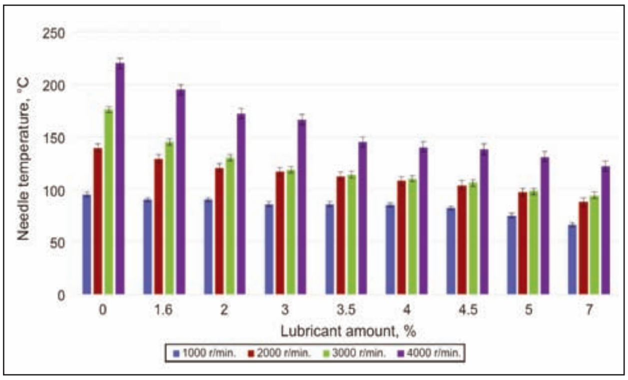

Fig. 5. Needle temperature at different speeds of sewing (80 tex thread with different amount of lubricant)

Feasible region of sewing

In a system involving three significant independent variables X_1, X_2 and X_3 the mathematical relationship of the response on these variables can be approximated by the quadratic polynomial equation:

$$Y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_{11} x_1^2 + \alpha_{22} x_2^2 \alpha_{33} x_3^2 + + \alpha_{12} x_1 x_2 + \alpha_{13} x_1 x_3 + \alpha_{23} x_2 x_3 + \alpha_4 x_1 x_2 x_3 \quad (1)$$

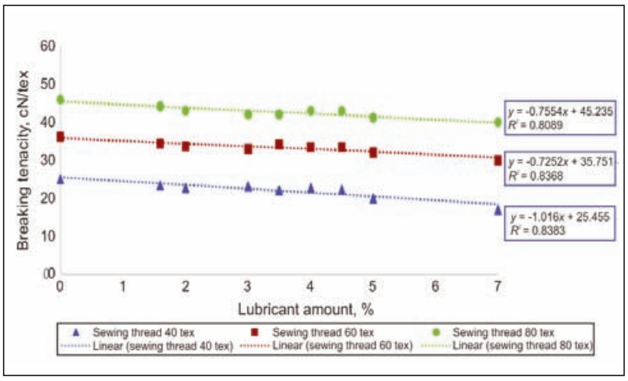

Fig. 6. Effect of lubricant amount on breaking tenacity of sewing thread (before sewing)

where:
Y is estimate response, α_0 is constant, α_1, α_2, and α_3 are linear coefficients, α_{12}, α_{13}, and α_{23} are interaction coefficients between the three factors, α_{11}, α_{22}, and α_{33} are quadratic coefficients.
In this model given in equation (1), a multiple regression analysis is done for Thread tenacity, needle temperature and extension at break to obtain the coefficients, and the equation can be used to predict the response.

Breaking tenacity

$$\begin{aligned}\boldsymbol{Y} = 30.54 - 0.002\,x_1 - 0.16\,x_2 + 0.118\,x_3 -\\ - 0.174\,x_2^2 + 0.0001 x_1 x_2 + 0.005\,x_2 x_3\end{aligned} \quad (2)$$

where:
Y is breaking tenacity [cN/tex];
X_1 – sewing speed [r/min];
X_2 – lubricant amount [%];
X_3 – thread count [tex].
Adjusted R^2 = 0.976 and P-value = 1.24*10–24 ≈ 0.

Needle temperature

$$\begin{aligned}\boldsymbol{Y} = -45.1 + 0.049\,x_1 + 14.21\,x_2 + 0.48\,x_3 -\\ - 0.004\,x_1 x_2 - 0.164 x_2 x_3\end{aligned} \quad (3)$$

where:
Y is needle temperature [°C].
Adjusted R^2 = 0.98 and P-value ≈ 0.

Extension at break

$$\begin{aligned}\boldsymbol{Y} = 9.17 - 0.0009\,x_1 + 0.826\,x_2 + 0.3117 x_3 - 0.076\,x_2^2 -\\ - 0.0017 x_3^2 - 0.015\,x_2 x_3 - 0.0001\,x_1 x_2\end{aligned} \quad (4)$$

where:
Y is extension at break [%].
Adjusted R^2 = 0.945 and P-value ≈ 0.

Figures 7–9 show the contour plots of needle temperature, breaking tenacity and extension at break of stitched thread laid one above each other. This graphical representation shows the effect of lubricant amount and sewing speed on needle temperature, thread tenacity and extension at break. It is visible from the contour plots that it's not economical to use lubricant if sewing speed is less than 2000 r/min, whereas for sewing speed of 2500 r/min and higher the most feasible region of sewing is for lubricant amount of 2–4 % (feasible region of sewing is shown by purple color lines in contour plots). The higher amount of lubricant decreases the needle temperature and thread tenacity. To obtain highest tensile properties and maximum sewing speed it is recommended to use 2–4% of lubricant amount, but if it's necessary to achieve lower needle temperature due to synthetic fabrics, then lubricant amount of more than 3% can be used. The effect is same for all three counts of PET-PET cores-pun thread.

CONCLUSIONS

Lubricants are mainly used for the reduction of friction coefficient of the sewing thread. It is true that the friction coefficient of the sewing threads and needle temperature decreases with the increase of lubricant amount, but higher amount of lubricant decrease the friction between fiber to fiber inside the thread, this slippery condition between fiber to fiber causes the decrease of breaking tenacity of sewing thread.
There is minor decrease in breaking tenacity of stitched thread with the addition of lubricant for

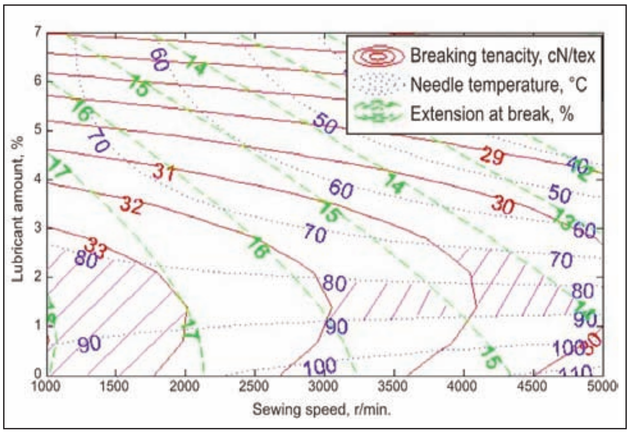

Fig. 7. Effect of lubricant amount and sewing speed on needle temperature, tenacity and breaking extension of sewing thread (40 tex)

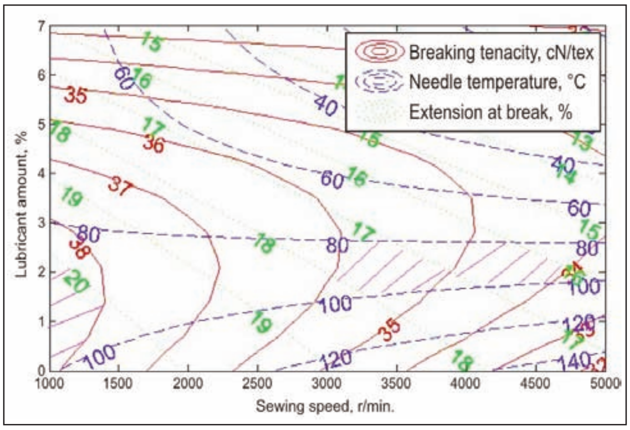

Fig. 8. Effect of lubricant amount and sewing speed on needle temperature, tenacity and breaking extension of sewing thread (60 tex)

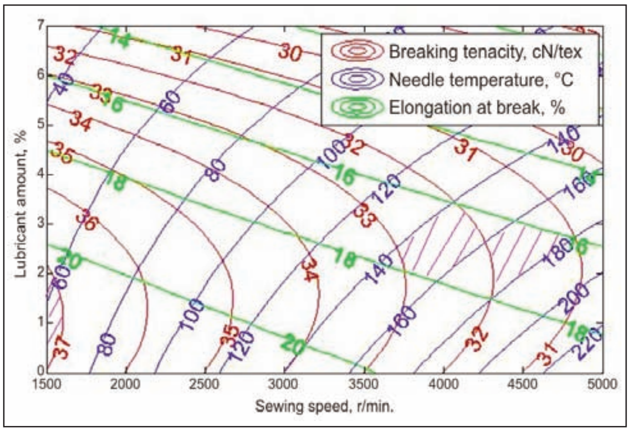

Fig. 9. Effect of lubricant amount and sewing speed on needle temperature, tenacity and breaking extension of sewing thread (80 tex)

sewing speeds till 2500 r/min. It's not economical to use lubricant if sewing speed is less than 2000 r/min whereas for sewing speed of 2500 r/min and higher the most feasible region of sewing is for lubricant amount of 2–4 %. The needle temperature is less than 130 °C at this sewing speed and has insignificant effect on the sewing thread.

It is advised to use the lubricant when sewing speed is 2500 r/min and higher. It is found that breaking tenacity is highest for lubricant amount of 2–4 %, where the breaking tenacity is 4–6 % higher as compared to other lubricant amounts. The higher amount of lubricant decreases the needle temperature and thread tenacity. To obtain highest tensile properties and maximum sewing speed it is recommended to use 2–4% of lubricant amount, but if it's necessary to achieve lower needle temperature due to synthetic fabrics then lubricant amount of more than 3% can be used. It is observed that coefficient of friction decreases with the increase in lubricant amount. There is nearly 35% decrease in coefficient of friction when the lubricant amount is 7%.

Needle temperature decreases linearly with the increase of lubricant amount; there is nearly 30% reduction in needle temperature when lubricant amount is 7% as compared to needle temperature without lubricant on sewing thread.

The effect of lubricant amount on tensile properties of thread should always be considered for sewing process.

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Authors:

RADNAN AHMED MAZARI
ANTONIN HAVELKA, ZDENĚK KŮS
Technical University of Liberec,
Faculty of Textile Engineering, Department of Textile Clothing,
Studentska 2, Liberec, 461 17, Czech Republic

Corresponding author:

ADNAN AHMED MAZARI
e-mail: adnanmazari86@gmail.com; adnan.ahmed.mazari@tul.cz

Branding process – An important factor in guiding the company towards success

OCTAVIAN ION NEGOITA
OLIVIA DOINA NEGOITA
CARMEN GHITULEASA
ANCA ALEXANDRA PURCAREA

REZUMAT – ABSTRACT

Procesul de branding – Factor important în orientarea companiei către succes

Unul dintre cele mai importante procese organizaţionale, aflat într-o strânsă conexiune şi interdependenţă cu toate celelalte procese organizaţionale este procesul de branding. În literatura de specialitate, puţini cercetători folosesc conceptul de “proces de branding”, majoritatea făcând referire la “branding”.
Obiectivul acestei lucrări este acela de a modela branding-ul ca proces organizaţional şi de a arăta rolul acestuia în abordarea procesuală a unei organizaţii din industria textilă.
Având ca punct de plecare analiza conceptului de brand şi utilizând modelarea procesuală, autorii acestui articol vă propun un model al procesului de branding ce poate fi supus în cadrul organizaţional unui proces de îmbunătăţire continuă.
Procesul de branding a devenit în organizaţiile care folosesc abordarea procesuală un proces integrator care influenţează celelalte procese organizaţionale, dar este la rândul său supus interacţiunii cu acestea, devenind astfel un factor determinant al succesului sau eşecului companiei.
Modelul propus al procesului de branding, permite o înţelegere a acţiunilor ce stau la baza unui astfel de proces, a implicaţiilor pe care aceste acţiuni le au atât în interiorul companiei cât şi în piaţa în care operează.

Cuvinte-cheie: Abordare pe proces, procesul de branding, modelarea proceselor, industria textilă

Branding process – An important factor in guiding the company towards success

One of the important processes of an organization being tightly connected and interdependent with other organizational processes is the process of branding. In the literature, there are few researchers addressing the branding process.
The objective of the paper is to show the relationship and interconnection between these organizational processes in textile and leather industries.
Starting from the analysis of a company's brand, using modelling process, the authors propose an effective model to improve the brand directed side of strategic management.
Branding has become, in organizations that use the process approach, a process integrator that influences other processes, but also depending on other processes, may be a determinant of success or failure of an organization.
The proposed model of the branding process allows a more accurate understanding of the activities underlying this process, of the implications that it has both inside the company and in the market in which it operates.

Keywords: Process approach, branding process, modelling process, textile and leather companies

CONTEXT

The Romanian textile and leather industry has a long tradition and experience in production, but also a good international recognition. In the Romanian economy, textile and leather industry has a significant contribution. In the past years, the industry brought 2.33% of GDP, achieved 3.63% of industrial production. Another important factor to be noted is that this industry occupies an important part of the labour force 13.8% [1]. Textile and leather industry sector faces a number of threats, but there are opportunities that run through proper management that can ensure and enhance the future of the sector. To cope with the competitive environment and to overcome problems faced by organizations it is necessary for textile and leather industry to make changes that allow them to become competitive and to ensure their long-term added value elements [2]. Acquiring recognition and a good reputation are key elements of an upward trend over a long period of time. These objectives are part of a branding process that not only creates a positive image and differentiate, but also allow, in time, maintaining a high standard of quality.
Brand and branding process – as it will be defined in this paper – may become key factors necessary of changes that this industry need, for stability and sustainable development.

RESEARCH METHODOLOGY

The authors have conducted a study – bibliographical research – in an attempt to investigate what brand approach can determine the sustainable development and obtain long-term competitive advantage of industrial organizations, in the textile and leather industry.

Under these circumstances, the empirical research has addressed the following objectives:

- to investigate the brand concept as it is definited in scientific papers.
- to define a brand approach capable to determine an organization's long-term sustainable development
- to develop recommendations for organizations in textile and leather industry, regarding the branding process.

Data analysis

Brand – definition, importance

American Marketing Association (***AMA***) defines brand as: "name, term, sign, symbol or a combination of these, in order to identify products or services of a company or group of companies and to differentiate them from competition products or services".

The accepted definition of the American Marketing Association did not make any reference to the contribution value or the consumer awareness of the brand, to the reputation it has on the market. AMA is restricted to what can be called generic "brand image elements" i.e., those elements which distinguish the products name, logo, design, package. [3]

The brand is, in the acceptance of another researcher, specializing in branding, Keller defined as "based a product, but one that brings another dimension that distinguishes it from other products that meet the same needs". Keller emphasizes that what distinguishes a brand and differentiates it from product is the sum of consumer perception and feelings that he has towards product attributes and how it performs.

Economic developments in recent years, financial crisis, further strengthens the idea that the most valuable asset of an organization is not the products, equipment, real estate values, but its intangible assets. Value of the assets of an organization is found in most of the intangible assets and the most valuable of these is the brand.

Brand, in essence, has several functions which are essential for the development of an organization. The first of these is the distinguishing function, marking the company's distinctive elements. For customers, brand simplifies choice, promises a certain quality, reduces risks and generates trust [4]. The brand has an important role in determining how marketing efforts – advertising, distribution, are justified or not. This is possible due to its construction which is based on product and its attributes; this is why consumer perception of the brand reflects the perception of the product.

Long time the idea that in business-to-business relations, predominant choice is based on rational criteria, efficiency targets and therefore the brand is a less important factor. Practice has proved the contrary. As Naurus Anderson (1998) and Blakett (1998) quoted by Kotler [5]: "[Brands]... facilitate identification of products, services and companies, differentiate them from competition, becoming an effective and persuasive means to communicate the value and benefits that a product can provide, represent a guarantee of quality, enhancing perceived customer value".

An important feature of business-to-business brands is that they not only get to the client but also to all stakeholders: investors, employees, suppliers, competitors, government officials, leading to knowledge and better coverage the economic and social environment in which it operates.

Quoting [3] we can say that:

- A brand is a promise.
- A brand is the totality of perceptions about a product, service or company.
- A brand holds a distinctive position in the minds of customers, based on previous experience and expectations of future ventures.
- A brand is a summary of attributes, benefits, beliefs and values that differentiate, reduce complexity and simplify the decision making process.

Brand – proposed model

The author's conception, on brand – as a generic concept – consists of (figure 1) [6]:

- Realization process product/organization – name, logo, slogan, packaging, font, colors etc. – Creating visual identity.
- The brand itself – perception, attitude, knowledge of the consumer product/organization.
- Brand Equity – is set associations and contributions to the awareness of consumers in the market, the company's financial results

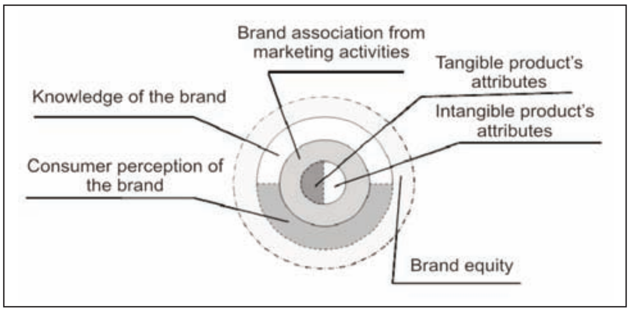

Fig. 1. Representation of a brand – brand components

RESEARCH FINDINGS – BRANDING PROCESS

From bibliographic research carried out, it has been observed that few researchers have focused explicitly on the branding process, most often focusing only on certain aspects of it.

The process of brand building by Philip Kotler

Kotler shows in his model: relevant processes that lead to the construction of a brand reference [5]. He says, "brand building begins with understanding key product attributes and understanding and anticipating customer needs". (figure 2).

Brand planning involves creating a climate in the organization's management to develop a brand strategy, i.e. development of a branding program.

Analysis based on the brand market research – customer and competition analysis – but includes a process of self-analysis.

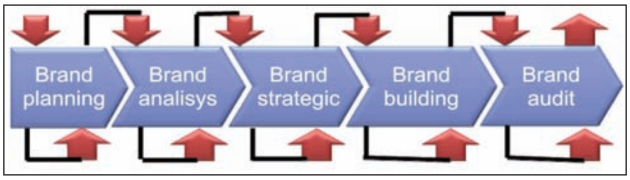

Fig. 2. The brand building process by Kotler

Brand strategy based on core brand values and its associations is described by Kotler as “the arrangement and ordering number and nature of common and distinctive brand elements that a company applies everywhere in the organization”.
Brand building is a continuous process and refers to the design of the logo, slogan and so on, which is what is meant by product brand.
Brand audit is a process of identifying strengths and weaknesses of a brand. To determine finally a brand's scorecard, measuring its performance in relation to customer preferences.
It is observed in this model that the brand building strategy, although the strategic management of the brand is established as a stand-alone process.

The strategic brand management process by Keller

Strategic brand management process developed by [3], shown in figure 3, involves four stages (figure 3) in its development:

- Identifying and establishing brand positioning and values.
- Planning and implementation of marketing programs.
- Measuring and interpreting brand performance.
- Increasing and sustaining brand equity.

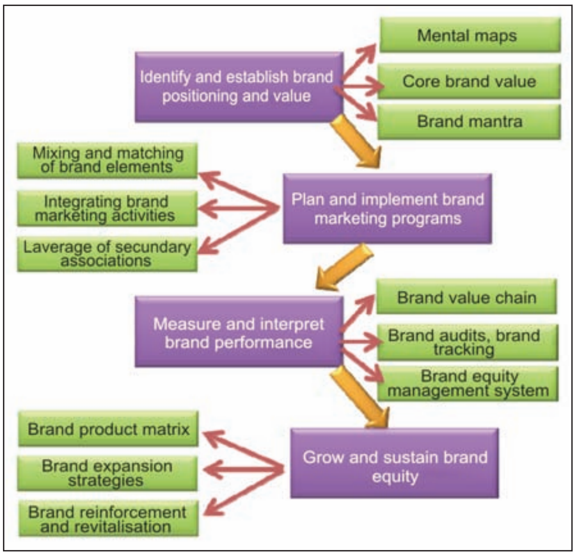

Fig. 3. The strategic brand management process by Keller

The branding process by authors

It is superficial and lacks vision the idea that the successful achievement of the brand is limited to creating only its constituents. A brand is much more. Elimination of phases not only shorten the life expectancy of a brand, but could lead to losses for the company.
Realization processes and strategic management process of the brand are fundamental processes in the activity of an organization. The two processes are closely linked, and therefore we present them as one, the branding process that constantly recreates the brand and aligns it with the external and internal conditions. To be performing a brand must be continuously adapted to the realities of the organization's external and internal environment, consumer needs, and financial realities of the moment. Based on the aspects studied in the literature and based on our experience in managerial achievement of Romanian brands, the model of the branding process, as will be used in developing the organization's interactions with other processes is presented (figure 4). A process that integrates two independent processes: the process of realization of the brand and the strategic management of the brand.

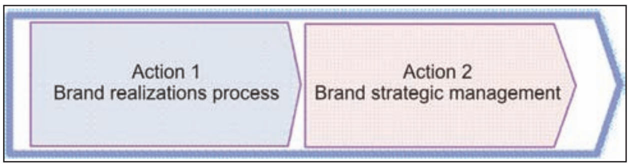

Fig. 4. Branding Process

Authors considered that the implementation of the brand is based on both the art and science of designer, going far beyond the creation of logo types, a slogan etc, and includes a process that has the power to influence consumer perception and attitude towards the product or company (brand creation process itself). (figure 5).

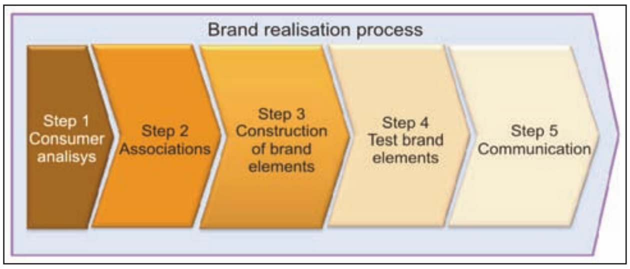

Fig. 5. Brand Realizations Process

Step 1 – Analysis of consumer behavior in the target market for the product that builds the brand.
Understanding the needs and expectations of target, mode of action – are the objectives of this stage. In practice that means building the “portrait” target consumer and building “bulls eyes target” – describes a day in targets' life. It penetrates the mind of the consumer trying to determine the reality that he perceives.
Step 2 – step of determining associations for both product features and those combinations that allow

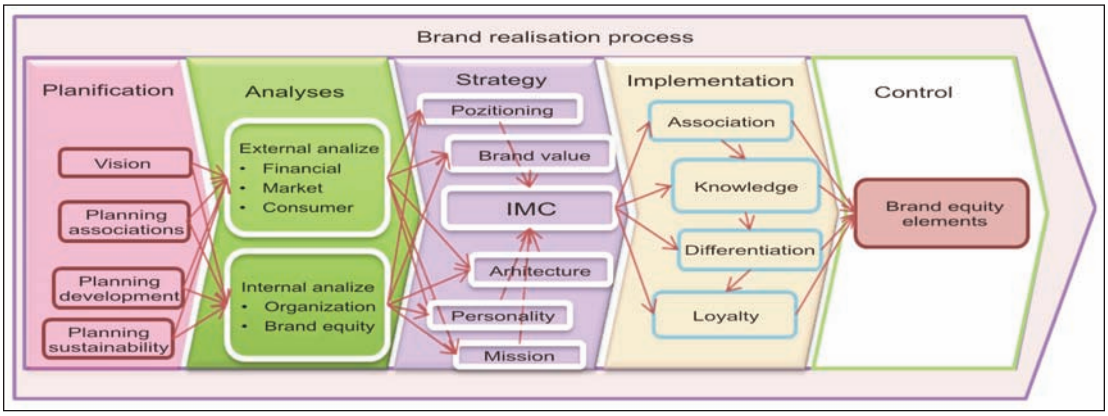

Fig. 6. Strategic Brand Management Process

the connection between company values with product added value and consumer values.

Because attitude is not instinctively learned, the joint role is to guide consumers toward a favourable attitude.

Step 3 – construction of brand elements.

Brand elements include: Name, Logo, USP (Unique Selling Proposition) = slogan, Packaging, Font, Colours

All these are created based on the target customer profile and suggested pairings.

Step 4 – Test brand items.

It is the stage of analysis, stage of presentation to the ideal consumer the new brand as it will be thrown into the market. It is an important step because the brand comes before the one for which it was created. Focus group is the most common method for testing such a "product" and the most effective of them.

Step 5 – construction of consumer perception. Stage is based on a focused action integrated marketing communication to transmit consumer brand elements and its associations.

Strategic brand management process is a holistic process across the organization. The entire organization participates in this process and is directly influenced by the deployment process. For an organization to be long term successful it is necessary to continuously identify opportunities for value – value exploration, promising new proposals embodied in value – value creation and not least to send offers value – value transmission.

Thus, strategic brand management process becomes a process that can provide long-term competitive advantage of the organization by creating brand equity that brings lasting value to the branding triangle: client, company, employees [5], shown in figure 6.

An organization that treats its brands as strategic devices must conduct a comprehensive review process of marketing, brand planning to succeed in its efforts to support and continuously develop its brands.

Continuous improvement of strategic brand management process is a long process, a process strongly correlated with the development strategy of the organization and involves the whole company [7].

Brand planning activity within the strategic brand management process is an essential step in this process that managers often neglected it. Brand planning should provide the whole picture of what is currently the brand, what you can become and where can you get with a proper plan (view on the evolution of the brand).

There is a sales planning, a marketing planning, there is a financial plan, planning of production and so on, each related to planning objectives that lead to the brand.

One of the key stages of the strategic brand management process is the analysis of the external environment and the internal environment of the organization. A thorough analysis of the market in which the brand will be present is primarily a source of information that could become the core brand values.

Industrial organizations from textiles and leather industry can obtain through such analysis relevant views of customers, suppliers, which can then be solved by product attributes or brand associations.

Juck Peddis quoted by Kotler [5] says that the essence of increasing company value lies in the ability to have competitive brand in the market.

Brand strategy is built based on a few items that will bring added value to the consumer perception:

- Brand Positioning
- Brand Mission
- Brand personality
- Brand Promise
- Brand Architecture

The implementation of brand strategy is achieved through the following steps:

- Establishing unique brand associations, meanings that step down the brand in the consumer's mind.
- Achieving brand differentiation from competition
- Increasing brand awareness
- Creating brand loyalty – by strengthening relations with customers

Each of the brand strategy implementation stages is the creation of marketing programs. These stages need time and ongoing attention and constant correction to maintain the brand's mission and values associated with it.

CONCLUSIONS

Dynamic environment in which they operate, the phenomena such as globalization, labour dynamics, all these issues, the rapid change has led to an approach to organization that is in the foreground -- organizational process. Due to the multitude of parameters and the difficulty to analyse the processes based on the data, we have designed models which can simulate behaviours and identify main phases. Modeling helps managers in decision making and simulation scenarios described through the impact they can have on organizational performance. Branding has become, in organizations that use process approach, a holistic process which influences other processes, and depending on other processes may be an important determinant of success or failure of an organization. Increasing economic development, globalization, have increased the value that brands bring to companies. The brand has become an intangible asset of the company that far exceeds the value of tangible assets. Brands are traded, brands are those that establish the price of a company. Long time, brands from industrial organizations and brands from textile and leather industries were included, operating in the B2B sector has been regarded as insignificant judging from their target group. Experience has shown that large companies' brands both operating in B2B markets and the B2C markets, have an increasingly role for creating long-term competitive advantage.

The conclusion reached is that branding is a process and not just any process, but a process of organization relating to activities in all sectors of the organization, covering all the important processes of the organization and an essential element of progress.

The proposed model of the branding process allows more accurate understanding of the activities underlying this process; it may have implications both inside the company and the market in which they operate.

Continuous measurement of market indicators, of financial and consumer perception and behaviour, should be a permanent concern of a dedicated team for branding process. Kotler in "B2B Brand Management" recalled Jim Collins's principle "it is not an end to be the best, it is not a strategy to be the best, no intention to be the best and not a plan in itself to be the best". It's all about understanding the domain where you can be the best, "it is the principle that underlies the performance of a brand". Understanding the industry in which the brand operates, understanding the close links between the branding process and other processes of the organization is the way to corporate success.

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Authors:

Dr. eng. OCTAVIAN ION NEGOIŢĂ
Lecturer dr. eng. OLIVIA DOINA NEGOIŢĂ
Prof. dr. eng. ANCA ALEXANDRA PURCĂREA
University Politehnica of Bucharest
Faculty of Entrepreneurship, Business Engineering and Management
313 Splaiul Independenței street, Bucharest
e-mail: octav.negoita@gmail.com; apurcarea@gmail.com
Dr. eng. CARMEN GHIŢULEASA
The National Research & Development Institute for Textiles and Leather
16 Lucretiu Patrascanu, Bucharest, Romania
e-mail: ghituleasa@certex.ro

Performance management practices in Romanian textile and clothing companies

ADRIANA GIRNEATA
ADRIANA GIURGIU
OCTAVIAN COSMIN DOBRIN
ION POPA
DOINA I. POPESCU
SUNHILDE CUC
LAURA VOICU

REZUMAT – ABSTRACT

Practici de management al performanţei în companiile româneşti de textile şi confecţii

Lucrarea își propune să analizeze nivelul de dezvoltare a practicilor de management al performanței în cadrul companiilor din sectorul de textile și confecții din România. Această lucrare prezintă corelația dintre dimensiunea societăților comerciale și activitățile incluse în programul de management al performanței, criteriile stabilite și indicatorii utilizați în procesul de evaluare anuală a performanțelor companiilor din această industrie. Sunt propuse, de asemenea, direcții viitoare pentru a îmbunătăți managementul performanței în organizațiile de textile – confecții din România, subliniind importanța componentei de resurse umane și a comunicării eficiente între manageri și angajați în ceea ce privește concordanța între obiectivele individuale și cele ale organizației.

Cuvinte-cheie: managementul performanței, industria română de textile și confecții, indicatori de performanță, sistem de evaluare a performanței

Performance management practices in Romanian textile and clothing companies

The present research aims to examine the development level of performance management practices within Romanian textile and clothing companies. This paper investigates the correlation between the size of companies and the activities included in the performance management program, the criteria assessed or the utilized indicators for evaluating the annual performance of companies. The paper also identifies future directions to improve the performance management in Romanian textile and clothing organisations emphasising the importance of the human resource component and that of efficient communication between managers and employees regarding the correspondence between individual and organisational goals.

Keywords: performance management, Romanian textile and clothing industry, performance indicators, performance evaluation system

INTRODUCTION

Performance management constitutes the sum of strategic interventions that influence long-term activity of the organization, leading to improved economic performance. In the literature, a clear distinction is made between performance management and the more mechanical 'business process management' tools that automate the creating, revising, and operating of workflow processes. Primarily, performance management aims at improving and synchronizing improvement in order to create value for and from customers with the result of economic value creation to stockholders and owners (Cokins, 2009). Furthermore, it seeks to enhance broad cross-functional involvement in decision making and calculated risk taking by providing greater visibility and accurate information, focusing mainly on the execution of organization strategy [1].

Due to the significant importance of leadership and communication in achieving high organizational results, the concept was initially regarded as part of the human resources and personnel system. In a narrower sense, performance management is considered the process of targeting and support for the employees in order to work as effectively and efficiently as possible in accordance with the organization's needs (Walters, 1995) [2]. Various studies and indicators (Campbell et al., 1998) demonstrate that the success and competitiveness of organizations depend largely on the professional performance of employees and the modalities to improve it must become a stringent and permanent preoccupation in the present competitive market conditions [3]. Armstrong (2009) defines performance management as a systematic process of improving organizational performance by developing the performance of individuals and teams [4]. Accordingly, the author underlined the necessity of a strategic and integrated approach to ensure the success of organizations by improving the performance for people who work within them and through the development of capabilities of teams and individuals (Armstrong & Baron, 2004) [5]. Moreover, performance management refers to the alignment of individual and organizational objectives to ensure that individuals acquire the intrinsic value of the corporation, so that their expectations are defined in terms of responsibilities and justification, skills and behaviours (Endres, Smoak, 2008) [6]. Some specialists consider that performance can be measured exclusively on financial information due to the fact that performance management systems were designed and operated preponderantly on the accounting and finance functions existent within the organization. This approach determined companies to administrate their projects based on relatively outdated costs and less developed finance-oriented measurements (Anderson & McAdam, 2004) [7]. Undoubtedly, performance management is not simply a performance measurement, indicators and statistics are merely components of the broad performance management framework. For instance, the balanced scorecard, a popular management tools for enhancing managerial performance, is not sufficient to create an effective performance management (Pulakos, 2009) [8] and evidence demonstrated that in order for this to have conclusive results it must be linked with other management processes (Cokins, 2004) [9].

We consider that performance management is a planned process in which the primary elements are understanding, measurement, feedback, positive attitude and dialogue. It refers to the measurement of results in the form of performance obtained compared to expectations expressed as objectives. It focuses on goals, standards, measures and performance indicators. Therefore, an efficient performance management is based on both behaviour parameters and expected results assumed and obtained.

Popescu et al. (2009) consider that the performance evaluation of enterprises not only in terms of quantity, but also of quality can be achieved by creating an index of European consumer enthusiasm regarding multiple periods, on the intertwined sections [10].

The importance of the textile and clothing sector in Romania

The importance of this study derives from the fact that the textile and clothing sector (T&C) represents an important segment of the European manufacturing industry, as well as a vital sector of the Romanian economy, giving employment to more than 200,000 people in 2012 in this country only (Girneata, 2013) [11]. Furthermore, the clothing industry is a branch with significant tradition, ranking third place in Romania's exports and fourth place in the EU clothing exports (Popescu, 2013) [12]. There are required concrete measures to enhance the performance of these companies and one of the solutions is implementing and developing the performance management practices within the companies that operate in this field.

METHODOLOGY

In order to obtain valid information on performance management practices in Romanian T&C companies and the correspondence between the existence of these managerial tools and the competitiveness of firms, the authors have performed an opinion survey amid the organizations that activate in the textile and clothing sector. A representative sample of 232 respondents received questionnaires and a 63% response rate was obtained. The data obtained from the questionnaires were analyzed through statistical techniques of descriptive statistical analyses (frequencies and percentages) in order to establish the performance management tools used in Romanian companies.

The four main objectives of the current research are:

Objective 1: Identifying the existence of an implemented performance management system in Romanian T&C companies;

Objective 2: Identifying the activities used preponderantly in the performance management evaluation system within Romanian T&C companies;

Objective 3: Identifying the present state of correspondence between performance management practices and the competitiveness of companies;

Objective 4: Determining the future development directions of the performance management practices regarding the needs of companies that activate in this sector.

RESULTS AND DISCUSSIONS

The study was conducted on a number of 146 companies in the T&C industry from all the development regions of Romania. The first section of the questionnaire contains general identification questions about the analysed companies: the number of employees, the region they belong to, the capital structure. The classification of companies regarding the capital nature indicated that from the total of 146, a number of 133 firms possess Romanian capital, while only 13 of them are mixed companies with foreign capital. The territorial structure of the sample investigated is detailed in table 1.

Considering the structure of firms by employees number, the highest percentages are represented by micro-enterprises (50%) and small firms (29.45%), as presented in table 2. The low percentage of medium and large enterprises in the sample, 19.18% and 1.37% respectively, is not surprising, considering the Romanian T&C industry is characterized by a large number of small and micro enterprises.

The information obtained in the second part of the question set **regarding the existent performance management programs** in Romanian T&C companies have a significant importance to the present

Table 1

THE COMPANIES' DISTRIBUTION ACCORDING TO THE DEVELOPMENT REGIONS			
No.	**Development region**	**No. of companies analysed**	**Percentage (%)**
1	North East	17	11.64
2	South East	15	10.27
3	South Muntenia	26	17.81
4	South West Oltenia	9	6.16
5	West	16	10.96
6	North-West	19	13.01
7	Centre	30	20.55
8	Bucharest and Ilfov	14	9.59
Total		**146**	**100**

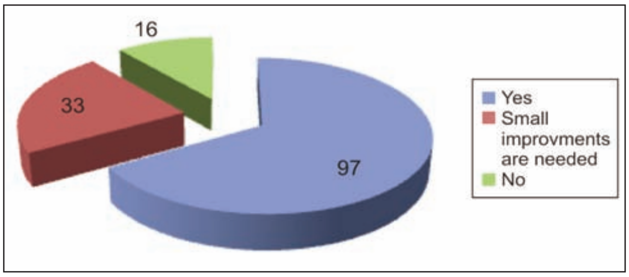

Fig. 1. Managers' perception regarding the existence of an efficient performance program in their companies

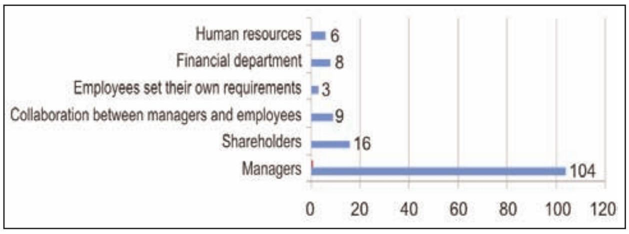

Fig. 2. Who sets the performance criteria for employees

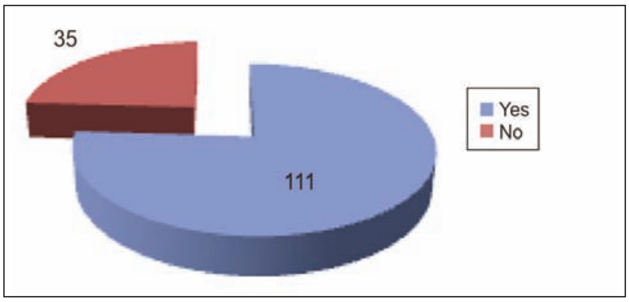

Fig. 3. Connection of performance objectives to the company's strategic goals

research. The answers received revealed that out of 146 managers, 66.44% consider that in their companies there is implemented an efficient performance program, 22.60% admit that improvements are needed and 10.96% of them assert that the performance management program is non-existent or ineffective (fig. 1).

Managers indicated that typically they set performance criteria for employees (71.23%), while 10.96% of the respondents stated that these are established by shareholders. Nine managers report that they collaborate with their employees in the process of setting performance criteria for the latter. Financial department (5.48%), employees alone (2.05%) or human resources (4.11%) elaborate performance requirements less often (fig. 2).

Furthermore, according to the respondents, in 111 firms the company's goals are connected to the performance objectives and in less than 24% of the companies (in 35 of them) such a link is absent (fig. 3).

Analysing the correlation between the activities used in the performance management program and the size of the companies, it was identified that a relatively wide range of activities are used by the companies of all sizes in the performance management program (table 3). However, the predominant activity is **employee evaluation**, found in over 61% of microenterprises surveyed, in more that 88% of small companies and in an overwhelming proportion of almost 93% and 100% in medium and large enterprises respectively. The majority of companies stated they have included several program activities in the performance management program and they were not limited to a single choice in the survey.

Another activity that is found in a relatively large number in all categories of companies is **performance goal setting**. Within 38.36% of microenterprises, managers stated that they use this tool to determine their employees to work more efficiently and achieve performance. Basically, they set a certain number of

Table 2

COMPANY SIZE BY NUMBER OF EMPLOYEES								
Total	**Micro-enterprise**		**Small**		**Medium**		**Large**	
	1-9 employees		10-49 employees		50-249 employees		over 250 employees	
	Nr.	%	Nr.	%	Nr.	%	Nr.	%
146	73	50.00	43	29.45	28	19.18	2	1.37

Table 3

CORRELATIVE ANALYSIS OF THE ACTIVITIES USED IN THE PERFORMANCE MANAGEMENT PROGRAM AND THE SIZE OF THE COMPANIES								
Activities featured in the performance management program	**Micro-enterprise**		**Small**		**Medium**		**Large**	
	73 respondents		43 respondents		28 respondents		2 respondents	
	Nr.	%	Nr.	%	Nr.	%	Nr.	%
Employee evaluation	45	61.64	38	88.37	26	92.86	2	100.00
Financial motivation/Rewards	12	16.44	19	44.19	20	71.43	2	100.00
Performance goal setting	28	38.36	21	48.84	23	82.14	2	100.00
Feedback	2	2.74	4	9.30	17	60.71	1	50.00
Training	11	15.07	6	13.95	19	67.86	2	100.00
360 feedback	-	-	1	2.33	3	10.71	-	-
Other	1	1.37	1	2.33	2	7.14	1	50.00

Table 4

CORRELATIVE ANALYSIS OF THE PERFORMANCE CRITERIA ASSESSED AND THE COMPANIES' SIZE								
Performance criteria	**Micro-enterprise**		**Small**		**Medium**		**Large**	
	73 respondents		43 respondents		28 respondents		2 respondents	
	Nr.	%	Nr.	%	Nr.	%	Nr.	%
Achievement of goals	17	23.29	16	37.21	12	42.86	1	50.00
Attendance	14	19.18	6	13.95	1	3.57	-	-
Quality of work	19	26.03	8	18.60	7	25.00	1	50.00
Quantity of work	21	28.77	9	20.93	3	10.71	-	-
Adaptability	2	2.74	3	6.98	3	10.71	-	-
Safety	-	-	1	2.33	2	7.14	-	-
Other	-	-	-	-	-	-	-	-

finished products that workers have to perform daily. This practice is common also in small (48.84%), medium (82.14%), and large companies (100%), but these use it in a greater proportion along with the financial motivation. Managers stated that technologists set the number of products to be made within the daily working hours and employees who decide to work overtime receive additional financial incentives. Financial motivation is not common in microenterprises (16.44%) due to the low financial power of these types of firms. Also, these do not put special emphasis on training. Only 15.07% of microenterprises and almost 14% of small companies use it as an activity in the program of performance management, invoking lack of time or too much cost needed. Medium and large companies see the importance of training in ensuring performance in the company and provide training for employees both qualification at work, and training during the year, whenever it is necessary in a proportion of 67.86% and 100%, respectively.

The correlative analysis of the performance criteria assessed and the size of the companies is presented in table 4. The most important criteria for microenterprises are **quantity of work** (28.77%), **quality of work** (26.03%), **achievement of goals** (23.29%) followed by **attendance** (19.18%). The managers of these companies focus on productivity in order to finalize on time the contracts obtained. Having a small number of employees determines them to prioritize the amount of work, and issues such as adaptability come last (2.74%). In the case of small and medium companies, the highest rates are for **achievement of goals** (37.21% and 42.86% respectively); whilst the two managers from the large companies asserted that the most important performance criteria are achievement of goals and quality of work. Of the 146 companies analyzed, only 21 firms gave **attendance** great importance and only eight of them prioritized adaptability on the performance criteria list.

After analyzing the correlation between the annual performance indicators and the size of the companies the following results were revealed (table 5):

- 58.9% of the investigated managers stated that financial indicators such as turnover and profit are the most significant annual performance indicators,

Table 5

CORRELATIVE ANALYSIS OF ANNUAL PERFORMANCE INDICATORS AND THE SIZE OF THE COMPANIES										
Annual performance indicators	**Micro-enterprise**		**Small**		**Medium**		**Large**		**Total**	
	73 respondents		43 respondents		28 respondents		2 respondents		146 respondents	
	Nr.	%	Nr.	%	Nr.	%	Nr.	%	Nr.	%
Financial indicators	56	76.71	21	48.84	8	28.57	1	50.00	86	58.90
Employee's evaluations	4	5.48	6	13.95	5	17.86	-	-	15	10.27
Goal settings	12	16.44	13	30.23	11	39.29	1	50.00	37	25.34
Comments	1	1.37	2	4.64	3	10.71	-	-	6	4.11
Other	-	-	1	2.33	1	3.57	-	-	2	1.37

followed by goal settings chosen by 37 managers (25.34%);

- A little over 10% of all respondents affirmed employee's evaluations are appropriate indicators of the company's annual performance;
- Six managers (4.11%) considered comments as the proper indicator, referring to customer comments and feedback;
- Two of the respondents affirmed that most important is goal progress or adapting to market demands and technological innovation.

Challenges faced by the companies and future directions to increase the performance management practices based on the analysis undertaken:

– performance evaluation results and scores are not always tied to rewards;
– managers focus primarily on financial indicators in determining company's performance;
– employees lack the accountability for achieving performance criteria;
– the documentation of performance reviews is sometimes inconsistent or missing, especially in medium and large companies;
– larger organizations report failures of supervisors to provide developmental feedback to employees, not wanting to risk jeopardizing the relationships with the individuals they count on to get work done;
– in most cases, performance objectives are not linked to the company's strategic goals or employee's objectives are not aligned with the business strategy of the company;
– the performance objective is not flexible enough to allow for minor changes in the job to occur and still apply the objective (for example: in microenterprises and small companies employees often move from one task to another at the request of supervisors and therefore they do not manage to complete the initial requirements);
– in the majority of cases, performance objectives do not provide a degree of challenge in order to remove the routine of work, yet still be achievable;
– employees are not sufficiently involved in the process of setting goals.

Future directions:

– managers need to focus on medium-term planning, not on analyzing recent activity, and to develop the performance management system calibrated on the need of the company and its organizational culture, designed to be congruent with the strategic goals of the organization;
– it is necessary to include, among performance indicators, the adaptation to market demands and technological innovation. In the current context of exacerbated competition, the decline of consumer loyalty to the brand, or the tendency of international companies to align with the fast-fashion current, firms need to appeal to innovation and creativity in order to maintain or increase their financial and management performances;
– managers and supervisors must communicate clear messages around performance based on goals and competencies as communication has a vital role in obtaining effective performance management;
– ongoing focus on dialogue, rather than on forms and graphics;
– managers must identify and prioritize strategic and operational projects in order to improve the organization's performance in financial, customer and people dimensions.

CONCLUSIONS

The performance management is used in organizations at individual level, managers aiming mainly to monitor employee performance in a precise context. Performance management should be seen as a key capability, central at the organizational level, generating competitive advantage. An effective performance evaluation system must be well articulated, with a clear definition of roles and goals for both managers and for those occupying positions of non-management within the organization.

The study revealed that the majority of managers in Romanian T&C companies consider their firms benefit from an efficient performance program. Overall, the preponderant activities featured in the firms' performance programs are employee evaluation, performance goals settings and financial motivation, yet, in a significant percentage of companies, the performance objectives are not connected to the company's strategic goals. Furthermore, it was established that the results in employees' evaluation are not invariably tied to compensation. The study also showed the challenges faced by the companies in the T&C sector regarding this matter. Moreover, the paper identified future directions to improve the performance management in Romanian textile and clothing organizations.

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Authors:

Ph.D St. ADRIANA GIRNEATA [1]
Prof. Dr. ADRIANA GIURGIU [2]
Prof. Dr. COSMIN OCTAVIAN DOBRIN[1]
Prof. Dr. ION POPA[1]
Prof. Dr. DOINA I. POPESCU[1]
Assis. Prof. Dr. SUNHILDE CUC[3]
Ph.D St. LAURA VOICU[1]

1. The Bucharest University of Economic Studies
Faculty of Management
6 Romana Street-010374 Bucharest, Romania
2. University of Oradea, Faculty of Economics, Romania,
3. University of Oradea, Department of Textile Engineering

e-mail: adriana_girneata@yahoo.com, agiurgiu@uoradea.ro, cdobrin@yahoo.com, iipopa@yahoo.com, doinaipopescu@yahoo.com, sunhilde_cuc@yahoo.com, vlauravioleta@yahoo.com

Corresponding author:

Prof. Dr. Ion Popa
iipopa@yahoo.com

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