PARAMETERS OF THERMO-PHYSIOLOGICAL COMFORT OF THE LITURGICAL CLOTHING STRUCTURE

Phd Student **Mihai CHIRILĂ**[1], Proffessor, PhD, engineer **Ioan CIOARĂ**[2], Associate Professor, PhD engineer **Daniela FĂRÂMĂ**[2]

[1]Doctoral School of the Faculty of Textile, Leather and Industrial Management,
[2]"Gheorghe Asachi" Technical University of Iasi, Faculty of Textile, Leather and Industrial Management, Iassy, Romania

REZUMAT. Au fost evidențiate îmbrăcămintea și cerințele de mediu pentru slujirea preoților creștini ortodocși în interiorul bisericii. Permeabilitatea la aer, vapori și căldură a fost analizată în condiții standard de laborator, în același timp a fost monitorizată influența coeficientului de umiditate asupra coeficientului termic. S-au găsit corelații ale transferului de căldură cu umiditatea și temperatura.

Cuvinte cheie: caracteristici structurale, transferul de căldură, umiditate, temperatură, permeabiliate.

ABSTRACT. The clothing and environmental requirements for serving Orthodox Christian priests inside the church were distinguished. The permeability to air, vapor and heat was analyzed under standard laboratory conditions, at the same time the influence of the coefficient of humidity on the thermal coefficient was monitored. Correlations of heat transfer with humidity and temperature have been found.

Keywords: structural characteristics, heat transfer, humidity, temperature, permeability.

1. INTRODUCTION

Wear comfort has been pointed out as the most important property of clothing demanded by users and consumers according to recent studies. A fundamental understanding of human comfort and knowledge of how to design textiles and garments to maximize comfort for the wearer is therefore essential in the clothing industry. Improving clothing comfort analyzes the latest developments in manufacturing comfortable clothing and discusses ways to improve the liturgical garments.

The present study was undertaken with an aim to explore suitable combination of various types of textile raw materials with good thermo-physiological properties, for improving the performances for clothing liturgical assemblies.

Comfort may be defined as a pleasant state of psychological, physiological and physical harmony between a human being and the environment. Today humans rely on clothing which protects body from cold and heat throughout full range of human activities, otherwise it leads to discomfort. Discomfort comes mainly from the accumulation of sweat on the skin and insufficient heat loss during overheating in hot environments.[1]

Extensive research has been published on the diverse aspects of simultaneous heat and moisture transfer both theoretically and experimentally. Results shows, that the ability of clothing materials to transport moisture vapor is a critical determinant of wear comfort, especially in conditions that involve sweating. So, for satisfactory performance of clothing comfort researchers recognize that clothing comfort has two main aspects. These are thermo-physiological and sensorial comfort.

Thermo-physiological properties of textiles determine the transport of heat, moisture vapor and liquid moisture from skin to environment through clothing and are therefore, crucial to provide comfortable microclimate to the wearer. Clothing layer worn next to skin should have two important properties: the initial and the foremost property is to absorb the perspiration from the skin surface and second property is to transfer moisture to atmosphere and make the wearer feel comfortable. The thermal properties along with air permeability and drying ability of textiles are equally important in determining the overall wearer comfort.

In this paper we are trying to understand the mechanism behind heat and moisture transmission along with postulated models, over the fabrics habitually used for clothing liturgical assemblies.

Details of evaluated properties and equipment used to measure heat and moisture transmission is also explained.

2. METHODS AND MATERIALS

Process involved in heat and moisture transport is an important factor which influences dynamic comfort of clothing. If ratio of evaporated sweat and produced sweat is very low, moisture will be accumulated in the inner layer of the fabric system, ultimately affect the thermal insulation of clothing [2]. It means there is a correlation between heat and moisture transmission through fabrics, which plays a major role in maintaining a wearer's body in comfort zone. Hence a clear understanding of heat and moisture transmission from clothing is required for designing new high performance fabrics for different application.

The clothing structures analyzed here are for Orthodox Christian priests who offer their services inside churches. Therefore, it is a closed environment in which its most important parameters are: air temperature t_a[°C] and radiant surfaces t_r [°C] (church walls), relative air humidity φ [%] and speed v [m/s]. The thermal balance of the human body is mainly determined by the temperature of the air that directly interferes with the thermoregulation process. Therefore, the variation in the temperature of the environment leads to changes in the other factors (activity, metabolism, duration of activity, air humidity, ambient temperature, etc.).

For the calculations in which they occur, the environmental parameters will work with the following values:

- the air temperature:

$$t_a = 5 \div 30 \text{ [°C]}$$

- relative air humidity:

$$\varphi = 60 \div 70 \text{ [\%]}$$

- air speed:

$$v = 0.1 \div 0.3 \text{ [m / s]}.$$

The clothing structures to be analyzed are composed of 5 types of garment products:

1. Underwear (U);
2. Shirt (S);
3. Mantle (M);
4. Surplice (S_i);
5. Phelonion (P_i).

Because the surplice and the phelonion are layers that are seen by the parishioners in a larger proportion, they were made of several types of textile material, the code of these garments containing the indices *i*.

The choice of textile materials for clothing products and, implicitly, of clothing structures was made taking into account the fibrous composition, in order to encourage the use of textile materials with as much as possible natural raw materials (cotton, lynn, natural silk), without diminishing of the importance and benefits of using chemical raw materials (PES, viscose, etc.). Taking into account the above mentioned, 14 textiles were chosen from which it is proposed the realization of 5 types of garments with which to obtain variants of clothing structures. Samples used were with the size of 10 x 10 cm.

The Textile Code consists of the letter corresponding to the clothing product X in which a numerical index (X_i) is also used.

The textile material coding for the five garments in the clothing structures to be further analyzed as well as their fibrous composition, the thickness g [mm] and the mass of the surface unit M [g / m2] are specified in Table 1.

Table 1 shows that materials from natural raw materials (cotton and linen) have been chosen or are in the immediate vicinity of the layers of fabric which come in direct contact with the skin (underwear, shirt). This choice is in correlation with the condition of the wearer tolerance (activity requiring little physical effort) and environmental conditions (inside the church).[3]

3. DETERMINATION OF THERMOPHYSIOLOGICAL CHARACTERISTICS OF TEXTILE MATERIALS

Taking into account the fact that the textile materials chosen for the research are intended to obtain garments for priests, it is accepted that the group of comfort characteristics determined on textile is also found in the garment which will represent both the material layer and the assortment of clothing.

Thermo-physiological function is influenced by factors such as:

- the nature, characteristics and quality of the wires;
- the structural characteristics of the textile material,
- cutting and clothing product model;
- finishing treatments applied.

The determinations of comfort characteristics for the materials selected for research were performed under static laboratory conditions (φ = 63%, t = 18.7 ° C).

The thermo-physiological characteristics of the textile materials analyzed in this paper are:

- vapor permeability Pv [g], vapor permeability coefficient:

$$Pv \text{ in g/m}^2\text{h} \qquad (3.1)$$

Table 1. **Description of the textile materials used during the experiments**

Criterion Number	**Textile Material/Destination**	**Code**	**Fibrous composition**	**Thickness g[mm]**	**Mass of the surface unit M[g/m²]**
1	Underwear knitted fabric in glat structure	U	Cotton Yarn 100%, Nm 54/1	0,61	135
2	Shirt with canvas bundle	S	Cotton 100 %	0,36	112,4
3	Mantle made of canvas bundle on the front and with hemstich on the back	M	50% cotton+50%linen	0,42	202,5
4	Surplice weaved with canvas bundle	S1	cotton100%	0,20	127,5
5	Surplice weaved with canvas bundle on the front and with hemstich on the back	S2	50% cotton +50%linen	0,42	202,5
6	Surplice from jacard fabric with Damasc effect	S3	100% natural silk	0,32	150,0
7	Surplice weaved with atlas bundle	S4	100% PNA	0,15	100,0
8	Surplice weaved with canvas bundle	S5	100% viscose acetate	0,09	87,5
9	Surplice weaved with canvas bundle	S6	100% lynen	0,27	182,5
10	Surplice weaved with atlas bundle	S7	100% PES	0,13	100,0
11	Phelonion from jacard fabric with Damasc effect	P1	100% PES	0,65	202,5
12	Phelonion from jacard fabric	P2	100% PES and Lame yarn	0,70	250,0
13	Phelonion from jacard fabric with Damasc effect	P3	100% natural silk	0,32	150,0
14	Phelonion weaved with canvas bundle	P4	100% wool	0,74	252,5

- vapor passing resistance:

$$Rv \text{ in mm}^2\text{h/g} \quad (3.2)$$

- air permeability:

$$Pa \text{ in m}^3\text{/min}\cdot\text{m}^2 \quad (3.3)$$

- air passage resistance.

$$Rpa \text{ in mm}^2 \text{ h/kg} \quad (3.4)$$

- thermal insulation by the coefficient of thermal conductivity:

$$\lambda \text{ in Kcal/m.h.C} \quad (3.5)$$

- porosity Pz [%].

The porosity was determined by the pycnometric method and the values obtained are shown in the table 2.

The vapor permeability Pv [g] and the vapor permeability coefficient [g / m²h] were used as vapor diffusion vapor permeability indicators and the vapor resistance Rv [mm2h h / g] as indirect indicators. The determinations were performed according to STAS 9005-79 and the mean values obtained from 20 determinations for each textile variant are shown in Table 2.

The determinations were made at a pressure difference of 5 mm equivalent. col. Water [STAS 5902-70]. The air permeability Pa [m³ / min. · m²] and the air passage resistance Rpa [mm2 h / kg] are shown in Table 2.

In order to assess the thermal insulation capacity, the coefficient of thermal conductivity [Kcal / mhC], which was determined in the Comfort and Functional Clothing Laboratory of the Textile-Leather Faculty, was chosen as an indirect indicator. It was used -Tex.-Tester apparatus, which works on the skin model principle. The values obtained for thermal insulation indicators are shown in Table 2.

Table 2. **Determination of thermophysiological characteristics of textile materials**

Code	P_z [%]	P_v [g]	P_a [m³/min.m²]	Rv [mm m² h/g]	[Kcal/mh°C]
U	74,32	2,111	35,2972	0,0136	0,0236
S	52,17	1,798	20,0236	0,0134	0,0200
M	47,39	1,77	11,11	0,01898	0,0272
S1	42,56	1,922	9,82	0,0083	0,0285
S2	47,39	1,77	11,11	0,01898	0,0272
S3	31,07	1,816	4,48	0,0140	0,0266
S4	31,07	1,886	12,82	0,00636	0,0312
S5	13,90	1,596	15,38	0,0045	0,0351
S6	29,83	1,670	24,78	0,0129	0,0323
S7	31,52	2,054	5,76	0,00469	0,0293
P1	67,65	1,674	9,61	0,0310	0,0248
P2	63,07	1,829	4,70	0,0306	0,0256
P3	31,07	1,816	4,48	0,0140	0,0266
P4	64,30	0,863	28,20	0,0686	0,0251

4.RESULTS AND DISCUSSIONS

Results shows, that the ability of clothing materials to transport moisture vapor is a critical determinant of wear comfort, especially in conditions that involve sweating. So, for satisfactory performance of clothing comfort researchers recognize that clothing comfort has two main aspects: thermos-physiological and sensorial comfort. The first relates to the way clothing buffers and dissipates metabolic heat and moisture, whereas the latter relates to the interaction of the clothing with the senses of the wearer, particularly with the tactile response of the skin, which includes moisture sensation on the skin [4].

The wear comfort of clothing is affected by physical processes include heat transfer by conduction, convection and radiation, meanwhile, moisture transfer by diffusion, sorption, wicking and evaporation. During higher activity level and/or at higher atmospheric temperatures sweat gland get activated which produce liquid as well as perspiration. [5] When the perspiration is transferred to the atmosphere it carries heat (latent as well as sensible) thus reducing the body temperature. The fabric being worn should allow the perspiration to pass through; otherwise it will result in discomfort. If moisture transfer rate is not adequate during sweating than it may result in heat stress due to increase in skin temperature. From last few decades the field of dynamic heat and moisture transport behavior of clothing and their influences on clothing comfort is main interest of researchers.

Clothing by its nature has an insulating effect and resists transfer of excess heat and moisture from the body. A still layer of air confined between the skin and fabric or between two fabric layers can make the wearer extremely uncomfortable due to its barrier effect. Thus the most important purpose of clothing is to provide a stable microclimate next to skin by maximizing the rate of heat and moisture loss from the body.

If ratio of evaporated sweat and produced sweat is very low, moisture will be accumulated in the inner layer of the fabric system, ultimately affect the thermal insulation of clothing. It means there is some correlation between heat and moisture transmission through fabrics, which play a major role in maintaining a wearer's body in comfort zone. Hence a clear understanding of heat and moisture transmission from clothing is required for designing new high performance fabrics for different application.

Starting from the idiom that there are 3 layers of clothing that make up the whole ensemble fashion: one layer is composed of underwear (T-shirt and shirt); layer 2 - priestly uniform (mantle); layer 3 - sacerdotal suit (surplice, epitrachelion, phelonion). This study captures clothing shells fired from inside the thorax. It is focused primarily on thermo-physiological comfort during priestly activity, but also in the rest state.

Phelonion, as textile clothing object has the following user demands: to allow free breathing and amplitude of movements imposed by common tasks and during gainful activities; allow a space for air between the body and the product needed to achieve thermal equilibrium, airflow, ventilation and removal of moisture from underclothing space; ensure correspondence with the aesthetic demands of the product, is in correspondence with current trends presentation and demeanor, harmonious shapes to emphasize the body and alleviate some of conformation and held accents. Epitrachelion is a strip of cloth or silk wide as long as 30 cm and surplice, or turtle top, so that it can enter the head to be then placed on his shoulders. At the lower end is adorned with fringes and the strip that hangs on the chest sewn or embroidered cross. [6]

Alb (surplice) is a first piece of clothing in priestly costume, having a flexible (unstable) as a garment. As a rule, in the form of flexible, as a feature presentations are made of a single layer of base material with small thickness and low rigidity. Form of textile product mentioned above is revealed only settlement on the human body or mannequin industry.

In this study, the theoretical model can be used to calculate the permeability of woven fabrics. The construction factors and finishing techniques affects the air permeability. It is influenced by several factors such as the type of fabric structure, the design fabric density, the amount of twist in yarns, the size of the yarns, the type of yarn structure, the size of the interstices in the fabric and etc.

The permeability and porosity are strongly related to each other. If a fabric has very high porosity, it can be assumed that it is permeable. A fabric with zero porosity can be assumed to have zero permeability in theory.

5. CONCLUSIONS

In conclusion, the place of liturgical garment towards the body (the degree of coverage body by textile product), the requirements for ergonomic, sensory, thermo-physiological comfort, and aesthetic properties of the raw materials of which requires manufacturing textile fabric, will lead to the establishment of the exact costs and optimize the use of the materials in a proficient manner.

Personal contribution within original research lies in evaluating the optimal parameters of different types of fabrics for increasing thermo-physiological comfort over clothing liturgical assemblies.

REFERENCES

[1] Slater, K., *Human Comfort,* Thomas Sprinfield, USA, 1985.
[2] Zhang, P., Watanabe, Y., Kim, SH., Tokura, H., *Thermoregulatory responses to different moisture-transfer rates of clothing materials during exercise,* Journal of the Textile Institute, China, 1992.
[3] Das, A., Ishtiaque, S.M., *Comfort Characteristics of Fabrics Containing Twist-less and Jollow Fibrous Assemblies in Weft*, *Journal of Textile and Apparel Technology and Management*, Volume 3, Number **4**, 2004.
[4] Andreen, J.H., Gibson, J.W., Wetmore, O.L., *Fabric Evaluations Based on Physiological Measurements of Comfort*, Textile Research Journal **23**, 1953.
[5] Li, Y., Zhu, QY, *A model of coupled liquid moisture and heat transfer in porous textiles with consideration of gravity*, Numerical Heat Transfer, **43**, 2003.
[6] Drăgan, Gleb acad., și colectiv de autori: *Dicționare explicativ pentru știință și tehnologie.Textile,* Ed. AGIR, București, 2006.

About the author

PhD Student **Mihai CHIRILĂ**
Doctoral School of the Faculty of Textile, Leather and Industrial Management, "Gheorghe Asachi" Technical University of Iasi, Romania

Graduate of the "Dumitru Staniloae" Faculty of Orthodox Theology of Al. I. Cuza, Iași, Pastoral Section - 1994. Graduate of the Master's Degree - Faculty of Orthodox Theology of "Ovidius" University of Constanta. At present PhD student at the Doctoral School of Textile, Leather and Industrial Management, Technical University "Gheorghe Asachi" Iasi, Prof. Univ. PhD. Eng. Ioan Cioară. Areas of expertise: expert in scientific investigation of works of religious art and archaeological textiles.