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The Influence of Knitting Structure on Heating and Cooling Dynamic

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The comfort provided by clothing depends on several factors, one of them being thermal comfort. Human thermal comfort depends on a combination of clothing, climate, and physical activity. It is known, the fibre type, yarn properties, fabric structure, finishing are the main factors affecting thermo-physiological comfort. The thermal property of knitted fabric is very important not only for its thermal comfort but also for protection against cross weather conditions. Most of the studies carried out have been devoted to measure static thermal properties. But it is very important not only amount of the heat released to the environment but also the dynamics of the heat transmission. The main goal of this work was to investigate the dynamic of the heat and cool transfer through the fabrics with different knitting pattern and different type of the yarns. Three different types of knitted fabrics were developed for this experimental work.
Keywords: knitting structure, air permeability, heat and cool interchange dynamic, heat insulation.

1. INTRODUCTION

Knitted fabrics not only posses stretch and provide freedom of movement but they also have good handle and comfort. That is why knitted fabrics commonly preferred for sportswear, casual wear, and underwear. The term comfort is a subjective concept, which is recognised by the person experiencing it. It can be defined as a natural state compared to the more active state of pleasure. A state of comfort can only be achieved when the most complex interactions between a range of physiological, psychological and physical factors taken place in a satisfactory manner, i. e. clothing comfort includes three main considerations: thermo-physiological, sensorial and psychological comfort [1, 2]. The comfort provided by clothing depends on several factors, one of them being thermal comfort. It is known, the fibre type, yarn properties, fabric structure, finishing treatments and clothing conditions are the main factors affecting thermo-physiological comfort [2 – 4].

Clothing must assist the body's thermal control function under changing physical loads in such a way that the body's thermal and moisture management is balanced and a microclimate is created next to the skin [5]. This physiological effect is extremely important, especially in the case of clothing for sports and active leisure. Items of clothing with poor thermo-physiological wear characteristics not only detract from well-being of the human but also impair his/her physical performance and may even act as a health hazard. Human produces heat continuously inside his/her body during all his/her activities because of metabolic processes. With greater physical exertion, and thus a greater level of heat generated by the body itself, heat transfer through the clothing is insufficient to compensate for the body's energy balance. In this case, we begin to sweat, the aim being to cool the body through evaporation of the sweat on the skin [5, 6].

Human thermal comfort depends on a combination of clothing, climate, and physical activity. The human organism is homoeothermic, which means that it has to maintain its core temperature within close limits around 37 °C. During all kinds of activity, the human body produces a certain amount of heat in the range of 80 W while sleeping, to even over 1000 W during intensive effort [7, 8]. The basic heat transfer mechanisms (conduction, convection and radiation) are well known to anyone in engineering. All three heat transfer mechanisms coexist in the heat transfer process from a heated surface through a porous fabric attached onto it. In general, heat transfer from the heated body to the fabric takes place by convection, conduction and radiation concurrently [9].

The thermal property of knitted fabric is very important not only for its thermal comfort but also for protection against cross weather conditions [9, 10]. The thermal resistance of clothing as a set of textile materials depends on the thickness and porosity of particular layer. Due to the fact that changes in the porosity of standard textile materials used in clothing are not large, the total thermal resistance of clothing is influenced by the material thickness [9]. The warmth of a fabric is due to insulation provided by air trapped between fibres and yarns. Fabrics from strain filament yarns remove heat rapidly by conduction when placed next to the skin. Fabrics from hairy yarns feel warm on contact with the skin due to the insulating air held between the fabric fibres and the skin [6].

Most of the studies carried out have been devoted to measure static thermal properties. But it is very important not only amount of the heat released to the environment but also the dynamics of the heat transmission. However, investigations in the field of the heat transfer dynamics through the knitted fabric are very low.

The main goal of this work was to investigate the dynamics of the heat and cool transfer through the fabrics with different knitting pattern and different type of the polyester yarns, herewith, the polyester yarns which are

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created for thermo controlling – CoolDry® and ThermoCool® yarns.

2. MATERIALS AND METHODS

Three different types of knitted fabrics were developed to determine the dependence of the thermal properties and heat/cool transfer dynamics on the knitting pattern and yarns type. The knitting structure of tested knitted fabrics is presented in Fig. 1 and characteristics of tested knitted fabrics are presented in Table 1.

The fabric *F1* is knitted in pattern presented in Fig. 1, a. The fabrics *F2* and *F3* are knitted in the same pattern, which is presented in Fig. 1, b. Uneven courses of fabrics *F1* and *F2* are knitted from PES treads with 8.3 tex linear density, and even courses are knitted from PES yarns with 16.4 tex linear density. Uneven courses of fabric *F3* are knitted from polyester CoolDry® threads with 8.3 tex linear density, and even courses are knitted from polyester ThermoCool® yarns with 16.4 tex linear density.

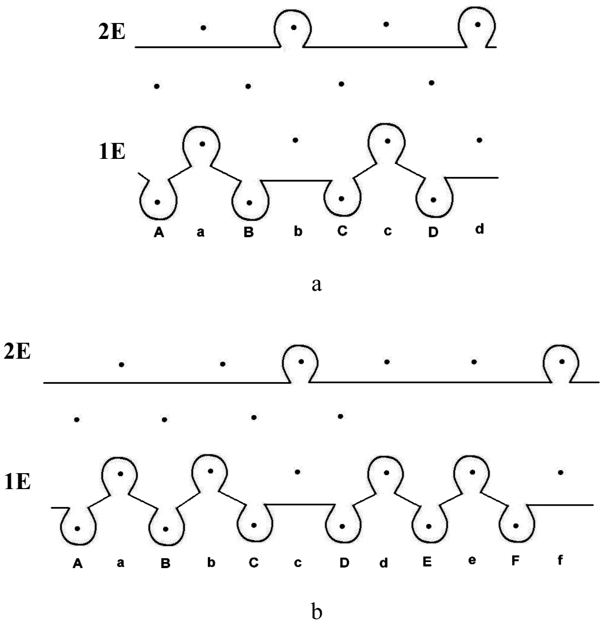


Fig. 1. The pattern of investigated knitted fabrics

CoolDry® threads and ThermoCool® yarns are made from polyester fibre with special surface geometry, created for quick dry and thermo controlling of the polyester fabrics.

All experiments were carried out in a standard atmosphere for testing according to the standard ISO 139:2005. Structure parameters of knitted samples were analysed according to the British Standard BS 5441:1998.

The air permeability tests of the investigated double-layered knitted fabrics were provided according to the standard EN ISO 9237:1997, using the head area of 10 cm^2 and pressure difference of 100 Pa. 10 tests per sample were performed. The air permeability R was determined according to the following equation:

$$R = \frac{D}{A} \cdot 167, \quad (1)$$

where D is the average of air flow rate, dm^3/min; A is the the operative area of sample, equal to 10 cm^2.

Heat interchange dependence on structure and raw material of knitted fabrics was investigated using the IG/ISOC (Giuliani Technologies, Italy) attachment designed for establishing of heat insulation. The knitted fabric was laid down on the heated plate and the thermo sensor was superimposed on the outward side of the fabric. A three stage experiment was prosecuted for this investigation. At the first stage the plate was heated up to 30 °C, at the second stage – up to 40 °C, and at the third stage – up to 50 °C. The temperature was recorded every 5 seconds. The experiment continued till the temperature has steadied.

The combinations of experimental fabrics and warm two-ply knitted fabric (pilot fabric) were designed for evaluation of the heat insulation of tested fabrics *F1, F2, F3*. The property of thermo insulation of the knitted fabrics was carried out in the freezing chamber STM472 (SATRA, Great Brittany) at the temperature of (–10) °C.

The temperature on the fabric surface was measured by the digital thermometer HD9214 with platinum sensor PT100 (DELTA OHM SRL, Italy). The changes of temperature were observed 20 minutes and recorded every 30 seconds, till the results began range in margins of error. Primarily, this experiment was carried out with the pilot fabric, for evaluation of influence of knitting structure and raw material upon the heat insulation of experimental fabrics.

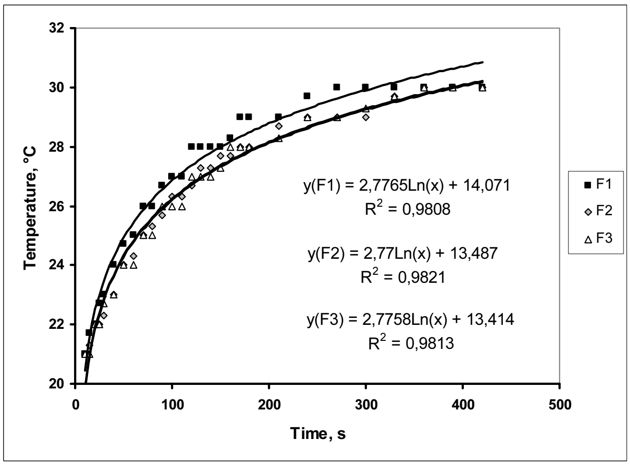
Table 1. Characteristics of tested knitted fabrics

Samples code	Yarns		Wale density, cm^{-1}	Course density, cm^{-1}	Loop length, mm	Air permeability, $dm^3/(m^2 \cdot s)$
	Linear density	Percentage composition				
F1	8.3 tex PES thread 16.4 tex PES yarn	71 % 29 %	12	15	3.10	848 ±20
F2	8.3 tex PES thread 16.4 tex PES yarn	85 % 15 %	12	16	3.24	801 ±21
F3	8.3 tex CoolDry® thread 16.4 tex ThermoCool® yarn	85 % 15 %	12	16	3.24	779 ±19

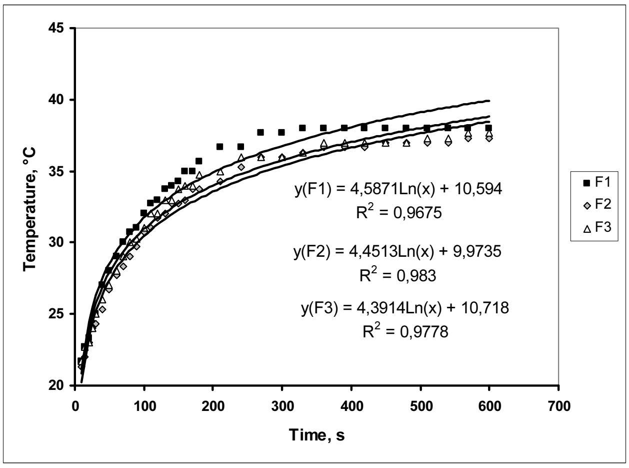
Note: the relative error of all counts δ is less than 5 %. In the Table 1 are presented values of absolute error of the air permeability.

3. RESULTS AND DISCUSSION

It is well known that heating and cooling depend on porosity of fabrics. Due to that the air permeability of specimens has been measured (see Table 1).



a



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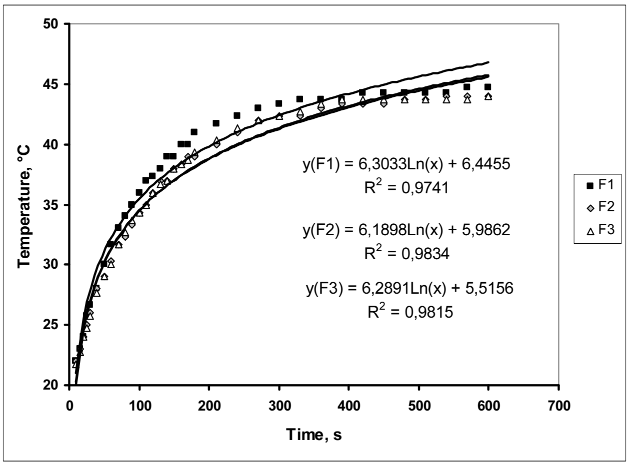

c

Fig. 2. Dynamic of heating through knits at different heated plate: a – at 30 °C, b – at 40 °C, c – at 50 °C

The results show that influence of structure of presented knits on air permeability is very low – the difference between air permeability values is less than ±5 %. So, it is possible to state that all the investigated knits have very close porosity one to other and due to that it is possible to expect that heating and cooling properties of presented knits will be also very close.

The measurements of heating of all investigated knits are presented in Fig. 2. The curves present average values calculated from three tests for each knit and at each temperature of heated plate. The differences of measurements for the same knit were not more than 1 °C.

As is seen from Fig. 2, all process can be described by logarithmical equations (coefficients of determination are high $R^2 = 0.9675 \div 0.9834$). The steadied temperature of all three knits are very close and depend only on the heated plate temperature, while the dynamical process of heating through investigated knits is not the same. The results of knits *F2* and *F3* are very close and differences are in the limit of errors. The calculated logarithmical equations also are very similar. The structure of fabrics *F2* and *F3* is tighter than structure of fabric *F1* because of different repeat of rib pattern. While heating process through knit *F1* is faster than through other knits. This faster process is observed in all three cases of different temperature of heated plate. Of course, the highest difference is observed in the case of heated plate temperature 50 °C and the analysis of dynamical process is better visible at this temperature. For example the temperature of 40 °C for knit *F1* is achieved after 160 s, while for knits *F2* and *F3* only after 210 s. So, the difference in time is more than 30 %. Because heating and herewith cooling process is faster, the wearing clothes manufactured from knit *F1* will be more comfortable. So, presented results show that even very low difference in knit pattern (see Fig. 1) has much higher influence on heating dynamic than usage of special polyester CoolDry® and ThermoCool® yarns, created for thermo controlling.

In the second part of investigations the dynamic of cooling has been analyzed. The dynamic of cooling is presented in Fig. 3.

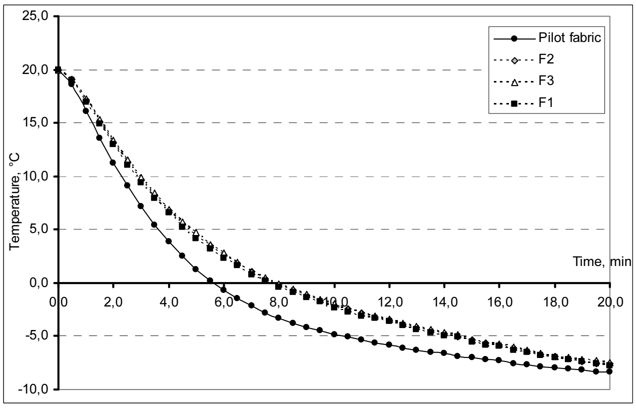

Fig. 3. Dynamic of cooling through fabrics

As is seen from Fig. 3, all three knits have a great influence on the cooling dynamic – the process proceed much slower than with only pilot fabric. The 0 °C temperature with only pilot fabric is obtained after 5.5 min, while in the case of pilot fabric without investigated knits 0 °C temperature is obtained after 7.5 min. The structure of investigated knits has only very small influence on dynamic of cooling. The maximum difference at the same time is less than 0.5 °C and is in the limits of error. So, it is possible to state that main influence on cooling dynamic in presented investigation had the layer of air between pilot fabric and investigated knits.

The similar results have been found by other researchers when the heat conduction process through multilayer textile packet was analysed [11 – 14]. So, that fact means that the structure of fabric has to small influence on heating or cooling dynamic in the multilayer textile packet because the layers of air between fabrics much higher influence on the heat conduction process and its dynamic.

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CONCLUSIONS

- The structure and raw material of investigated knitted fabrics have small influence on the air permeability of knits – difference is les than ±5 %.
- The steadied temperatures do not depend on structure of knits, but the heating process through knits differs.
- Dynamic process of heating through knits manufactured with the same pattern but from different kinds of yarns (*F2* and *F3*) is similar, while pattern of knits influence on dynamic of heating process. Pattern has much higher influence on heating dynamic than usage of special created for thermo controlling CoolDry and ThermoCool yarns.
- The main influence on cooling dynamic has air layer between fabrics. The influence of pattern and raw material in multilayer textile packet is not so much visible.

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