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THE EFFECT OF KNIT MATERIALS STRUCTURAL PARAMETERS ON THE ADIATHERMIC PROPERTY

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ABSTRACT

In this work, we study the adiathermic property of knits related to thermal comfort. This property is a function of the structural parameters of knits, dealing with permeable porous media conveying energy and mass. The adiathermic property is related to porosity and air permeability.

KEY WORDS

Knits, garment comfort, adiathermic property, porosity, air permeability.

NOMENCLATURE

- ε : porosity (%)
- K_a : air permeability ($L/m^2.s$)
- PA: adiathermic property (%)
- U, U_0 : Supply voltage of resistance (V)

INTRODUCTION

Garment comfort has become an important purchasing criterion sought by consumers. Thus, textile companies try to find a compromise between materials and styles in order to produce comfortable clothing.

One major aim of comfort oriented research is to find an ambient temperature adapted to an individual or a group of individuals. This property can be evaluated physically by measuring the thermal conductivity of fabric.

Thermal comfort of garments permits to maintain the optimal heat exchange between wearers and clothing systems. In order to characterize thermal comfort, the adiathermic property is used to quantify the thermal insulation of textile materials.

In textile markets, there is a strong need for producing comfortable knits because they can offer several advantages (Samuel (2002)). Technically, knitting machines have high productivity than weaving looms; knits can be more quickly realized; and the related production cost is about 50% less expensive than weaving.

Knits can be produced from any types of fibres and then they present a diversity of structures, mechanical and chemical treatments…

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Knit structures are important because they offer several advantages. Physically, they are strongly related to properties of comfort such as high elasticity, conformity with the shape of the body, softness and better touch feeling of freshness. Porosity is also one of the important physical properties having an influence on comfort and the other applicative features of end-products.
However, the research work related to knitting and knits have rarely appeared in the literature due to the complexity of their structures.
Knitting fabrics are produced by curvilinear interlacing of yarn. The voids or vacuums existing inside a textile fabric can play a major role in a variety of consumer-oriented and industrial applications, including comfort properties, thermal insulation efficiency, barrier fabric performance and precision of filter media.
These pores are in relation to the physical and chemical properties. Indeed absorption and thermal comfort of materials are influenced according to size, shape and distribution of these interstices. Moreover, porosity characterizes any phenomenon of mass and heat transfer.
The porosity of knit structures has attracted many researchers. In fact, existing theoretical studies on knitted fabric geometry took interest in defining the shape of the loop. In purely geometrical models proposed by Pierce (1947), Leaf (1955) and Suh (1967), the loop shape was first assumed and then geometrical parameters were adjusted to fit experimental data. Moreover, several studies investigated the mechanics of knitted fabrics structures using force analysis like Postle et al. (1967), Shanahan (1973) Hepworth (1976, 1978), in which the action of forces and couples can be localized at single points of yarn. Using symmetry consideration and condition of the relaxed fabric, some components of forces and couples could be eliminated. Other works used geometrical and physical principles to assume the loop shape function, which is improved by adopting a buckled elastic rod theory by Semnani etal. (2003).

However, empirical methods (Munden (1959, 1962) and Sokolnikoff (1956)) were still used to fit these models to experimental results.
All these geometric models are complex and require many parameters to characterize the loop shape geometry. So we suggest in our previous study (Benltoufa et al. (2007)) a model processing classical knitting parameters: course (C), wale (W), loop length (l), fabric thickness (t) and yarn diameter. We found geometry modelling is a suitable and the easiest method to determine porosity and it can be generalized for any conformation.
MARMARALI and al. (2006) studied the influence of the material on the thermal comfort of the socks. SHINJUNG and BARKER (2005) related the thermal comfort to the state of activity of the subject.

In this work, we approach a study of the adiathermic property of knits according to construction parameters and the effect of two physical properties (porosity and air permeability) on this property which translates thermal comfort.

1. METHODS OF KNITTING PROPERTIES DETERMINATION

1.1. ADIATERHIMC PROPERTY DETERMINATION

The standard **NFG** 07-107 deals a physical property of thermal resistance, called adiathermic property (PA).
The principle consists to place a sample around a cylindrical radiator and to measure the energy which should be provided to maintain the difference in temperature between the interior of the cylinder and the external surrounding air at 20°C and 65 % of relative humidity. The used apparatus is illustrated in figure 1.
The part external of the sample is left free in a controlled environment in temperature, and relative humidity.

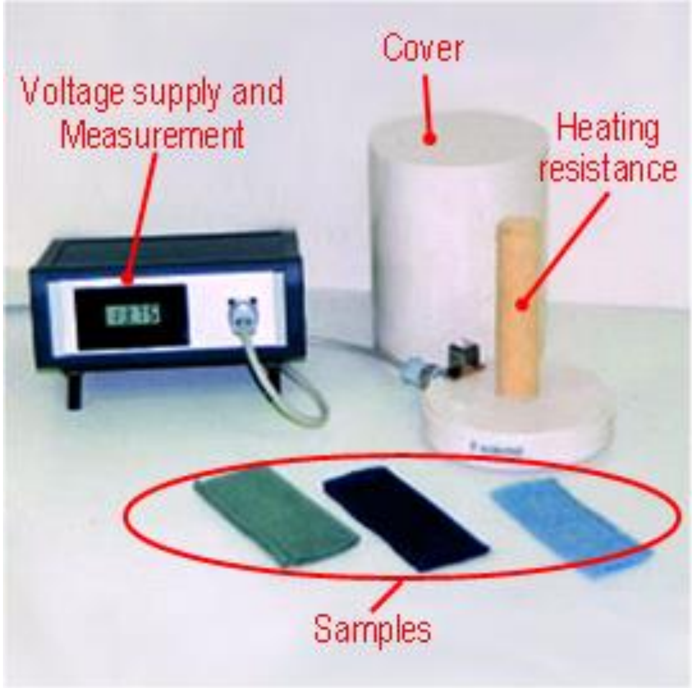

Figure 1 : Experimental device of the property adiathermic determination

We make two measures: one with the radiator covered by the sample and another without sample. So the adiathermic property is:

$$PA(\%) = \left(\frac{Q_0 - Q_1}{Q_0} \right) \times 100 \qquad (1)$$

Where Q_0 and Q_1 define the consumption of energy dissipated of the radiator, respectively, not covered and covered by the test-tube.
Thus, the adiatermic property is also:

$$PA(\%) = f\left(U, U_0\right) \qquad (2)$$

Here, U_0 is the supply voltage of heating resistance, non-covered with the test-tube and U is the supply voltage of heating resistance, covered by the test-tube.

The adiathermic property is determined according to the calibration curve of the apparatus figure 2:

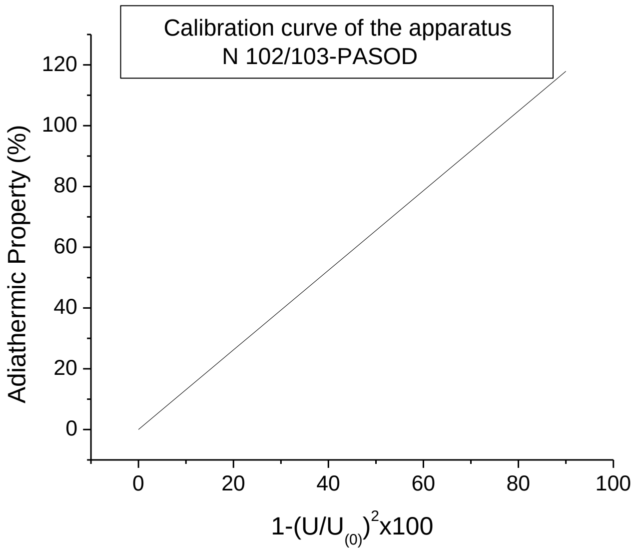

Figure 2 : Calibration curve of the apparatus N102/103-PASOD

According to calibration curve the adiathermic property is:

$$PA(\%) = 1.31\left(\left(1 - \frac{U^2}{U_0^2} x100\right)\right) x0.389 \tag{2}$$

1.2. POROSITY DETERMINATION

The method consists of calculating porosity resulting from the geometrical representation of the elementary loop shape, with a circular section yarn as hypothesis. This is illustrated on figure3:

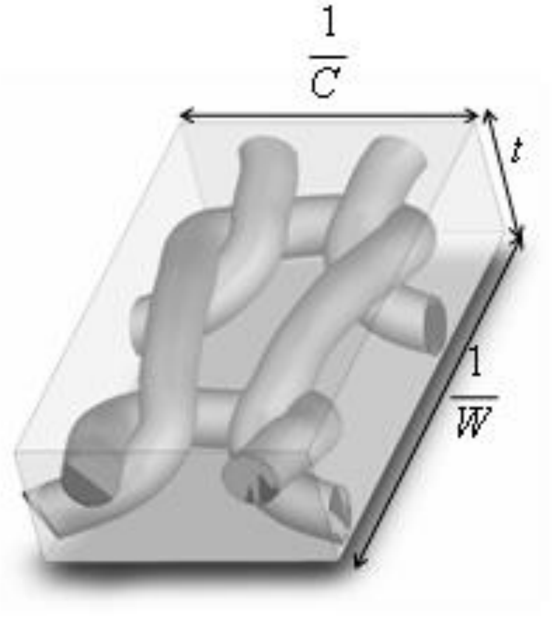

Figure 3 : 3D elementary jersey loop shape.

Yarn length of the elementary shape presented in figure 3 is 2×(loop length). By determining the course (m), wale (W) per cm, thickness (t), diameter (d) and loop length (l), we find that, porosity is:

$$\varepsilon = 1 - \frac{\text{Yarn Volume}}{\text{Total Volume}} \tag{3}$$

$$\text{Yarn Volume} = \frac{\pi d^2.2.l}{4} = \frac{\pi d^2 l}{2} \tag{4}$$

However

$$\text{TotalVolume} = \frac{1}{C}\frac{1}{W}t = \frac{t}{WC} \tag{4'}$$

Thus, porosity becomes

$$\varepsilon = 1 - \frac{\pi d^2 lCW}{2t} \tag{5}$$

Where:

- t : sample's thickness (cm) ;
- l : elementary loop length (cm) ;
- d : yarn diameter (cm) ;
- C : number of Courses per cm ;
- W: number of Wales per cm.

1.3. PERMEABILITY DETERMINATION

The air permeability is defined by the standard ISO 9237 as being the speed of a flow of air passing perpendicularly through a sample under conditions of surface test, and pressure losses.

Air permeability is determined using Air Permeability Tester TEXTEST FX 3300, illustrated by figure 4.

Figure 4 : Air Permeability Tester TEXTEST FX 3300

2. RESULTATS AND DISCUSSIONS

2.1. INFLUENCE OF CONSTRUCTION PARAMETERS ON THE ADIATHERMICPROPERTY

To study the effect of the parameters of construction on PA, we used samples with properties presented on table1.

Table 1 : Properties of used samples

Structure	Material	Bit numbers	Nm	Gauge
1x1 rib	acrylic	1 bit	15	5

The variation of knitting parameters is obtained by adjusting the stitch cams and thus the needle height.

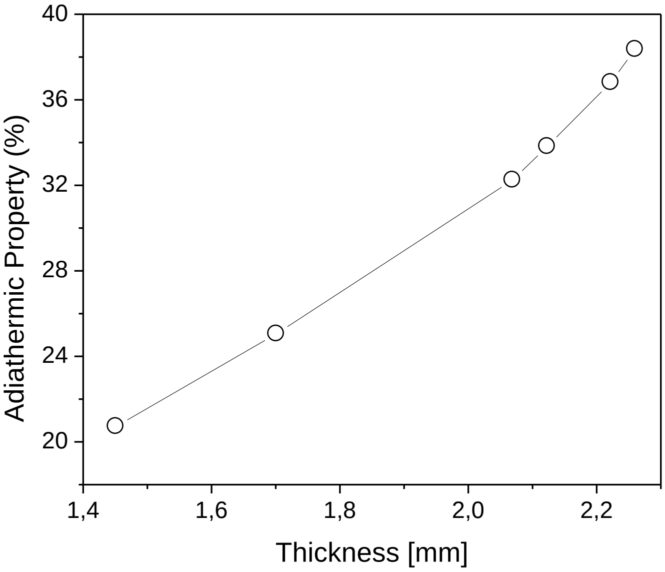

Figure 5 : Influence of thickness on PA

From figure 5, we notice that PA is proportional to the thickness; this is explained by the fact more knitting is thicker more than the air is trapped and more the heat insulation is better. Indeed the heat insulation of the air is 5 times more significant than textile materials.

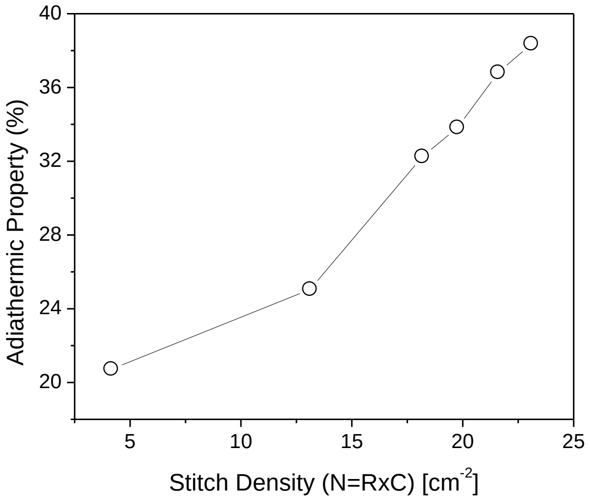

Figure 6 : Influence stitch density on PA

In the same way according to figure 6, the stitch density is proportional to PA. Indeed for structures dense (N significant) the sample is able to confine the air and thus the heat insulation is improved.

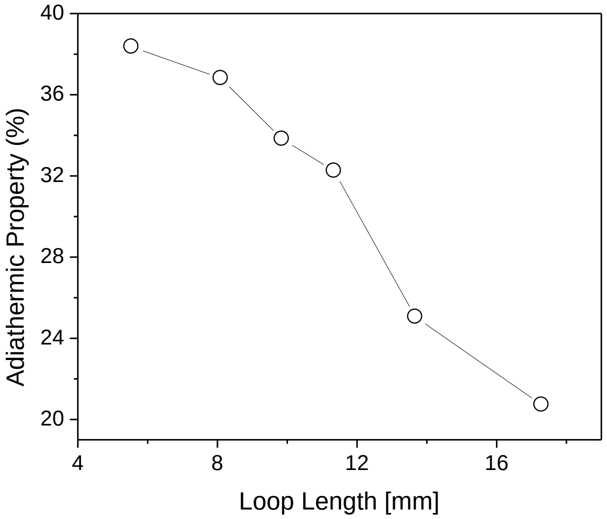

Figure 7 : Influence loop length on PA

According to figure 7, for the Loop length, we notice an opposite effect. Indeed more the loop length is significant more the structure is dense so more significant is the PA. This is explained by the fact that N (stitch density) and Loop length are inversely proportional, and obey to **Munden law**: $N=\frac{\text{Constante}}{(\text{Loop length})^2}$.

2.2. EFFECT OF STRUCTURE ON ADIATHERMIC PROPERTY

Used samples have properties presented on table 2:

Table 2 : Properties of used samples

Needle height	Material	Bit number	Nm	Gauge
13 divisions	acrylic	2 bits	15	5

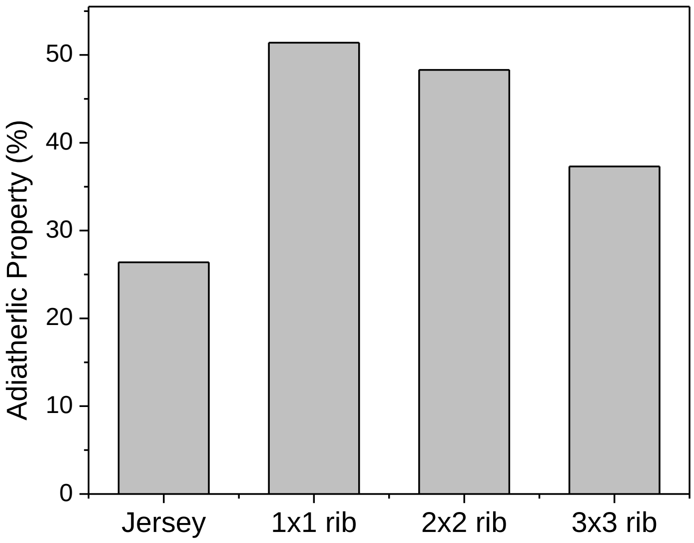

Figure 8 : Effect of structure on the Adiathermic Property

According to figure 8, the best Adiathermic Property is given by 1x1 rib, indeed there are less floated and the structure confines more air. While passing from the 1x1 rib to 3x3 rib the number of floated increases and thereafter the heat insulation decreases this is explained by the fact that floating lets pass the air from where thermal energy.

2.3. EFFECT OF MATIERIAL ON THE ADIATHERMIC PROPERTY

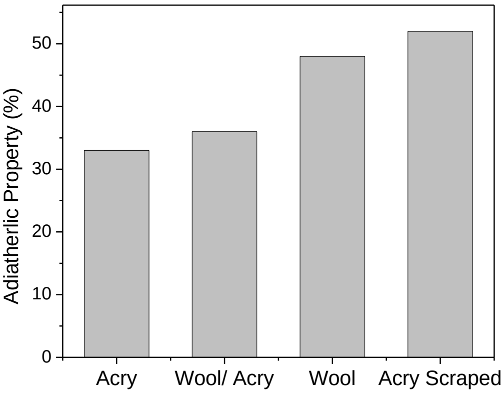

Figure 9 : Effect of material on Adiathermic Property

The natural fibres have an adiathermic property more significant than that of synthetic fibres. Wool knitting has a great capacity to keep heat thanks to its chemical structure and its capacity to confine the air. Scraping is a treatment consists in arising from fibres superficially in order to obtain a fluffy aspect and to thus increase surface thickness the improvement of the adiathermic property.

2.4. EFFECT OF POROSITY AND AIR PERMEABILITY ON The Adiathermic Property

Properties of used samples are presented on table 3:

Table 3 : Properties of used samples

Structure	Material	Bit number	Nm	Gauge
1x1 rib	acrylic	2 bits	15	7

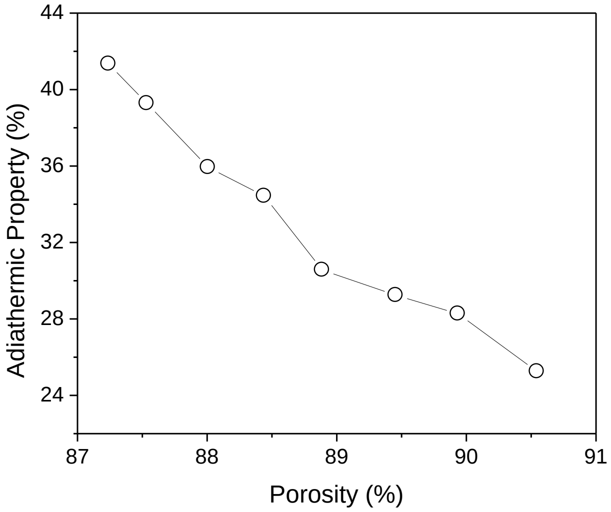

Figure 10 : PA variation according to porosity

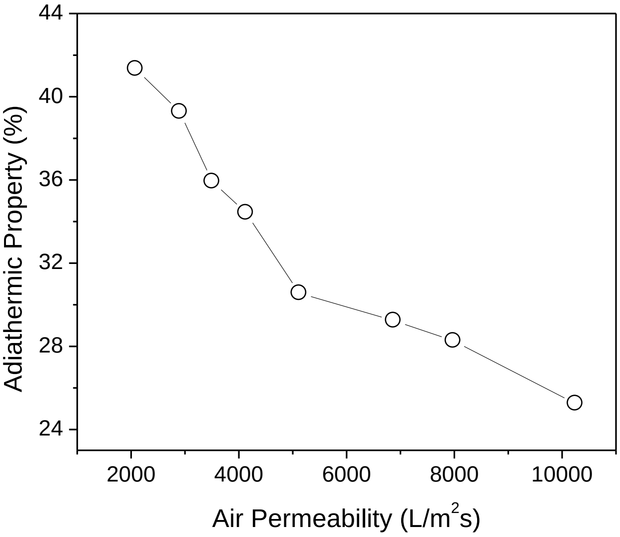

Figure 11 : PA variation according to air permeability

According to figures 9 and 10, porosity and the air permeability are inversely proportional to Adiathermic Property. Indeed more than the structure is light more that lets pass the air and conveys the temperature from where heat insulation is weaker.

CONCLUSIONS

In this paper, the adiathermic property as thermal comfort parameter is studied. Results show that this property is related structural conformation of knitting and used materials. The best thermal insulation is obtained for structures having ability to confine air. The adiathermic property is closely related to porosity and air permeability.

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