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Heat and Water Vapour Transfer Through Ironed Plain Woven Fabrics

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***Abstract*— Satisfaction of wearing of clothing is generally affected by physical processes include heat and moisture transfer. Ironing is one of the most finishing process which is extensively used in garment manufacturing. This paper deals with the effect of ironing on thermo-physiological comfort properties of plain woven fabrics. Different fibre composition were selected for this study. Thermal conductivity, thermal resistance and thermal absorptivity of these fabrics were measured by the ALAMBETA tester. Moreover, water vapour permeability and air permeability were experimentally determined. Consequently, ironing affected the thickness, thermal properties, air permeability and water vapour permeability.**

***Keywords*—Plain woven fabrics, Ironing, Thermal comfort properties, Water vapour permeability**

I. INTRODUCTION

Comfort may be defined as a pleasant state of psychological, physiological and physical harmony between the human body and the environment [1,2]. Nowadays, clothing is not only a belonging of aesthetic reasons but also comfort parameters, so textile fibre manufacturing industry is being flourished by new special fibres which have influential thermal and physiological comfort properties [3]. In fact, fibre type, yarn properties, fabric structure, finishing treatments and clothing conditions are the main factors affecting thermo-physiological comfort [4]. The thermal comfort is involving into fabric ability to sustain the temperature of the skin through transfer of heat and sweat produced from human body [5]. One of the most finishing process which is extensively used in the garment manufacturing is ironing either hand irons or buck press [6,7] Ironing is a process carried out on textile fabric to eliminate undesirable wrinkles and to restore its shape by applying mechanical pressure with heat, either in dry state or in presence of steam [8]. Furthermore, it provides elegance and good appearance of the garment. The pressing action is frequently enhanced with the presence of steam discharged through holes in the iron sole plate. It is a basic medium to transmit thermal energy to the fabric. It is a fast effective method to transmit significant heat quantity to the fabric. This not only makes the fabric to achieve definite temperature but also it can make it to obtain certain humidity[9].

Due to the importance and the extensive use of ironing in clothing manufacturing as a finishing treatment and daily use process, many works studied the pressing conditions in order to optimize steam pressing [7]. Other work described the influence of washing/ironing cycles on hand, shrinkage and surface roughness of cotton weave [10]. Some studies investigated the effect of ironing on dimensional [11,12] and mechanical properties [12] of textile fabrics.

Few studies were conducted to investigate the effect of ironing on heat and moisture transfer through fabrics.

The aaim of this study is to evaluate the effect of ironing on thermal properties and water vapour permeability. Thus, the ironing effect on thermal comfort of some woven fabrics. Plain weave fabrics with different fibre compositions (100%Linen, 100% cotton, 58%/42% Linen/cotton, 100% polyester and 100% polypropylene) were selected.

II. MATERIALS AND METHODS

A. *Materials and Testing*

In this study, five plain woven fabrics were used. Their fibre content, fabric weights and their thickness are listed in table 1. Air permeability was measured with the TEXTEST Air permeability Tester (FX3300) at 100 Pa air pressure.

TABLE I
COMPOSITION OF FABRIC SAMPLES

Sample code	Fabric content	Fabric weight [g/m^2]	Thickness [mm]	Air Permeability [mm/s]
1	58% Linen, 42% Cotton	210	0.59	1050
2	100% Linen	185	0.54	630
3	100% Cotton	170	0.44	423
4	100% Polyester	180	0.40	150

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5	100% Polypropylene	230	0.60	100

B. *Thermo-physiological Comfort Properties and Testing*

After a simple domestic washing, all samples were analyzed for thermal properties and water vapor permeability. Then, samples were hand ironed and we have remeasured them.

1) Thermal Conductivity: Thermal conductivity shows the capacity of material to transfer heat. Thermal conductivity is anisotropic in nature and to a great extent; it relies on the material structure. Many studies have been conducted for hypothetical examinations of heat transfer through fabrics [13,14,15]. Their outcomes demonstrate that the procedure of high temperature exchange through fabrics essentially happens by conduction, which is represented by:

$$q = \frac{\lambda \Delta T}{h} \qquad (1)$$

Where q indicates heat flux [Wm^{-2}], T is temperature [K], λ shows thermal conductivity [$Wm^{-1}K^{-1}$] and h represents thickness [m]. Thermal conductivity coefficient λ presents the amount of heat, which passes from 1 m2 area of material through the distance 1 m within 1 s and create the temperature difference 1 K. Thermal conductivity of textile structures generally extends from 0,033 to 0,01 W/m/K. Thermal conductivity of steady air by 20°C is 0,026 W/m/K. while thermal conductivity of water is 0,6 W/m/K, which is 25 times more. That is why the water presence in textile materials is undesirable [14]. Thermal conductivity of dry fabrics needs to rely upon the structure and properties of the yarns or filaments. Crow explains that two components which play a very critical role in this context, are thickness of the fabric and fibre arragements. [16].

2) *Thermal Absorptivity:* Thermal absorbtivity b of fabrics was introduced by Hes [17] to characterise thermal feeling (heat flow level) during short contact of human skin with the fabric surface. Providing that the time of heat contact (τ) between the human skin and the textile is shorter then several seconds, the measured fabric can be simplified into semi-infinite homogenous mass with certain thermal capacity ρc [J/m^3] and initial temperature t_2. Unsteady temperature field between the human skin (with constant temperature t_1) and fabric with respect to boundary conditions offers a relationship, which enables to determine the heat flow q [W/m^2] course passing through the fabric:

$$q = \frac{b(t_1 - t_2)}{(\pi\tau)^{1/2}}, \; b = (\lambda \rho c)^{1/2} \qquad (2)$$

Where ρc [J/m^3] is thermal capacity of the fabric and the term b presents thermal absorbtivity of fabrics. The higher is thermal absorbtivity of the fabric, the cooler is its feeling.

3) Thermal Resistance: Thermal resistance expresses the thermal insulation of fabrics and is inversely proportional to thermal conductivity. Thermal resistance R [m^2K/W] depends on fabric thickness h and thermal conductivity λ:

$$r = \frac{\lambda}{h} \qquad (3)$$

Equation 3 demonstrates that thickness has a direct connection with thermal resistance. Any change in thickness can change the thermal resistance of a fabric.

4) Relative Water Vapour Permeability: Relative water vapour permeability is the rate of water vapour transmission through a material.

The ALAMBETA instrument was used in this study for the measurement of the following thermal parameters: thermal conductivity, thermal absorbtivity, thermal resistance and sample thickness. The ALAMBETA simulates the dry human skin and its principle depends in mathematical processing of time course of heat flow passing through the tested fabric due to different temperatures of bottom measuring plate (22°C) and measuring head (32°C). When the specimen is inserted, the measuring head drops down, touches the fabrics and the heat flow levels are processed in the computer and thermo-physical properties of the measured specimen are evaluated [17]. The measurement lasts for several minutes only. Thus, reliable measurements on wet fabrics are possible, since the sample moisture during the measurement keeps almost constant.

The instrument PERMETEST was used for measuring water vapor permeability. All samples were put in the testing laboratory, where relative humidity was between 20-22% and temperature was in the range of 24-26 °C. Each sample was tested three times to calculate the mean values. The amount of heat which passes through the thermal model of human skin is measured on the PERMETEST instrument [18]. For testing purpose, samples are put on measuring head, which is covered with a semi-permeable foil. After putting sample, it is exposed to parallel air flow. Velocity of air is 1 ms^{-1} . All measurements are carried out under controlled thermal conditions (23.0 ±0.5 °C). The PERMETEST instrument is connected with a computer, on which the results of the evaporative resistance (Ret), and relative water vapour permeability (RWVP) of fabric following the modified ISO 11092 standards are displayed. The higher RWVP means that lower Ret is and it means better thermo-physiological comfort. RWVP (%) is calculated using the following equation:

$$RWVP = \frac{q_s}{q_0} \times 100 \qquad (4)$$

Where q_s presents the heat flow determined by the instrument when the sample is placed on the measuring head of the instrument, and q_o is the heat flow measured without the sample.

III. RESULTS AND DISCUSSIONS

Based on the experimental methodology, the thermal comfort properties plain woven fabrics were determined.

The effect of ironing on thermal conductivity, thermal absorptivity, thermal resistance and relative water vapour permeability were investigated

A. *Thermal Conductivity*

Thermal conductivity (λ) is fundamental to determine the heat transfer through fabrics. According to figure 1, Polypropylene sample has the highest thermal conductivity value.

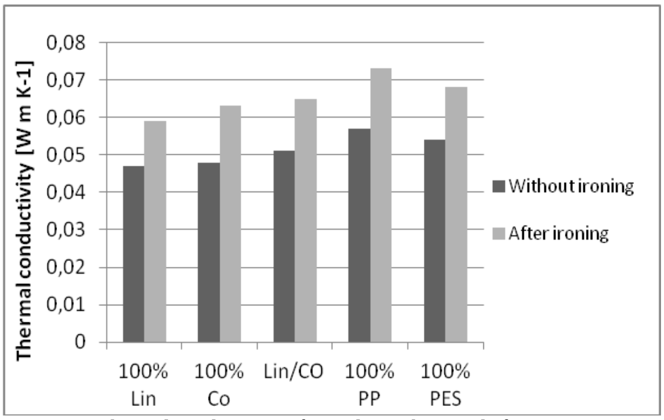

Fig.1 Thermal conductivity of samples without and after ironing

It can be explained by the amount of entrapped air in the fabric. As the weight increases (the amount of fiber per unit area increases), the amount of air layer decreases. As known for textile materials, still air in the fabric structure is the most important factor for conductivity value, as still air has the lowest thermal conductivity value when compared to all fibers (λair = 0.025). Thus, heavier fabric (polypropylene sample) with lowest air permeability (100 mm/s) has the highest thermal conductivity values. however, the fabric with 100% Linen has the highest air permeability and the lowest thermal conductivity value.

After ironing, thermal conductivity of all samples increases. This is due to the compression pressure applied that make fabric more compact.

Thermal conductivity of fabrics made of synthetic fibres (polyester and polypropylene) perceived higher than the fabric made of natural fibres (cotton and linen). This phenomena occurred by the water absorption and swelling of these fibers in fabrics [19].

B. *Thermal Absorptivity*

Thermal absorptivity is the warm-cool feeling of fabrics. If the thermal absorptivity is high, it gives a cooler feeling at first contact with the skin. The surface character of the fabric greatly influences this sensation [17]. The results show that samples made of synthetic fibres have lowest thermal absorptivity. While, samples made of natural fibres have the highest thermal absorptivity and, at the same time, the coolest feeling at the moment of contact of the fabric with human skin.

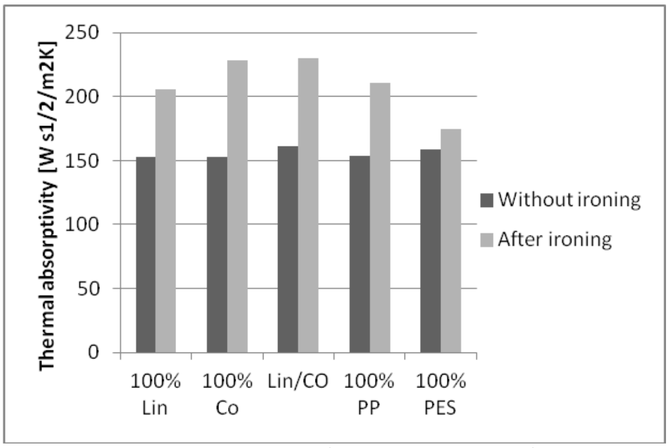

Fig.2 Thermal absorptivity of samples without and after ironing

After ironing, thermal absorptivity increases because the applied pressure and the temperature of iron affect the surface of the fabric. It become soft and smooth (wrinkles are removed).

C. *Thermal Resistance*

Thermal resistance expresses the thermal insulation of fabrics and is inversely proportional to thermal conductivity.

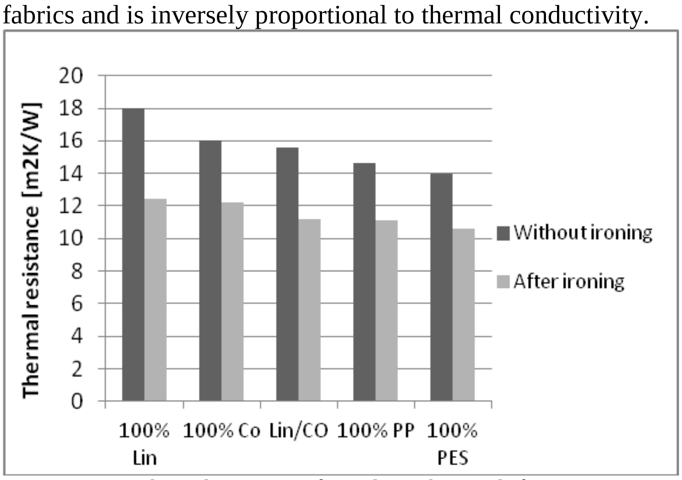

Fig.3 Thermal resistance of samples without and after ironing

According to figure 3, sample made of 100% Linen showed higher value of thermal resistance. Other samples have almost the same thermal resistance.

After ironing, thermal resistance increases as the fabric thickness decreases. As expected, there is an inverse relationship between thermal conductivity and thermal resistance.

D. *Relative Water Vapour Permeability*

Relative water vapor permeability is the rate of water vapor transmission through a material. According to results, it is apparent that Sample made of blend Linen/Cotton has a higher water vapor permeability, while polyester and polypropylene samples exhibit lower values.

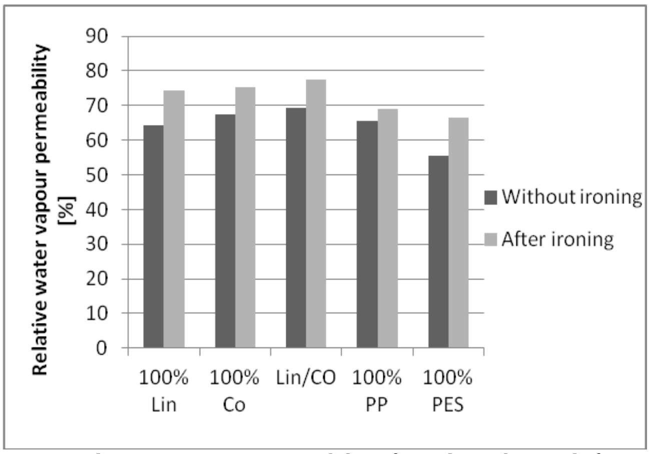

Fig.4 Relative water vapour permeability of samples without and after ironing

The higher value of relative water vapour permeability indicates better moisture transport and a lower value indicates that the fabric is less breathable to vapour transmission.

For fabrics with high relative water vapour permeability values, it is easier for water vapour to pass through the fabric and into the environment, resulting in drier skin thereby improving comfort.

After ironing, fabrics become more breathable. It may be explained that the thickness is increased.

IV. CONCLUSIONS

Ironing is a process used to provide more elegance to clothing. It removes the crumpled zones from the fabrics. This finishing process provides a better arrangement of yarns on fabric and an improvement of its quality. The ironing depends on the fabric quality, its chemical composition, and its initial moisture content. It is concluded from the above results that the ironing treatment has a significant effect on thermo-physiological comfort properties. 100% Linen fabric has the best thermal insulation and the blend Linen/cotton gives 'cooler' feeling and it is the most breathable fabric.

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