Assessment of Thermal and Transport Properties of Multilayer Fabric Structure used in Sport Shoes

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Abstract— The present paper reports a detailed study on thermal and transport properties of multilayer fabric structure used in sports shoes. The kind of textiles worn close to the body inside the footwear (such as socks and liners) has a major impact on the rate of heat and sweat transport, which in turn is critical to microclimate parameters and comfort. Excessive humidity may also lead to the development of harmful microorganisms, and, as a consequence, to chronic foot diseases. In response to the thermal effect, the human organism reacts by dilation of skin vessels and increased skin blood flows, which may result in an excessive load on the vascular system in the lower extremities. Four samples of multilayer fabric have been prepared. PVC and PU coated thermal bonded nonwoven fabric used as the upper layer. 3D mesh fabric and PU foam used as the middle layer. Polyester knitted fabric used as the inner layer, common for all samples. In this, an attempt was made to study the thermal and transport properties such as thermal insulation, water vapour permeability, absorbency of fabric and air permeability of different type's multilayer fabric structure used in sports shoes.

Key words: Multilayer Fabric Structure, Sport Shoes

I. Introduction

When you wear the shoes, the amount of moisture released from a skin of the foot, called insensible perspiration and amount of tension sweat (mental sweating) get increased. In addition sweating by the motion of legs (mainly thermal sweating) also increases.[2]During playing games, the amount of sweat produced by the foot increases significantly - up to an average of about 7 g of sweat per hour. During hard physical work in a hot environment, this figure may rise to about 15 g per hour. Excessive humidity may also lead to the development of harmful microorganisms, and, as a consequence, to chronic foot diseases. In response to the thermal effect, the human organism reacts by dilation of skin vessels and increased skin blood flows, which may result in an excessive load on the vascular system in the lower extremities.[4] Improvement of hygiene and comfort requires control of factors like temperature and moisture. An internal shoe temperature between 29 and 34 °C is deemed comfortable.

Therefore, appropriate insulation must ensure that the human foot neither cools down nor heats up excessively.[3] Shoe construction material greatly affects the temperature and humidity and wearing feeling in the shoes.[1] Textile materials used in sports footwear play a predominant role in determining their suitability for sports footwear functions. Some features of sports footwear are protection, shock absorption, performance and comfort. The optimal functionality of sports footwear is achieved through the correct design of upper and lower part of shoes, correct and technical selection of materials and components and correct shoe contractions. [5] Heat and water vapour transfer through fabrics play a predominant role in determining their suitability for clothing. The thermal resistance of fabrics is a primary determinant of body heat loss in environments. Generally, high thermal resistance values of the clothing are required to maintain the body under thermal equilibrium conditions. In hot environments or at high activity levels, evaporation of sweat becomes an important avenue of body heat loss and fabrics must allow water vapour to escape in order to maintain the relative humidity between the skin and the first layer of clothing - at about 50%.[6] Multi-layered fabrics are preferred in unusual weather conditions. Mainly, the moisture vapour transmission and thermal characteristics of such fabrics govern the comforts of the human being.[7] Multilayered fabrics structure for sports shoes consists of at least three layers(Figure 1) of different functions: The inner layer which performs mainly the sweat absorption, direct cooling of the skin, transmission and tactile functions. The middle layers help still-air entrapment to provide insulation and transmission. Outer is primarily a shell layer for protection from extreme environmental factors, like rain, wind, chemical, heat, radiation, etc. [5].

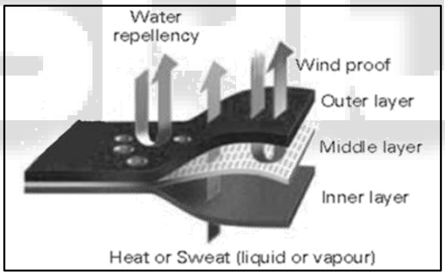

Fig. 1: Example of multilayered fabric used in sports shoes

II. Methods and Tests

A. Method

Four samples of multilayered fabrics consisting of the outer layer, middle layer and inner layer were prepared. Polyester warp knitted fabric as an inner layer in all four samples. Two different types of the middle layer were used. Two types of the coated fabrics namely thermal bonded PVC coated fabric and thermal bonded PU coated fabrics were used as an outer layer. The details of the fabrics used in layers are given in the tables 1. The polyester fibre of the staple length 58 mm and fineness 3denier was used to produce thermally bonded nonwoven of the 220 GSM and thickness 1.31 mm. The multilayered fabrics samples were made by the synthetic rubber adhesive SR 998. The particulars of multilayer fabrics are given in table 2.

Samples	Outer layers	Mid-layer	Inner layer
Samples 1	PVC coated non-woven	PU foam	Knitted fabric
Samples 2	PU coated	PU	Knitted

	non-woven	foam	fabric
Samples 3	PVC coated non-woven	3D Mesh fabric	Knitted fabric
Samples 4	PU coated non-woven	3D Mesh fabric	Knitted fabric

Table 1: Details of fabrics used in layers.

Samples	GSM g/m^2	Thickness mm	Bulk density g/cm^3
Samples 1	966.16	4.85	0.096616
Samples 2	818.52	4.75	0.081852
Samples 3	1092.46	4.93	0.10924
Samples 4	944.82	4.79	0.09448

Table 2: Particulars of multi-layered fabrics used in sports shoes.

B. *Tests*

1) *Air Permeability*

ISO 9273 method was used for measurement of air permeability of fabrics. Samples were conditioned at 27^0C and 65% RH. The test was performed at the constant pressure drop of 200 Pascal.

2) *Absorbency of Fabric*

AATCC 79 method was used for measurement of absorbency of fabric. In this test, a drop of water is allowed to fall from a fixed height onto the taut surface of a test specimen. The time required for the specular reflection of the water drop to disappear is measured and recorded as wetting time.

3) *Thermal Resistance and Water Vapour Permeability*

The sweating guarded hot plate instrument, simulating the heat and moisture transfer from the body surface through clothing material to the environment, was designed for the measurement of thermal resistance and water vapour permeability of fabrics, relating to comfort characteristics.

ISO 11092 sweating hot plate method was used for measurement of thermal resistance and water vapour permeability of fabric at steady state condition.

For the determination of the thermal resistance of the sample, the air temperature is set to 20 ^{0}C and the relative humidity is controlled at 65%. Airspeed generated by the air flow hood is 170.05 m/s. After the system reaches steady state, total thermal resistance of the fabric is governed by:

$$Rt = \frac{A(Ts-Ta)}{H} m^2\,^0C/W \quad (1.1)$$

Where Rt is the total thermal resistance of fabrics plus the boundary air layer (m2 ^{0}C/W), A the area of the test section (m2), Ts the surface temperature of the plate (^{0}C), Ta the temperature of the ambient air (^{0}C), and H the electrical power (W).

The test fabric is placed above the membrane. The electrical power to maintain the plate at a constant temperature of 35 ^{0}C is an indicator of water evaporation rate. Air temperature is set at 35 ^{0}C and relative humidity is controlled at 40%. After a steady state is reached, the total evaporative resistance of the fabric is calculated by:

$$Ret = \frac{A\,(Ps-Pa)}{H} \quad m^2\,Pa/W (1.2)$$

Where Ret is the total evaporative resistance provided by the liquid barrier, fabric and boundary air layer (m2 Pa/W), A the area of the test section (m2), Ps the water vapour pressure at the plate surface (Pa), Pa the water vapour pressure of the air (Pa), and H the electrical power (W).

The water vapour transmission rate given by:

$$WVP = \frac{1}{Ret\ \Phi}\Delta p \quad g/m^2/h (1.3)$$

Where Φ is the latent heat of vaporization of water at test temperature and Δp is the difference of water vapour pressure.

III. RESULT AND DISCUSSION

A. *Air Permeability*

Figure 2 shows the air permeability of different types of multilayered fabrics. Sample 4 shows higher air permeability front side and back side among them .PU coated outer layer used samples have more air permeability then PVC coated out layer used samples. In middle layer used as 3D mesh fabric samples having more air permeability then PU foam. The front side of samples has more air permeability then back side of samples.

B. *Water Absorbency*

Figure 3shows the water absorbency of different types of multilayered fabrics. The water absorbency of fabrics impotence because sweat produced by the human body will absorb by fabric next to the skin.it will not maintain then the body does lose heat unnecessarily through having a wet skin. Sample 2 shows lower time taken to absorb the water among them. PU foam used as the middle layer in samples have less time taken to absorb the water then 3D mesh fabric used as the middle layer.

C. *Thermal Resistance*

Figure 4 shows the thermal resistance of different types of multilayered fabrics. The PVC coated nonwoven has higher thermal resistance then PU coated nonwoven used as the outer layer. The PVC coated nonwoven has 60% to 70% more thermal resistance then PU coated nonwoven used as the outer layer. Mass per unit area of fabrics affects the thermal resistance property. Mass per unit area of fabrics increases the thermal resistance of fabrics also increases. Sample 2 has minimum thermal resistance and sample 3 has maximum thermal resistance.

D. *Water Vapour Permeability*

Figure 5 shows the water vapour permeability of different types of multilayered fabrics. It is impotent property essential factor affecting the endues application. The water vapour permeability in sample 2 is higher than all other samples. Compering the samples, the outer layers used as PVC coated nonwoven fabrics have a lesser water vapour permeability then PU coated nonwoven. Water vapour permeability also depends on the mass per unit area of fabrics. As the mass per unit area increase, the water vapour permeability of fabrics decreases.

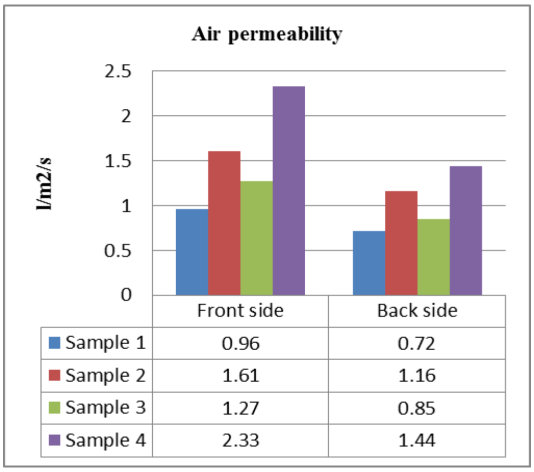

Fig. 2: Air permeability of samples.

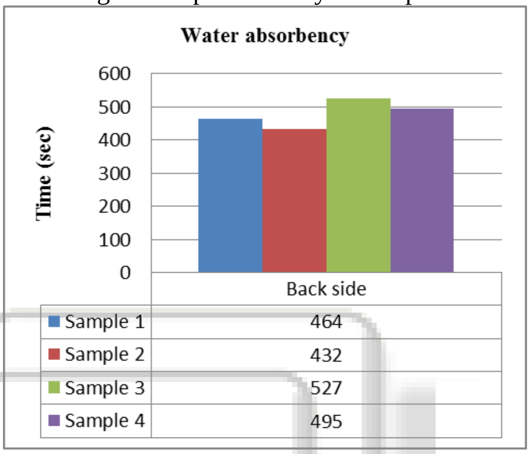

Fig. 3: Water absorbency of samples.

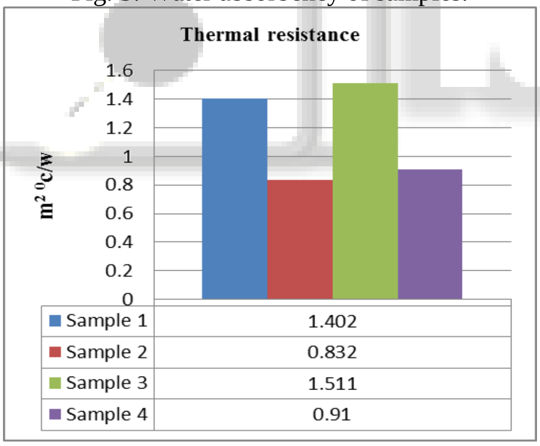

Fig. 4: Thermal resistances of samples.6

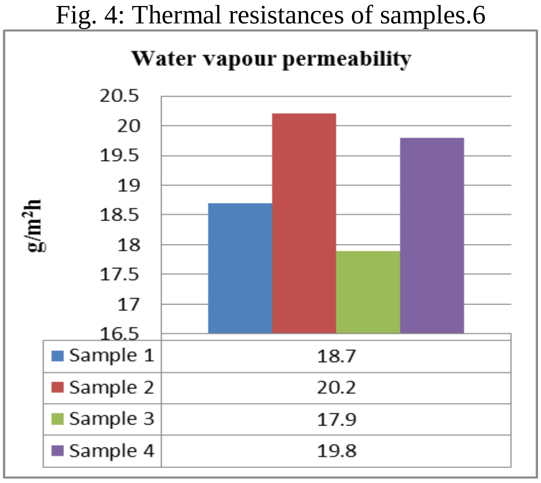

Fig. 5: Water vapour permeability of samples.

IV. CONCLUSION

1) The air permeability of multilayered fabrics higher in front side to the back side lower on back side to front side.
2) The water absorbency of multilayered fabrics depends on the inner layer and the middle layer of fabrics.
3) The thermal resistance of multilayered fabrics increase with increases in mass per unit area.
4) The water vapour permeability of multilayered fabrics decreases with increases in mass per unit area.
5) PU coated nonwoven used as outer layer has lower thermal resistance and higher water vapour permeability the PVC coated nonwoven.
6) Type of fibre used to produce the fabric and type of finish play vital role in the transmission of thermal and transport properties.

REFERENCES

[1] Michiko Mitsui, Kazue Yoshida, Yasuhiro Ishii, Kunio Shirai, Yasumasa Chonan, and Hiroshi Okamura," Part 1: Effect of shoe materials on wear comfort and microclimate between shoes and skin." Journal of the Japan Research Association for Textile End-Uses, Vol. 40, pp.333-341, 1999.
[2] Yasumasa CHONAN, Yasuhiro ISHII, Kunio SHIRAI , Michiko MITSUI, Kazue YOSHIDA, and Hirosh OKAMURA," Part 2 Studies on the behaviour and Accumulation of the sweat component in worn shoes" Journal of the Japan Research Association for Textile End-Uses, Vol. 41, pp.692-699, 2000.
[3] Emilia Irzmanska, Jacek Konrad Dutkiewicz and Robert Irzmanski," New approach to assessing comfort of use of protective footwear with a textile liner and its impact on foot physiology", Textile Research Journal 2014 84: 728 originally published online 21 November 2013.
[4] Gulnara Fauland, Patrick Hofer, Werner Nachbauer and Thomas Bechtold," Moisture management properties of ski-boot liner materials", Textile Research Journal 2012 82: 99.
[5] R. Shishoo,"Textiles in sport", Woodhead publishing Pvt Ltd.
[6] Jianhua Huang," Review of heat and water vapour transfer through multilayer fabrics", Textile Research Journal 0(00) 1–12 may 2015.
[7] A Das, Shabaridharan & B Biswas, "Study on heat and moisture vapour transmission characteristics through multi-layered fabric ensembles", Indian Journal of Fibre & Textile Research Vol. 36, December 2011, pp. 410-414
[8] Apurba Das and R. Alagirusamy," Science in Clothing Comfort" Woodhead publishing Pvt. Ltd.

