Air, moisture and thermal comfort properties of woven fabrics from selected yarns

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REZUMAT – ABSTRACT

Proprietățile de confort la aer, umiditate și termic ale țesăturilor din fire selectate

Sunt studiate proprietățile de transport ale aerului și umidității ale țesăturilor cu legatură pânză, realizate din bumbac 20^sNe_c în urzeală și fire pure de tencel, modal, pro-modal, bambus, polyester și bumbac 20^sNe_c în direcția bătăturii. Caracteristicile majore adăugate acestui studio include permeabilitatea la vaporii de apă, permeabilitatea la aer, timpul de umiditate și viteza de capilaritate. Comparând cele șase eșantioane diferite de materiale cu compoziție diferită în direcția bătăturii, permeabilitatea la aer a firelor de tencel a fost minimă, iar cea a poliesterului a fost maximă, în timp ce rezultate opuse au fost observate pentru ambele eșantioane în cazul permeabilității la vapori de apă. Dintre amestecurile cu bumbac, conductivitatea termică a bambusului și absorbția termică a poliesterului au obținut valori maxime, în timp ce rezistența termică minimă a fost observată pentru firul pro modal în bătătură. Un model similar a fost observant în viteza de împrăștiere și timpul de umezire a poliesterului atunci când este observat din partea superioară sau inferioară. Proprietățile de confort ale firelor de bambus și pro modal, având valori aproape similare, sunt sugerate a fi utilizate în articolele de îmbrăcăminte utilizate pentru golf.

Cuvinte-cheie: proprietăți de management al umidității, permeabilitate la vapori de apă, permeabilitate la aer, proprietăți de confort termic și umiditate

Air, moisture and thermal comfort properties of woven fabrics from selected yarns

Air and moisture transport properties of plain woven fabric made from 20^sNe_c cotton in warp and 20^sNe_c pure yarns of tencel, modal, pro-modal, bamboo, polyester and cotton yarn inweft direction are studied. Major characteristics added for this study include water vapour permeability, air permeability, wettingtime and wicking speed. In comparison of six different samples of variously composed materials in weft direction, the air permeability of tencel was minimum and polyester was maximum, whereas the reverse results were observed for both the samples in case of water vapour permeability. Among the blends with cotton, thermal conductivity of bamboo and thermal absorptivity of polyester was found maximum whereas the minimum thermal resistance was observed for pro modal yarn in weft. Similar pattern was observed in spreading speed and wetting time of the polyester when observed from either side top or bottom. Air and moisture comfort properties of bamboo and pro modal, having nearly similar values are suggested to be used in garments used for golf players.

Keywords: moisture management properties, water vapour permeability, air permeability, wetting and *thermal comfort properties*

INTRODUCTION

In addition to provide a physical cover to human aesthetics, comfort and protection are the essential features of apparels. Woven fabricsare the backbone for production of apparel manufacturing mainly due to both comfort and cost of manufacturing that makes it preferable over others. Similarly, the demand of comfortable fabric is increasing for general and specific purposes like players in the sports field need breathable fabric during their practices. Hence, yarn should be properly selected and strengthened during the production of fabric that should fulfill all the basic considerations. Additionally, it should not restrict the movement and should provide ease for the user of the garments [1]. Natural as well as regenerated fibers have increased importance with aspects of textile industry to meet performance challenges. Apparels have highest rates of strength comfort and drape by using these fibers [2].

In addition to popularity of trend, garment-fitting and fashion, the clothing comfort is also important and can be measured by various aspects related to physiological comforts of garments [2]. Human comfort is the state of mind expressing the level of satisfaction provided by the environment around an individual. The surrounding environment changes with the change in temperature and with the result of this thermal change, human comfort level changes. Therefore, human comfort and thermal comfort are counter parts of each other. The major factors incorporating for apparel comfort are mixing, yarn twists, texturizing, fabric structure and its properties, mechanical treatments, moisture- and vapour-permeability and finish treatments [3, 4]. Moisture management and breathability of fabric are related to ease of fabric provided to individuals [5]. Especially during sports, body presipitates a lot and when the prespiration occurs the body feels comfortable and cool. Therefore, the garments manufactured fulfilling said purposes allow comfortability.

The regenerated fibers have many excellent properties with respect to tenacity, thermal conductivity and water and perspiration absorption. Cotton on the other hand has best absorbency and breathability. All regenerated fibers are having progressive values when compared to synthetic fibers [6, 7]. The fabrics made from 100% bamboo were comfortable and have excellent moisture and temperature management properties [8]. Regenerated fibers are used in different apparels including sports textiles, socks, t-shirts and in ligerie products [9]. Tencel due to good moisture absorption characteristics could be used to enhance the moisture handling and other properties of sportswear fabrics while at the same time improving the aesthetics [10]. Similarly, modal and pro-modal, containing soft and cozy fibers also show good moisture management properties.

A lot of resaerch has already been established for investegating the comfort properties of woven fabrics [11]. Hereby, the work is done to investigate the influence of regenerated yarns in weft direction and compare the comfort properties of woven fabric with fabric made from 100% cotton fixed at warp direction. In this study, testing of air permiaility, wetting, wickbility and water vapour permeability of plain fabrics is investigated.

MATERIALS

The pure yarns of 100% modal, tencel, pro-modal, bamboo, polyester, cotton yarns were produced in a local spinning mill in Pakistan. The count of all yarns was fixed at $20^{s}Ne_{c}$. The characteristics of various yarns are given in table 1.

WEAVING AND PROCESSING

The fabric was woven on an air jet loom in local weaving mill according to given specifications, where warp count was fixed at $20^{s}Ne_{c}$ for cotton yarn only and all above yarns were used in weft for production of 6 different samples (**A-F**) of fabric. In this work, the plain woven fabrics were chosen to be weaved. The fabric samples were scoured and bleached according to standard recipe, the geometrical properties of fabric are presented in table 2 and the related comfort properties with respect to each fabric are given in table 3.

METHODS

Different experiments were done to evaluate the comfort properties of given fabric samples.

TESTING

All the finished fabric samples before testing were conditioned at standard atmospheric temperature 20ºC ± 2 ºC and relative humidity of 65 ± 2%. The tests that had been conducted for fabric samples (**A-F**) are air permeability, fabric mass, water vapour permeability, and moisture management. The tests were

Table 1

Weft yarns	Modal	Tencel	Pro modal	Bamboo	Polyester	Cotton
Linear irregularity (U%)	7.01	7.55	7.58	7.71	10.34	11.73
Thin place/km (–50%)	0	0	0	0	0	3
Thick place/km (+50%)	2.0	3.5	6.3	8.3	1.3	204
Neps/km (+200%)	2.5	5.8	10.5	17.8	5.3	141
Hairiness	5.23	6.11	6.09	4.44	5.23	7.05
Count strength product	3637	4400	3700	2601	4949	2050
Single yarn strength	956	1013	823	656	930	439
Elongation at break %	11.81	9.78	10.20	12.30	13.20	3.47
Tenacity RKM	32.40	34.30	27.85	22.24	31.50	14.89

Table 2

Sample	Warp yarn	Weft yarn	Ends per inch	Picks per inch	Warp cover factor (K_1)	Weft cover factor (K_2)
A	100% Cotton	100% Modal	60	60	13.6	13.1
B		100% Tencel	60	60	13.6	13.1
C		100 %Pro Modal	60	60	13.6	13.1
D		100% Bamboo	60	60	13.6	13.1
E		100% Polyester	60	60	13.6	13.1
F		100% Cotton	60	60	13.6	13.1

Table 3

Sample	Thickness [mm]	Fabric weight [g/m^2]	Air permeability [cm^3/cm^2/sec]	Water vapour permeability [g/m^2/day]	Top wicking	Bottom wicking	Top wetting	Bottom wetting
A	0.61	171	193.2	623.38	4.89143	4.81872	2.9673	2.967
B	0.66	163	166.02	818.83	4.775896	4.58564	2.941	3.04661
C	0.66	168	180.2	603.27	4.045	3.93809	3.1813	3.28856
D	0.62	177	226	703.71	3.83287	3.68287	3.1547	3.18051
E	0.64	155	230.8	536.11	1.702366	4.54823	5.248	3.9885
F	0.60	157	228	724.47	4.47424	4.54823	2.9943	3.0436

conducted in National Textile University, Faisalabad and Pakistan Council for Scientific and Industrial Research (PCSIR) laboratories, Lahore, Pakistan. The standard procedure followed for moisture management test was ASTM D1776, for Water vapour permeability ASTM E96 and air permeability was tested by ISO 9237. All thermal comfort properties tests (thermal-, resistivity, absorptivity and conductivity) were performed in Technical University of Liberec, Czech Republic.

RESULTS AND DISCUSSION

Wetting time

The wetting time is shown in figure 1. When observed from top, the results specify that wetting time is higher in sample ***E*** composed of 100% polyester material. Similar effects were observed for the polyester when observed from bottom [7]. All other material shows similar tendency towards wetting time from both sides, top and bottom. In sum, low ability to have moisture management transfer is due to the fact that wettability of the fabric depends on the material being used. The testing of samples ***A-D*** and ***F*** clearly predicts about their good moisture management property.

Wicking

The top and bottom spreading speed of samples ***A*** and ***B*** is higher due to higher GSM and better moisture management transfer. Here again the the value for top spreading speed is less in case of sample ***E***. The experimental results shows that wicking property of fabric depends upon the characteristics and structure of fibers (figure 2). The wicking behavior of fabric is relevant on the structure of the constituent yarns, their direction in the fabric, the fabric structure, the pretension and the force applied.

Air permeability

The air permeability of different materials observed is given in figure 3. The variation in the results shows that material has high significance on the air permeability of the fabric. As the weft material changes in the fabric, the change in air permeability occurs. The air permeability of sample ***E*** is the best as compared to other material samples. Due to round structure and low fiber density and porosity in these materials show in increased value of air permeability, whereas as the moisture absorption was less in ***E*** due to fewer number of fibrils in its cross section as compared to samples ***B***, ***C*** and ***D***. Therefore, good air permability was observed in sample ***E***. Similarly, the sample ***F*** shows

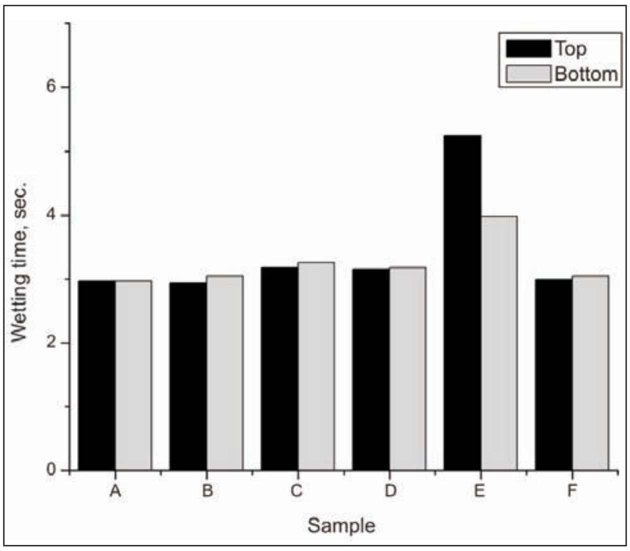

Fig. 1. Wetting time in seconds for different weft material from top and bottom

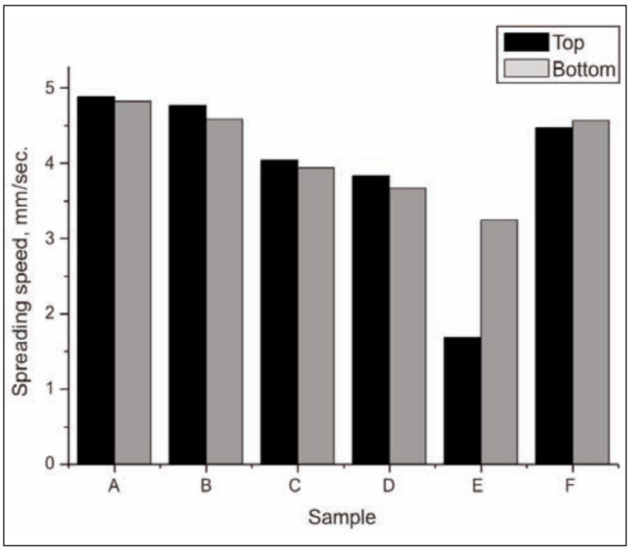

Fig. 2. The spreading speed from top and bottom of different materials

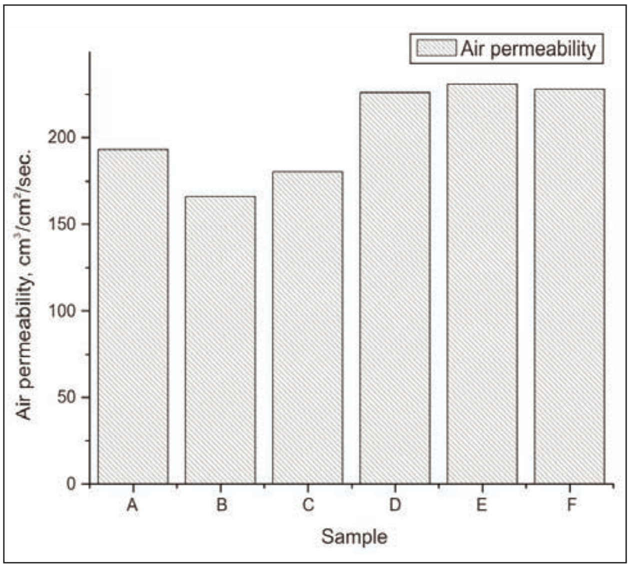

Fig. 3. The air permeability of variously structured weft materials

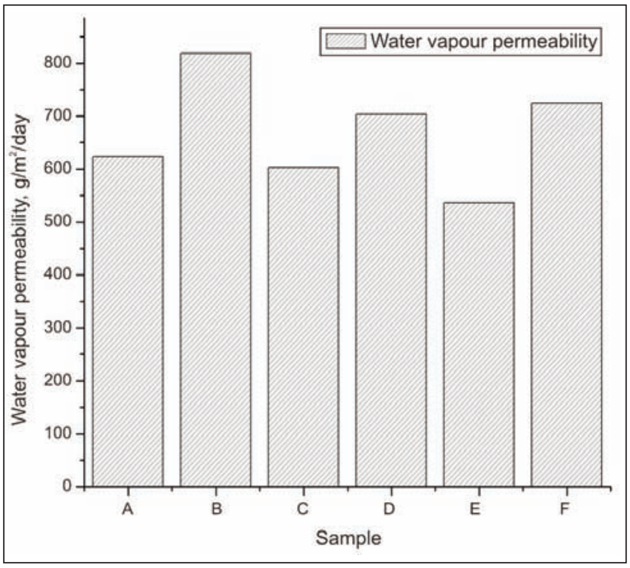

Fig. 4. Water vapour permeability of 100% pure weft yarns based fabrics

greater value as compared to sample ***D***. The same reason lies in this case where less crystallanity and bigger amorphous region of sample ***F*** gives more air permeability than sample ***D***. Similarly, sample **A** shows better air permeability value as compared to sample ***B***. Cotton is caracterized by ribbon like twist structure. These fibers like convolutions form hairiness in cotton yarn due to which air resistance of cotton yarns increases. When tencel is used with cotton the effect of air permeability shows its lowest values as tencel fiber itself has air conditioning property. Air permiabilty also decreases as the fiber fineness increases. This effect is also well elaborated as sample A shows good airpermeability value with respect to sample ***C***. It means sample a has more coarser fibers while using 100% modal in weft direction. Sample ***C*** gives higher number of fibers per yarn cross-section in weft direction due to which the fabric is less open and have low value of permeable structures so less air permeability occurs.

Water vapour permeability

Ability of fabric to transport its water in form of vapours through it is called water permeability. Figure 4 illustrates that water vapour permeability of sample ***B*** is much higher than other fabrics. As the microdenier, synthetic and natural fibers give good moisture absorption so sweat can easily be vaporized from these types of fabrics. Similarly, sample ***F*** also shows good behavior in water vapour permeability and hence thermo-comfortability. On the third number is sample ***D*** that shows more permeability than ***A*** and ***C***, whereas sample ***E*** stands at last position for this test. Lesser the value of water vapour permeability less will be the value of prespiration, due to which more vapours will accumulate and discomfort will be more. Sample ***D*** shows more higher value than ***A*** and ***C*** as bamboo has higher moisture regain value. The water vapour permeability also depends on macroporous structure of the constituent fibers. Therefore, the higher values of vapour permeability was observed for sample ***B*** as compared to other samples. The tencel has nanostructures due to which their moisture transportation is excellent, whereas the modal is compact from outside, its inner side is porous and the inner fiber skin is semi permeable. Therefore moisture absorption of modal will be lower than tencel.

Thermal parameters testing

Thermal parameters such as thermal conductivity, thermal absorptivity and thermal resistance play an important part in thermal comfort of human body when interaction of fabric with human body [11]. Thermal parameters have their values that any kind of irregularity in thermal equilibrium in human body can cause discomfort in body (figure 5). Thermal properties are very sensitive to measure. Sensora™ company in Czech Republic has developed an instrument called *Alambeta* which measures thermal properties accurately. The samples which have been used in this study were measured under controlled environment of 20–22 °C and relative humidity of 24–25%.

Thermal conductivity of fabric is total impact of chemistry of fiber and composition of fabric. Fabric is composed of polymer, air and moisture. Thermal

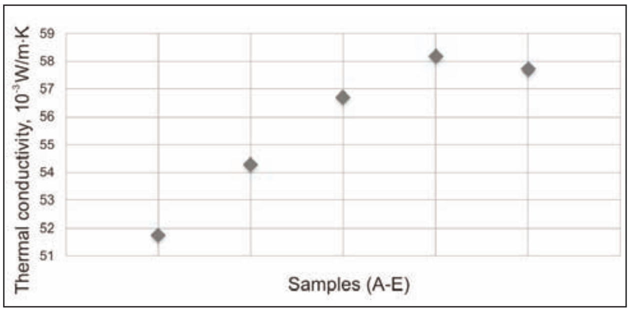

Fig. 5. Thermal conductivity of the samples

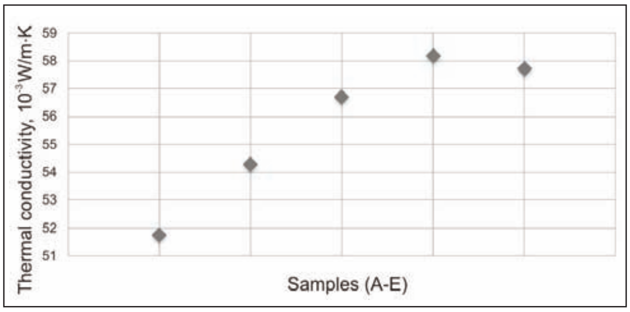

Fig. 6. Thermal absorptivity of blended fabrics

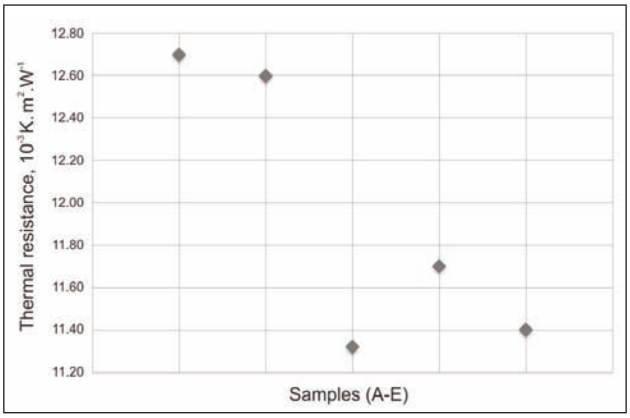

Fig. 7. Thermal Resistance of samples

conductivity of polymer is quite different from the thermal conductivity of fabric made of same polymer. For example, thermal conductivity of polyester fiber is different from thermal conductivity of fabric made using 100% polyester, mainly due to the presence of other factors like, air, moisture, textile auxiliaries, dyes molecules etc. Keeping this point in view, it was more likely that thermal conductivity of differently woven fabrics (***A-E***) will be different due to a lot of variation in increase in area of contact that can increase the thermal conductivity. It is mainly due to fewer spaces for air to be trapped as the surface of fabric and it becomes flat and more contact points are available to touch the skin. It facilitates the heat flow and more heat flow is a sign of higher thermal conductivity.

Thermal absorptivity is a vital characteristic of fabrics and it is the subject of numerous studies as well. It relies on the thermal conductivity of fibers, density and specific heat of the material. Thermal absorptivity demonstrates the capacity of a material to give warm-cool feeling when a material is touched for a short time approximately for two seconds. Thermal conductivity is anisotropic in nature and relies on the structure and chemistry of the material. Density of fabric depicts the mass per unit volume of a fabric [Kgm^{-3}]. It indicates the ratio of solid and void area in the fabric (figure 6). Fabric consists of polymers (filaments), air trapped inside fabric and dampness in voids in case of humid environment. Thermal absorptivity [$Wm^{-2}s^{-1/2}K^{-1}$] is linked with the thermal conductivity [$10^{-3}\,W\,m^{-1}\,K^{-1}$] and thermal capacity of fabric [$Jm^{-3}\,K^{-1}$]. Thermal capacity is a product of density [Kgm^{-3}] and specific heat [$JKg^{-1}\,K^{-1}$].

Thermal resistance is directly proportional to thickness of the slab and indirectly proportional to thermal conductivity of the material. It has been observed from figure above that different fiber types correlate differently between contact points and hence show different thermal conductivity. As thermal conductivity increases, there is a definite decrease in thermal resistance (figure 7). It shows that fabric having smooth surface provides less heat resistance and gives a cool effect, whereas, fabric with low number of contact points is better to keep body temperature intact and provides a thermo-physiological comfort to wearer. The above results show that as the fabric ratio and blends are changing and are imparting different impact on the thermal properties of fabric. For example, when the blend comes with different weft- and warp-wise directions these above results shows that blending do play a role in the thermal properties of fabrics.

CONCLUSION

Knitted fabrics are less air permeable than weaved fabrics so the moisture management parameters of woven fabric made from Tencel, modal, pro modal, bamboo, polyester and cotton were analyzed. The properties like air permeability, wetting, and wicking and water vapour permeability had been studied. The fabrics in which bamboo and pro modal were used in weft showed average values of the all above properties. Since this work is established on 100% pure weft yarns and single construction of the fabric so in future the fabric construction will be varied from 20*20/61*59 with respect to 100% cotton, however the same study can be done on pure yarn other than cotton on warp with other blended fabrics as well with different constructions. Herein, the bamboo and promodal due to their nearly similar moisture management properties and the most economic prices, in comparison with tencel and modal, make it preferable choice in many practical applications including sports garments.

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