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Comfort Characteristics of Fabrics Containing Twist-less and Hollow Fibrous Assemblies in Weft

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Abstract

Comfort characteristics of plain-woven fabrics, containing viscose staple fiber twist-less and hollow fibrous assemblies and core-sheath type DREF-III yarn in weft, have been reported in the present paper. The twist-less and hollow fibrous assemblies are the individually separated parallel core and annular sheath components respectively of core-sheath type DREF-III yarn. In all these fabrics the same warp yarn, i.e. two-ply ring spun yarn was used. Three different types of weft yarn were prepared in DREF-III system; (i) 59 tex yarn with staple viscose fiber in both core and sheath, (ii) 118 tex yarn with staple viscose fiber in core and water soluble staple PVA fiber in sheath, and (iii) 118 tex yarn with staple PVA in core and staple viscose in sheath. The core-sheath ratio was kept 50:50% for all the DREF-III yarns. The idea is to maintain the same weft yarns count (59 tex) in all the three finished fabrics (after removal of PVA component), with different structure of fibrous assembly in weft. The structure of fibrous assemblies in weft has great impact on the comfort related properties, i.e. air permeability, thermal conductivity, percentage water vapor permeability, wicking and water absorbency.

Keywords: Core, DREF-III yarn, Fibrous assembly, Hollow, Sheath, Twist-less

1 Introduction

The most important property of any apparel is comfort. Comfort is an experience that is caused by integration of impulses passed up the nerves from a variety of peripheral receptors smell, smoothness, consistency and color etc in the brain. Comfort is a qualitative term and it is one of the most important aspects of clothing. The clothing comfort can be divided into three groups, i.e. psychological, tactile and thermal comfort[1]. Psychological comfort is mainly related to the latest fashion trend and acceptability in the society and bears little relation to the properties of fabrics. The tactile comfort has relationship with fabric surface and mechanical properties. The thermal comfort is related to the ability of fabric to maintain the temperature of skin through transfer of heat and perspiration generated within the human body. Saville[2] distinguished two aspects of wear comfort of clothing; i) “thermo-physiological wear comfort which concerns the heat and moisture transport properties of clothing and the way that clothing helps to maintain the heat balance of the body during various levels of activity”, and ii) “skin sensational wear comfort which concerns the mechanical contact of the fabric with the skin, its softness and pliability in movement and its lack of pricking, irritation and cling when damp”. There is a general agreement that the transmission of air, heat and water vapor through a garment are probably the most important factors in clothing comfort. Comfort, as felt by the user, is a complex factor depending on the above attributes. Some early study[3-6] reported various aspects of comfort related properties of fabrics.

The comfort characteristics of fabrics mainly depend on the structure and types of yarn used. The development of new yarn structures raises questions about the nature and quality of fabrics made from the new yarns. Among the different yarn structures, DREF-III yarn has got typical core-sheath structure, where core and sheath components in the yarn have completely different fiber configurations. We have already reported[7] the tensile and some handle related properties having twist-less staple fiber core and the surrounding hollow sheath components individually within the fabrics. But the comfort characteristics of these types of fabrics are totally unknown. Little research exists in this area.

The main objective of this study is to investigate the comfort characteristics of woven fabrics made out of staple twist-less and hollow fibrous assemblies and to compare with the characteristics of fabric with DREF-III core-sheath type of yarn. Our specific objective is to assess the ability of these types of unique structures to enhance the comfort characteristics.

2 Materials and Methods

2.1 Raw Materials

Three types of DREF-III yarns with different combinations of core and sheath fibers were used in the weft, as given in Table 1. The fibers used for producing DREF-III yarns consisted of viscose staple fibers (44 mm long, 1.5 denier linear density, 18.8 cN/tex tenacity and 19.2% breaking elongation) and PVA staple fibers (40 mm long, 1.68 denier linear density, 41.9 cN/tex tenacity and 37.4% breaking elongation). In all the fabrics, the warp yarn was the same (two-ply cotton ring spun yarn with resultant count of 78.73 tex, tenacity 10.61 g/tex, breaking elongation 5.7% and initial modulus 213.19 cN/tex).

2.2 Sample Preparation

The three different core-sheath combinations of weft yarns were produced on a Fehrer AG type DREF-III friction spinning machine. The linear density of both viscose and PVA finisher draw frame slivers was maintained at 3.0 ktex. There was one sliver for core fibers and five slivers for sheath fibers. The feed rate and draft of drafting units I and II were adjusted in such a way that the core-sheath ratio become 50:50%. The spinning-drum speed and the yarn delivery speed were kept constant at 4500 rpm and 150 m/min respectively for all the samples. The count of DREF-III yarn, with 100% viscose in both core and sheath, was 59 tex. To study the behavior of fabrics with twist-less fibrous assembly in weft, the sliver with 100% viscose fiber was placed in the core (i.e. in drafting unit I) and 100% PVA slivers were placed in the sheath (i.e. in drafting unit II). When the behavior of fabric with hollow fibrous assembly in weft was studied, the placement of the viscose and PVA slivers were just reversed i.e. PVA sliver was placed in the core (i.e. in drafting unit I) and viscose slivers were placed in sheath (i.e. in drafting unit II). The linear density of these two yarns, where PVA fibers were used in sheath and core respectively, was kept exactly double, i.e. 118 tex. The idea was that to have exactly same yarn count (59 tex) in the weft for all the three samples when 50% of the water-soluble PVA portion completely removed.

The plain weave fabric samples were prepared in a rapier loom using same warp yarn with identical constructional parameters. Three different types of fabrics with different types of DREF III yarn in weft were produced, as given in Table 1, i.e. Fabric A (59 tex yarn with staple viscose fiber in both core and sheath in weft), Fabric B (118 tex yarn with staple viscose fiber in core and water soluble staple PVA fiber in sheath in weft) and Fabric C (118 tex yarn with staple PVA in core and staple viscose in sheath in weft). All three weft yarns were used one after another, so that the three fabric samples could be washed afterwards as a single piece to have similar treatment in all the fabrics. To have the staple viscose twist-less and hollow fibrous assemblies individually in weft, the PVA fibers must be removed from the sheath and core portions respectively from the weft yarn. PVA is soluble in water at 60^{o}C, and dissolved PVA should be removed from fabric thoroughly before drying. All three fabric samples were used as single piece and treated with hot water, using a laboratory jigger, at 90^{o}C for 2 hours. Care was taken to remove the PVA portion completely. The fabric A, in which the weft yarn consisted of 100% viscose staple fibers, was also given the same treatment to normalize the effect hot water shrinkage. After complete removal of PVA fibers the fabrics B and C were having twist-less viscose fibrous assembly and hollow viscose fibrous assembly respectively in the weft. The details of finished fabric are also given in Table 1.

2.3 Testing Procedure

The linear density and tensile properties of single fiber were measured by Lenzing Vibroskop-400 and Vibrodyn-400 respectively. The end and pick densities were measured with a pick glass at ten randomly selected positions for each sample. The count of weft yarns from fabric was measured by electronic balance. Thickness of fabrics was measured at 20 g/cm^2 pressure. The Shirley air permeability tester was used for measuring the air permeability of fabrics. The volume of air in cm^3 which passes per second through 1 cm^2 of fabric under head of 1 cm water-column is the measure of air-permeability. Thermal conductivity of fabrics was measured on SASMIRA thermal conductivity tester. The test specimen was placed between the heated lower plate and an insulated top plate. The time taken by the hot plate to cool down from 50^{0}C to 49^{0}C was measured and corresponding "Clo" value was determined from graph. The "Clo" value in turn converted to the more frequently used "Tog" value using the formula, Tog = 0.645*Clo. The higher the "Tog" value means higher the thermal resistance i.e. lower thermal conductivity. To assess the moisture transmission behavior of fabric three different types of tests were performed, i.e. water vapor permeability, wicking and water absorbency. The water vapor permeability was measured by the cup method. The specimen under test was sealed over the open mouth of a cup containing water. Evaporation takes place under standard atmospheric conditions and loss in weight of cup after 24 hours was measured and then converted in terms of water vapor permeability. The water vapor permeability of the specimen was then expressed as the percentage of water vapor permeability of reference fabric (Fabric A). The wicking behavior of fabrics was measured by suspending a strip of rectangular specimen (10" x 1") vertically with its lower edge in a reservoir of distilled water. The height of rise by water in a given time (i.e. 1 min, 3 min and 5 min) was the measure of the wicking behavior. Water absorbency is a quality of fabric to absorb water. It is a method for measuring the total amount of water that a fabric will absorb. The circular test specimen of 8 cm diameter was immersed in distilled water until it was uniformly wetted out and left overnight sandwiched between two wetted sponges. The original mass and the mass of the specimen after 24 hours was recorder. The absorption is mass of water absorbed expressed as the percentage of original mass of specimen.

3 Results and Discussion

All the comfort related properties (air permeability, thermal conductivity, percentage water vapor permeability, wicking height and water absorbency) of the fabrics are shown in Table 2.

3.1 Air permeability

It is clear from Table 2 that the fabric B (with twist-less fiber assembly in weft) had the highest air permeability where as fabric C (with hollow fiber assembly in weft) had the lowest. Diameter, structure and crimp of yarn and flattening of fibrous structure affect the air permeability of a fabric. The very low air permeability of fabric C may be attributed due to the very bulky structure of the hollow fibrous assembly in weft resulting in blocking the inter yarn spaces. For the same count of weft (59 tex) the effective diameter of hollow fibrous assembly (sheath component) was higher as compared to the twist-less fibrous assembly (core component) and normal core-sheath type DREF-III yarn. Blocking of inter yarn spaces may also be due to partial flattening of hollow structure after removal of the core component[8] resulted in reduction of air permeability. The twist-less fibrous assembly and the DREF-III yarn in the weft resulted comparatively higher inter yarn space due to their compact packing which in turn resulted higher air permeability than fabric C.

3.2 Thermal conductivity

It is evident from Table 2 that fabric A showed the maximum thermal conductivity and fabric C (with hollow fibrous assembly in weft) showed minimum thermal conductivity values. Fabric B (with twist-less fibrous assembly in weft) had intermediate thermal conductivity value. The minimum thermal conductivity of fabric C may be attributed to a very bulky structure of hollow fibrous assembly in the weft works as an insulating medium. It entrapped air in the hollow spaces and did not allow heat of the inner layer to transmit to outer layer. On the other hand, fabric B with twist-less fibrous assembly and with a flattened structure, resulted in a greater barrier to the heat transfer than fabric A. The relatively open structure of fabric A resulted in higher thermal conductivity through it by convection and radiation.

3.3 Water vapor permeability

Water vapor permeability is an important parameter in evaluating comfort characteristics of a fabric, as it represents ability to transfer perspiration coming out of the body. Table 2 shows that fabric C had highest water vapor permeability where as the fabric B had the lowest value and the fabric made out of core-sheath type DREF-III yarn (fabric A) having intermediate water vapor permeability value. The very high water vapor permeability value of fabric C (with hollow fibrous assembly in weft) may be attributed due to a very bulky structure of hollow fibrous assembly in weft. Yarn character plays important role in the transmission of water vapor. Open structure allows more water transmission. Hollow yarns have a better cover factor which allows water vapor to transfer from inside to outside through diffusion. When the transmission occurs through pores, the rate is independent of water vapor concentration. A larger amount of liquid mass can be retained in larger pores, which facilitates the diffusion process from inner layer to outer layer. Small pores of fabric B retained less amount of water mass in fabric resulting in lower water vapor permeability.

3.4 Wicking

The wicking property of a fabric mainly depends on characteristics of fiber and structure of component yarns and the fabric. Table 2 shows the wicking height of fabrics in the warp and weft directions for different time durations. It can be seen from Table 2 that the fabric B has highest wicking value in weft direction followed by fabric C; fabric A shows lowest wicking in the weft direction. The warp wicking for all the fabrics are almost same which may be due to the same warp yarn for all three fabrics. Wicking can only occur when fibers assembled with capillary spaces between them are wetted by a liquid. Capillary forces are responsible to drive the liquid in capillary spaces. The fiber surface properties and pore structure are the main determinants of wicking properties. The capillary principle dictates that smaller pores are filled first and are responsible for the front movement of the liquid. As the smaller pores are completely filled, the liquid then moves to the larger pores. The size and spaces of fibers as well as their alignment will influence the topology of the inter-fiber spaces or pores, which are channeled with widely varying shape and size distributions. The fabric B has twist-less and parallel-channeled fibrous assembly in weft. The twist-less fibrous assembly is due to more parallel fibers; small pores and channels absorb more water through capillary pressure. Small, uniformly distributed and inter-connected pores and channels facilitate fast liquid transport. The wicking height increases with the time for all the fabrics, as evident from Table 2.

3.5 Water absorbency

The water absorbency of a fabric mainly depends on the moisture regain of component fiber and open space within the fabric structure, and is an indication of sweat holding capacity of the fabric. The fiber components in all three fabrics are exactly the same, so the amount of voids within the structure of fabric plays an important role in water absorbency. It is clear from Table 2 that fabric C has the highest water absorbency where as fabric B has the lowest water absorbency. The very high value of fabric C may be attributed to the very bulky structure of hollow fibrous assembly in the weft. Water replaced the air in the hollow fibrous assembly and thus it can hold more water. On the other hand, fabric B shows the least water absorbency value, which may be due to compact and parallely aligned twist-less fibrous assembly which does not have sufficient open space to hold extra water. The fabric made out of core-sheath type DREF-III yarn has intermediate water absorbency value.

4 Conclusions

4.1 The fabric with twist-less fibrous assembly in the weft shows the highest air-permeability, whereas the fabric with the hollow fibrous assembly in the weft resulted in the lowest air-permeability.

4.2 Thermal resistance of fabric with hollow fibrous assembly in the weft is found to be higher than the fabric with twist-less fibrous assembly in the weft. The fabric with core-sheath type DREF-III yarn in weft shows least thermal resistance.

4.3 The water vapor permeability of fabric with the hollow fibrous assembly in the weft is found to be higher than other two types of fabrics. The fabric with twist-less fibrous assembly in weft shows least water vapor permeability.

4.4 The weft wise wickability of fabric with twist-less fibrous assembly in the weft is highest, followed by the fabric with hollow fibrous assembly in weft and the fabric with core-sheath type DREF-III yarn in the weft, which has the least wicking property.

4.5 The fabric with hollow fibrous assembly in the weft shows the highest water absorbency, whereas the fabric with twist-less fibrous assembly in the weft has the least value.

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Table 1: Details of fabrics

	I. GREY FABRIC	Weft			Finished fabric[a] Weft		Fabric sett, epi x ppi	Fabric weight, g/m^2	Fabric thickness, mm
	Yarn type	Core/ Sheath	Core : Sheath	Count, tex	Type	Count, tex			
A	DREF-III	Viscose/ Viscose	50 : 50	59.0	Viscose-Viscose in core-sheath	59.0	40x39	246	0.70
B	DREF-III	Viscose/ PVA	50 : 50	118.0	Viscose twist-less fibrous assembly	59.0	41 x 39	248	0.73
C	DREF-III	PVA/ Viscose	50 : 50	118.0	Viscose hollow fibrous assembly	59.0	39 x 40	243	0.79

[a]After treating with hot water

Table 2: Comfort related properties of fabrics

Sample	Air permeability, cc/sec/cm^2	Thermal conductivity, tog	Water vapor permeability, %	Wicking height, cm						Water absorbency, %
				Warp			Weft			
				1 min	3 min	5 min	1 min	3 min	5 min	
Fabric A	**48.67**	**0.3225**	**100.0**	**1.2**	**2.8**	**3.6**	**1.4**	**2.7**	**3.6**	**136.04**
Fabric B	**53.00**	**0.5015**	**94.8**	**1.0**	**2.9**	**3.4**	**4.9**	**6.8**	**8.7**	**129.23**
Fabric C	**13.23**	**0.6950**	**107.4**	**1.2**	**2.9**	**3.7**	**3.2**	**5.5**	**6.4**	**142.53**