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A study of wicking properties of cotton-acrylic yarns and knitted fabrics

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Abstract

This paper investigated wicking properties of cotton-acrylic rotor yarns and knitted fabrics. The effect of yarn wicking on wicking of fabric in both wale and course directions was also discussed. One way ANOVA results of the experimental study suggested that wicking abilities of yarns and fabrics increased with the increase in acrylic content in the blends and with the use of coarse yarns. Besides, yarn wicking had a significant effect on fabric wicking.

Keywords

Yarn wicking, fabric wicking, cotton-acrylic yarn blends, rotor yarns, single jersey fabric

Introduction

Comfort is one of the most important aspects of clothing, as it strongly affects the choice of people when buying the clothes. Moisture transition in textile fabrics is one of the critical factors affecting physiological comfort and is also very important especially for underwear and sportswear. When the metabolism is very high, people sweat and perspiration spreads all over the skin, in that case, clothes should transfer the perspiration outside to make people feel comfortable. To express the moisture transport, wicking is often used. Wicking is a spontaneous transport of a liquid driven into a porous system by capillary forces.[1] Wickability describes the ability to maintain capillary flow, on the other hand wettability describes the initial behavior of a fabric or yarn in contact with liquid.[2,3] There are several techniques to study wicking properties. The first one consists of weight variation measurement by a Wilhemy balance during capillary wicking.[4] The second technique involves setting liquid sensitive sensors regularly along the yarns.[5] The last focuses on observing and measuring the capillary flow of a colored liquid and the height is recorded against the time.[6] In this paper, the third capillary rise method was employed to determine the wicking properties of the yarns and fabrics under discussion.

The literature review showed that there is a very limited number of reports on comfort properties of textiles from cotton-acrylic blend fibers, despite the fact that the use of such blends is common place in the market. Das et al. studied the effects of yarn fineness, shrinkable acrylic proportion and twist level on various properties of cotton-acrylic blended bulk yarns and found that vertical wicking heights for all the bulked yarns were found to be higher than comparable 100% cotton yarn.[7,8] They also found that plain woven fabrics from cotton-acrylic blended bulk yarns had improved thermal resistance, air permeability and moisture vapor transmission as compared to that of 100% cotton fabric. Arai also studied the physical properties of water absorbent porous acrylic fibers related to wearing comfort and concluded that water absorbent acrylic fibers dried easily, had a warmth retention intermediate between those of cotton and acrylic fibers and, had difficulty in losing their air permeability even when wet.[9]

The literature review also showed that there are some studies on the wicking behaviors of yarns. In one of these reports which investigated the behavior of cotton-acrylic bulked yarns, it was found that

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although cotton-acrylic blended yarns had higher wicking heights than 100% cotton yarn, acrylic proportion had very little effect.[7] Also the authors concluded that the bulking process provided more capillary space which in turn increased the wicking performance of the yarns. Perwuelz et al., on the other hand, worked on liquid organization during capillary rise in yarns. It was found that capillary rise was dependent of the capillary diffusion coefficient of the yarn and twist increase reduced the average value of the diffusion coefficients.[10] Diffusion coefficient of viscose fibers is higher than the diffusion coefficient of cotton fibers. Viscose fibers have more amorphous places, absorb more water and have higher wickability.[11] When a high twist is introduced into the yarn, fibers near the yarn center may buckle due to twist retraction. This can harm the pore structures between fibers and affect wicking behavior of the liquid.[12] Wang and Zha investigated wicking property of the yarns and found that the wicking behavior of the yarns improved with the increase in cross-sectional area due to a larger number of capillaries in yarns.[13] Moreover, another study showed that wicking velocity increased with the increase in cross-sectional area of yarn and decrease in liquid viscosity.[14] In accordance with the literature, packing density of the yarns also influences wicking property. Compact yarns have higher packing density than conventional ring spun yarns, as a result of that they show lower wickability.[15]

The studies on the wicking performance of knitted fabrics and on the influence of yarn wicking on fabric are scanty. Moreover, mainly, ring spun and/or filament yarns have been studied for their wicking performance. Consequently, the study discussed in this paper was conducted in an attempt to investigate the wicking properties of cotton-acrylic rotor yarns and their influence on wicking performance of single jersey knitted fabrics. Apart from the previous researches, we studied the wicking behavior of rotor spun yarns from regular acrylic fibers and their blends with cotton and discussed the influence of fiber type and yarn count on wicking of yarns as well as the influence of yarn wicking on knitted fabric wicking.

Experimental work

Materials

Single jersey fabric samples from Ne 20 and Ne 30 rotor yarns were produced on a Mayer & Cie Relanit 1.2 circular knitting machine (30 inches in diameter and 96 feeders) at the same tightness factor. The fiber compositions were 100% acrylic, 50/50 cotton/acrylic, 85/15 cotton/acrylic and 100% cotton, in turn. Cotton fibers have the average fineness of 1.5 dtex and 2.5 % span length of 31.5 mm, whereas the acrylic fibers have the average fineness of 1.4 dtex. Cut length of 38 mm for acrylic fiber was used for the yarn production. The yarns were produced with a twist coefficient of $\alpha_e = 3.6$. Properties of the yarns utilized to knit fabric samples are, however, given in Table 1. Before the measurements were taken the samples were conditioned under the standard atmospheric conditions of $20 \pm 2\,^{\circ}C$ and $65 \pm 2\,\%$ of relative humidity for two weeks. The properties of fabric samples are given in Table 2, in which so far as the fabric coding is concerned the first number indicates the fiber composition percentage, C is for cotton, A is for acrylic, the second number shows the yarn count employed.

Method

Wicking of dry relaxed fabrics was measured in accordance with DIN 53924,[16] but with the difference that in addition to the height of water in 5 minutes measured at 30 seconds intervals, the weight variation in the fabrics during capillary wicking was also measured. According to the DIN 53924 standard, the water transport rate is determined by a vertical strip wicking test. One end of the strip (25 mm wide and 170 mm long) was clamped vertically with the dangling end immersed to about 3 mm in distilled water at 21°C. This test method was used to determine the wicking of fabrics in both wale and course directions. Wicking measurements of the yarn samples were done by an in-house testing method based on Liu et al.,[12] such that both ends of yarns were clamped, with one end immersed about 3 mm into distilled water. The wicking height was measured at intervals of 30 seconds and noted. For each treatment five replicates were performed. The statistical evaluation of the data obtained was performed with SPSS 16 software package.

Results and discussion

The results obtained are discussed below with the help of the tables (see Tables 3–4).

Yarn wicking

Table 3 shows yarn wicking results over a 5 minute period. The statistical analysis of the results showed that at a 95% confidence interval, fiber composition was the most significant categorical variable affecting yarn wicking. The other statistically significant categorical variable was the yarn count. For each yarn count, the 100% acrylic yarns had the highest yarn wicking values. The better wicking ability of the acrylic yarns might be due to lower moisture absorption capability of the regular acrylic fiber which does not allow water to

Table 1. Tested properties of the yarns

Yarn type	100% acrylic Ne 20/1	50/50% cotton/acrylic Ne 20/1	85/15% cotton/acrylic Ne 20/1	100% cotton Ne 20/1	100% acrylic Ne 30/1	50/50% cotton/acrylic Ne 30/1	85/15% cotton/acrylic Ne 30/1	100% cotton Ne 30/1
Yarn property								
Yarn count (Ne)	19.2	19.5	19.3	19.7	29.0	29.2	29.4	29.4
Yarn count CV (%)	0.59	0.63	0.50	1.30	0.55	1.04	0.72	0.75
Hairiness (H)	7.10	5.91	5.83	5.16	6.65	5.86	5.71	4.85

Table 2. Properties of the fabrics

Fabric property	Fabric weight (g/m^2)	Fabric thickness (mm)	Stitch length (cm)	Stitch density ($loops/cm^2$)	Fabric porosity (%)
Fabric code					
100A-20	177.8	0.58	0.35	180	72
50/50C/A-20	189.6	0.69	0.34	192	79
85/15C/A-20	185.8	0.67	0.35	204	79
100C-20	183	0.68	0.34	208	81
100A-30	126.1	0.52	0.32	210	76
50/50C/A-30	134.3	0.58	0.31	238	82
85/15C/A-30	132.6	0.60	0.31	238	82
100C-30	131.2	0.59	0.31	234	83

Table 3. Wicking height of the yarn (mm)

Time (min) Yarn code	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
100A-20	21	28	33	37	40	42	42	43	44	44
50/50C/A-20	7	12	16	19	21	23	24	27	30	30
85/15C/A-20	17	22	25	30	31	33	34	35	36	36
100C-20	1	1	2	2	2	3	3	3	3	3
100A-30	17	22	25	27	29	30	30	30	31	31
50/50C/A-30	7	11	13	15	19	22	23	24	27	29
85/15C/A-30	2	3	3	3	4	5	7	7	7	8
100C-30	1	2	3	5	6	6	6	7	7	8

Table 4. Wicking height (mm) and weight (g) of the fabrics in wale and course direction

	Wicking height (mm)		Wicking weight (g)	
Fabric code	Wale	Course	Wale	Course
100A-20	40	40	0.275	0.299
50/50C/A-20	16	19	0.220	0.275
85/15C/A-20	32	45	0.354	0.415
100C-20	8	9	0.149	0.158
100A-30	38	38	0.222	0.277
50/50C/A-30	9	12	0.145	0.166
85/15C/A-30	6	7	0.124	0.129
100C-30	2	6	0.106	0.127

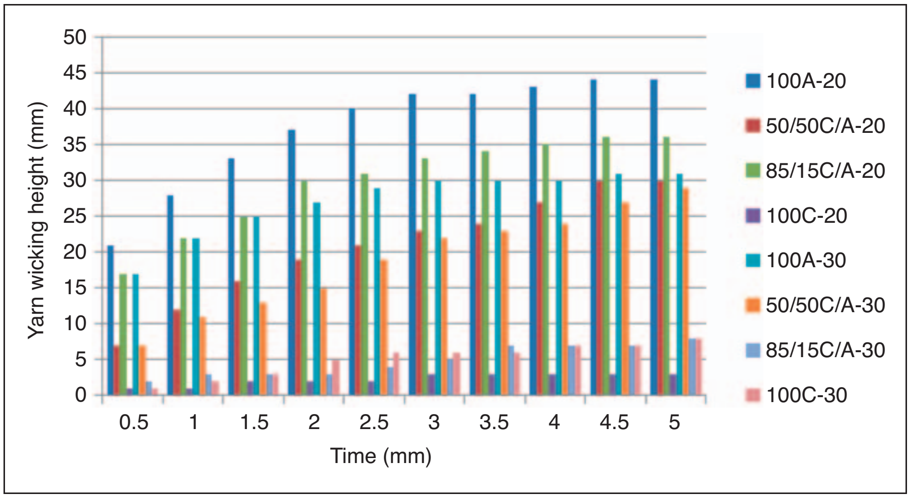

Figure 1. Yarn wicking.

enter inside. As a result, water movement and absorption occurs only on the acrylic fibers's surface. However, moisture absorption of cotton fiber is higher. Water diffuses into the cotton fiber and cotton starts to swell immediately after water absorption. This might be the reason for the lower wicking ability of the cotton yarns. In addition to that, differences in yarn surface roughness cause differences in wicking of yarns and fabrics made from those yarns.[17] Increase in yarn roughness due to random arrangement of its fibers gives rise to a decrease in the rate of water transport because the effective advancing contact angle of water on the yarn is increased as yarn roughness is increased and the continuity of capillaries formed by the fibers of the yarn seems to decrease as the fiber arrangement becomes more random. Cotton fibers might have formed rough yarns of high apparent contact angle due to their convolutions and might be more randomly distributed whereas acrylic fibers might have smoother surface which would affect the contact angle.

Our results also showed that wicking height of the yarns tended to increase with the increase of the acrylic ratio (see Table 3 and Figure 1) however the tendency was not the same for the different yarn counts studied. Also, the wicking heights of Ne 20 yarns were generally higher than those of Ne 30 yarns, which agrees with the literature findings[7,18] such that coarser yarns wick faster than the finer yarns as higher capilarity is expected from those yarns. However, the randomness of the internal structure of the rotor yarns, especially in the sheath part, might have given rise to differences in wicking of the yarns having different counts. The studied yarns are rotor yarns that have a core part with a relatively dense structure, a sheath part with a less dense structure and belly-bands. Due to the mentioned differences in the rotor yarn structure, wicking behavior of water in the core part is expected to be different to that in the sheath part and over all yarn wicking might be affected by the compactness degree of these two parts of the yarns studied (i.e. Ne 20 and Ne 30). Differences in wicking of the mentioned parts of the rotor yarns were also examined microscopically by Sengupta and Murthy.[19,20]

Fabric wicking

Wicking in wale and course directions. ANOVA results indicated that the categorical variables, i.e. fiber composition and yarn count, had statistically significant effects on wicking performance of the samples in both wale and course directions at a 95% confidence interval. The results obtained also suggested that yarn wicking values had a positive and high correlation with the fabric wicking in each direction ($r^2_{\text{course direction}} = 0.84$ and $r^2_{\text{wale direction}} = 0.82$). The statistical analysis also showed that the influence of yarn wicking on fabric wicking in course direction was higher than its influence on fabric wicking in wale direction. This may have resulted from the fact that in the course direction the water follows the capillary spaces along the same yarn which in turn decreases the discontinuity of the capillarity. Regarding the wicking heights and weights obtained for fabrics after a 5 minute period, Table 4 is presented. As it may be seen from the table, wicking behavior of the fabrics show the similar trend as that of the yarns.

The results revealed that the wicking height and amount of fabrics from coarser yarns are comparatively higher than those properties of the ones from finer yarns. A greater number of fibers in the cross-section of coarse yarns might lead to higher capillarity and continuity of capillaries formed by the fibers. The higher wicking ability of the fabrics from coarser yarns may be partly a result of their higher thickness values, as the fabric thickness can provide more space to accommodate water, which can lead to more water transferred, depending on the capillary space available as well as the capillary pressure present.

Despite the fact that the fabric porosity values presented in Table 2 did not differ greatly for fabrics from different yarn counts, there might be significant changes in the pore-size distribution of the fabrics resulting from randomness of the arrangement of the fibers in the rotor yarns. In addition to that the greater variation in the diameter and cross-sectional shape of the cotton fibers in comparison to the acrylic ones and also the changes in the geometry of the cotton fibers due to swelling might have lead to different wicking behaviors in the cotton yarns and fabrics. Finally, liquid–solid interfacial dimensions as well as contact angle may vary depending on the fiber type, i.e. cotton and acrylic, which in turn may cause differences between the wicking behavior of the yarns and that of the fabrics. The differences in the contact angles and surface tensions of the studied fibers together with some other fiber types and influence of these parameters on wicking would be the subject of a further study.

Conclusions

The study discussed in this paper was conducted to investigate the wicking properties of rotor yarns and their influence on wicking behavior of cotton-regular acrylic knitted fabrics. The results showed that the presence of acrylic fiber and yarn count had a significant impact on wicking performance of single jersey knitted fabrics. Moreover, the statistical analysis of the data revealed that yarn wicking played a major role in fabric wicking in each direction, i.e. in wale and course direction. The randomness of the rotor yarn structure seemed to affect the wicking behavior of both yarns and fabrics. Finally, the influence of yarn wicking on fabric wicking in the course direction tended to be higher than its influence on fabric wicking in the wale direction.

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