Wicking behaviour of regular ring, jet ring-spun and other types of compact yarns

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The wicking behaviour of a series of regular ring, jet ring-spun and other types of compact yarns produced by Rocos and Elite systems has been studied. A total of 36 yarn samples with three linear densities have been produced from 100% cotton, scoured and then tested using vertical wicking test; no dye is used in the wicking studies. Compact yarns show lower wickability compared to conventional ring-spun yarns which is attributed to their greater packing density. Washburn’s equation is obeyed quite well when the time constant is near 0.5. In view of the fact that the time constants for Elite and Rocos compact yarns are exceptionally higher than those of jet ring-spun yarns, these can be considered as measures of compact yarns.

Keywords: Compact yarn, Cotton, Elite yarn, Jet ring-spun yarn, Rocos yarn, Wicking height

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1 Introduction

Wetting is an important aspect for textile processing and performance. The comfort properties of clothing made from cotton are related to moisture absorbency. Wetting and wicking are synonymous. A liquid that does not wet fibres cannot wick into a fabric and wicking can only take place when fibres assembled with capillary spaces between them are wetted by liquid. The resultant capillary forces drive the liquid into the capillary spaces. Fibre wickability is, therefore, a prerequisite for wicking. Wickability describes the ability to sustain capillary flow.

When liquid is taken up in a yarn or fabric, apparently two aspects can be distinguished, namely (i) the amount of liquid absorbed per unit of surface of mass; and (ii) the velocity with which wicking takes place. The vertical wicking test, i.e. the determination of the height of rise \( H \) in a yarn as a function of time \( t \), that cover both the above aspects which are characterized by simplicity and acceptable duration of determination has been selected.

A liquid wicks in a textile yarn or yarn system such as a woven fabric under the circumstances where the effect of gravity is described by the equation \( S = K t^{1/2} \), where \( S \) is the distance traveled; \( t \), the time in second; and \( K \), a constant characteristic of the yarn liquid system. There are numerous mechanisms that can operate to move fluids through porous materials, but the viscous flow of water by capillary action accounts for the major portion of the flow that actually occurs. Washburn’s fundamental work in the hydrodynamics of capillary flow has been used to describe water movement in a number of porous materials including paper, soil and leather.

Hollies et al.\(^2,3\) have applied Adam's work to develop a theoretical model for water transport in yarns and fabrics and demonstrated with experiments that the model is a good representation of actual condition that can occur in textile materials. They have shown that the yarn construction features, such as size, number of fibres, fibre size, randomness of

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the internal structure and twist, affect the rate of water transport insofar they control the size of the interface capillaries, large capillaries in general producing higher wicking rates, narrow capillaries slowing down and sometimes even stopping the movement of water.

Minor et al. have studied a number of non aqueous solvents and a number of yarns made from different materials both natural and synthetic and demonstrated that the work of hollies et al. is generally valid. They used filament bundles as yarn bundles and studied the ease of wicking where the liquid available is limited. Lord studied the wicking behaviour of rotor-spun yarns and compared it with ring-spun yarns. He conducted limited tests, and concluded that the wicking height is not very sensitive to changes in the twist of the rotor-spun yarns.

DeBoar has suggested the three types of measuring methods, namely (i) vertical wicking test, (ii) determination of saturation value, and (iii) drop test; these cover both the parameters of any amount of liquid absorbed and the rate of absorption. Sengupta and Sreenivasanmurthy investigated the wicking behaviour of ring and rotor yarns with various twist factors and arrived at a general conclusion on the effect of twist on wickability. They have indicated that the hard twisted yarns have a lower wicking tendency than those of soft twisted yarn and the wicking time increases as the twist increases. Wicking in rotor yarn is, however, less sensitive to twist than in the corresponding ring-spun yarns. Subramaniam et al. have reinterpreted the Sengupta’s results and pointed out that the wicking test is more appropriate for rotor yarns than was previously thought. The only change that has been suggested is that wicking height should be plotted against square root of time.

Thus, a number of researchers have carried out studies on the wicking behaviour of yarns. Recently, the wicking behaviour of compact yarns and fabrics has been reported by Chattopadhyay. The present study is therefore aimed at comparing the wicking behaviour of regular ring, jet ring-spun and other types of compact yarns produced from various compact systems.

2 Materials and Methods

2.1 Materials

A series of regular ring, jet ring-spun and other types of compact yarns produced at identical conditions by jet ring-spun, Rocos and Elite systems from a standard spinning mill was used for the wicking studies. The production of jet-spun yarn using various jets made out of brass, aluminium and teflon was accomplished in the ring frame by fitting the nozzles between front roller nip and lappet (as retrofit in conventional ring frame for compaction). The nozzles used were single, double and triple for studying the characteristics of yarn produced. A total of 36 samples produced from 100% cotton with different linear densities [19.68 tex (30 Ne), 14.76 tex (40 Ne) and 11.81 tex (50 Ne)] were tested.

2.2 Methods

All the yarn samples were scoured, lowered into the distilled water with no dye and then tested for wicking behaviour using the vertical wicking test method.

The time required for the water to rise along the yarn was recorded. The experiment terminated when the travelling water arrived at 3 cm or the measuring time exceeded 24 h. The distance of water travelled along the yarn was determined as a function of time. The paired comparison t-test was used to determine any statistically significant difference with a confidence limit of 95%. The mean of 20 tests was taken to represent wicking height.

3 Results and Discussion

It is interesting to note that the wicking height in respect of jet ring-spun yarn is lower than that of conventional yarn. It is apparent that the wicking height (6.5, 5.5 and 4.5 mm) shows a reduction as the count becomes finer respectively and this is due to the variation in thickness and twist. The jet ring-spun yarn produced from single brass air jet shows a significant reduction in wickability implying that the compactness achieved is good. It may be noted that the wickability can be taken as a measure of compactness; the lower the wickability, the better is the compactness and vice versa.

Figure 1 shows the trend in wickability of the regular ring and the commercial compact yarns, such as Rocos and Elite yarns. Figure 2 shows the wicking behaviour of regular ring, jet ring and other compact yarns for 19.68 tex (30 Ne), 14.76 tex (40 Ne) and 11.81 tex (50 Ne). Elite compact yarn shows a significant reduction in wickability compared to conventional yarns. This is in substantial agreement with the findings of Chattopadhyay. It is also apparent that beyond 1800 s, there is no change in wicking. This agrees well with the prediction by Miller, showing that after an initial deceleration, the rate of downward wicking should become essentially constant. Wicking height increases with time, and the rate of rise is very fast at the beginning and slows
down gradually. After 180s, the differences are noticeable between the yarns. Ring yarns have been found to wick faster compared to compact yarns. The compact yarns are characterized by higher packing density, and it is expected that the average capillary size would be less in them. The slowing down of height increases with the increase in time for any yarn can be attributed to the gravity action of the water column within the capillary which acts against the capillary pressure.

Figure 2 shows that there exists a saturated zone and an unsaturated zone in the yarn. Once the liquid starts wicking in the yarn, it fills the interstices between fibres. In vertical wicking, where the role of gravity is significant, the velocity of wicking decreases with the lapse of wicking time and eventually reaches to zero when the upward driving force due to capillary pressure is balanced by the downward gravitational force. Since the capillary size of intra-yarn pores is smaller than that of inter-yarn pores, liquid continues to wick in the yarns due to higher capillary pressure, even when liquid has stopped wicking the interstices between them.

Two methods were used to analyse the wicking results obtained in this study. In the first method, from the vertical wicking results, the logarithm of the wicking time was plotted against the logarithm of the wicking height (Fig. 3). It is found that the values of the time exponents in Washburn equation range between 0.4 and 0.49. In most of the cases, the time exponents in vertical wicking are near 0.5 which is the Washburn value.1

Figure 4 shows the wickability of regular and compact yarns in logarithmic values. Values of the time exponent (k) in vertical wicking are shown in Table 1 (Model assumed to calculate the time exponent k is: $H = Ct^k$, where C is the constant;
gives the correlation coefficient and regression taken as a measure of compactness of yarns. Table 3 ring-spun yarns which are attributed to greater yarns such as Rocos and Elite are different from jet Furthermore, the values of k for commercial compact counts, Washburn’s equation holds good very well. They taken from Table 2). It is apparent that k values show an interesting trend for counts 40 Ne and 50 Ne. They show progressive increase implying that for finer counts, the values of k can also be taken as a measure of compactness of yarns. Table 3 gives the correlation coefficient and regression equations for the regular and compact yarns [Model assumed is: $\log (H) = k \log t + \text{constant}$].

In the second analysis, the wicking height was plotted against the square root of time and the correlation coefficient and regression equations were computed. Table 3 gives the values of slope and intercept (Model assumed is: $H = K t^h + \text{constant}$, where K is the slope). It is apparent that Rocos and Elite yarns for all counts have given lower values of slopes and intercepts compared to other yarns implying that they have lower wicking ability. No doubt, the slopes of the jet ring-spun yarns are lower

$$t, \text{ time; and } H, \text{ distance travelled. The values of k are taken from Table 2). It is apparent that k values show an interesting trend for counts 40 Ne and 50 Ne. They show progressive increase implying that for finer counts, Washburn’s equation holds good very well. Furthermore, the values of k for commercial compact yarns such as Rocos and Elite are different from jet ring-spun yarns which are attributed to greater compactness. Therefore, the values of k can also be taken as a measure of compactness of yarns. Table 3 gives the correlation coefficient and regression equations for the regular and compact yarns [Model assumed is: $\log (H) = k \log t + \text{constant}$].

$$In the second analysis, the wicking height was plotted against the square root of time and the correlation coefficient and regression equations were computed. Table 3 gives the values of slope and intercept (Model assumed is: $H = K t^h + \text{constant}$, where K is the slope). It is apparent that Rocos and Elite yarns for all counts have given lower values of slopes and intercepts compared to other yarns implying that they have lower wicking ability. No doubt, the slopes of the jet ring-spun yarns are lower
than those of regular yarns. The correlation between wicking height and square root of time shows higher values for Rocos and Elite spun yarns. These yarns stand uniquely in the wicking tests.

4 Conclusions

4.1 A good linear relationship between the logarithm of the wicking length and the logarithm of the duration of wicking time is found.

4.2 Washburn’s equation is obeyed quite well when the time constant is near 0.5. In respect of Rocos and Elite compact yarns, the time exponent is significantly higher compared to the regular ring-spun yarns.

4.3 Another relationship in which the wicking height is plotted against square root of time shows that the slopes are lower for Rocos and Elite yarns which implies that they have good compactness. The correlation between wicking height and square root of time is also found to be quite good for these commercial compact yarns.

4.4 The values of time constant k show an increase with finer counts indicating that with less number of fibres in cross-section, wickability improves. In view of the fact that time constants for Elite and Rocos compact yarns are exceptionally higher than those of regular ring-spun yarns, they can be considered as measures of compact yarns.

4.5 Compact yarns show lower wickability compared to conventional ring-spun yarns. This is attributed to their greater packing density.

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References

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<tr>
<th>Spinning system</th>
<th>Regression equation</th>
<th>Correlation coefficient</th>
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<tr>
<td>Regular ring</td>
<td>$H = 4.137t^{0.5} + 9.336$</td>
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<td>Elite compact</td>
<td>$H = 3.341t^{0.5} + 3.978$</td>
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Table 3—Regression equations of the form $H = Kt^{0.5} + $ constant with intercept and correlation coefficients for various yarns