Effect of fibre length and fineness on tenacity of rotor-spun yarn

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Received 20 June 1988; revised and accepted 26 September 1988

The effect of fibre length and fineness on fibre migratory behaviour, spinning-in-coefficient and twist efficiency in relation to tenacity of rotor-spun yarn has been studied. Migration parameters, spinning-in-coefficient and twist efficiency decrease with increase in fibre length, resulting in a lower tenacity. The finer fibres give higher tenacity compared to coarser fibres.

Keywords: Migration parameters, Spinning-in-coefficient, Twist efficiency, Viscose fibre, Wrapper fibres, Yarn tenacity

1 Introduction

The main drawback of the rotor-spun yarn is its lower tenacity compared to that of ring-spun yarn due to structural differences in the yarn. The migratory behaviour, spinning-in-coefficient and packing density are the three important parameters which are mainly used for understanding the internal structure of the spun yarn. Hearle et al.\(^1\) concluded that the low strength of most open-end spun yarns can be attributed to the poor fibre extent and inferior fibre migration within the yarn body. Ishtiaque\(^2\) observed that the packing density of rotor-spun yarn is less than that of ring-spun yarn. Various research workers have shown the effect of fibre length and fineness on yarn tenacity but they do not agree to one another. Lord\(^3\) stated that beyond a certain fibre length, there is no further increase in yarn strength. Salhotra and Talal\(^4\) observed that the yarn tenacity increases initially with the increase in fibre length up to 38 mm and then it drops with further increase in fibre length whereas London and Jordon\(^5\) observed that the strength of rotor-spun yarn is relatively insensitive to fibre length. Simpson\(^6\) predicted that an increase in the number of fibres per cross-section may reduce the strength loss of open-end spun yarns. On the contrary, Sultan and El-Hawraii\(^7\) concluded that the reduction in strength of open-end spun yarn could be minimized by using a coarser fibre. But nobody has so far reported, in a single study, the effect of fibre length and fineness on the fibre migratory behaviour, spinning-in-coefficient, twist loss and percentage of wrapper fibres, which ultimately affect the yarn tenacity. Therefore, in the present study, the effect of fibre length and fineness on the above mentioned parameters in relation to yarn tenacity has been studied.

2 Materials and Methods

2.1 Sample Preparation

The characteristics of the fibres used are given in Table 1. 0.25% coloured (black) viscose fibres, used as tracer fibre, were mixed thoroughly with the undyed samples in each of the six cases. The samples were then processed in a miniature card and a 4/4 conventional miniature draw frame to get a sliver of 0.17 hank. These slivers were pro-
cessed in Sussen open-end spin tester to produce 16s viscose yarn with 4.0 TM using the following machine parameters: rotor speed, 40,000 rpm; opening roller speed, 5000 rpm; and rotor diameter, 56 mm.

2.2 Test Methods

The tracer fibre technique originally developed by Morton and Yen\(^8\) was used for studying the migratory behaviour and spinning-in-coefficient. A mixture of liquid paraffin (39\%) and monobromonaphthalene (61\%) was used for submerging the yarn and optically dissolving it so as to see the black tracer clearly in two planes. A projection microscope with vertical and horizontal scale on the screen was used for measuring the fibre helix radius \(r\) and the yarn radius \(R\) (Fig. 1) for calculating a parameter \(y\) equal to \((r/R)\). The migration parameters, e.g. mean fibre position, root mean square (rms) deviation, mean migration intensity, were calculated using the method suggested by Hearle and Gupta\(^9\) and the coefficient of migration was calculated using the procedure followed by Morton\(^10\) as given below:

\[
\text{Mean fibre position} = \frac{\sum y}{n}
\]
\[
\text{rms deviation} = \left[\frac{\sum (y - \bar{y})^2}{n}\right]^{1/2}
\]
\[
\text{Mean migration intensity} = \left[\frac{\sum (dy/dz)^2}{n}\right]^{1/2}
\]
\[
\text{Coefficient of migration} = \frac{1}{RZ} \sum_{i=1}^{n} r_i Z_i
\]

where \(Z\) is the length along the axis for two successive troughs. Fifty tracers were observed for each yarn sample.

Spinning-in-coefficient was calculated by the formula used by Kasparek\(^11\) as given below:

\[
\text{Spinning-in-coefficient} = \left(\frac{\sum_{i=1}^{n} L_i / M}{L}\right)
\]

where \(L_i\) is the individual fibre extent; \(L\), the measured mean fibre length in the product examined; and \(n\), the number of observations. One hundred fibres were considered for each sample.

The actual twist in the yarn was measured by untwist-twist method using 10 cm gauge length.

Twenty-five readings were taken for each sample. The twist efficiency was calculated by using the following formula:

\[
\text{Twist efficiency (\%)} = 100 - 100 \left(\frac{T_m - T_a}{T_m}\right)
\]

where \(T_m\) is the machine twist; and \(T_a\), the actual twist in the yarn.

The number of wrapper fibres was counted among three hundred tracer fibres for each sample and hence the percentage of wrapper fibres was calculated.

3 Results and Discussion

3.1 Effect of Fibre Length and Fineness on Migration Parameters

With the increasing mean fibre length, more and more fibres form wrapper. The proportion of fibre constituting the core component will, therefore, decrease gradually with increase in fibre length. But the twist loss depends on the proportion of the fibre constituting the core component. So, the twist at yarn formation point could be expected to be less in the longer fibres, and also in coarser fibres because of less fibres in the yarn cross-section as compared to finer fibres. The forces acting on the fibres in the radial direction increase with the increase in the level of twist and hence migration effect increases correspondingly\(^12\). Therefore, this force would be less in the case of higher mean fibre length due to greater loss of twist, resulting in a decrease in fibre migration, as shown in Figs 2 and 3, though there is
a very marginal effect on root mean square deviation due to twist variation.

3.2 Effect of Fibre Length and Fineness on Spinning-in-Coefficient

It is observed from Fig. 4 that the spinning-in-coefficient decreases with increasing mean fibre length and it is lower in the case of coarser fibre. This observed phenomenon can be explained on the basis of formation of hooked fibre and wrapper fibres in the yarn.

3.2.1 Hooked Fibre

For a particular opening roller speed the chances of fibre breakage are more in the case of longer fibres than in the case of shorter fibres. Moreover, a longer fibre is more likely to bend due to greater flexibility. So, the mean fibre extent decreases more in the case of longer fibres due to fibre breakage and bending. On the other hand, a relatively shorter fibre is expected to be better separated than a longer fibre at a given opening roller speed and the better individualization helps the accelerating air flow to orient the fibre properly. The opening roller throws the coarser fibres against the transport tube wall with higher centrifugal forces. So, the chance of fibre bending is more in the case of coarser fibres.

3.2.2 Wrapper Fibres

The fibres which are laid across the peripheral twist extent (PTE) become wrapper fibres in the yarn body. But the probability of a fibre to be laid across the PTE is given by $L/2\pi R$, where $R$ is the rotor radius and $L$ is the fibre length. So, for a particular rotor, the higher the mean fibre length, the more is the chance of becoming wrapper fibres (Fig. 5).

3.3 Effect of Fibre Length and Fineness on Twist Efficiency

The twist efficiency directly depends on the retaining force at the yarn formation point in the rotor. Since the fibre-metal frictional force is almost constant for a particular fibre and machine parameter, the retaining force is directly proportional to the number of fibres in the yarn core. With the increase in mean fibre length the number of fibres in the yarn core decreases due to high wrapper fibre percentage which indicates lesser retaining force, causing the yarn end to slip with higher twist loss. This is in agreement with the finding of Salhotra. Though the wrapper fibres in the yarns made from 1.2 denier and 1.5 denier fibres are nearly the same, the total number of fibres in the yarn cross-section is more in the case of yarn made from finer fibre. This indicates the more number of fibres in the yarn core, resulting higher twist efficiency (Fig. 6) as compared to that in the case when coarser fibre is used.

3.4 Effect of Fibre Length and Fineness on Yarn Tenacity

It is observed from Fig. 7 that the yarn tenacity decreases with increase in mean fibre length for both the yarns made from 1.2 denier and 1.5 den-
higher inter-fibre frictional forces because of
more number of fibres in the yarn cross-section.

4 Conclusions
4.1 Fibre migration decreases with increasing
mean fibre length.
4.2 Spinning-in-coefficient decreases with increasing
mean fibre length. It is lower for coarser fibre.
4.3 Wrapper fibres increase with increasing mean
fibre length.
4.4 Twist loss is greater in the case of longer and
coarser fibre.
4.5 Yarn tenacity decreases with increasing mean
fibre length and the finer fibre gives higher tenac-
ity compared to coarser one.

Acknowledgement
The authors are thankful to Dr S M Ish-
tiaque, Department of Textile Technology, IIT,
Delhi, for valuable guidance and discussion.

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