The Effect of Twist Angle on the Modulus in Worsted and Semi-Worsted Staple Yarns

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ABSTRACT

This paper is concerned with the prediction of the tensile properties of worsted (spun wholly from combed wool in which the fibres are reasonably parallel) and semi-worsted (in which combing operation is skipped) yarns spun from 100% Wool, Polyester, Nylon, Viscose and Acrylic fibres. In the review of the literature, the work done by various researchers on continuous filament yams is highlighted.

In the experimental work, it was found that the reported equations for modelling the behaviours of continuous filament yams were useful for predicting the behaviour of staple yarns, i.e., those spun from fibres of limited lengths. Although the published theoretical work did not fit the practical case exactly, the equations relating yam and fibre moduli gave acceptable values for staple yarns once an appropriate correction factor was introduced.

1.0 INTRODUCTION

Much has been published on the tensile behaviour of yams. Most of the research concerns continuous filament structures, very little relates to staple yams. Researchers in yarn mechanics have not fully understood the tensile mechanics of staple yams because of their complex structures. A detailed understanding of the structural mechanics of staple yams is made difficult by two factors, namely, the discontinuities in the yarn structure owing to the staple fibre lengths, and the slippage of fibres during extension. Fibre migration and twist in spun yarn are also important factors in the study of a yam structure. The lateral pressure of a spun yam cannot be developed without migration. The transfer of stress from fibre to fibre is determined by the distribution of the radial pressures from the fibres within yarns. This is of vital importance since spun Yarns are made of relatively short staple fibres (Backer, 1993; Albrecht, 1993; Backer and Hearle, 1969).

2.0 MATERIALS AND METHODS

2.1 Yarn is tensile behaviour

A number of researchers, particularly Backer (1993), Backer and Hearle (1969) have discussed the subject of yarn structural mechanics. Backer dealt with different approaches to the analysis of yarn mechanics. Hearle concentrated on a theoretical approach to the investigation of the extension behaviour of twisted continuous filament and staple yarns. He refers to an idealized yarn structure and assumes the yarn is circular in cross-section, and is composed of a series of concentric cylinders of differing radii. He then reports the following relationship:

$$\varepsilon_f = \varepsilon_y \cos^2 \theta \quad \text{......} 1$$

Where: ε_f = Filament strain; ε_y = Yarn strain; θ = Helix or twist angle

From this relationship, it is clear that at the center (i.e. where the helix angle is zero) the filament and yarn strain are equal. Also, the filament strain decreases to a value $\varepsilon_f = \varepsilon_y \cos^2\alpha$ at the yarn surface, where α is the surface angle of twist.

Considering the force acting along the filament axis, derived an expression for the yarn tension, T, which is of the form:

$$T = (\pi R^2 E_f \varepsilon_y / V_y) \cos^2\alpha \quad \text{......} 2$$

Where: R = Yarn radius; E_f = Filament modulus; V_y = Yarn specific volume and α = surface angle of twist

The yarn specific stress, α and modulus can be calculated from this expression thus:

$$\sigma = T \times (V_y / \pi R^2)$$
$$= E_f \varepsilon_y \cos^2\alpha \quad \text{......} 3$$

Yarn tensile modulus, $E_Y = E_f \cos^2\alpha$ 4

This expression shows that yarn modulus decreases with an increase in the value of twist angle as $\cos^2\alpha$.

2.2 Experimental Design

The experiments carried out involved: grilling of the Polyester, Nylon, Viscose, combed Wool and acrylic slivers obtained in top form; production of five different rovings corresponding to the gilled slivers; spinning of yarns from each of the rovings at six different twist levels (ranging from 320 to 902 twist / metre) and five different counts (ranging from 30 to 50 tex). This was done on an H6 series Rieter worsted Ring Spinning frame fitted with a double apron model K2R-M drafting system, and a ring diameter of 65 mm.

All the synthetic fibres were of three-denier fineness and of a maximum fibre length of 150 mm. The mean fibre length was 55 mm. The combed wool was 64 quality, 21 microns fineness and 60-mm staple length.

2.3 Testing

2.3.1 Fibre Modulus

Fibre modulus was measured with an Instron 1026 tensile testing instrument, which works on the principle of constant rate of extension. It makes use of bonded resistance strain gauges to detect the tensile load applied to the sample. A wide variety of specimens can be accommodated because interchangeable load cells that contain the strain gauges may be used.

The load cell is placed in a central position in the fixed crosshead. The upper jaw is suspended from the cell through a universal coupling. Using a range of gear changes can vary the speed of crosshead, which is the rate of extension of the specimen.

A suitable computer program was written to automatically determine the required Fibre modulus. The load-extension curve was displayed on the screen and the results printed out after each test (Xu, 1993).

2.3.2 Yarn Modulus

A Textechno Statimat M was used to determine yarn modulus. The test length was set at 500 mm. The yarn from the bobbin was then passed under a metallic tension rod, through several guides and finally into the testing zone. A few initial tests were done to establish the general shape of the load-extension curves and to determine suitable percentages of extension at which the yarn modulus should be measured taking into account the yield point. This was necessary because, as expected, the yarns tested produced different shapes of load-extension curves, with different yield points.

The Statimat machine automatically analyzed the data and gave an average tenacity-extension curve, plus the mean yarn modulus on a computer.

2.3.3 Twist Angle

The twist angles of the yarns were measured using a microscope having a rotating stage with its periphery graduated in degrees. A filar micrometer eyepiece was calibrated against the stage micrometer. The stage was set at zero degrees. After the yarn was mounted on a suitable holder and brought into focus, the movable hairline of the eyepiece was adjusted to correspond with the yarn axis. The twist angle was obtained by rotating the stage until the hairline was tangential to the helix of the twisted fibres on the surface and the value was then read from the stage.

3.0 RESULTS

The experimental results for the ratio of yarn modulus to fibre modulus (E_y/E_f) and the corresponding twist angles for 30, 40 and 50 tex yarns were represented as shown in Figs. 1-3.

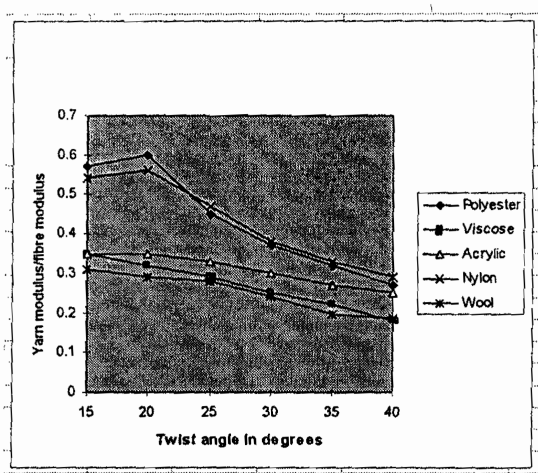

Fig. 1 Ratio of yarn modulus to fibre modulus against twist angle for 30 tex yarns

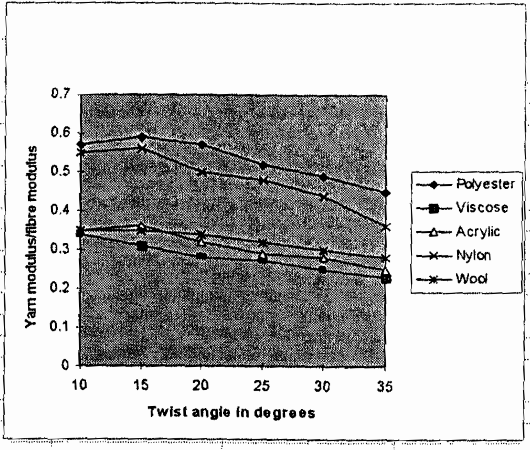

Fig. 2 Ratio of yarn modulus to fibre modulus against twist angle for 40 tex yarns

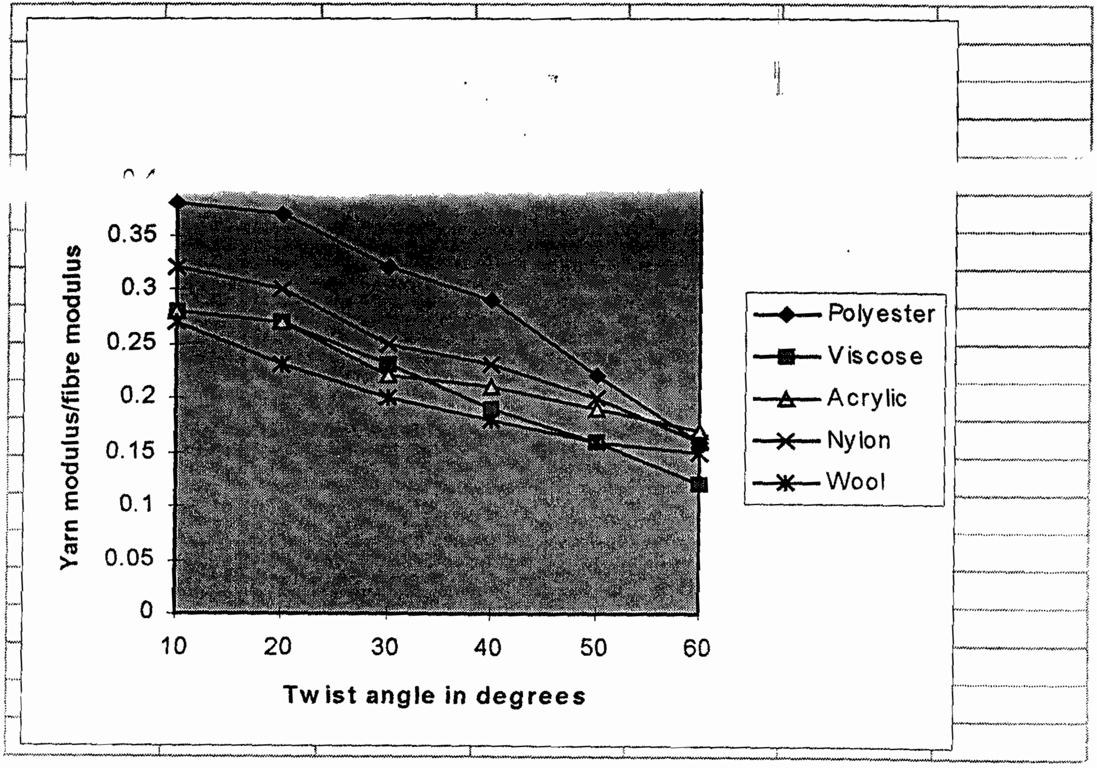

Fig. 3 Ratio of yarn modulus to fibre modulus against twist angle for 50 tex yarns

4.0 DISCUSSION AND CONCLUSIONS

The graphs in Figures 1, 2, and 3 show the relationship between the ratio of yarn modulus to fibre modulus and twist angle for 30, 40, and 50 tex Polyester, Viscose, Acrylic, Nylon, and Wool staple yarns.

The results show the yarn moduli to decrease with increased yarn count; the moduli for the 30 tex yarns are the highest while those for the 50 tex yarns are the lowest. From the experimental results of twist angles and yarn and fibre moduli, the following expression was derived for the relationship of the ratio of the yarn modulus/fibre modulus with twist angle:

$$\frac{E_y}{E_f} = \mathrm{Cos}^2\alpha[1 - A \sec\alpha] \qquad \ldots\ldots\ldots\ldots \qquad 5$$

Where: A is a correction factor.

The value of correcting the factor (A) was 0.50 for Polyester and Nylon, 0.62 for Acrylic and Wool, and 0.65 for Viscose. The theoretical equation, $E_y = E\,\mathrm{Cos}^2\alpha$, relating to continuous filament yarns, does not fit exactly the practical measurements in the case of staple yarns. However, there is some agreement between theory and practice in that the theoretical equation seems to work well after the term $(1 - A\sec\alpha)$ is introduced.

As would be expected, the experimental results showed that at low twists the strength of staple yarns is low owing mainly to low frictional forces present.

This study shows that the effects of obliquity developed for continuous filament yarns, together with those of fibre slippage explain adequately the behaviour of twisted staple yarns. Fibres can be made to slide past each other at small twist angles.

However, this would appear not to be possible at large twist angles, since in such cases the increase in tension eventually raptures the yarn by breaking the constituent fibres.

From the experimental results it can be concluded that the mechanics of continuous filament yarns can be used to predict the behaviour of staple yarns. Though the theoretical analysis does not fit the practical case exactly, the results show that, in the case of staple yarns, the theoretical relationship considered works reasonably well after the introduction of a factor which it is believed relates to the structural parameters of the yarn (Wambua, 1995).

The yarn modulus decreases with increased yarn count. Also, the yarn modulus decreases with the angle of twist and can be predicted using a simple mathematical equation.

5.0 ACKNOWLEDGEMENT

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