Optical Yarn Assessment System for Twist Measurement in Rotor-Spun Yarn

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ABSTRACT

This paper presents the development of an optical yarn assessment system for evaluation of twist and structure of twisted yarn. The system comprises a yarn carriage unit, a video microscope and a personal computer. This system was used in conjunction with the well-known tracer fibre technique. This system enables digital images to be grabbed and continuous movies of the yarn to be recorded in order to facilitate the measurement of twist and the analysis of yarn structure.

Yarn samples from polyester, viscose and cotton with 35tex and 485 turns/meter were spun from the roving with 2.3% of black fibres on the SKF laboratory ring frame. In order to measure the twist in the rotor yarns with the optical yarn assessment system, a set of yarn samples from same fibres were spun on RU 14 rotor machine with 35 tex and 475 turns/meter. The twist was measured with the optical yarn assessment system and sixty tests of each sample were carried out on the Zweigle D301.

It is clear from the results that there is consistency in the twist of ring-spun yarn measured by the optical yarn assessment system. However, the measured twist with the Zwiegle D301 is inconsistent in the different yarns. The difference in the mean twist measured with the optical twist measuring system and the double untwist-twist method was not significant at a 5% probability level when data was analyzed with *t* test by using SPSS (Statistical Package for Social Sciences).

The optical yarn assessment system was also found suitable for measuring the twist in rotor yarns spun from all types of fibre. This is because the system measures the twist in the yarn body without untwisting the yarn.

Key Words: **Rotor Spinning, Twist Testing, Optical Yarn Assessment System, Tracer Fibres, Twist Structure.**

1. INTRODUCTION

The determination of twist in ring-spun yarn is very simple because here the fibres are so arranged that they form a single layer and almost all of them are parallel when the yarn is untwisted to zero twist level. Both direct and indirect methods can measure the twist in the ring-spun yarns with reasonable accuracy. Unlike ring-spun yarn, rotor-spun yarn fibres are arranged in different layers. In rotor spinning, the

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fibres have some freedom of movement during twist insertion. Because of the free movement [1], they form a tripartite structure [2].

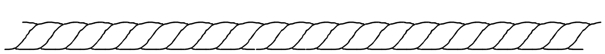
An inner zone of the yarn, commonly known as the yarn core, consisting of about 80% of the fibres [3]. The fibres in the core are substantially aligned and have a migrated structure similar to the ring spun yarn [4].

An intermediate zone extends into the solid boundary of the yarn and contains less fibre migration. In addition, because of fibre slippage [5,6], the core is twisted differently from the intermediate zone.

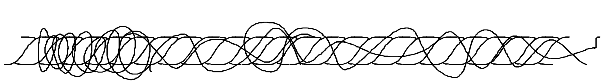
The outer zone containing hairs and wrapper fibres, which have been picked up directly by the yarn instead of being deposited on the collecting surface. The rotation of the radial yarn end about its own axis will cause these wrappers to have a higher degree of twist than fibres in the core and in the intermediate zone of the yarn.

However, a simpler two-zone structure was proposed by Shaw [7], Barella, et. al. [8], Lawrence, et. al. [9] and Kasparek [10]. They included firstly, densely packed aligned core fibres with the helix of the nominal yarn twist. This forms a bulky portion of the yarn. Secondly, a layer of wrapped fibres around the core. These outer zone fibres are twisted around the core at differing angles that are significantly greater than the core twist. They have an opposite twist direction [10]. They are commonly called wrapper fibres or wrappings. They are also known as bellybands, because sometimes their winding concentration is so high that they appear like belts on the surface of the yarn. Further study [11] in this area has confirmed the two-zone structure of the rotor-spun yarn. Fig. 1(a-b) shows the sketches of an ideal and a rotor-spun yarn.

Therefore, it is not possible, in the case of rotor-spun yarn, to reach a zero twist during twist testing with the conventional untwisting and re-twisting methods [12,13].



(a)THE IDEAL YARN



(b)THE ROTOR-SPUN YARN

FIG. 1. THE SKETCH OF YARNS

Many attempts have been made to develop a twist testing method that can accurately measure the twist in rotor yarn. Louis [14] spun black and white stripped yarns and wound on a 23x13cm heavy cardboard at 7.87 wraps per cm. A white 13x20cm index card was ruled into 0.76cm increments along the short side, and 1.27 cm increments along the long side of the card. Alternate 0.76cm strips were tinted with a vivid colour and the strips from 1 through 13, starting from the second strip, were numbered. The prepared index card then was inserted between the cardboard and the yarn so that a 1.27cm segment was left at each end. The yarn board was placed under the microscope or image analyzer and the yarn twist structure was examined along the length of the 20cm yarn, starting from strip one. The amount of twist was determined in the 1.27cm segments, where the twists are easily discernible segments (TDS). The value was recorded as twist/1.27cm, the number of twists/1.27cm were calculated, and this figure was divided by the number of TDS and multiplied by 2 to obtain the average twist/2.54cm of yarn.

Kueny, et. al. [15] claimed that their method was more accurate but it was not applicable even for research purposes because the production of stripped yarn was not so easy. Lord, et. al. [6] compared three twist testing methods viz. the Rockbank, twist-untwist and torsional equilibrium methods. They reported that the twist results of torsional equilibrium were higher than the results achieved with the Rockbank and untwist-twist methods. Nevertheless, the twist measured with this method was lower than the machine twist. They explained that the reason for the lower twist in the yarns was fibre slippage during yarn formation within the rotor. However, Shah [16] and Grosberg [17] have rejected the concept of fibre slippage inside or outside the rotor groove during spinning. This means that the above method did not give accurate results.

Schutz, et. al. [18] found that the double untwist-twist method with the pretension load of 0.98 cN/tex was suitable for cotton rotor spun yarns. Their method of twist testing was supported by Barella and his collaborators [19]. However, Shah [16] reported that the twist in rotor yarns could not be measured accurately with the conventional untwisting based twist-testing methods in normal circumstances. Salhotra [20] supported Shah's statement and reported that the twist in the rotor yarns could be measured more accurately when wrappings around the yarn body were removed.

Jhatial, [21] confirmed that the measured twist was less than that of actual twist in rotor spun yarns when twist was tested with double untwist-retwist methods. However, the measured twist in cotton yarns was higher than that in polyester rotor yarns. This was because the staple length of polyester was higher than that of cotton therefore length of wrappings were higher. As a result the lengthy wrappings had more influence on untwisting and re-twisting during twist testing.

The literature review and preliminary investigations made it clear that there was no accurate twist testing method that could measure the twist in rotor-spun yarns. Although Cybulska [22] assessed the yarn with image analysis, he reported that only surface fibres could be analyzed. This procedure was not suitable for measuring the twist in rotor-spun yarns, because rotor-spun yarn has wrapper fibres with different twist levels from the yarn core.

We report in this paper an optical yarn assessment system which can be used to examine the yarn twist and structure in all radial layers of rotor spun yarn from different fibers.

1. DESIGN OF OPTICAL YARN ASSESSMENT SYSTEM

The experiments were carried out using the tracer fibre technique. Preliminary experiments had indicated that a video camera image of yarn on the computer display would be suitable as a means of counting the twist in the yarn. The optical twist testing system comprises of yarn carriage unit, a video microscope, an interfacing card and a personal computer. Figs. 2-3 show a block diagram and a photograph of the optical yarn assessment system.

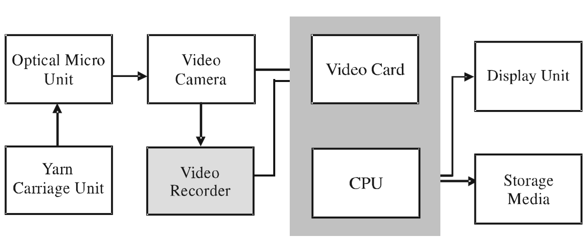


FIG. 2. A BLOCK DIAGRAM OF OPTICAL YARN ASSESSING SYSTEM

2.3% black fibres of the same material were used in white cotton, viscose and polyester fibres as tracer fibres. A mixture of liquid paraffin and mono-bromo-naphthalene was found to be suitable for tracer fibre technique [23]. The properties of liquid used for the yarn samples prepared from the different fibres was calculated, using the following formula:

$$N = \frac{V_1 n_1 + V_2 n_2}{V_1 + V_2} \qquad (1)$$

Where N is required refractive index, n_1, n_2 is refractive indices of the two liquids used, and V_1, V_2 is volume of two liquids.

Immersing each yarn in the appropriate mountant (liquid) rendered the bulk of the yarns semi-transparent, allowing the tracer fibres to be clearly observed.

The system uses transmitted light under the specimen. A small fluorescent tube light was placed under the metallic stage. Different light diffusers and filters were used to set the contrast and make the image clear. The yarn being tested was threaded through the tensioning device and the guides in the rectangular transparent glass trough to the winding wheel. The yarn was drawn by hand wheel.

A mixture of paraffin oil and Mono-Bromo-Naphthalene was poured into the trough so that the yarn was immersed in the liquid. The glass trough was placed on the moving part of the metallic stage with 6 inch high legs. The stage moved from left to right and back by means of a knurled knob. The length of movement of the moving stage is read from the scale which was fixed on the back of the stage. In order to facilitate measurement of the wrapping length, yarn was drawn off from the glass trough by means of

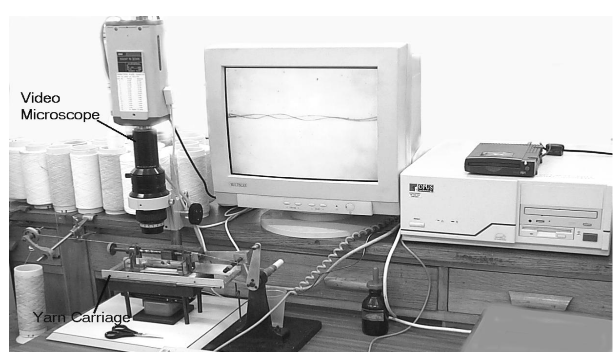


FIG. 3. OPTICAL YARN ASSESSMENT SYSTEM

specially designed pulleys and a wooden bar. The wooden bar was mounted on the moving stage at the right side. During twist testing, a sufficient length of yarn was needed to count the twist. A hand wheel enabled the yarn to be wound off after taking the twist reading. This wheel had an 80mm long plastic rod of 12mm diameter to wind the tested yarn (Fig. 3). Some of the images taken with reported system are shown in Fig. 4.

2. TWIST MEASUREMENT WITH OPTICAL YARN ASSESSEMENT SYSTEM

The irregular layer of fibre sheath surrounding the yarn body was clearly visible. The sheath consists of both wrapper and loose fibres. Separate measurement of the twist in each layer was difficult because the yarn body consists of a number of layers and each layer has a different twist level. Therefore, the twist was counted in the tracer fibres of all the layers except for the sheath fibres. It was assumed that the proportion of tracer fibres in each layer was equal. The image was clear and it was not only easy to count the twist, but also easy to differentiate the twist and the crimp in the fibres.

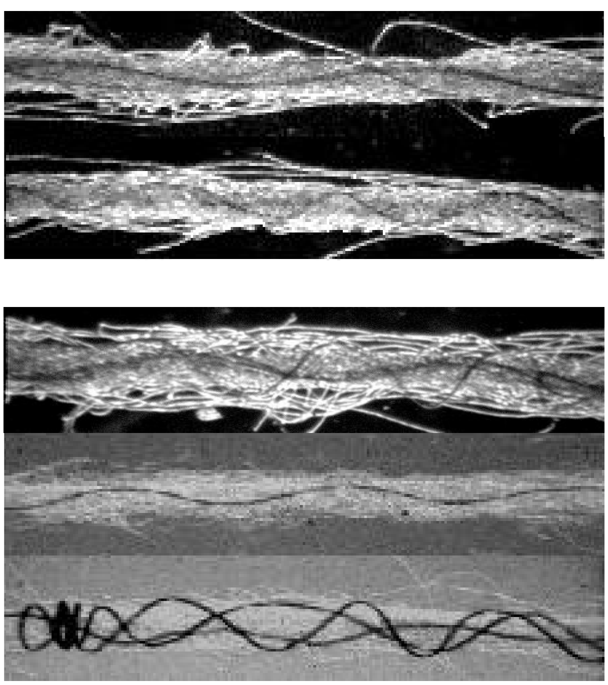


FIG. 4. THE IMAGES TAKEN WITH THE OPTICAL YARN ASSESSEMENT SYSTEM

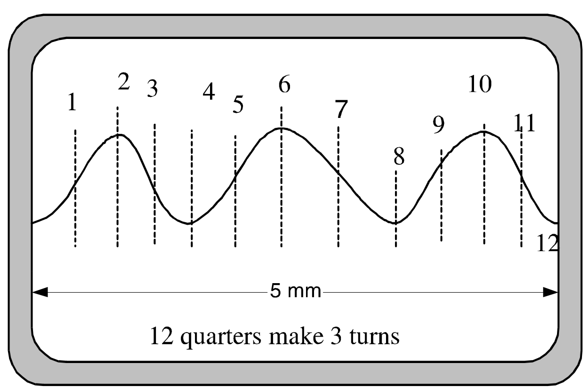
To make the measurement easier and more accurate, one full turn in a black fibre was divided into four quarters. The twist measurement method is shown graphically in Fig. 5. The number of quarters of a twist per frame was counted and transformed into the number of turns per frame. For example, if there were twelve quarters in a frame, the reading was taken as three turns per frame. The twist was measured in the fibres constituting the yarn body. Twist in the wrapper fibres was deliberately not counted because it was not regular throughout the wrapping length.

A hand-made plastic bobbin was used to wind the yarn. To avoid counting twist in the same fibre or the same group of fibres, at least 75mm of yarn was pulled between consecutive measurements by rotating the winding wheel twice (2xπD) before taking the next measurement. The yarn wound on the bobbin was discarded after completion of one layer of the yarn on the bobbin. Twenty such measurements were taken continuously and 100 readings were taken for each yarn sample. Five metres of yarn were discarded before every twenty readings. The results were analyzed statistically using the SPSS. The number of turns/metre was calculated from turns per frame by using the following relation.

$$\text{Twist (t/m)} = \frac{t_f}{L_f} \times 1000$$

Where t_f is number of turns per frame, and L_f is frame length in mm

A hundred readings of the number of turns/frame were used to calculate each twist value.



TWIST (T/M) = NUMBER OF TURNS PER FRAME x 1000/FRAME LENGTH IN MM

FIG. 5. GRAPHICAL REPRESENTATION OF TWIST TESTING PROCEDURE

4. EVALUATION OF THE OPTICAL YARN ASSESSMENT SYSTEM

The twist testing by the optical yarn assessment system was a new technique that required calibration with a standard method. The literature review revealed that there was no twist testing method available to measure the twist in a rotor yarn accurately. Therefore, a set of yarn samples with tracer fibres was spun on a ring frame and twist was measured with this system. The twist was also measured with double untwist-twist method by using the Zweigle D301. This provides an accurate measure of twist in ring-spun yarns. It was believed that, if the optical twist testing system measured the twist in the ring-spun yarns accurately, then it would also measure the twist in the rotor-spun yarns with reasonable accuracy.

Yarn samples from polyester, viscose and cotton with 35tex and 485 turns/meter were spun from the roving with 2.3% of black fibres on the SKF laboratory ring frame. The twist was measured with the optical system according to the procedure given in previous Section and sixty tests of each sample were carried out on the Zweigle D301.

In order to measure the twist in the rotor yarns with the optical yarn assessment system, a set of yarn samples from same fibres were spun on the RU14 rotor machine with 35 tex and 475 turns/meter. Specification of fibres are given in Table 1. The twist in the yarn samples was tested with both the optical system and the Zweigle D301. The data of measured twist by both the measuring system, i.e. optical yarn assessment system and double untwist-retwist method was analyzed statistically with *t* test by using SPSS package [21].

5. RESULTS AND DISCUSSION

5.1 TWIST IN RING-SPUN YARNS

The results obtained from the twist testing methods discussed above are summarized in Table 2.

Fig. 6 shows the measured twist tested and Fig. 7 gives the coefficient of variation. From Table 2 and Fig. 4, it is clear that there is consistency in the twist measured by the optical yarn assessment system. However, the measured twist with the Zwiegle D301 is inconsistent in the different yarns. The difference in the mean twist measured with the optical twist measuring system and the double untwist-twist method was not significant at a 5% probability level.

The CV (Coefficient of Variance) of the twist measured with the optical system is higher than that in twist tested with the Zweigle D301. The higher CV in the twist measured by the new system does not mean that this system is inaccurate but is caused by the smaller test specimen. The specimen length in the optical twist testing system is only five millimetres. Due to the smaller sample length, the short-term variations in the twist are inevitably larger. As a result, the CV% in the twist tested with the optical twist testing system is higher.

Furthermore, if the test sample length in the optical system were 500mm, the CV% of variation would be very low when twist was tested with the optical twist measuring method. This is because the error in this system is only of one quarter twist in 5mm length and will be the same even if twist is counted in 500mm. Therefore, the variation with longer samples will be less than that from an automatic twist tester. However, it was not possible to count the twist in the test sample of 500mm using the optical system because of the small amount of black fibres in the yarn cross-section. The small amount of tracer fibres makes the distribution of the black fibres not uniform along the length of the yarn. A little higher percentage of black fibres and automatic scanning may enable the system to count the twist in longer test specimens.

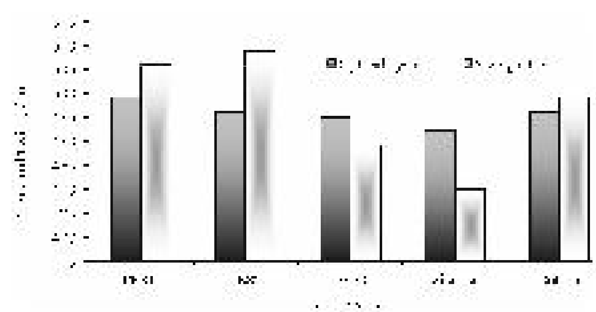


FIG. 6. MEASURED TWIST IN RING-SPUN YARN

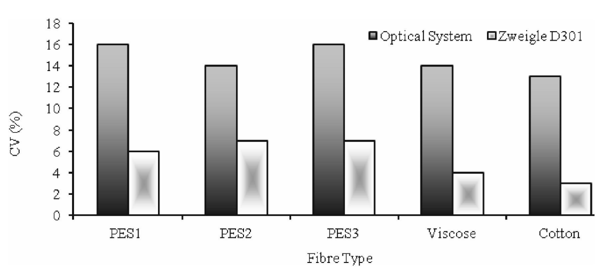


FIG. 7. CV% OF TWIST MEASURED IN RING-SPUN YARNS

5.2 TWIST IN ROTOR-SPUN YARNS

The results of the twist in the rotor-spun yarns are summarized in Tables 3-4. Fig. 8 depicts the measured twist and Fig. 9 shows the CV% of the twist measurements.

* Apparent Loss of Twist = Machine Twist – Measured Twist

** The TTE (Twist Translation Efficiency) η_T is the ratio of actual twist $T_{M,}$ which is measured with a standard twist testing system and the theoretical twist T which is calculated from $T = \frac{N_R}{Vd}$ (t/m). The TTE may be defined as:

$$\eta_T = \frac{T_M}{T} \times 100\ \% \tag{3}$$

TABLE 1. DETAILS OF FIBRES USED IN THIS STUDY

Fibre Type	Code	Staple Length (mm)	Linear Density (dtex)	Cross-Section	Tenacity (cN/tex)
Bright Polyester	PES1	38	1.2	Circular	64.1
Polyester (Trevira)	PES2	38	1.6	Circular	46.0
Polyester (Trevira)	PES3	38	2.4	Circular	26.3
Viscose (85% Trilobal 15% Regular)	Viscose	38	2.3	Trilobal	18.0
American Cotton	Cotton	32	1.7	Kidney-Shaped	18.1

TABLE 2. RESULTS OF TWIST TESTING IN THE RING-SPUN YARNS

Yarn Type	Optical System			Zweigle D301		
	Mean	Standard Deviation	Coefficient of Variation (%)	Mean	Standard Deviation	Coefficient of Variation (%)
PES1	499	77.5	16	506	31.9	6
PES2	496	70.7	14	509	33.9	7
PES3	495	78.3	16	489	33.4	7
Viscose	492	66.6	14	480	17.9	4
Cotton	496	65.4	13	499	15.9	3

TABLE 3. TWIST IN THE ROTOR-SPUN YARN MEASURED WITH THE OPTICAL YARN ASSESSMENT SYSTEM

Fibre Type	Twist (t/m)	Standard Deviation	Coefficient of Variation (%)	Apparent Loss of Twist (t/m)	Twist Translation Efficiency (%)
PES1	467	70.7	5	274	98.2
PES2	468	76.3	6	245	98.4
PES3	474	79.6	13	197	99.8
Viscose	474	76.0	11	126	99.8
Cotton	475	60.5	2	14	99.9

TABLE 4. TWIST IN THE ROTOR-SPUN YARN MEASURED WITH THE ZWEIGLE D301

Fibre Type	Twist (t/m)	Standard Deviation	Coefficient of Variation (%)	*Apparent Loss of Twist (t/m)	** Twist Translation Efficiency (%)
PES1	201	10.1	5	274	42.4
PES2	230	14.2	6	245	48.5
PES3	278	35.5	13	197	58.5
Viscose	349	38.5	11	126	73.5
Cotton	461	7.1	2	14	97.1

It is clear from Table 4 and Fig. 8 that the twist measured by the optical yarn assessment system is equal to the machine twist. In contrast, the twist measured with the Zweigle D301 is lower in the yarns spun from finer polyesters. It is well known that the conventional untwisting based twist measuring methods cannot measure the twist in the yarns spun from polyester accurately. It has already discussed in previous Sections that the twist in the cotton yarns is closer to the machine twist but lower in the yarns spun from polyester fibres because of structural differences. The number, type and length of the wrappings in the yarns spun from different fibres are not the same as in the case of cotton yarns. Many factors influence these parameters. The main factors are the fibre properties, such as length, fineness, stiffness and surface properties. The PTE (Peripheral Twist Extent) also influences the wrapping. The longer the PTE, the more the wrappings will be. Again, the PTE is influenced by the properties of the fibre. As a result, the measured twist with untwisting based twist testing is lower than the actual twist.

Unlike the fine fibres, the coarser fibres have higher stiffness and more resistance to the torque produced by the yarn arm. Some twist in the coarser fibres slips away from the open end of wrapper fibres. The wrappings are therefore more loosely wrapped around the yarn body as shown in Fig. 10 (a-c). There is less resistance to the untwisting of the yarns spun from the coarser fibres than to that of the yarns spun from the finer fibres. Hence, the twist measured with the untwist-twist method is higher in the rotor yarn spun from coarser polyester than in the yarns spun from finer polyester fibres.

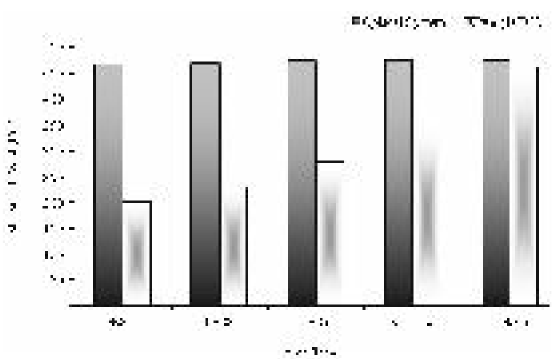


FIG. 8. MEASURED TWIST IN ROTOR-SPUN YARNS

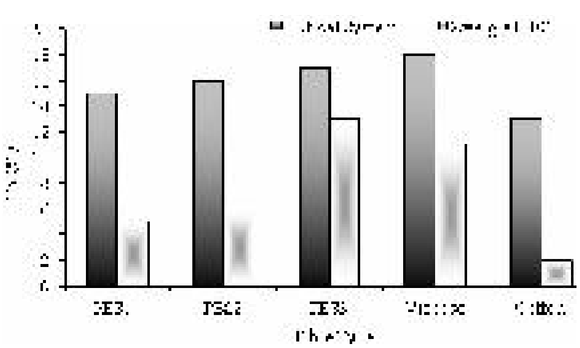


FIG. 9. CV% OF TWIST IN ROTOR-SPUN YARNS

From Table 4 and Fig. 9, it is clear that the CV% of the twist measured with the optical twist testing system is consistent for yarns spun from different fibres. However, the CV% of twist tested with the Zweigle D301varies with fibre type. It is only 2% in the cotton yarns but is 11 and 13% respectively in the yarns spun from viscose and coarser polyester fibres.

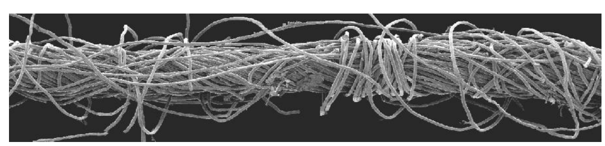
6. CONCLUSIONS

The following conclusions can be drawn based on the twist testing of ring and rotor-spun yarns with the optical yarn assessment system and the conventional double untwist-twist method.

There is no significant difference in the twist tested by the two systems for ring-spun yarns. Hence, the twist testing by the optical system is accurate for testing the twist in rotor-spun yarns.

The measured twist for the rotor-spun yarns from polyester and viscose when twist is tested with the

(a) YARN SPUN FROM PES1



(b) YARN SPUN FROM PES2

(c) YARN SPUN FROM PES3

FIG. 10. MICROGRAPHS OF THE YARNS SPUN FROM FINER AND COARSER FIBRES

untwisting and re-twisting method is lower than that for the yarn spun from cotton because of the yarn structure. However, the fibre properties influence the structure of the yarn.

The optical yarn assessment system is suitable for measuring the twist in rotor yarns spun from all types of fibre. This is because the system measures the twist in the yarn body without untwisting the yarn. Therefore, there is no question of resistance to untwisting during twist testing.

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REFERENCE

[1] Lord, P.R., "The Structure of Open-End Spun Yarn", Textile Research Journal, pp.778-784, September, 1971.

[2] Nield, R., "The Formation and Structure of Rotor Spun Open-end Yarns", Ph.D. Thesis, UMIST, pp. 125, 1974.

[3] Oxtoby, E., "Spun Yarn Technology", Buttersworth and Co. Publishers, pp. 136-157, London, 1987.

[4] Sengupta, K., Dutta B., and Krishnaiah, P.R., "Studies on Fibre Belts in Rotor Spun Yarns", Textile Research Journal, pp. 228-230, April, 1980.

[5] Lord, P.R., and Senturk, N., "The Nature of Break-Spun Yarn", Textile Industries, pp. 89-97, February, 1969.

[6] Lord, P.R., and Grady, P.L., "The Twist Structure of Open-End Yarns", Textile Research Journal, pp. 123, February, 1976.

[7] Shaw, H.V., "Open-End Spun Yarns: Their Processing Performance and Fabric Characteristics", The Yarn Revolution, Annual Conference of The Textile Institute, pp. 62-75, 1976.

[8] Barella, A., Tura, J.M., and Vigo, J.P., "Belts in Open-End Yarns; Influence of Rotor Diameter and Statistical Distribution", Textile Research Journal, pp. 389-394, June, 1977.

[9] Lawrence, C.A., and Finikopulos, E., "Factor Effecting Changes in the Structure and Properties of Open-End Rotor Yarns", Indian Journal of Fibres & Textile Research, Volume 17, pp. 201-208, December, 1992.

[10] Kasparek, J.V., "Spinning in the 70s", Edited by Lord, P.R., Merrow, Watford, pp. 215, 1970.

[11] Xiubao, H., and Reiyao, Z., "Tensile Behaviour of Rotor Spun Yarns", Journal of China Textile University (Engineering Edition), Volume 7, No.1, pp. 13-22, 1990.

[12] Zhang, B., and Huang, X., "Measuring and Signal Processing for PTE in Rotor Spinning", Journal of China Textile University, No. 2, pp. 43, 1986.

[13] Shaw, H.V., "A Study of the Macrostructure of Break-Spun Yarns", M.Sc. Thesis, UMIST, 1972.

[14] Louis, G.L., "Determining Open-End Yarn Twist by the Stripped Yarn Method", Textile Research Journal, pp. 293-295, May, 1978.

[15] Kueny, M., Chatlier, J., and Schutz, R.A., Bull. Xcient, Institute of Textile, pp. 92, France, 1975.

[16] Shah, K.C., "The Formation and Structure of Rotor Spun Open-End Yarns", Ph.D. Thesis, UMIST, pp. 64-67, 1972.

[17] Grosberg, P., and Mansour, S.A., "The Maximum Twist Limit in Rotor Spinning", Rotor Spinning: Technical and Economic Aspects, Edited by E. Dyson, The Textile Trade Press, pp. 249, 1975.

[18] Schutz, R.A., Hunzinger, S., and Reitzer, M.T., Annual Scientific Textile Belges, pp. 9, 1975.

[19] Barella, A., Vigo, J.P., and Castro, L., "A Contribution to the Study of Twist Measurement of Open-End Yarns", Textile Institute and Industry, pp. 305-307, September, 1977.

[20] Salhotra, K.R., "The Role of Sheath Fibres in Influencing Twist Loss in Rotor Spinning", Textile Research Journal, pp. 710-714, November, 1981.

[21] Jhatial, R.A. "Twist Translation Efficiency in Rotor Spinning", Ph.D. Thesis, UMIST, Manchester, pp. 88-109, UK, 2001.

[22] Cybulska, M., "Assessing Yarn Structure with Image Analysis Methods1", Textile Research Journal, No. 69 pp. 369-373, 1999.

[23] Morton, W.E., and Summer, R.J., Journal of Textile Institute, Volume 34, pp. 19, 1947.