Fiber Alignment and Straightening in Opening for Open-End Spinning

S. ULKU

Department of Textile Engineering. Uludag University, Gorukle, Bursa. Turkey

M. ACAR AND T. G. KING

Department of Mechanical Engineering, Loughborough University of Technology, Loughborough LEJ J 3TU, United Kingdom

B. OZIPEK

Department of Textile Engineering, Istanbul Technical University, Istanbul, Turkey

ABSTRACT

Sliver separation is an essential operation in open-end spinning. Ideally, the sliver should be separated down to individual fibers, each of which is transported in a fully extended configuration. In reality, however, fiber behavior is far from ideal. Because yam properties are affected by the effective fiber length, alignment of fibers in the air flow should be achieved and maintained, and the fibers must be delivered onto the spinning surface of the spinner in a parallel, well oriented condition. To obtain straight fibers in the air flow to the twisting process, the fibers must be removed in a straightened form, or straightened during removal, from the pin-clothing of the opening roller.

Many research workers have studied the state of fibers in rotor spinning and observed fiber behavior be- tween the opening roller and rotor using different techniques. Nield [6] studied the effect of fiber separation, collection, and twisting operations on fiber configurations by comparing fiber shapes in the feed material with those found in spun yam, using a tracer fiber technique on an OE rotor spinning machine. Chen [3] made a theoretical analysis of the possible forces acting on fibers during their transfer from the opening roller and of fiber trajectory in the transfer channel. He supported this theoretical analysis with high speed cinematography. Chattopadhyay [1] studied the pattern of hook extent distribution in the fiber ring produced in rotor spinning, using a tracer fiber technique to ex- amine fiber configuration. Lawrence and Chen [5] studied fiber configurations found in open-end spinning during their transfer from the opening roller down the transfer channel to the rotor. They used high speed photography and developed a technique for quantifying fib.er configurations in three-dimensional space. In another study, Lawrence and Chen [4] used high speed cinematography to examine the removal of fibers from the opening roller and their passage through the transfer channel during rotor spinning. They also analyzed the effects of the cross section of the transfer channel on fiber straightness.

From the existing literature, it is clear that different techniques can be used to study fiber configurations. Tracer fiber techniques are commonly accepted approach, and they have also been used to study fiber breakage during the opening stage in OE spinning [2, 7-9]. But with these techniques, only about 0.1% of the fibers can be analyzed as tracers. In addition to this limitation, the physical properties of the tracer fibers may be affected by the process used to render them distinctive (typically dyeing). During the studies in which the fibers are classified according to their configurations by photographic techniques, the number of fibers in the cross section of the flow needs to be small to obtain clear photographs of the fiber shapes. The higher the fiber flux, the greater the difficulty in identifying fiber configurations. For these reasons, we have developed a different method for this study to analyze high speed films for alignment and straight of fibers leaving the opening roller.

Materials and Methods

MATERIALS

We used cotton (28.9 mm effective length and 1.31 dtex) and polyester (38.0 mm length and 1.50 dtex) fibers in the form of second draw frame slivers. The linear density of the slivers was 3.19 ktex for the cotton and 2.60 ktex for the polyester.

The experimental rig consisted of feeding, opening, and air suction units. The feeding and the opening units were similar to those used on Platt Saco Lowell OE spinning machines, as shown in Figure 1. Air suction was provided at the end of an extension piece connected to the "whistle'," which is a channel from the opening roller to the extension piece. The front wall of the whistle was made of transparent acrylic material, and the surface of the opening roller and the rear side of the whistle were painted matt black to reduce optical reflections.

HIGH SPEED PHOTOGRAPHIC EQUIPMENT

For the high speed photography, we used a Photec IV 16 mm cine-camera fitted with an f4, 80 mm Mamiya-Sekor Macro C lens. This rotating prism camera has a maximum frame rate of 10,000 pictures per second using a full height prism, and we fitted a half height prism to double this to 20,000 half-frame pictures per second.

Illumination was provided by a 10watt copper-vapor laser (Oxford Lasers CU IO), which produces pulses of visible (yellow/green) light at repetition rates up to around 20,000 Hz. These were electronically synchronized with the camera to give a very short duration (-15 ns) flash exposure of each cine frame, thereby providing the exceptional "motion stopping" capability required for successful photography of very small diameter fibers (15 nm) moving at speeds in excess of 20 m/s. Ilford HP5 500 ASA black and white films were used throughout the tests.

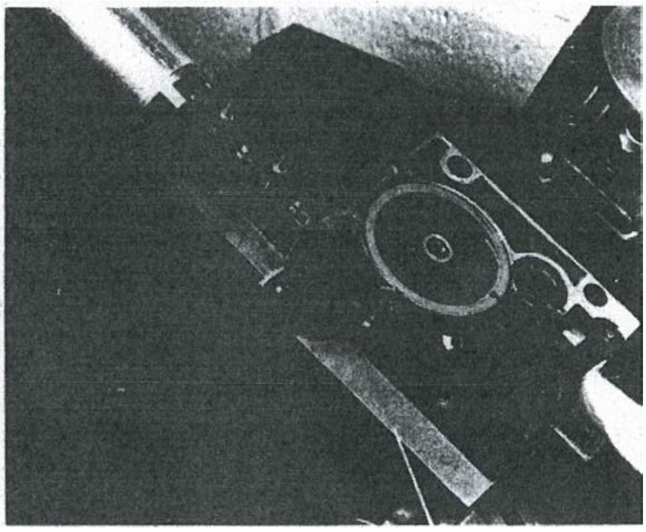

Figure 1. The feeding, opening, and air-suction units of the experimental rig

ANALYSIS OF HIGH SPEED FILMS

Twelve high speed films were produced for this study, with the fiber, air flow, and opening roller speed conditions as shown in Table I. Air flow speeds were measured using a pitot tube and a manometer. The speeds given in Table I are for the center of the perpendicular plane in the extension piece, since the variation in the axial flow speed across its section, investigated by traversing the pitot tube, was negligible. High speed films were taken in the region where fibers leave the opening roller and in the following 28 mm of the flow path. Each film consisted of 6000 frames and covered a period of about 0.3 seconds. During the study, we analyzed two hundred frames from each film using an analysis cine-projector. To indicate the degree of fiber straightness, we counted for each frame the number of intersection points of the fiber images with three straight lines drawn parallel to the nominal flow direction and dividing the frame into four equal areas, as shown for a typical film frame in figure 2. We calculated a mean number of intersections for each test condition filmed from two hundred frames. The smaller the mean number of intersections, the straighter and more aligned the fibers along the axis of air/fiber flow.

TABLE I. High speed films and corresponding test conditions.

Film no.	Fiber material	Surface speed of feeding roller, m/min	Surface speed of feeding roller, m/s	Airflow speed, m/s
1	cotton	1.0	13.04	38.06
2	cotton	1.0	16.30	38.06
3	cotton	1.0	19.56	25.03
4	cotton	1.0	19.56	38.06
5	cotton	1.0	19.56	44.90
6	cotton	1.0	22.82	38.06
7	cotton	1.0	26.08	38.06
8	cotton	1.0	29.34	38:06
9	polyester	1.0	22.82	25.03
10	polyester	1.0	22.82	38.06
11	polyester	1.0	22.82	44.90
12	polyester	1.0	26.08	38.06

For different opening roller speeds, the mean intersection number does not give a direct indication of fiber straightness, as it is also a function of the number of fibers in the cross section. For this reason, we calculated I_1 as the ratio of the mean number of intersections to the number of fibers in the cross section just leaving the opening roller. I_1 may be written as

$$I_1 = I/n \qquad (1)$$

where I is the mean intersection number and n is the number of fibers in the cross section given by

$$n = S_{tex}V_{fr}/F_{tex}V_{or} \qquad (2)$$

where dtex is the linear density of sliver (tex), F_{tex} is the linear density of fiber (tex), V_{or} is the circumferential speed of the opening roller (m/s), and V_{fr}, is the circumferential speed of the feeding roller (m/s).

An improvement would be to take account of fiber breakage during the opening process and recalculate the number of fibers; n may then be rewritten as

$$n = [S_{tex}V_{fr}/F_{tex}V_{or}](1+f_b) \qquad (3)'$$

where f_b, is the fiber breakage given by

$$f_b, = (L_1-L_2)/L_2 \qquad (4)$$

where $L1$ is the mean fiber length in the sliver and $L2$ is the mean fiber length after the opening process.

The draft can be defined as the ratio of the speed of fibers leaving the opening roller to the speed of fibers 28 mm downstream from the opening roller. As an approximation, we may assume that the speed of the fibers at the different stages of the process is equal to the speed of the feeding roller, the opening roller, and the air flow in the extension piece (at 28 mm downstream from the opening roller), respectively.

Draft (V) may therefore be approximated by

$$V = V_{af}/V_{or} \qquad (5)$$

where V_{or} is the speed of opening roller (m/s) and V_{af} is the speed of air flow after 28 mm from the opening roller (m/s).

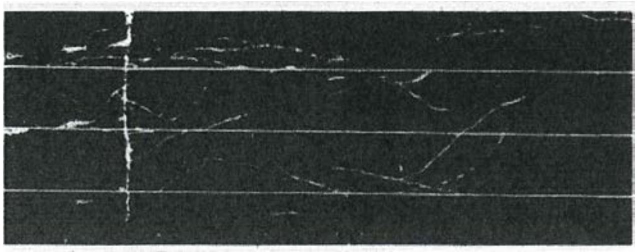

FIGURE 2. Illustration of the intersection points of the fiber images with three straight lines.

Results and Discussion

Table II shows the fiber breakage values and the number of fibers in the cross section, calculated from Equations 3 and 4. In the same table, the values of the mean number of intersections /1 and the draft are also given.

TABLE II. I_1 and draft values of the films.

Film no	Fiber breakage, f_b	Number of fibers, **n**	Mean number of intersections, I	No of fibers in the cross section, I_1	Draft, V
1	0.010	31.4	14.45	0.460	2.07
2	0.025	25.5	14.14	0.SS4	1.76
3	0.062	22.0	11.66	0.148	1.16
4	0.067	22.1	14.02	0.634	1.53
5	0.062	22.0	11.8S	0.629	1.73
6	0.126	20.0	14.34	0.717	1.37
7	0.171	18.3	13.36	0.730	1.26
8	0.226	16.9	14.19	0.839	1.17
9	0.362	17.3	19.53	1.129	1.05
10	0.377	17.5	17.61	1.006	1.37
11	0.372	17.4	17.04	0.979	1.54
12	0.431	15.9	17.52	1.102	1.26

The ratio of the mean number of intersections to the number of fibers in the cross section (Ii) shows a gradual increase with opening roller speed for constant air flow speed as shown in Figure 3. The same ratio decreases with increased air flow speed at constant roller speed, as shown in Figure 4.

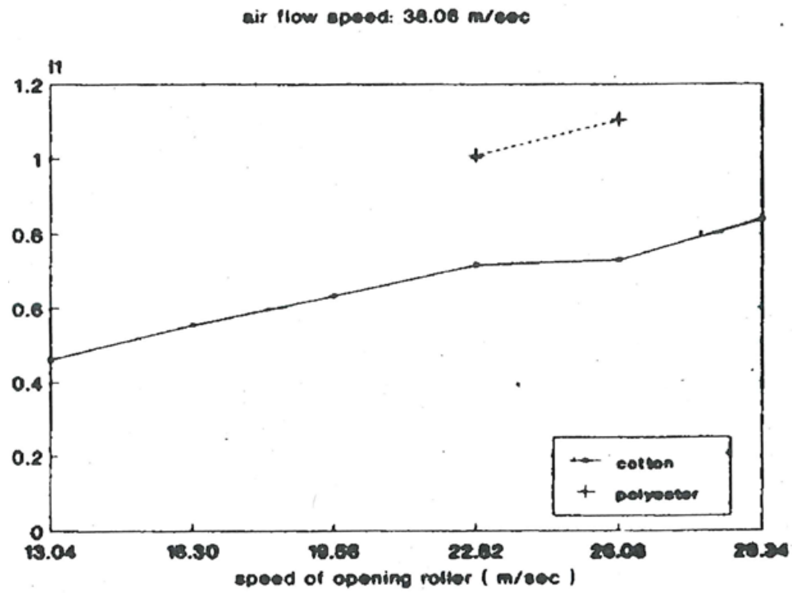

FIGURE 3. Variations of I_1 with the speed of opening roller at constant air flow speed.

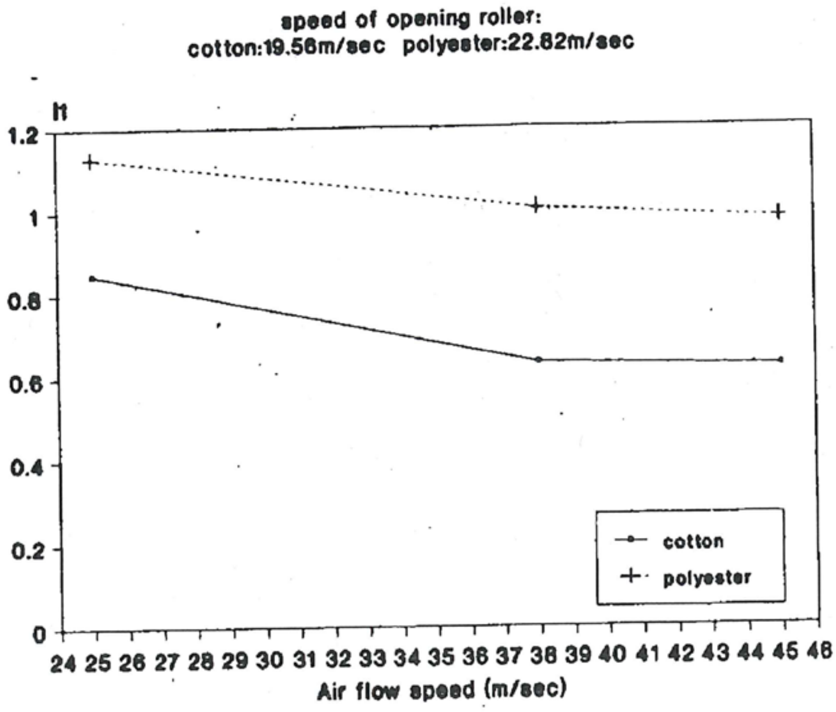

FIGURE 4. Variations of I_1 with air flow speed at constant opening roller speed.

The values in Table II show that the higher the draft, the lower the /1 value. In other words, as the draft increases, the degree of fiber straightness improves along the axis of flow because the higher drafting forces produce wider differences between the speeds of the leading and trailing ends of the fibers. Coefficients of correlation calculated between draft and /1 are shown in Table III.

TABLE Ill. Coefficients of variation

	Coefficient of correlation	
	Cotton	Polyester
V'_{of} is constant	-0.979	
$\alpha = 0.05$	(N = 6)	
V_{or} is constant	-0.945	-0.984
$\alpha = 0.10$	(N = 3)	(*N* = 3)

From the high speed photographic records, we observed that fiber separation is influenced by the opening roller speed. At the low roller surface speeds used in the tests (*e.g.,* 13.04 and 16.30 m/s), fiber flow was not completely uniform. Denser groups of fibers were interspersed with periods of lower fiber density. However, autocorrelation analysis did not reveal a simple relationship between the frequency of occurrence of fiber groups and opening roller rotational frequency.

Conclusions

At constant air flow speed, as the speed of the opening roller is increased, fiber straightness and degree of alignment along the axis of flow deteriorate. At constant opening roller speed, as air flow speed increases, fiber straightness and degree of alignment along the axis of flow improve. We observed these trends for both cotton and polyester fiber.

ACKNOWLEDGMENTS

We would like to thank Platt Saco Lowell (U.K.) Ltd. for their support in undertaking this work. Special thanks are due to Mr. Brian Garside of the PSL for his assistance and enthusiasm. Acknowledgement is also due to the Science and Engineering Research Council, without whose support for textile machinery research at Loughborough University this work would not have been possible.

Literature Cited

1. Chattopadhyay, R., Comparison of Hook Extent Distribution of Fibres in Feed Sliver and Rotor Fibre Ring, *Ind.J. Textile Res.* 13 (12), 218-219 (1988)
2. Chattopadhyay, R., and Sinha, T. K., Length Distribution Pattern of Broken Parts of Cotton Fibre Generated During Fibre Separation in Rotor Spinning, *Ind.J. Textile Res*. 13(9), 143-145 (1988).
3. Chen, K., The Optimisation of the Fibre Transfer Channel Geometry for the Improvement of Rotor Spinning, Doctoral thesis, UMIST, 1984.
4. Lawrence, C. A., and Chen, K. Z., A Study of the Fibre Transfer Channel Design in Rotor Spinning, *J. Textile Inst.* 79 (3), 367-392 (1988).
5. Lawrence, C. A., and Chen, K. Z., High Speed Photo- graphic Studies of the Fibre Configuration During Transfer from the Opening Roller of a Rotor Spinning Unit, *J. Textile Inst.* 77 (3), 201-211 (1986).
6. Nield, The Formation and Structure of Rotor Spun Yam, Doctoral thesis, UMIST, 1974.
7. Salhotra, K. R., and Chattopadhyay, R., Incidence and Mechanism of Fiber Breakage in Rotor Spinning, *Textile Res. J.* 52 (5), 317-320 (1982).
8. Salhotra, K. R., Kambo, N. S., and Chattopadhyay, R., Probability Model for Estimating Fiber Breakage in Ro- tor Spinning, *Textile Res. J.* 53 (7), 435-438 (1983).
9. Simpson, J., and Murray, M.F., Effects of Combing Roll Wire Design and Rotor Speed on Open-End Spinning and Cotton Yarn Properties, *Textile Res. J.* 49 (9), 506- 512 (1979).