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TECHNICAL NOTE

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Identification of Some Synthetic Fibers by Their Birefringence

Methods for differentiating or identifying various fibers have been worked out in detail by the Textile Institute, Manchester [*1*]. Heyn [*2,3*] has suggested that refractive index and birefringence may prove useful in differentiating synthetic fibers; however, most of the work reported in the literature deals with differentiating one type of fiber from another. For fibers of only one type, presumed to be identical in chemical composition, only average values are given. Because all types of synthetic fibers except glass and Vinyon HH® are more or less birefringent, work was undertaken to investigate the significance, if any, of this property. Further, no data on fibers of Indian manufacture are available in the literature. The present paper reports the results of these studies on seven samples of Terene® (polyester) fibers manufactured by four factories in India.

Experimental Procedure

Seven samples of Terene fibers, manufactured and supplied by four factories, were used (Table 1). Five fibers of each sample were chosen at random. Each of these was mounted in Canada balsam on a microscope slide, and care was taken to avoid stretching. The thicknesses of the fibers, which were the same as their diameters because of their circular cross section, were measured with a screw micrometer eyepiece. The optical retardation Γ_λ was measured by using a compensator with an Ehringhaus composite calcite plate and a Polmi A polarizing microscope. The birefringence X is given by:

$$X = (\mu_\parallel - \mu_\perp) = \Gamma_\lambda / T$$

where $\mu_\parallel$ and $\mu_\perp$ are indices of axial and transverse refraction, respectively.

Results and Discussion

The average birefringence $\overline{X}$ for each of the seven samples, together with the range of values obtained, is reported in Table 1. The data are also shown in Fig. 1.

It is instructive to compare fibers of constant denier manufactured by different factories and fibers of different denier manufactured by the same factory. Fibers of the same denier but from different manufacturers had different values of birefringences. Thus, for

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TABLE 1—*Birefringence of Terene staple fibers (staple length 38 mm [1.5 in.]).*

	Binny Ltd., Madras	Chemicals & Fibres of India Ltd., Bombay			Nirlon Synthetics,[a] Bombay	Indian Organic Chemicals & Fibres Ltd., Madras	
Measurement	I	II	III	IV	V	VI	VII
Denier[b]	1.5	1.5	2.25	3.0	2.35[c]	2.20	3.0
Average birefringence,[d] $X \times 10^2$	15.42	16.30	16.11[e]	15.77	16.44	16.86[e]	16.71[e]
Range, $X \times 10^2$	15.31 to 15.46	16.25 to 16.37	15.89 to 16.26	15.66 to 15.85	16.34 to 16.51	16.78 to 17.07	16.55 to 16.96

[a] The sample was supplied as filament yarn of 80 denier and 34 filaments.
[b] Denier values reported are those supplied by the manufacturers.
[c] Denier of filament from yarn of 80 denier and 34 filaments.
[d] Represents the average of the mean birefringence of five fibers of each sample.
[e] Represents the average of the mean birefringence of four fibers of each sample.

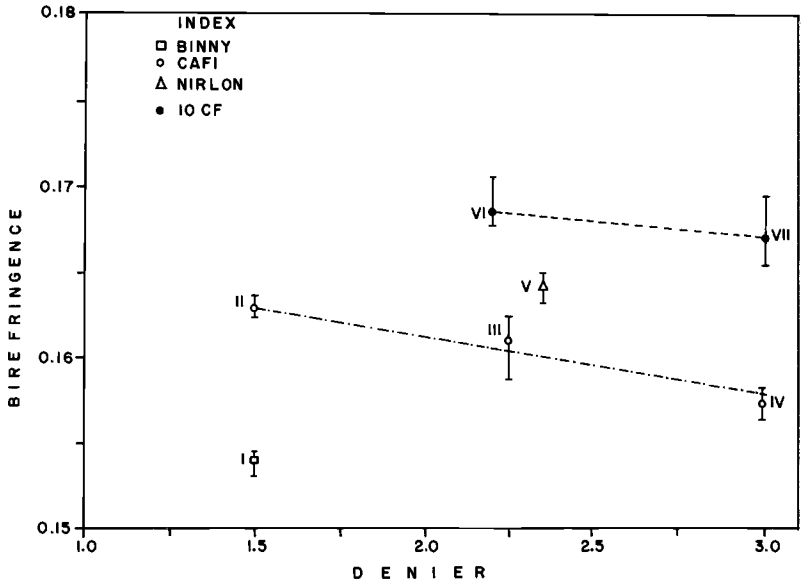

FIG. 1—*Variation of birefringence of Indian Terene fibers with denier (Roman numerals are sample numbers).*

example, fibers of 1.5 denier from Binny Ltd., Madras, and Chemicals and Fibres of India Ltd., Bombay, had birefringences of 0.1542 and 0.1630, respectively. Similar differences were also observed for the 3.0-denier fibers.

For fibers from a given factory, for the limited number of samples available, birefringence varied linearly with denier, as shown by the dotted lines in Fig. 1.

Statistical Analysis

The statistical problems presented in this investigation are the determination of (1) the variation of birefringence within a sample, (2) the variation of birefringence of the fibers

of one sample as compared with the fibers of another sample, and (3) the significance of these variations.

To determine the degree of uniformity of birefringence within a sample and to ascertain the reliability of sampling, indices of birefringence level for each of the seven samples were prepared by treating the $\overline{X}$ level as 100 (see Table 2). The indices of birefringence of various fibers within a sample cluster around the average value, giving a negligible spread, and therefore the birefringence of various fibers within a sample is almost homotypic. The average values of birefringences were further examined by calculating the standard deviation SD, the percentage of coefficient of variation $\%CV$, and the standard error SE, as reported in Table 3. The statistical data indicate that the samples are very homogeneous and the within-sample variation is very small.

To determine whether or not the difference between the average birefringence of any two of the seven samples examined was statistically significant, the t test was used. In this instance, the static t is defined [*4,5*] as:

$$t(N_1 + N_2 - 2) = \frac{|\overline{X_1} - \overline{X_2}|}{S\sqrt{(1/N_1) + (1/N_2)}} \tag{1}$$

where S, the pooled standard deviation, is given by:

$$S = \sqrt{\frac{(N_1 - 1)SD_1^2 + (N_2 - 1)SD_2^2}{(N_1 + N_2 - 2)}} \tag{2}$$

where

$\overline{X_1}$ = average of the first sample,
$\overline{X_2}$ = average of the second sample,
SD_1 = standard deviation of the first sample,
SD_2 = standard deviation of the second sample,
N_1 and N_2 = sample sizes, and
$(N_1 + N_2 - 2)$ = degrees of freedom.

The test procedure and criterion used are as follows: the t value is calculated from the averages of two given samples and their respective SD by using Eqs 1 and 2. The significance of the calculated t value is then assessed by comparing it with the tabulated value

TABLE 2—*Indices of birefringence level of different Terene fiber samples.*

	Sample						
Fiber	I	II	III	IV	V	VI	VII
1	100.1297	99.8160	100.9311	100.1268	99.9392	99.6441	99.4016
2	100.2594	99.6933	100.1241	100.5073	100.4258	99.5255	99.0425
3	99.2866	100.0000	100.1862	100.4439	99.3917	99.6441	101.4961
4	100.2594	100.4294	98.6344	99.5561	99.9392	101.2456	...
5	100.1297	100.0613	...	99.3025	100.4258	...	100.1795
Mean	100	100	100	100	100	100	100
Actual average birefringence,[a] $\overline{X} \times 10^2$	15.42	16.30	16.11	15.77	16.44	16.86	16.71

[a] The values are those reported in Table 1.

TABLE 3—*Average birefringence, standard deviation, coefficient of variation, and standard error.*

Value	I	II	III	IV	V	VI	VII
Average birefringence,[a] $\bar{X} \times 10^2$	15.42	16.30	16.11	15.77	16.44	16.86	16.71
Standard deviation[b]	0.00063	0.00046	0.00163	0.00085	0.00071	0.00139	0.00182
Coefficient of variation,[c] %	0.4114	0.2811	1.0100	0.5371	0.4301	0.8226	1.0871
Standard error[d]	0.00028	0.00020	0.00081	0.00038	0.00032	0.00069	0.00091

[a] The values are taken from Table 1.
[b] $SD = (\Sigma|X - \bar{X}|^2/N - 1)^{1/2}$, where N is the total number of fibers studied.
[c] $\%CV = (SD \times 100)/\bar{X}$
[d] $SE = SD/N^{1/2}$

of t [4] at $P = 0.05$ (= 5%), $P = 0.01$ (= 1%), and $P = 0.001$ (= 0.1%) probability levels for $N_1 + N_2 - 2$ degrees of freedom (df).

In the present case, the lowest acceptable level of significance is fixed at $P \leq 0.05$. Thus, the significance of the difference between two averages has been determined for all 21 possible combinations of the seven samples under study. The calculated values of t together with their levels of significance are given in Table 4. The results indicate that in 13 out of 21 combinations of averages tested the differences in the averages are highly significant at the 0.1% probability level, and all but one of the others are significant at the 1% and 5% probability levels.

Thus it can be stated, on the basis of the data obtained from these seven similar Terene fiber samples, that the birefringence averages differ significantly from sample to sample, but in the same sample they are quite constant, even from fiber to fiber. Admittedly, the number of fiber samples investigated is rather small, and it is possible that fibers of the same denier from the same factory may exhibit variations in birefringence. However, these were the only samples available, and with this limitation in view, it can be concluded that birefringence may be used as one of the criteria for differentiating (1) fibers from different factories even of the same denier and (2) fibers of different denier from the same factory.

It is worthwhile mentioning here that two nylon filament yarns were also obtained from two factories. Results showed a similar significant difference in their birefringence values. Because only two samples were available, the results are not reported here.

Summary

This paper has reported the results of studies on the birefringence of seven Terene (polyester) fibers of Indian manufacture. Fibers of constant denier from different manufacturers gave different values of birefringence. For a given manufacturer, as the denier of the fiber increased from 1.5 to 3.0, the birefringence was found to decrease from 16.30 to 15.77 $\times 10^{-2}$. The results indicate that this factor may serve as a useful criterion for differentiating (1) fibers from different manufacturers and (2) fibers of different denier.

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TABLE 4—*Calculated* t *values and their significance.* [a]

Sample	I	II	III	IV	V	VI	VII
I	0.0000	25.1407[b] (8)	8.8065[b] (7)	7.3946[b] (8)	24.0068[b] (8)	20.9071[b] (7)	14.9970[b] (7)
II	...	0.0000	2.5291[c] (7)	12.3047[b] (8)	3.7149[d] (8)	8.5911[b] (7)	4.9345[d] (7)
III	...	...	0.0000	4.0787[d] (7)	4.1284[d] (7)	7.0168[b] (6)	4.9209[d] (6)
IV	...	...	...	0.0000	13.5768[b] (8)	14.6260[b] (7)	10.3750[b] (7)
V	...	...	...	...	0.0000	5.9429[b] (7)	3.0871[c] (7)
VI	...	...	...	...	...	0.0000	1.3127[e] (6)
VII	...	...	...	...	...	...	0.0000

[a] Figures in parentheses indicate the degrees of freedom, that is, $N_1 + N_2 - 2$.
[b] Significant at the 0.1% probability level.
[c] Significant at the 5% probability level.
[d] Significant at the 1% probability level.
[e] Insignificant.

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