A Study of the Response of Open End and Ring Spun Yarns to Zinc Chloride and Sodium Hydroxide

V. SUBRAMANIAM,* U. SELVAMURUGAN, S. THAMBIDURAI, and V. KRISHNASAMY†

Department of Textile Technology, Alagappa College of Technology, Anna University, Madras-600 025, India

SYNOPSIS

An investigation of the swelling behavior of open end and ring spun yarns in slack condition in 64.5% (w/w) aqueous zinc chloride and sodium hydroxide 22% (w/w) for different intervals ranging from 30 to 90 min is reported. The results show that the response of the yarns to the swelling agents is different in that the products treated with zinc chloride are found to possess higher strength and higher bending rigidities but low elongation. Swelling of yarns with sodium hydroxide has resulted in large increase in elongation. The other properties, namely, coefficient of friction and abrasion resistance, are found to be slightly higher than that of the yarns treated with sodium hydroxide. Degree of set of open end yarns is significantly higher than that of the ring spun yarns. Coefficient of friction and abrasion resistance of the zinc chloride treated yarn samples are found to be slightly higher than that of the sodium hydroxide treated samples.

INTRODUCTION

The swelling behavior of cotton fibers in sodium hydroxide and zinc chloride has been dealt with extensively in the literature by such authors as Warwicker,[1] Betrabet et al.,[2] Patil et al.,[3] Pandey and Nair,[4] Lokhande,[5] Radhakrishnan et al.,[6] Rebenfeld,[7] Orr et al.,[8] Rajagopalan et al.,[9] Krishna Iyer et al.,[10] and Bhama Iyer et al.[11] Recently Bhama Iyer et al.[11] have reported on the response of cottons to zinc chloride and sodium hydroxide.

Warwicker[1] and many other workers have given only tenacity and elongation of the ring spun yarns treated, and other aspects such as the surface properties and low stress mechanical properties have not been dealt with. Moreover, literature on the response by open end and ring spun yarns to the swelling agents is comparatively scanty, and hence this investigation was undertaken. For the first time, data on the objective measurements of yarns, namely, bending and compression, are presented to have a better understanding concerning their handle.

* To whom correspondence should be addressed.

† Department of Chemistry, College of Engineering, Anna University.

Journal of Applied Polymer Science, Vol. 42, 1275–1283 (1991)

CCC 0021-8995/91/051275-09$04.00

EXPERIMENTAL

Materials. Yarns of 16's count (36.8 tex) having a twist of 20 tpi made on a rotor and ring spinning frame from a common mixing were used for the investigation.

Methods. Yarns were scoured and treated with 64.5% (w/w) zinc chloride (specific gravity at 31 ± 1°C = 1.8336) in slack form at room temperature. The swelling times were for 30, 60, and 90 min. For NaOH, a concentration of 22 (w/w)% and a temperature of about 31°C was chosen after analyzing the results of preliminary experiments, which showed that both higher temperature and higher concentration were detrimental to strength even when the swelling time was limited to 10 min. They were then washed in running water for 10 min, and immersed in 0.5 *N* acetic acid for 30 min to remove the excess caustic soda. They were again washed for 30 min to remove the traces of alkali. The $ZnCl_2$ treated yarns were washed with hot water (60–68°C) and then with water at room temperature (25–30°C) for 30 min each. (Solubility of $ZnCl_2$ in water is 31.8 mol L^{-1} at 25°C). After washing, a sample of 5 g was kept in 1000 mL of double distilled water for 2 h and the solution was concentrated to 5 mL and tested for chlorine ion using silver nitrate (0.05 *M*) solution. The results showed negative, indicating thereby that the solvent has been removed.

The yarn samples were designated as N30, N60, N90, Z30, Z60, and Z90, indicating that each sodium hydroxide and zinc chloride treatments were given for 30, 60, and 90 min, respectively.

Scanning Electron Microscopy Analysis. The treated yarn samples were examined in the scanning electron microscope (type JSM–820) after gold coating by sputtering.

Measurement of Physical Properties. Yarn to yarn friction was measured by Howell's[12] method.

Abrasion Resistance. Abrasion resistance of yarns was measured by the instrument fabricated on the combined principle of Faasen and Van Harten[13] and Veer.[14] The mean of 50 readings was taken in each case.

Degree of Set. The method suggested by Lindberg,[15] and adopted by Shishoo and Bergh[16] was followed for measuring set of yarns. The values of l_0 were calculated after setting treatments for 10 min in the appropriate solutions. Untreated specimens were then extended by 3% based on the above measured value of l_0, and these were then set for 30 min. In all setting treatments, $l_1 = 1.03 l_0$. The value of l_2 was measured after removal of the specimen and conditioning in an unloaded state in an atmosphere at 25°C and 65% RH. The conditioning time was 5 min. The value of degree of set was calculated from l_0, l_1, and l_2:

$$\text{Degree of set} = \frac{l_2 - l_0}{l_1 - l_0}$$

where l_i = as-received length, l_0 = the length after treatment in the free-relaxed state for 10 min, l_1 = length after stretching before setting, and l_2 = the length after solvent setting. The setting treatment for a fiber is characterized by the degree of set, and for complete setting the degree of set = 100.

Packing Factor. Packing factor of the treated yarns was calculated by the following formula:

$$V = \frac{78{,}570 \times d^2}{T} \qquad \text{cc/g}$$

where V is the specific volume of the yarn, d is the diameter in cm, and T is the tex:

$$\text{packing factor} = \frac{\text{specific volume of fiber}}{\text{specific volume of yarn}}$$

The diameter of the yarn was measured by using a projection microscope. For each sample, 50 readings were taken and the mean was taken.

Moisture Regain. All the treated samples were conditioned at 65% RH at 25°C for 24 h and their weights were measured using a balance. These samples were dried in an oven for 1 h at 105°C till constant weights were obtained. From the original and dry weights, the moisture regain was calculated.

Shrinkage. For shrinkage measurements, a load of 1 g was hung on the yarn and two fiducial marks were made 10 cm apart on it. The yarns were submerged in sodium hydroxide and zinc chloride solutions for 30 min at room temperature, namely, 31°C, and the distance between the two marks was measured, and the difference in length was expressed as percentage.

Tenacity and Elongation. Tenacity and elongation of the treated yarns were measured by the Instron Tensile Tester using a gauge length of 30 cm. Prior to testing, the yarns were conditioned at 65% RH and 25°C for 48 h. The mean of 30 tests was taken in each case. Yarn tex was calculated from the weight of the broken pieces.

Measurement of Bending Parameters. The bending behavior of the yarns was examined by using a bending tester fabricated as per the design of Owen.[17] The sample consisted of 30 yarns laid parallel and stuck on card board with double-sided tape before insertion in the jaws. The gauge length was about 5 mm. The maximum limit at 90° gives roughly 0.28 mm^{-1} curvature. The bending rate was 1 cm^{-1}/min. The relation between the bending moment and yarn curvature was plotted to determine the coercive couple, initial elastic flexural rigidity, and bending recovery.

Compression Properties. For measuring the yarn compression properties, a band of yarns was prepared and stuck at both sides with cellotape. This was compressed by placing it on a thickness gauge and measuring the thickness by placing suitable weights. Percent compression was measured using the following formula.

$$\%\ \text{compression} = \frac{\text{thickness at } 0.5\ \text{g/cm}^2 - \text{thickness at } 50\ \text{g/cm}^2}{\text{thickness at } 0.5\ \text{g/cm}^2} \times 100$$

This is based on the method suggested by Kaswell et al.[18]

Time Effects. The influence by the duration of swelling on the properties of treated yarn is evident from Table I, in which it is noticed that a swelling

Table I Tenacity and Elongation Data for Open End and Ring Spun Treated Yarns

Yarn	Treatment	Tenacity (g/tex)	Elongation (%)
Open end	1. Scoured	11.85	6.8
	2. 64.5% (w/w) $ZnCl_2$ at 31 ± 1°C		
	a. Swollen slack for 30 min	11.9	7.8
	b. Swollen slack for 60 min	10.7	6.6
	c. Swollen slack for 90 min	11.7	6.9
Ring spun	1. Scoured	15.65	6.2
	2. 64.5% (w/w) $ZnCl_2$ at 31 ± 1°C		
	a. Swollen slack for 30 min	15.16	7.4
	b. Swollen slack for 60 min	15.17	6.6
	c. Swollen slack for 90 min	16.00	6.4
Ring spun	1. Scoured	15.65	6.2
	2. 22% (w/w) NaOH 31 ± 1°C		
	a. Swollen slack for 30 min	14.6	15.8
	b. Swollen slack for 60 min	14.7	17.1
	c. Swollen slack for 90 min	13.4	16.3
Open end	1. Scoured	11.85	6.8
	2. 22% (w/w) NaOH at 31 ± 1°C		
	a. Swollen slack for 30 min	10.2	15.3
	b. Swollen slack for 60 min	9.86	14.9
	c. Swollen slack for 90 min	8.9	11.3

time by 30 min is adequate for bringing about a change; with respect to open end yarns, a swelling treatment by 90 min has led to a considerable drop in the tenacity and elongation.

RESULTS

Tenacity and Elongation

A summary of the data on the properties of yarns is given in Table I. It will be noticed that there is a slight reduction in the tenacities of the open end and ring spun yarns treated with sodium hydroxide for 60 and 90 min. The elongation values are significantly higher.

Yarns treated with zinc chloride for various times show different trend in that tenacity values are higher. Open end yarns show somewhat lower values. In all the cases, the elongation is low compared to the untreated control yarn. Slack mercerization with sodium hydroxide has resulted in very large increases in elongation of the ring spun yarns compared with open end yarns, which is quite interesting.

The differences observed in tenacity and elongation of the treated yarns are attributable to their structure and swelling propensity in swelling agents. Zinc chloride acts like a plasticizing agent compared with sodium hydroxide.

Table II Packing Factors of the Treated Yarns

Sample	Ring Spun	Open End
Scoured	0.91	0.71
N30	0.405	0.401
N60	0.403	0.401
N90	0.402	0.402
Z30	0.395	0.391
Z60	0.394	0.389
Z90	0.393	0.388

Packing Factor

To demonstrate this effect, the packing factors measured for these yarns are given in Table II. There is not much difference in the packing factors following swelling, but it appears that sodium hydroxide makes the yarns more compact. However, it is evident that following swelling there is a considerable reduction in the packing factor of both the yarns. Although the ring spun yarn appears to be more compact compared to the open end yarns in the scoured state, there is not much difference between the swollen yarn samples.

Coefficient of Friction

Coefficient of friction values of the open end and ring spun yarns are given in Table III. Treatment

Table III Coefficient of Friction of the Treated Yarns

	Open End			Ring Spun		
Samples	20 gf	40 gf	60 gf	20 gf	40 gf	60 gf
Scoured	0.518	0.418	0.379	0.442	0.379	0.344
N30	0.751	0.741	0.732	0.729	0.719	0.708
N60	0.741	0.732	0.721	0.713	0.702	0.694
N90	0.728	0.719	0.708	0.697	0.682	0.675
Z30	0.811	0.799	0.781	0.791	0.778	0.765
Z60	0.801	0.792	0.780	0.782	0.771	0.759
Z90	0.798	0.782	0.772	0.778	0.765	0.758

Table IV Abrasion Resistance of Treated Yarns (Number of Cycles)

	Ring Spun			Open End		
Samples	20 g	40 g	60 g	20 g	40 g	60 g
Scoured	543	93	29	802	195	31
N30	894	156	35	1092	302	42
N60	876	150	33	1080	295	40
N90	860	144	32	1065	289	38
Z30	862	172	39	1165	316	49
Z60	946	168	38	1152	315	47
Z90	843	164	36	1149	312	45

with $ZnCl_2$ has led to a significant and consistent increase in friction as is evident by the results of open end yarn. This increase in friction is due to the increase in the area of contact following swelling treatments.

Abrasion Resistance

Abrasion resistance of open end and ring spun yarns following treatments is given in Table IV. It is clear that treatment with zinc chloride has resulted in a significant increase in abrasion resistance, and open end yarns show a better performance.

Shrinkage of the yarns is found to be higher in sodium hydroxide, and open end yarns have a tendency to show an increase compared to the ring spun yarns, as the following figures in Table V will demonstrate.

Table V Shrinkage Percentage of Yarns in Swelling Agents (31°C)

Treatment	Ring Spun	Open End
Sodium hydroxide	17.1	19.8
Zinc chloride	5.8	8.8

Bending Parameters

Bending parameters, namely, coercive couple, initial elastic flexural rigidity, final flexural rigidity, and bending recovery are shown in Table VI. It will be noticed that zinc chloride treatment makes the yarn stiffer, as seen from the initial and final flexural rigidity values. Open end yarns show higher values compared to ring spun yarns, indicating thereby that the response of this yarn is quite different from the swelling agents. Bending recovery values are marginally better in the case of open end treated yarns, and all treated yarns show a deterioration in recovery compared with the untreated controls. This is probably due to the lack of freedom of fibers in the treated yarns.

Moisture Regain

Moisture regain data of the treated yarns are given in Table VII. An increase in the moisture regain of all the treated samples can be noticed. However, it is observed that in all the cases, open end yarns show a slightly higher value which could be due to their structure. Zinc chloride treated samples show a slight increase in the moisture regain compared

Table VI Bending Parameters of Treated Yarns

	Ring Spun				Open End			
Sample	C_0 (mN mm)	G_0 (mN mm^2)	$G\phi$ (mN mm^2)	Bending Recovery (%)	C_0 (mN mm)	G_0 (mN mm^2)	$G\phi$ (mN mm^2)	Bending Recovery (%)
Untreated	1.02	0.75	3.2	74	1.14	0.78	3.6	74
N30	2.65	2.37	5.26	68	3.42	2.69	5.56	71
N60	2.56	2.28	4.9	69	3.32	2.66	4.95	72
N90	2.47	2.27	4.5	69	3.19	2.20	4.86	72
Z30	3.00	3.20	6.00	68	4.00	4.39	7.00	69
Z60	2.95	3.10	5.61	69	3.90	4.27	6.22	69
Z90	2.92	2.78	4.30	69	3.86	4.15	5.05	70

Table VII Moisture Regain Percentage of the Treated Yarn Samples

Sample	Ring Spun	Open End
Untreated	7.2	7.3
N30	10.69	10.93
N60	10.52	10.88
N90	10.46	10.72
Z30	10.98	11.10
Z60	10.82	11.05
Z90	10.78	11.10

to sodium hydroxide treated yarn samples; this shows that treated open end yarns have greater accessibility.

Degree of Set

Finally, the degrees of set values, which are given in Table VIII, show that, in the case of open end yarns, the values are significantly higher than those of the ring spun yarns.

Treated yarns, which have been subjected to the setting treatment again, also show a higher value. This shows that treated yarns, owing to their change in the structure, tend to have better recovery properties. A higher degree of set would indicate that the material tends to become more elastic in nature; this is also evidenced by the increase in elongation.

Compression Properties

Table IX shows the results of the compression properties. The parameter softness, which is the ability of the material to deform under a compressive load, is significantly higher for the ring spun yarn which has been scoured. The compression of the open end and ring spun yarns following swelling in zinc chloride is equivalent. With respect to the yarns swollen in sodium hydroxide, the ring spun yarns appear to be softer.

Scanning Electron Microscopy of Treated Fibers

Figures 1 and 2 indicate the surface morphology and fiber packing arrangements both in the open end and ring spun yarns. Appearance of convolutions confirms the characteristic features of cotton fibers. The extent of foldings of these convolutions are slightly different from each other mainly because of the way in which these yarns are manufactured.

Table VIII Degree of Set for the Treated Yarns

	Sodium Hydroxide		Zinc Chloride	
Samples	Ring Spun	Open End	Ring Spun	Open End
Untreated	58.79	61.50	59.11	63.62
Scoured	63.90	66.69	64.26	68.79
NaOH swollen	68.95	91.75	69.36	73.87
$ZnCl_2$ swollen	69.81	73.01	70.03	75.21

Table IX Percentage Compression of the Treated Yarns

	EMC % Compression Values	
Sample	Open End	Ring Spun
Scoured	12	23
N30	8	19
N60	14	24
N90	18	25
Z30	20	16
Z60	21	21
Z90	21	19

Figures 3–6 indicate that when yarns were treated either with $ZnCl_2$ or NaOH, it was observed that swelling is more in the case of open end yarn (see Figs. 3 and 5) as compared with ring spun yarn (see Figs. 4 and 6). This may be due to the mode of packing of these cotton fibers in NaOH. This in turn gives differences in swelling behavior of yarn. This very well supports the observation made in the SEM (see Figs. 3–6). However, the extent of swelling of these cotton fiber in the yarn is more in the case of yarns treated with NaOH (Fig. 5) rather than the yarns treated with $ZnCl_2$ (Fig. 6).

DISCUSSION

Treatment with zinc chloride has led to an increase in the tenacity of the open end and ring spun yarns, although the ring spun yarns still show an increase in strength, compared to open end yarns. The findings of the study reveal that some of the results obtained with sodium hydroxide are in agreement with the results of Nelson and O'Connor.[19] Low stress mechanical properties show an increase which reflects to some extent the plasticizing effect of the zinc chloride. Shrinkage values of the yarns swollen in sodium hydroxide are generally higher than those of the zinc chloride treated one. This shows that sodium hydroxide is capable of swelling the yarns to a considerably greater extent than that of zinc chloride. By and large, it is observed that open end yarns are more susceptible to the swelling agents: This could be attributed to the very nature of the open end yarn which consists of wrapper fibers and possesses greater bulk.

CONCLUSIONS

In conclusion, it appears that the chief difference, between the zinc chloride and sodium hydroxide for

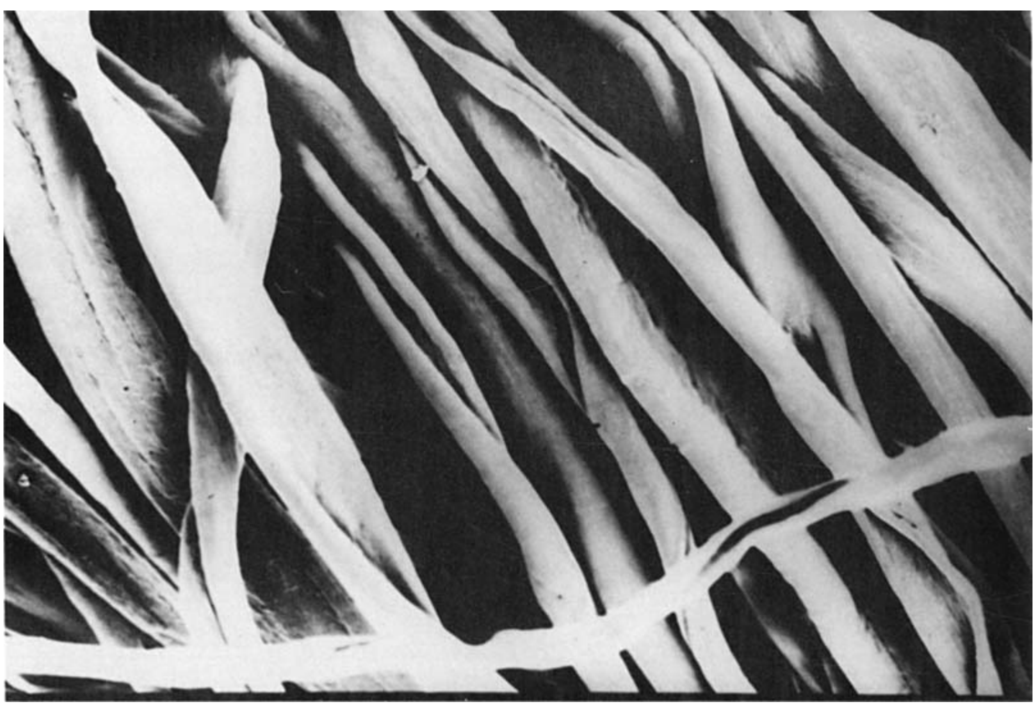

Figure 1 Scanning electron micrograph of scoured, $ZnCl_2$- and NaOH-treated yarns: scoured open end yarn.

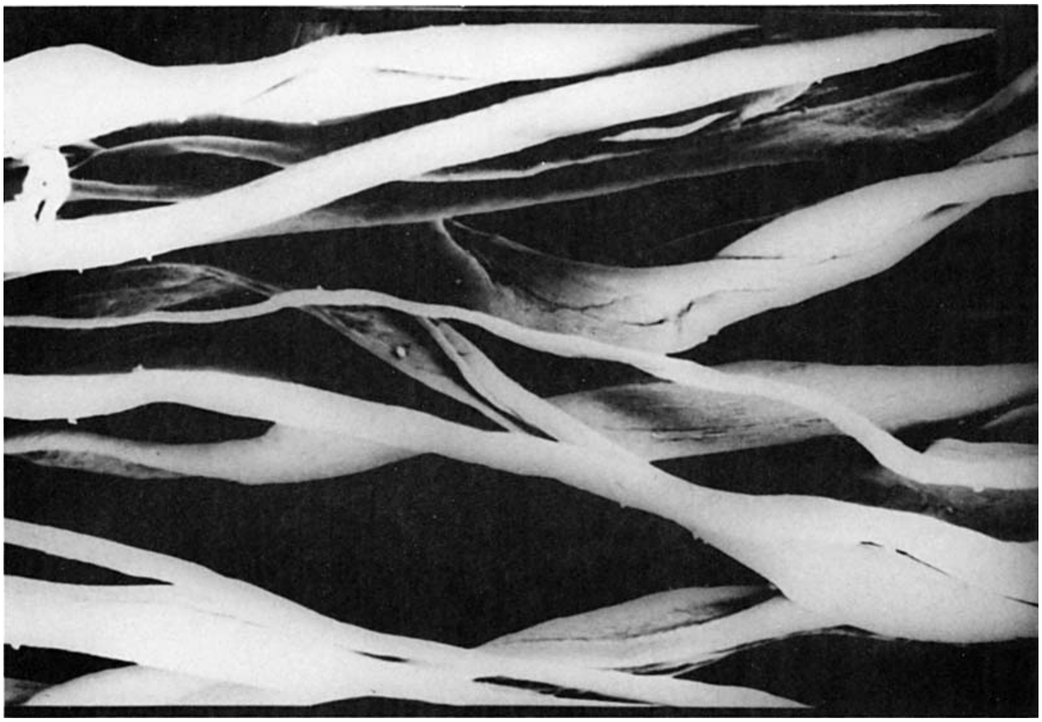

Figure 2 Scanning electron micrograph of scoured, $ZnCl_2$- and NaOH-treated yarns: scoured ring spun yarn.

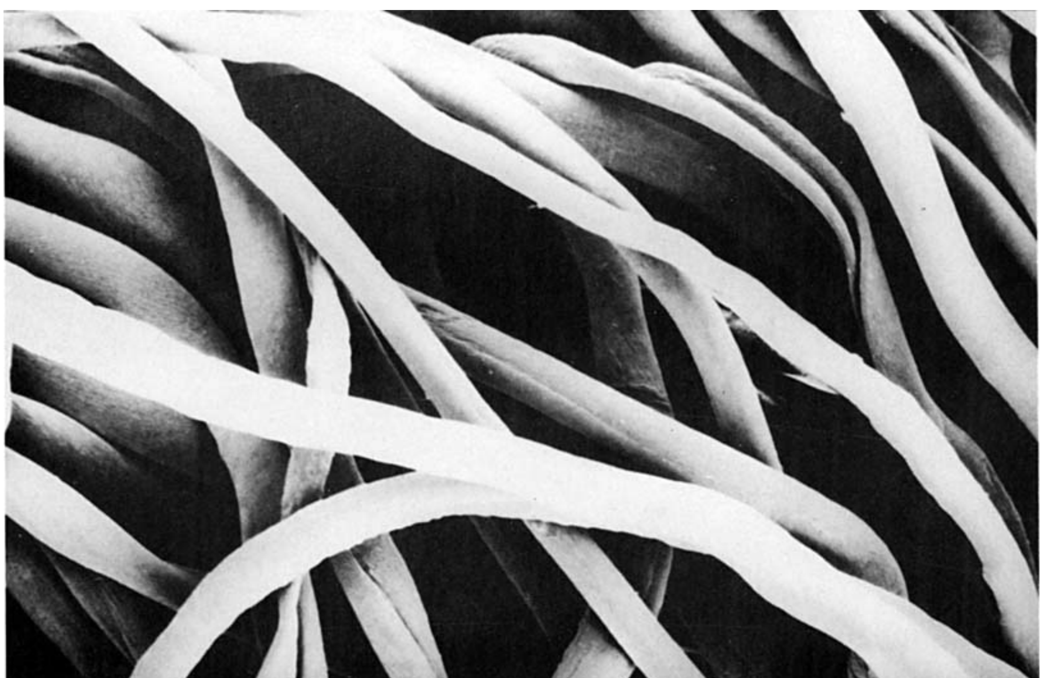

Figure 3 Scanning electron micrograph of scoured, $ZnCl_2$- and NaOH-treated yarns: $ZnCl_2$ 64.5% (w/w) treated for 90 min of open end yarn.

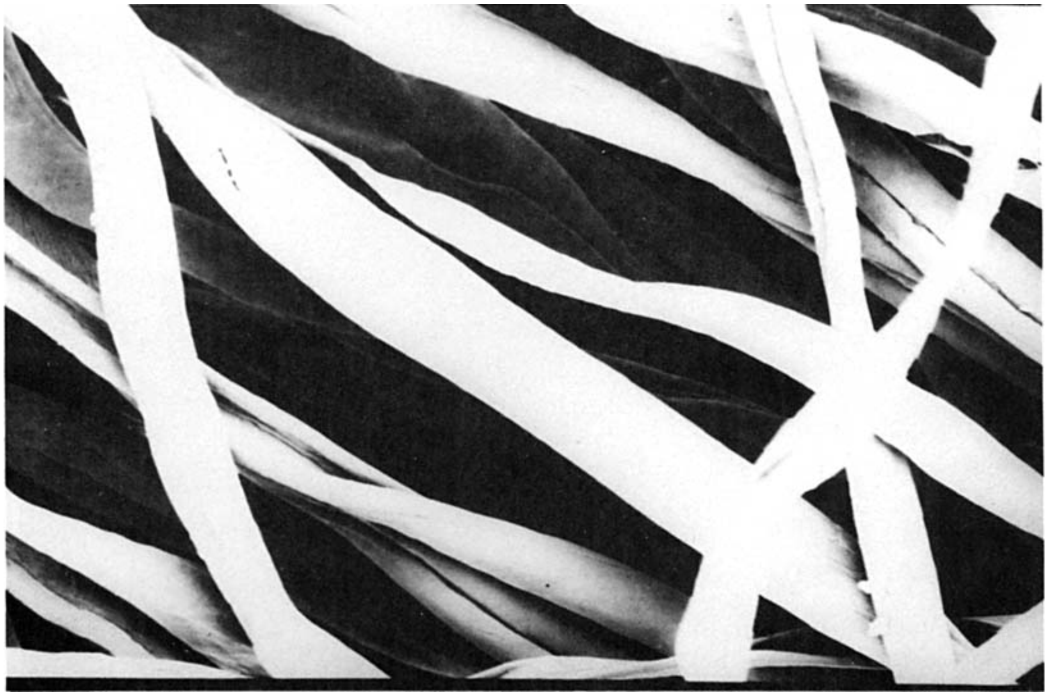

Figure 4 Scanning electron micrograph of scoured, $ZnCl_2$- and NaOH-treated yarns: $ZnCl_2$ 64.5% (w/w) treated for 90 min of ring spun yarn.

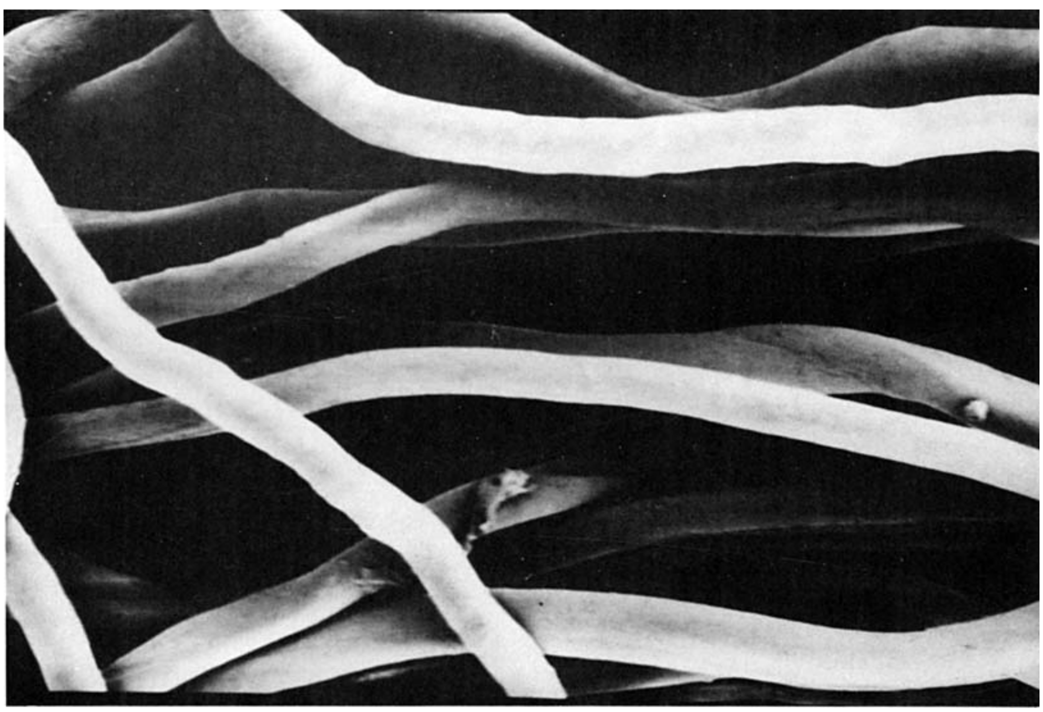

Figure 5 Scanning electron micrograph of scoured, $ZnCl_2$- and NaOH-treated yarns: NaOH 22% (w/w) treated for 90 min of open end yarn.

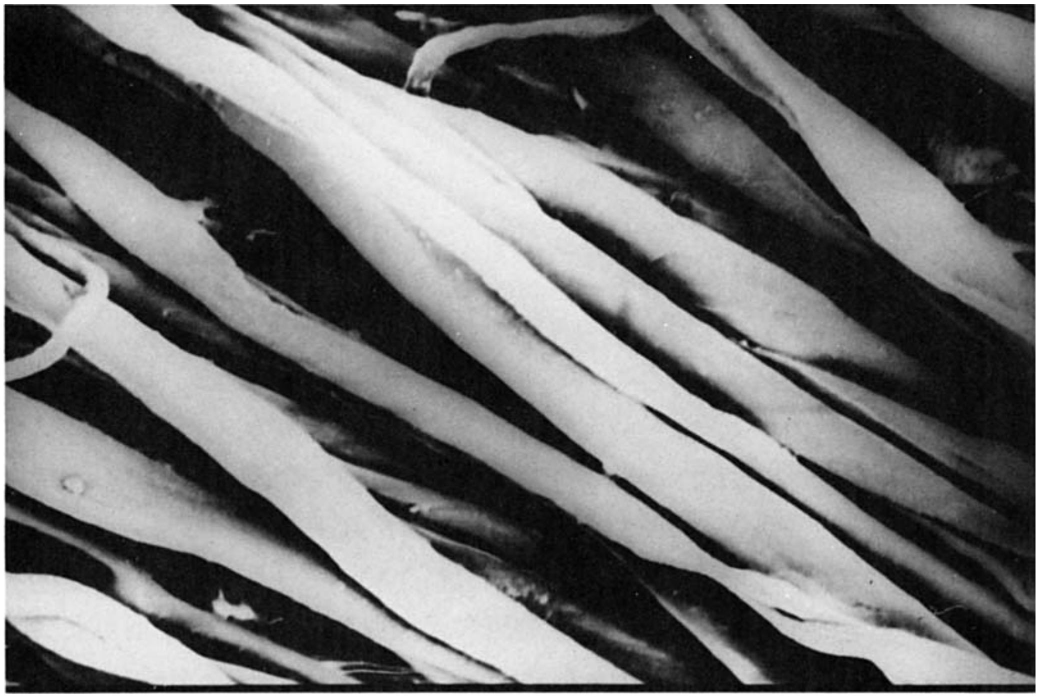

Figure 6 Scanning electron micrograph of scoured, $ZnCl_2$- and NaOH-treated yarns: NaOH 22% (w/w) treated for 90 min of ring spun yarn.

mercerization, is in their behavior during swelling. The fact that the tenacity and elongation values are independent of the duration of the swelling treatments shows that the swelling is rapid at the shortest time. Packing factor of the treated yarns seems to be identical in both cases. Shrinkage values of open end yarns are significantly higher than those for the ring spun yarns in both the solvents; and treatment with sodium hydroxide had led to a greater shrinkage in both the cases. Yarn-to-yarn friction has been found to be slightly higher in the zinc chloride treated yarns. Abrasion resistance of the yarns also follows the same trend. It will be desirable to carry out the experiments under stretch conditions for these yarns, and a similar work is contemplated.

REFERENCES

1. J. O. Warwicker, in *A Review of the Literature on the Effect of Caustic Soda and Other Swelling Agents on the Fine Structure of Cotton,* Shirley Institute, Pamphlet No. 93, Manchester, U.K., 1966, p. 168.
2. S. M. Betrabet, E. H. Daruwalla, H. T. Lokhande, and M. R. Padhye, *Cell. Chem. Technol.,* **3,** 309 (1969).
3. N. B. Patil, N. E. Dweltz, and T. Radhakrishnan, *Text. Res. J.,* **35,** 517 (1965).
4. S. N. Pandey and P. Nair, *J. Appl. Polym. Sci.,* **20,** 525 (1976).
5. H. T. Lokhande, *J. Appl. Polym. Sci.,* **22,** 533 (1978).
6. T. Radhakrishnan, B. V. Iyer, G. S. Viswanathan, and H. Wakeham, *Text. Res. J.,* **29,** 322 (1959).
7. L. Rebenfeld, *Text. Res. J.,* **28,** 462 (1958).
8. R. S. Orr, A. W. Burgis, F. R. Andrews, and J. N. Grant, *Text. Res. J.,* **29,** 349 (1959).
9. A. Rajagopalan, G. M. Venkatesh, and N. E. Dweltz, *Text. Res. J.,* **45,** 409 (1975).
10. K. R. Krishna Iyer, N. B. Patil, and R. P. Nachane, *Indian J. Text. Res.,* **2,** 129 (1977).
11. P. Bhama Iyer, S. Sreenivasan, G. S. Patel, K. R. Krishna Iyer, and N. B. Patil, *J. Appl. Polym. Sci.,* **34,** 1081 (1987).
12. H. G. Howell, *J. Text. Inst.,* **42,** T521 (1951).
13. N. I. Faasen and K. Van Harten, *J. Text. Inst.,* **57,** 269 (1966).
14. L. S. Veer, *J. Text. Inst.,* **68,** 424 (1977).
15. J. Lindberg, *The Setting of Fibre and Fabrics,* J. W. S. Hearle and L. W. S. Miles, Eds., 1971, Merrow, U.K., p. 166.
16. R. L. Shishoo and K. M. Bergh, *Text. Res. J.,* **47,** 56 (1977).
17. J. D. Owen, *J. Text. Inst.,* **58,** 589 (1967).
18. E. R. Kaswell, L. Barish, and C. A. Lermond, *J. Text. Inst.,* **52,** 508 (1961).
19. M. L. Nelson and R. T. O'Connor, *J. Appl. Polym. Sci.,* **8,** 1325 (1964).

Received July 20, 1989
Accepted May 14, 1990