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Development of New Technique for Production of High Tenacity Cotton Yarns

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ABSTRACT

The work aims to study the properties of solution stretched ring spun cotton yarns for their application as sewing thread. For this treatment a stretching device was specially fabricated. Stretching of yarns in presence and in absence of sodium hydroxide solution was carried out in the stretching device with continuous rotations. The stretched yarns were tested for their crystallinity, packing fraction and tensile properties. The changes in fine structure were evaluated by infra red spectroscopy whereas scanning electron microscopy serves as a proof for the swellability and packing of fibers in the yarns. Yarns stretched in presence of solution show improvement in tensile properties. The tenacity of solution stretched ring spun yarns is much higher than NS-Ring yarns. A considerable increase in the work force of WS-Ring yarns explains the toughness of the yarns.

Keywords: *packing fraction, stretch, tensile, sodium hydroxide*

Introduction

Swelling of cotton materials though a technically simple process, causes profound changes in the structure of cotton fibers at both molecular and macro molecular levels. A great deal of work has been done on the swelling behavior of cotton using various swelling agents like sodium hydroxide, zinc chloride, liquid ammonia, ethylenediamine etc. in the past years[1-5]. Extensive studies report the effect of slack swelling on the properties of cotton yarns[6-9]. The properties of yarns swollen in sodium hydroxide and then stretched to different stretch levels in the presence of solution were also discussed by many workers[10-13].

However investigation on the spectacular changes in the properties of slack swollen cotton yarns when stretched in the presence of swelling agent seems to be scanty in the literature. Any study which involves a new technique is quite interesting. In this present work high tenacity cotton ring spun yarns were prepared by swelling the cotton yarns in sodium hydroxide solution and re-stretching them in presence and in absence of sodium hydroxide. The prepared yarns were tested for their fine structural changes, packing fraction, tensile, properties. The significant change in properties was discussed under the light of their use as sewing threads.

Experimental Materials and Methods

Ring spun cotton yarn of 16's count (37 Tex) was used for the present study. The chemicals used for all the treatments were of laboratory grade. Yarn samples consisting of twenty yarns in lea form were prepared by wrap reel, scoured conventionally and used for all the treatments.

Stretching Treatment

The treatment was divided into two methods. In the first method the slack treated yarns were stretched to 96% in the presence of sodium hydroxide solution whereas in the second method the slack swollen yarns were stretched in the absence of solution. All the stretching treatments were carried out in a device fabricated for the study.

Method I

The scoured ring spun yarns were slack treated in 21% aqueous sodium hydroxide for 5 minutes and then stretched to 96 percentage in the stretching device by fixing the yarns between the two endpins. While stretching, continuous rotations were given to the yarns at constant speed (1 rpm) for remaining 25 minutes in the presence of swelling solution (21% sodium hydroxide). The same method was repeated by varying the swelling time as 10, 15, 20, 25 minutes and then stretched to 96 percentage of their original length and rotations were given for 20, 15, 10, 5 minutes respectively. The yarns were first washed with hot water and then cold water in the stretched state. They were then taken out, washed with hot water, cold water, neutralized with dilute acetic acid and finally air-dried during which they remained at lengths already established. In each treatment, the trough was filled with required level of solution with required concentration. These samples were designated as With Solution Ring spun (WS-Ring) yarns.

Method II

In this method, scoured ring spun yarns were slack swollen in 21% aqueous sodium hydroxide and stretching was given in the absence of solution with same continuous rotations at constant speed in the stretching device. These samples were designated as No Solution Ring spun (NS-Ring) yarns.

Infra Red Spectroscopy

Infrared index values were calculated from the ratio of the absorbances at 1372cm^{-1} and 2900cm^{-1} band by base line technique. Earlier infra red spectra were recorded with Perkin-Elmer Spectrum RX 1 Model using KBr pellet technique.

Scanning Electron Microscopy

The stretched yarn samples were examined in the scanning electron microscope (type Joel JSM 8404) after gold coating by sputtering method. The instruments were operated at 20 KV with amplification of X1000 and 10 m resolution.

Packing Fraction

Packing fraction is the ratio of the specific volume of fiber to that of the yarn. Specific volume of the fiber was taken as the reciprocal of fiber density while specific volume of yarn was calculated from the diameter and Tex values.

$$\text{Specific volume of yarn (V)} = \frac{78570 \times d^2}{T}$$

Where d is the diameter in cm and T is the Tex of the yarn. Diameter of the yarn samples was measured at fifty different places along the length of the yarn at a magnification of about 50X using a Metz-782 model projection microscope and the mean was considered.

Tensile Properties

The tensile properties namely tenacity, breaking elongation and breaking work (work done) of the treated cotton yarn samples were measured on Tensomaxx 7000 at a gauge length of 500 m with a pre- tension of 0.5 CN / Tex. The test sample fixed in between the two clamps was made to elongate at a constant rate and the mean of 35 readings was taken in each case.

RESULTS AND DISCUSSION

From FTIR studies, the infra red index of the treated yarns is calculated and presented in Table 1. With an increase in swelling time a considerable decrease in the infra red index value is noted. This could be explained by the increase in penetration of sodium hydroxide which would have produced considerable decrystallisation. NS-Ring yarn has higher infra red index value than WS-Ring yarn. The FTIR spectra of the stretched yarn samples are given in Figure 1.

Table 1: Infra red Index of Stretched Ring Spun Cotton Yarns

Swelling Time (min)	WS - Ring	NS - Ring
Scoured	0.711	0.711
5	0.619	-
10	0.598	-
15	0.599	0.608
20	0.590	-
25	0.584	-

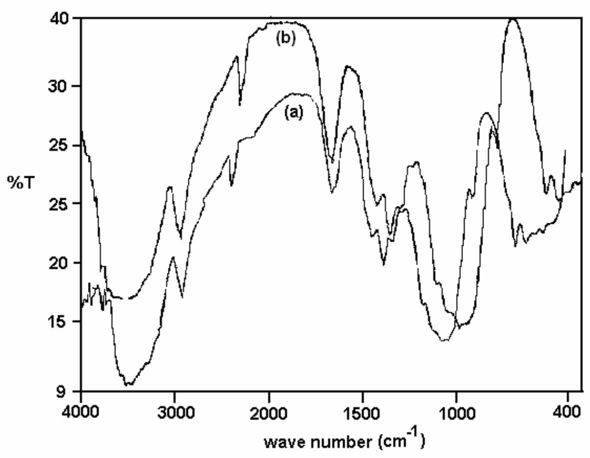
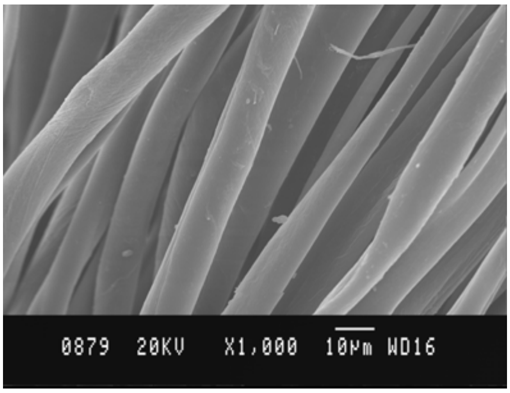
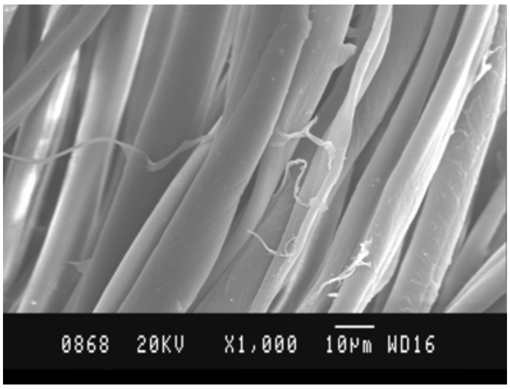


Figure 1: FTIR Spectra of Stretched Ring Spun Cotton Yarns
(a) WS-Ring (5 minutes swelling / 25 minutes stretching)
(b) WS-Ring (25 minutes swelling / 55 minutes stretching)

SEM photographs of fibers in treated ring spun yarns are shown in the Figure 2. The photographs serve as a proof for the swellability of yarns. It is clear that the fibrils arrange themselves closer in the case of WS-Ring yarns explaining the increment observed in the packing fraction of the yarns. The closer packing of fibrils may also contribute to higher tenacity observed in these stretched yarns.





(a) (b)

Figure 2: Scanning Electron Micrograph of Stretched Ring Spun Cotton Yarns
(a) NS-Ring (15 minutes swelling / 15 minutes stretching)
(b) WS-Ring (15 minutes swelling / 15 minutes stretching)

The stretched ring spun yarns are evaluated for their packing fraction and the values are given in Table 2. At lower stretching time, the fiber gets excessive swelling resulting in increased diameter which in turn reduces the packing fraction values. WS-Ring yarns show higher packing fraction values than NS-Ring yarns which shows that the effect of stretch is more pronounced when the yarns are stretched in presence of swelling solution.

Table 2: Packing fraction of Stretched Ring Spun Cotton Yarns

Swelling Time (min)	WS-Ring	NS-Ring
Scoured	-	-
5	0.435	0.392
10	0.408	0.388
15	0.388	0.378
20	0.360	0.363
25	0.358	0.374

Table 3 presents the tensile properties of NS-Ring and WS-Ring yarns. NS-Ring yarns show a gradual increase in their tensile strength whereas a remarkable increase is observed in the case of WS-Ring yarns with increase in swelling time. The steady increase noted in WS-Ring yarns may be explained by the fact that slack swollen yarns while stretched in presence of sodium hydroxide, the fibrillar elements are free to move and would align themselves in a better way resulting in higher orientation and improvement in the uniformity of strength along the fibers. With solution stretching treatment the tenacity of ring spun yarns have been considerably improved for their application as sewing thread.

Table 3: Tensile Properties of Stretched Ring Spun Cotton Yarns

Swelling Time (min)	Tenacity (g/Tex)		Percent Elongation		Work Force (Kgfm)	
	NS - Ring	WS - Ring	NS - Ring	WS - Ring	NS - Ring	WS - Ring
Scoured	14.65	14.65	5.99	5.99	855.67	855.67
5	14.94	15.27	6.23	6.35	943.69	946.03
10	14.77	15.79	6.23	6.28	928.33	975.32
15	14.76	15.93	6.22	6.23	916.96	996.61
20	14.99	16.61	6.38	6.32	960.84	988.42
25	15.10	16.65	6.53	6.53	998.92	972.13

Both NS-Ring and WS-Ring yarns exhibit a steady increase in their percent elongation at higher swelling time. This increase in elongation may be explained by the effect of more swelling and less stretching. It is noted that there is a decrease in yarn elongation with increase in packing.

The work force values of NS-Ring and WS-Ring yarns increase with increase in swelling time. WS-Ring yarns are characterized by higher work force values than NS-Ring yarns. Greater work has to be done to elongate the yarns stretched in presence of the solution which explains the toughness of the yarns. This could be well correlated with the elongation values.

Conclusion

The following conclusions are drawn from the present study of stretching of ring spun cotton yarns in presence and in the absence of swelling solution. Crystallinity of WS-Ring yarns decreases with increase in swelling time. WS-Ring yarns align themselves closely resulting in higher packing fraction. The tenacity of solution stretched yarns show improvement than NS-Ring yarns. The increase in work force of WS-Ring yarns shows the toughness of solution stretched yarns.

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