A Study on the Mechanical Properties and Fiber Damage in Combed and Carded Rotor Cotton Yarns

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Abstract

Rotor spinning is considered as the most common spinning system among the various new systems. This system has some research potential for yarn quality enhancement and combing process is recently introduced as one of the areas. In this research, carded and combed rotor yarns (30 Ne) were produced and the effect of combing process on some physical and mechanical properties was studied and compared with that for carded yarns. The results show that combing process improves the yarn evenness and yarn strength and reduce the hairiness of yarns. Statistical test (t-student) in 95% confidence interval confirms the statistical difference between the tenacity of combed and carded rotor yarns. Fiber damage was studied in terms of length distribution curves and SEM observations. The results show that fiber damage is more pronounced for the combed yarns. That is while mean length and effective length remained superior and short fiber content remained lower than that in carded yarns. Also, time study revealed that the end breakage in producing of combed yarns was less than carded yarns; i.e. better spinning stability. The likely mechanism of fiber damage during the conversion of fibers to yarn is discussed for both yarns.

Keywords: Rotor spinning; combing; Fiber damage; Tenacity; Yarn hairiness.

Introduction

The rapid developments of rotor spinning since its commercial introduction in 1967 has had limited influence at the short staple yarns production, where ring spinning is generally preferred [1]. In contrast to coarse yarn spinning, there are several possible reasons for this. At finer counts speed increasing is not feasible in rotor spinning for some technical reasons. The minimum number of fibers in the ring yarn cross section has touched a figure as low as 17 and that is while in rotor spinning this figure is 90 for carded rotor yarns, which implying a limit in producing of fine counts. Moreover, the stiffness of coarser fibers limits the critical peeling of fibers from the rotor groove into the yarn tail, regardless of yarn count, encouraging a trend toward the use of finer man-made fibers by the rotor-spinning sector. Rotor spinning is particularly sensitive to trash accumulations. At the much higher angular speed of the rotor, even a small trash particle exerts enough centrifugal force to break the fine yarn. Hence, finer yarns sometimes require a reduction in rotor speed. Energy consumption per unit weight of yarn relative to ring spinning increases steeply at fine count, being 1.5 times as high as ring spinning and winding at a count of 30Ne. The superior evenness of rotor yarns at coarse counts vanishes at about 22tex; at finer counts, rotor yarns are typically more irregular. The wrapper fibers, which help explain the discrepancy of yarn strength between ring and rotor yarns, constitute an increasing proportion of fibers as the yarn becomes finer. So, rotor spinning is traditionally coarse to medium count spinning system [2].

As the advantages of rotor spun yarn have become universally accepted, and the rotor speed increased to over 150,000 rpm it has become economically attractive to use the rotor-spinning machine for finer yarn count[1].

The requests for rotor yarn in the count range Ne 30 to 50 (20 tex – 12 tex) are steadily increasing [1].

High-speed rotor spinning of fine yarns requires careful consideration of raw materials and preparatory processes. It is well known that trash and other impurities interfere with the spinning of fine rotor yarns and can cause excessive end breakage[1].

Additionally the yarn quality of fine yarns is more important than that of coarse yarns, and therefore optimization of raw materials and processing techniques is a key consideration.

To optimize the spinning process and obtain improved yarn values a series of research works have been carried out to determine the influence of combing cotton on rotor spinning [1-5]. The results of these works clearly show that the use of combing as one of the preparatory processes for rotor spinning results in better yarn characteristics, improved spinning stability, less hairy yarn and increased fabric strength.

While the cotton fibre failure has received enough attention in literature [6], study on the damage of combed cotton fibres in rotor spinning may provide some information about the processing behaviour and its interaction with the yarn properties.

Experimental

Combed and carded sliver of four different types of cotton were spun into yarns (30 Ne). The four types of cotton were (a) grade one Sahel (50%); (b) grade two Sahel (25%), (c) grade one Varamin (15%); (d) grade two Varamin (10%). Properties of these types, as measured on the Spinlab HVI instrument, are brought in Table I.

Combed yarn was spun from sliver comber on Rieter E7 comber with 18% noil removal. Also, a yarn from carded sliver was spun for further studies. Both carded and combed slivers were produced on the same spinning line (Rieter).

Combed and carded slivers were fed to an Ingolstadt spinning machine and the sliver weight was the same for both spinning tests (0.13 Ne). To assess the damaging effect of the opening roller on carded and combed yarns, samples were collected from the rotor groove.

Table I. Cotton fiber properties

Type of cotton	Mean length (mm)	Effective length (mm)	Length uniformity (%)	Strength (cN/tex)	Extension (%)
Grade One (Sahel)	16.5	31.9	52	30.5	5..3
Grade Two (Sahel)	16.5	32.0	52	29	5..3
Grade One (Varamin)	15.9	31.5	50.2	33	5.7
Grade Two (Varamin)	15.8	31.0	49.9	31.1	5.6

Spinning parameters in this production were as following:
rotor diameter (40 mm), theoretical twist (1127.4 tpm),
opening roller speed (8100 rpm) and rotor speed (65,000 rpm).

Both yarns were produced in a temperature of 26°C and relative humidity of 60%.

In this study the effect of combing on the fiber micronaire was considered by measuring carded and combed fibers micronaire, based on air flow method, using SDL Shirley cotton fineness meter. The results are brought in Table II.

Fiber length and length distribution are important parameters in spinning processes, and can provide useful data for considering the fiber damage during the yarn manufacturing. Any changes in fiber length may be due fiber fracture and this will lead to fiber length distribution changes. Therefore, for studying the effect of combing on fiber failure in rotor spinning the length distribution curves were prepared and fiber length parameters like mean length, effective length and short fiber content were measured from these curves. A Comb-sorter instrument was used for conducting these tests.

Table III shows the results of measurements that were carried out on carded and combed fibres before and after feeding to rotor spinning frame. The mean value of 5 tests on each type is listed in this table.

The combing machine can effectively remove trash from cotton and greatly reduces the trash content. Time study during the yarn production revealed that the end breakage in producing of combed yarns was less than carded yarns; i.e. better spinning stability.

Fractography is another way to study the fiber damage and to recognize the fiber fracture mechanism. One of available techniques for this purpose is Scanning Electron Microscope (SEM), which can record high lucidity pictures for considering materials structure and surface morphology. In this research, samples of carded and combed fibers were studied by SEM and images were captured from samples before and after rotor spinning process. A Philips X230-seriB scanning electron microscope was used for this purpose and samples were coated by gold with a sputter coater. Figure 1 shows some of the SEM studies results.

After producing the carded and combed yarns with 30Ne count, the effect of combing process on some of the physical and mechanical properties of yarns was assessed including the evenness, strength and hairiness of yarns. An Uster4 evenness tester was employed for determining the evenness parameters of yarns, such as CV%, U%, thin and thick places and neps. Each yarn was tested at a rate of 400 m/min and 5 min for five times. Mean results of these tests are shown in Table IV.

Strength tests were done using a Zwick Universal tensile tester at gage length of 25 cm. The mean value of yarn tenacity and extension from 30 tests on each yarn are listed in Table V.

TableII. Carded and combed fibers micronaire values

Type	microniare	CV%
Carded sliver	4	1.46
Combed sliver	4.48	1.58

Yarn hairiness was tested using a yarn hairiness/friction tester Y098/6. For each yarn five tests were taken at rate of 60 m/min and yarn length of 100 m. Mean values of these tests which show the average number of hairs with 3 mm or longer length per 1 cm length of yarn, could be seen in Table VI.

Results and Discussion

3.1. Fiber micronaire

The comber removes the short and immature fibers that have the fineness less than mean fineness of fibers, and this normally results in slight increase in the average fiber fineness. Results of this research (Table II) show the micronaire value increases by approximately 0.5 as a result of combing.

3.2. Fiber damage

Combing process increases the orientation of fibers in sliver so it is expected that the effect of combing roller wires on the fiber fracture to get decreases. The results of this research indicate the incidence and rate of fiber damage for combed fibers. That increased the short fiber content in combed fibres which was more pronounced than carded fibers. This may be due the fact that the fibre length under impact loading of opening roller was longer in combed fibres, hence these fibres are more prone to the damage.

The probability of occurrence of micro defects such as micro voids and micro cracks in combed fibers is more than carded fibers, due to superior average length of combed fibers. So, the fiber damage is increased. Fig 1.a shows SEM image of combed fibers, which were collected from rotor groove. The effect of opening roller on fiber surface is shown in Fig 1.b. Fibre damage may lead to the reduction in fiber length as demonstrated in Fig 1.c. Figure 1.d shows a fractured end of a damaged fibre. Although the results of this study show that damage of combed fibers in rotor spinning is more than carded fibers, comparison of length parameters of combed and carded fibers shows that the mean length and effective length of combed fibers remain superior after rotor spinning and it can cause the positive features for the produced yarn.

Table III. Length parameters of carded and combed fibers (before and after rotor spinning)

Sample type	Mean length (mm)	Maximum length (mm)	Effective length (mm)	Short fiber content (%)
Carded fibres in sliver before feeding to rotor	22.1	33.8	30.75	23.75
Combed fibres in sliver before feeding to rotor	26.2	35.5	33.5	12.43
Carded fibres collected from rotor groove	21.2	32.5	30.0	27.12
Combed fibres collected from rotor groove	23.5	32.5	30.5	14.16

Table VI. Evenness parameters of carded and combed yarns

Type	U (%)	CVm (%)	Thin (+50%)	Thick (-50%)	Neps (+280%)
Carded yarn	11.55	14.89	10	12	5
Combed yarn	11.20	14.48	6	5	3

Table V. Strength and breaking elongation of carded and combed yarns

Type	Breaking Load (cN)	Elongation (mm)	Stress (cN/tex)	Strain (%)
Carded yarn	119.22	11.478	6.057	4.591
Combed yarn	141.06	12.151	7.166	4.866

3.3. Yarn evenness

Table IV compares the value of evenness parameters of combed and carded yarns. The combed yarn shows a very slight improvement in yarn CV%, thin places and thick places in comparison with carded yarn. The nep count of yarn was considerably reduced by the combing process. In general, the combing process increases the evenness of sliver and reduces neps depending upon the noil percentage, so improves the yarn evenness.

3.4. Yarn strength

From the value of carded yarn and combed yarn strength shown in Table V, it is obvious that combed yarn has a better strength. The contribution of combed fibers, with superior average length, on the yarn strength is more than that of the carded fibers. Also, the orientation of combed fibers in the yarn structure is higher. Statistical test (t-student) in 95% confidence interval confirms the statistical difference between the tenacity of combed and carded rotor yarns.

3.5. Yarn breaking elongation

The results could be observed in Table V which shows the combing process has no significant effect on the yarn elongation. This may be due to the deterioration of combed fibres when experiences the severe action of opening roller.

3.6. Yarn hairiness

The combing process reduces the hairiness of rotor yarn significantly, as shown in Table VI. Increase of average fiber length by combing process cause the increase of wrapper fibers in rotor and these fibers control the hairs on the yarn surface. Removal of short fibers is another reason for reduction of the yarn hairiness as a result of combing process.

Conclusion

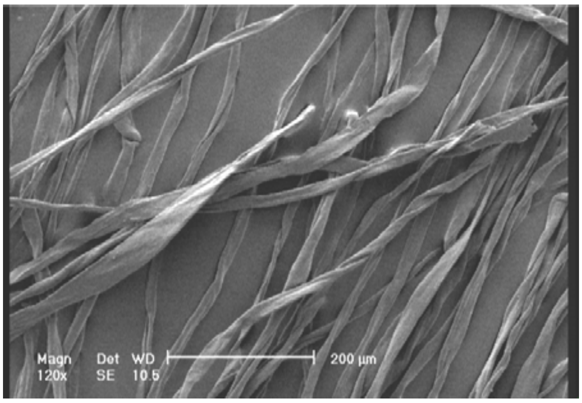
On the basis of the experimental work carried out on the test fibres and yarns it can be concluded that combing process of cotton fibres, as a part of the sliver preparation for rotor spinning can affect the yarn properties positively.

The results show that combing process improves the yarn evenness and yarn strength and reduce the hairiness of yarns. Statistical tests confirm the difference between the tenacity of combed and carded rotor yarns and evenness properties.

Fiber damage was studied in terms of length distribution curves and SEM observations. The results show that fiber damage is more pronounced for the combed yarns. That is while mean and effective length remained superior and short fiber content remained lower than that in carded yarns.

Table VI. Carded and combed yarn hairiness

Yarn type	Hairiness	CV%
Carded yarn	15.1	13.55
Combed yarn	7.9	4.12



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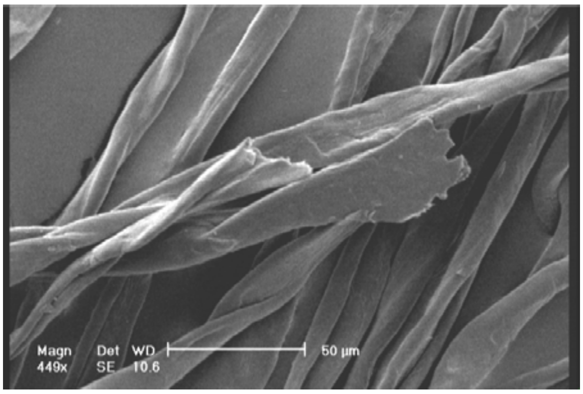

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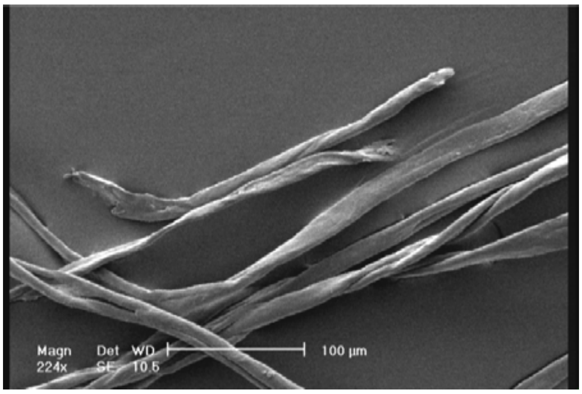

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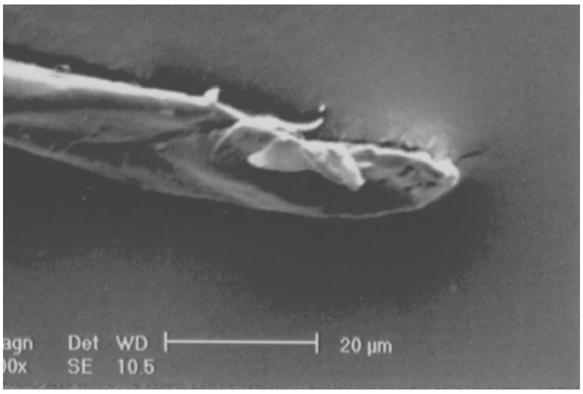

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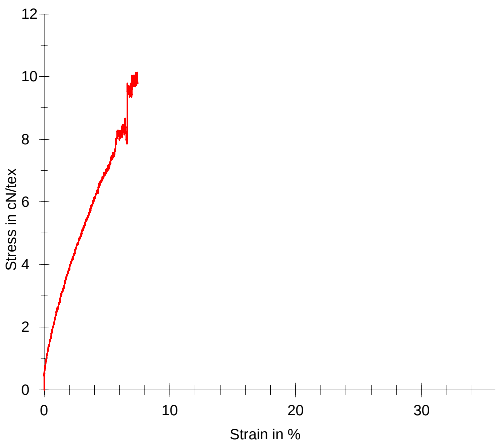
Fig.1. SEM images of combed fibers: (a) Combed fibers in rotor groove, (b) Effect of beater on fiber, (c) Reduction of fiber length, (d) The fractured fiber end.



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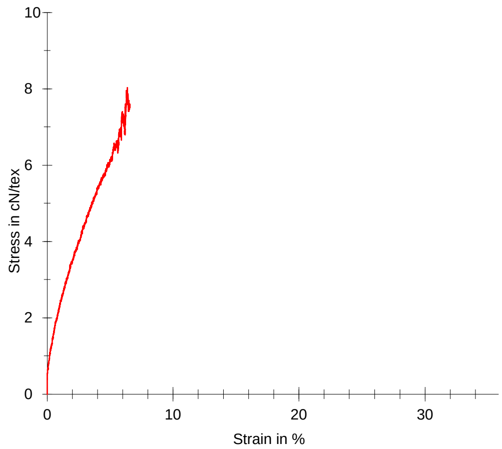

(b)

Fig.2. Typical stress-strain curves of: (a) combed rotor yarn. (b) carded rotor yarn.

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