Hong-Cai Ma[1,2,3], Long-Di Cheng[1,3], Gui-Xiang Yan[4], Shi-Ping Xu[5]

Studies of Negative Pressure and Cleaning Condition Effects on Gathering for Ramie Compact Spinning with a Suction Groove

[1)]**Key Laboratory of Textile Science & Technology, Ministry of Education, Donghua University,**
Room 5027, Textile College Building 3, 2999 North Renmin Road, Songjiang District, Shanghai 201620, People's Republic of China
E-mail: ldch@dhu.edu.cn

[2)]**College of Textile and Clothing, Dezhou University**
566 West University Road, Dezhou, Shandong 253023, People's Republic of China

[3)]**College of Textile, Donghua University**
Room 5028, Textile College Building 3, 2999 North Renmin Road, Songjiang District, Shanghai 201620, People's Republic of China
E-mail: dzxymhc@126.com

[4)]**Hunan Huasheng Dongting Flax Industry Ltd**
1 Dongting Avenue, Yueyang, Hunan 414000, People's Republic of China

[5)]**Dechang Precision Textile Machinery Co., Ltd**
1 Yangfan Road, Science and Technology Park, Ningbo, Zhejiang 315040, People's Republic of China

Abstract
The application of the compact spinning technique with a suction groove could reduce the spinning triangle to a minimum and dramatically decrease the hairiness of ramie yarn. The change range of negative pressure was discussed when the hairiness index was reduced to a minimum for the best gathering effect. The relationship between the doffing time and hairiness index of compact yarn was studied. When the suction groove was not cleaned, the spinning times influenced the fibre number accumulated inside the suction groove. The cleaning suction groove made airflow run smoothly, and the gathering effect of fibres was basically unchanged; thus the hairiness index of yarn rarely fluctuated. For compact yarn compared with 100% 27.8 tex traditional ring-spun yarn, the 4 mm hairiness index and above decreases by more than 79.72%. The result shows that ramie compact spinning with a suction groove could gather edge fibres effectively and reduce harmful hairiness markedly.

Key words: *suction groove, compact spinning, ramie, negative pressure, hairiness index.*

Introduction

The purpose of compact spinning is to reduce or eliminate the spinning triangle for decreased yarn hairiness, improved yarn break strength and elongation at break, as well as to decrease the usual faults [1]. This technique has made a great contribution to the development of the textile industry, but existing compact spinning techniques mainly concentrate on the short-staple spinning system. Their main principle is that the fibre bundles are condensed by negative pressure airflow, which is produced by the compact system, such as a perforated roller, lattice aprons and punched apron etc [2 - 6]. Because the average length of ramie fibre is more than 88 mm, these compact spinning techniques can not satisfy its compact spinning and it is hard to realise a good gathering effect. The reason is that they do not provide effective condensed space to adapt to the length of ramie fibre. The compact spinning technique with a suction groove is different from other compact spinning techniques, that is mechanical and airflow combined-type compact spinning technology. This technique uses a gathering mechanism of shape and airflow, where one end of the fibre bundles is free and the other end compacted and twisted, thus it has a good condensing effect on ramie fibre.

Zhu and Zhang etc. established the computational fluid dynamic model for compact spinning with an inspiratory groove for cotton, carried out numerical calculations and characterised the flow state in the compact zone [7, 8]. Dou etc. derived the motion trajectory of cotton fibre in the flow zone utilizing the self-designed MATLAB procedure and analysed the compact effect of fibre strands due to that of airflow [9]. Zou etc. studied the twist transmission mechanism in compact spinning with a pneumatic groove for cotton [10]. All authors above discussed compact spinning with a suction groove for cotton but did not study long staple fibre in this technique. This paper studied ramie yarn produced by adjusting the negative pressure and cleaning conditions in compact spinning with a suction groove, measured the hairiness variation rule and discussed the compact effect. Compared with conventional ring spun ramie yarn, hairiness changes in ramie yarns were discussed.

Materials and methods

The 100% ramie's roving weight was 0.505 ktex, the moisture regain 7.5%, and the twisting 28 t.p.m. 27.8 tex yarn was manufactured using a conventional spinning frame and compact spinning frame with a suction groove for long staple, respectively. Yarn properties compared and analysed for conventional yarn and compact yarn. Testing conditions were a temperature of 25 °C and relative humidity of 65%. The breaking strength was measured with a YG092A Full Automatic Single Yarn Strength Tester, at a yarn feeding speed of 420 mm/min and strength of 100 - 2000 cN. Uster evenness was measured with an Uster Tester3, at a yarn feeding speed of 400 m/min and yarn tension of 37.5%. The twist was measured with a YG133 Twist Tester. The hairiness was measured using a YG171L Yarn Hairiness Tester, at a yarn feeding speed of 30 m/min, with a fragment length of 10 m. To minimise any possible data fluctuation, we used 10 spindles at random on a compact spinning machine with a suction groove.

Figure 1 [11 - 13] shows the gathering equipment of compact spinning with a suction groove for long staple fibre which consists of one gathering roller added onto the front roller after drafting and before twisting in the conventional ring spun frame. The gathering roller has a groove which has equally distributed suction holes and uses a windshield to position the gathering area. There are twelve suction holes in the gathering area, playing the compacting role of airflow, with the groove performing the shape compacting function. The fibre bundles delivered from the front nip are contracted and their width narrowed in the gathering area, therefore the spinning triangle was decreased or eliminated to reduce hairiness.

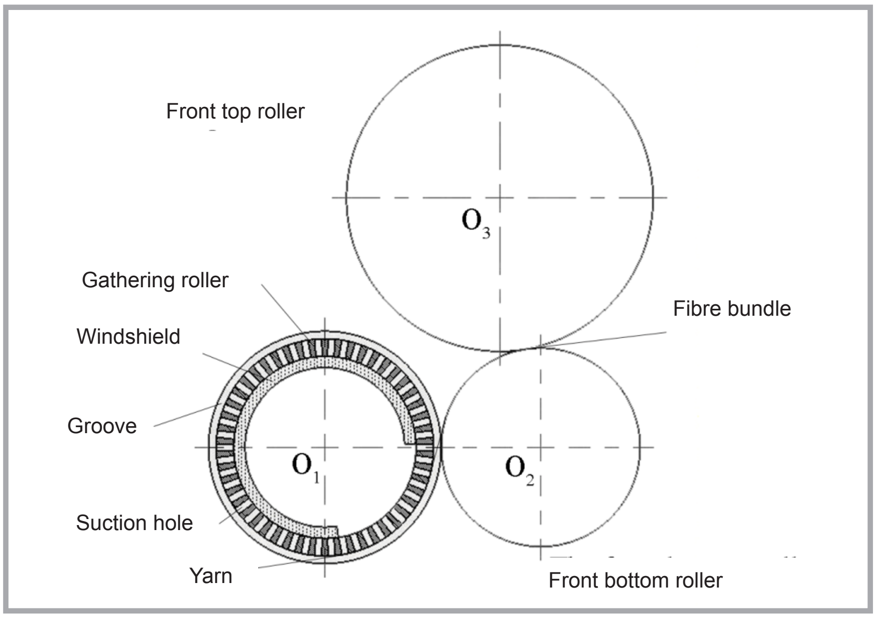

Figure 1. *The gathering equipment of compact spinning system with suction groove.*

Results and discussion

The purpose of compact spinning with a suction groove is to reduce yarn hairiness, such as in ramie and wool yarn etc. The negative pressure influences the compact effect of ramie fibre, but a higher negative pressure will also increase the motor load and bring about excessively high electricity costs for the enterprise. Moreover the cleaning state inside the suction groove also impacts the gathering effect of fibre bundles in the compact area. Therefore this study used compact spinning with a suction groove for ramie, and ramie compact yarn was produced by adjusting the negative pressure and cleaning state. The hairiness variation and compact effect were researched and analysed, and the rules for compact yarn and ring spinning yarn compared for ramie.

Relationship between frequency and negative pressure

The change curves of negative pressure and frequency are different because of different fan power. ***Figure 2*** shows the relationships between the frequency of the fan and negative pressure in compact spinning with a suction groove for long staple fibre for a fan power of 5.5 kW. It can be seen from the Figure that the frequency is approximatively proportional to the negative pressure, with related data being provided to adjust the negative pressure for the enterprise.

Relationship between negative pressure and hairiness

In ***Figure 3***, it can be seen that the 4, 6, 8 and 10 mm hairiness of ramie compact yarn are compared in relation to different negative pressures. From this graph the hairiness index varies according to the different negative pressures. The maximums of the 4, 6, 8 and 10 mm hairiness indices are 9.49, 2.08, 0.62 and 0.29, respectively, and their minimums are 7.65, 1.75, 0.53 and 0.13, respectively. The compact effect is the best because yarn hairiness reduces to a minimum when the negative pressure equals -2.1 kPa. This means that the compact effect is not the best when the negative pressure is bigger or smaller. Appropriate negative pressure can obtain the best gathering effect. In view of the frequency and motor load, when the draught fan power is 5.5 kW, the best negative pressure is between -1.9 kPa and -2.5 kPa.

Relationship between doffing times and hairiness

Figure 4 (see page 56) shows that the variation in hairiness for different doffing times in compact spinning. From the chart, we can see that the hairiness index of yarn is higher when the spinning starts in cold conditions, then begins to decline from the second doffing and finally to rise after the fifth doffing; hence the total variation in the hairiness index is high-low-high. Because the hairiness index of each individual spindle is higher, the hairiness index of yarn in the fourth doffing is bigger than that in the third

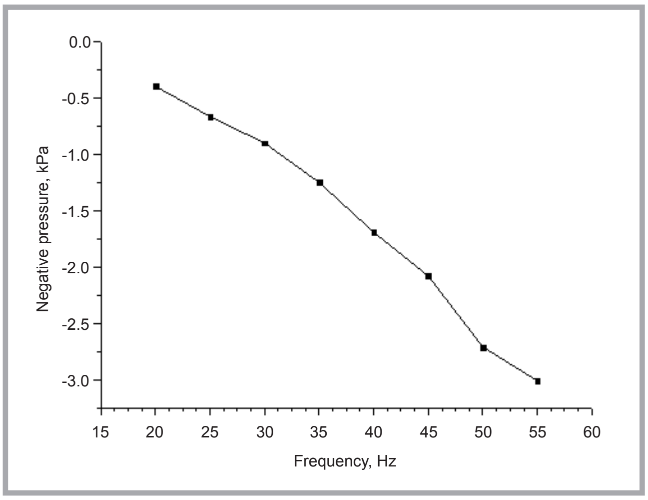

Figure 2. *Relationships between frequency and negative pressure.*

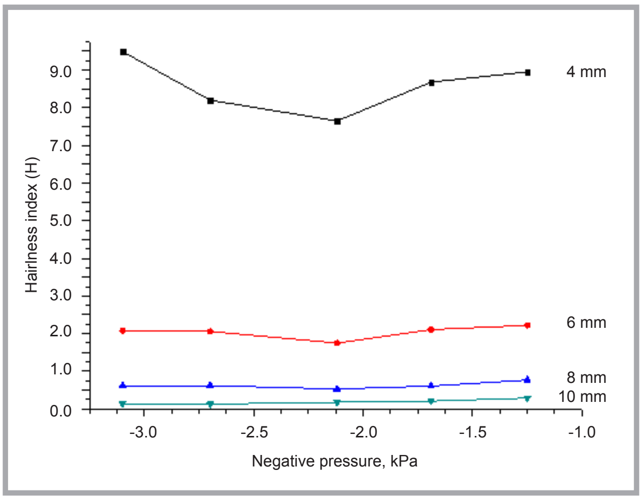

Figure 3. *Change rule of hairiness at different negative pressures.*

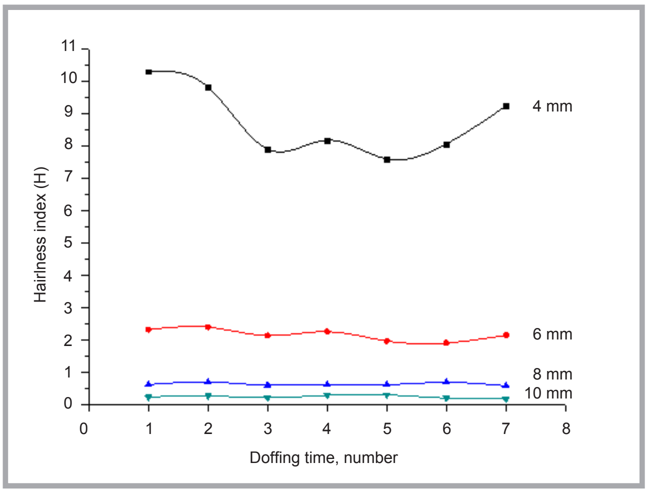

***Figure 4.** Variation in hairiness for different doffing times.*

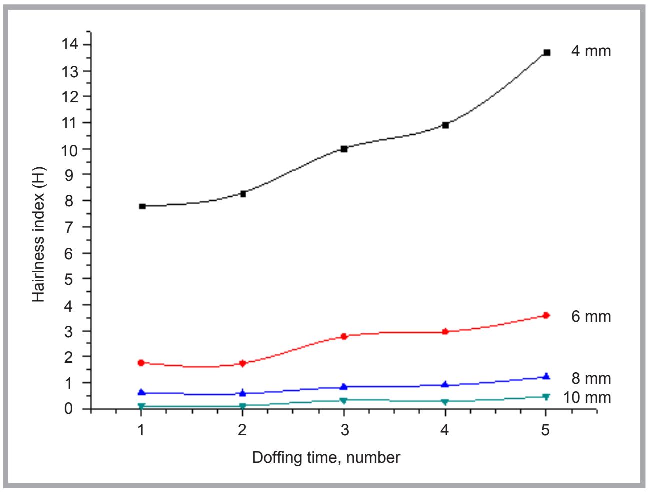

***Figure 5.** Hairiness variation of each doffing in unclean conditions.*

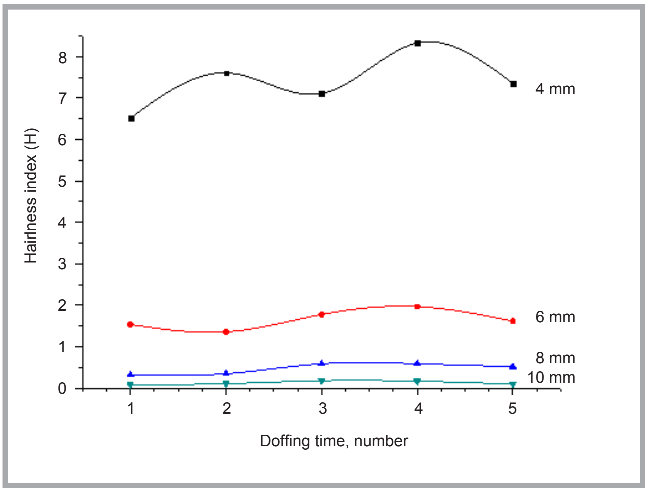

***Figure 6.** Hairiness variation of each doffing in clean conditions.*

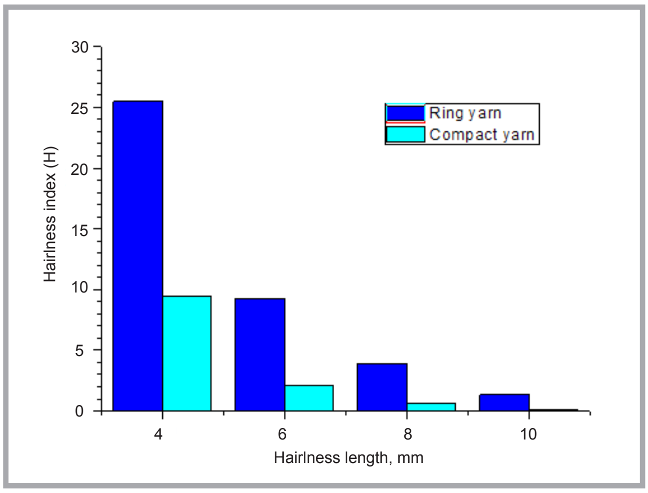

***Figure 7.** 4, 6, 8 and 10 mm hairiness of compact and ring yarn.*

doffing. The result has illustrated that the yarn easily fluffs in cold conditions. When the spinning frame works for some time, the temperature will reach normal spinning condition; thus the hairiness index of yarn starts to decrease in the third doffing. However, due to a small amount of fibres being adhered to the internal channel of the suction groove, the airflow channel will narrow and the air volume of suction holes be reduced, as a result of which the gathering effect deteriorates and the hairiness index increases.

***Table 1.** Test results of compact and ring yarn properties.*

Item	Compact	Ring
Breaking strength, cN	735	646
Breaking strength, CV%	18.68	18.15
Breaking elongation, %	3.9	3.0
Breaking tenacity, cN/tex	26.70	23.10
Uster, CV%	19.35	19.23
Thin, -50%	243	187
Thick, +50%	193	227
Neps, +200%	132	167
Actual twist, T/m	586.4	531
Twist CV%	6.45	5.49

Variation of hairiness in clean or unclean conditions

In the spinning process, the suction groove absorbs some fibres into its interior due to the existence of negative pressure. The fibres gradually adhere to wall of the suction groove with the extension of the spinning time, which hinders the flow of airflow and influences the compact effect.

Figure 5 shows the 4, 6, 8 and 10 mm hairiness variations in 27.8 tex ramie compact yarn in unclean conditions. It can be obtained from the graph that 4, 6, 8 and 10 mm hairiness indexes gradually increased from the first doffing to the fifth doffing, with the largest being in the fifth doffing. When the suction groove was not clean, fibres gradually accumulated therein . These fibres make the internal channel of the suction groove obstruct and block the gathering airflow, which affects yarn hairiness and makes it gradually increase.

Figure 6 shows the 4, 6, 8 and 10 mm hairiness variation of 27.8 tex ramie compact yarn in clean conditions. In the graph, the change range of the 4, 6, 8 and 10 mm hairiness indexes is not big from the first to the fifth doffing, illustrating that the interior of the suction groove has no fibre and its internal channel is smooth no matter how long the spinning time is in clean conditions; thus the fibre compact effect essentially changed and the hairiness index of yarn had few fluctuations.

Comparison of the hairiness of ramie 27.8 tex compact and ring yarn

In ***Table 1*** it can be seen that the breaking strength, elongation at break and tenacity of compact yarn are higher than for conventional ring spun yarn. The reason for these changes is that the fibres are gathered by air flow and machinery, where edge fibres are tightly contracted on the main body of yarn. But the breaking strength CV% and Uster CV% of compact yarn also increase because a part of short fibres is sucked by air flow in the condensing process, as a result of which the thin places increase and thick places and neps reduce. The twist of compact and conventional ring yarns has a great difference. The twist and its unevenness in compact yarn is higher and its loss is reduced, thus twisting efficiency is enhanced, which improves production efficiency.

Figure 7 shows the 4, 6, 8 and 10 mm hairiness indices of 27.8 tex ramie compact and ring yarn. It can be obtained from the column chart that the 4, 6, 8 and 10 mm hairiness indexes of compact yarn were reduced by 79.72%, 88.12%, 94.12% and 94.85%, respectively, comparing with ring yarn. This means that the harmful hairiness of yarn can be significantly reduced when compact spinning technology with a suction groove is used in ramie spinning. Thus it could improve the utilisation of fibre and yarn performance, thereby reducing production costs and providing high quality yarn products to consumers.

Conclusions

Compact spinning technology with a suction groove could effectively control fibre transfer and spinning tension in the ramie spinning process, especially edge fibres, and significantly reduce the long hairiness of yarn.

In practice, the negative pressure may be adjusted by the motor frequency, and the reduced hairiness number varies for different negative pressures. Using suitable negative pressure, the hairiness can be reduced to the minimum and the gathering effect is the best.

The change rule of the compact yarn hairiness index is high-low-high. Following the spinning time extension, the cleaning condition of the suction groove will influence the fibre number accumulated inside it and the gathering effect. In clean conditions, the fibre compacting effect does not essentially changed and the hairiness index of yarn rarely fluctuates.

Compared to the ring spinning system, compact spinning with a suction groove can increase the breaking strength, breaking elongation, breaking tenacity and twist, and reduce much hairiness. This shows that this compact spinning system could signally reduce the harmful hairiness of yarn in ramie spinning. However, this system needs its structure improved so as to obtain a better compact effect.

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