STUDY ON THE COTTON RECOMBING PROCESS BASED ON FIBER LENGTH DISTRIBUTION BY WEIGHT

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Abstract

Recombing technique is widely used in wool and ramie spinning. Due to the high production rate and better yarn quality after recombing, the utilization in cotton spinning is inspiring researchers' attention. To explore the effect of separating gauge and feeding length on fiber length changes, production rate and the noil percentage, this paper employed numerical calculation based on forward feeding process in combing, and it could be concluded that under the same production rate in combing and recombing process, SFC after recombing is apparently reduced. And the length irregularity of the recombed sliver lowers 0.5%~1.0% per increase 2mm of separating gauge.

Introduction

Recombing technique, as the name suggests, is combing for twice. It was firstly used in wool spinning to make the wool straight and parallel after top dying. Recombing the wool would achieve the assigned parameters, blend the fibers sufficiently, and bring additional profits (Zhang, 2003). Such technique is also widely applied in ramie spinning, because it can contribute to a high production rate and better yarn quality (Zhang *et al*. 1998). Recently, the application of recombing technique in cotton spinning receives researchers' attention (Zhuang, 2007).

The noil percentage, the production rate and level of impurity transfer are the critical measures in assessing the efficiency of a comb. And the internal relations among them are obvious. The noil percentage depends strongly upon the processing parameters and the fiber length distribution of the fiber being combed (Kirby *et al*. 2004). Based on fiber length distribution by weight, we represented the relationship among the fiber lengths and processing parameters in combing, and discussed the effect of separating gauge and feeding length on fiber length changes, production rate and the noil percentage by employing numerical calculation.

Analysis of Forward Feeding Process in Combing

Figure 1 shows the combing process of cylinder and top comb on the strand. Here, Ⅰ—Ⅰ is the rearmost position of nipper; Ⅱ—Ⅱ is the foremost position of nipper; Ⅲ—Ⅲ is the nip of separating rollers; R is the separating gauge (mm); a is the shortest distance between the fillet of cylinder and the nipper (mm), where the strand can't be combed; F is the feeding length (mm); α_1 is the feeding coefficient, which means the feeded length of the strand is $\alpha_1 F$ before the top comb starts to work. The nipper is moving backward until Position (3) in Figure 1, where the cylinder begins to work on the strand; and then, the nipper moves forward, meanwhile, the strand feeding is realized. Let L_1 be the length of the longest fiber in the noil, and L_2 be the length of the shortest fiber in the web, then,

$$L_1 = R + (1 - \alpha_1)F \tag{1}$$

$$L_2 = L_1 - F = R - \alpha_1 F \tag{2}$$

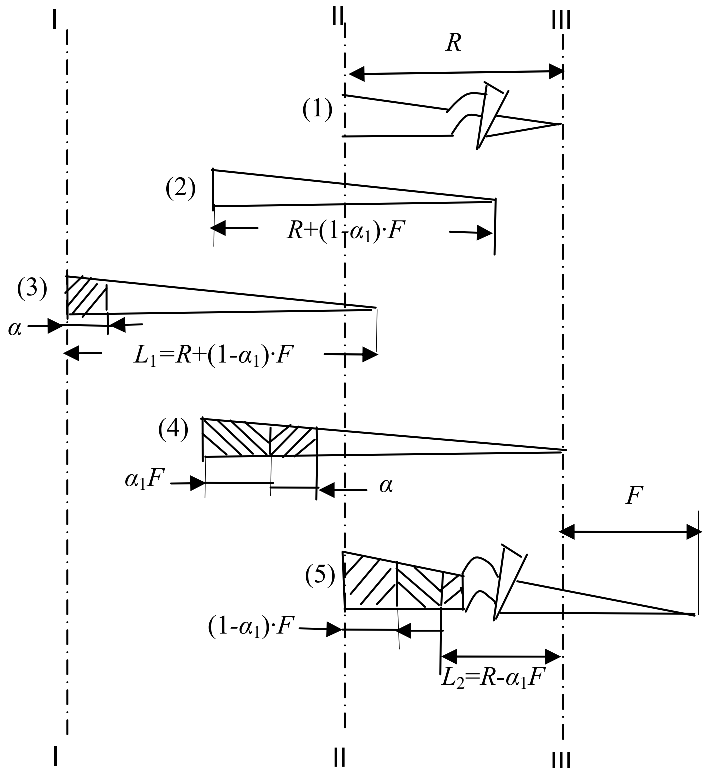

Figure 1. Forward feeding process in combing (Yu, 2009).

Model Development

For the convenience of further discussion, we designated fiber length as l with length probability density function by weight $f(l)$, and assume that if the fiber with length l, and $l<L_2$, the fiber will be removed to the noil; If the fiber with length l, and $l> L_1$, the fiber will go into the web; If the fiber with length l, and $L_2<l<L_1$, the probability of the fiber to be combed out is q. And no fiber breaks or is damaged during combing.

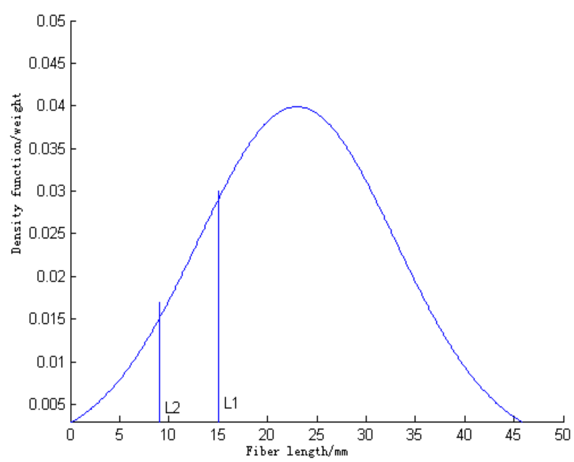

Figure 2. The sketch of fiber length distribution.

Consequently, the noil percentage S can be expressed as

$$S = \int_0^{L_2} f(l)dl + q\int_{L_2}^{L_1} f(l)dl \tag{3}$$

and the length density function $g(l)$ of the fibers in the web is

$$g(l)=\begin{cases}\dfrac{(1-q)f(l)}{(1-q)\int_{L_2}^{L_1}f(x)dx+\int_{L_1}^{\infty}f(x)dx}, L_2\le l\le L_1\\ \dfrac{f(l)}{(1-q)\int_{L_2}^{L_1}f(x)dx+\int_{L_1}^{\infty}f(x)dx}, L_1<l<\infty\end{cases} \quad (4)$$

So, the mean length $\overline{L}$, length irregularity $CV(l)$%, and SFC (with upper limit 16mm) of the fibers in the web can be obtained respectively:

$$\overline{L}=\int_{L_2}^{\infty} lg(l)dl \quad (5)$$

$$CV(l)\%=\frac{\sqrt{D(l)}}{E(l)}\times 100\%=\frac{\sqrt{\int_{L_2}^{\infty} l^2 g(l)dl-(\overline{L})^2}}{\overline{L}}\times 100\% \quad (6)$$

$$SFC\%=\int_{L_2}^{16} g(l)dl\times 100\% \quad (7)$$

Sample Preparation

A sample of cotton lap was selected, and the fiber lengths were determined on aQura Length Testing Instrument (Premier Electronics Co., Ltd., India), and the averages of 5 readings were taken as the representative values. The results are shown in Table 1 and Figure 3. Based on the tested histogram, Figure 3 also illustrates the smooth and normalized non-parametric kernel estimate of the density function of fiber length using the method in reference (Lin *et al*. 2008) by employing the standard normal distribution function as the kernel function. And the estimated density function will be used in the following calculation.

Table 1. Fiber length properties

Items	Principal length/mm	Effective length*/mm	Mean length/mm	Length irregularity/%	SFC(16mm)/%
Sample	32	30.78	25.84	30.94	14.56

(*Effective length equals to the upper quartile length)

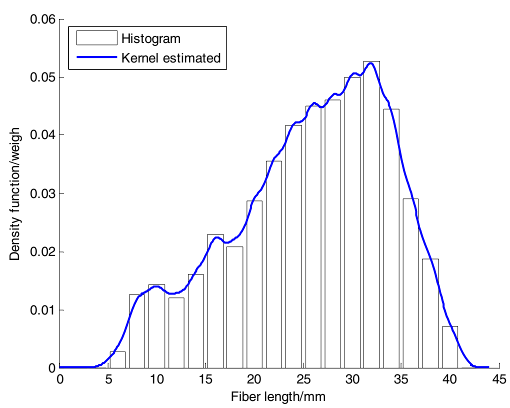

Figure 3. Fiber length distribution.

Results and Discussion

Comparison between Combing and Recombing

According to the parameters of FA251A combing machine, we compared the fiber length changes before and after the combing/recombing process. Let α_1=0.5, q=0.5 to facilitate computation (and the same as below).

Table 2. Designed parameters of feeding length and separating gauge.

Parameters \ Items	Combing	Recombing once	Recombing twice
Feeding length /mm	6	6	6.5
Separating gauge /mm	18	15	17

The fiber length changes in combing and recombing are given in Figure 4 - Figure 5 and Table 3. With the same production rate, the mean length and length regularity after recombing have improved to a certain extent, and SFC is apparently reduced. On the other hand, if SFC is constant, it's advisable to predict that the recombing technique could increase the production rate.

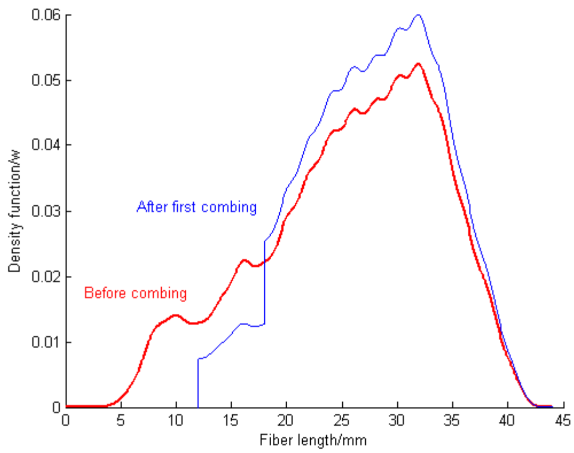

Figure 4. Fiber length changes in combing.

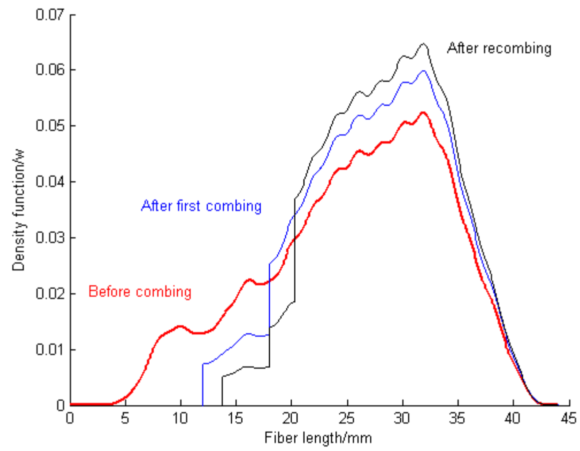

Figure 5. Fiber length changes in recombing.

Table 3. Fiber length changes in combed and recombed slivers.

Parameters \ Items	Lap	Combed sliver	Recombed sliver once	Recombed sliver twice
Mean length/mm	25.8402	28. 6608	27.8479	28.6679
Length irregularity/%	30.94	19.91	22.53	19.64
SFC in sliver (16mm)/%	14.56	2.13	3.89	1.31
Noil/%	----	19.04	12.71	7.12
SFC in noil (16mm)/%	----	67.23	82.69	36.38
Production rate/%	----	80.96	87.2900	81.0750

Effect of Separating Gauge on Recombing

The increasing values of separating gauge (listed in Table 4) were designed, and the fiber length changes before and after the recombing are shown in Figure 6 and Table 5.

Table 4. Designed parameters of separating gauge (feeding length=6mm).

Items	Once	Twice (1)	Twice (2)	Twice (3)	Twice (4)	Twice (5)	Twice (6)
Separating gauge /mm	15	11	13	15	17	19	21

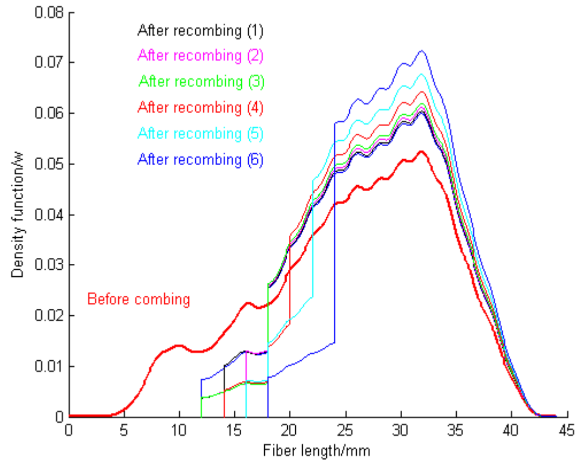

Figure 6. Effect of separating gauge on fiber length changes in recombing.

Table 5. Effect of separating gauge on fiber length changes in recombing.

Items / Parameters	Lap	Once	Twice (1)	(2)	(3)	(4)	(5)	(6)
Mean length/mm	25.8402	27.8479	27.9624	28.1124	28.2637	28.6673	29.1445	29.6586
Length irregularity/%	30.94	22.53	22.02	21.48	20.98	19.67	18.36	17.19
SFC in sliver (16mm)/%	14.56	3.89	4.0	3.95	2.01	1.14	0	0
Noil/%	----	12.71	0.83	1.98	3.2	7.02	11.9	17.55
SFC in noil (16mm)/%	----	82.69	100	100	60.62	39.74	32.69	22.17
Production rate/%	----	87.29	86.5655	85.5617	84.4967	81.1622	76.9025	71.9706

As reflected in Figure 6 and Table 5, it's reasonable that the SFC and production rate of the recombed slivers are reduced gradually with the increase values of separating gauge. And the length irregularity of the recombed lowers 0.5%~1.0% per increase 2mm of separating gauge.

We chose another group of separating gauge (listed in Table 6), and the calculation results are shown in Table 7. It can be concluded that if we exchange the values of separating gauge in the first and the second comb, it shows minor effect on the final recombed sliver.

Table 6. Designed parameters of separating gauge for comparison the exchanging effect (feeding length=6mm).

Items	(I)		(II)	
	R_1=11	R_2=15	R_1=19	R_2=15

(R_1, R_2 mean the separating gauge in the first and the second comb, respectively.)

Table 7. Effect of exchanging separating gauge on fiber length changes in recombing.

Items / Parameters	Lap	(I) R_1=11	R_2=15	(1) R_1=15	R_2=11	(II) R_1=19	R_2=15	(5) R_1=15	R_2=19
Mean length/mm	25.8402	26.8403	27.9624	27.8479	27.9624	28.9929	29.1484	27.8479	29.1445
Length irregularity/%	30.94	26.47	22.02	22.53	22.02	18.93	18.32	22.53	18.36
SFC in sliver (16mm)/%	14.56	4.08	3.17	3.89	4.0	0	0	3.89	0
Noil/%	----	5.92	8.04	12.71	0.83	21.79	1.4	12.71	11.9
SFC in noil (16mm)/%	----	100	71.14	82.69	100	61.4	0	82.69	32.69
Production rate/%	----	94.08	86.5233	87.29	86.5655	78.21	77.1151	87.29	76.9025

Effect of Feeding Length on Recombing

We adopted the increasing values of feeding length (listed in Table 8), and the fiber length changes before and after the recombing are shown in Figure 7 and Table 9. It should be noted that feeding length doesn't have significant effect on the fiber length changes in recombing as what is shown in changing the separating gauge.

Table 8. Designed parameters of feeding length (separating gauge=15mm).

Items	Once	Twice		
		(a)	(b)	(c)
Feeding length /mm	6	5.2	6	7.1

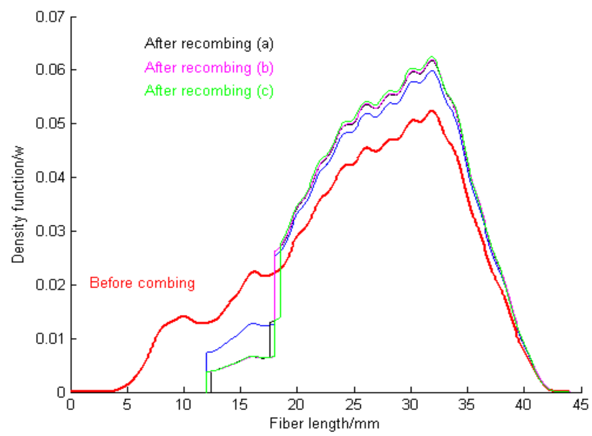

Figure 7. Effect of feeding length on fiber length changes in recombing.

Table 9. Effect of feeding length on fiber length changes in recombing.

Items / Parameters	Lap	Once	Twice		
			(a)	(b)	(c)
Mean length/mm	25.8402	27.8479	28.2339	28.2637	28.3068
Length irregularity/%	30.94	22.53	21.08	20.98	20.77
SFC in sliver (16mm)/%	14.56	3.89	2.01	2.01	2.03
Noil/%	----	12.71	2.95	3.2	3.86
SFC in noil (16mm)/%	----	82.69	65.76	60.62	50.26
Production rate/%	----	87.29	84.7149	84.4967	83.9206

Conclusions

Under the assumed combing/recombing conditions, we compared the effect of processing parameters on fiber length changes. It can be concluded as follows:

- With the same production rate in combing and recombing, the mean length and length regularity after recombing have improved to a certain extent, and SFC is apparently reduced.
- The SFC and production rate of the recombed slivers are reduced gradually with the increase of separating gauge. And the length irregularity of the recombed lowers 0.5%~1.0% per increase 2mm of separating gauge.
- If the values of separating gauge in the first and the second comb are exchanged, it shows minor effect on the recombed sliver.
- Feeding length alone doesn't have significant effect on the fiber changes in recombing.

Acknowledgements

The authors wish to thankfully acknowledge Dr. William Oxenham for his patience and direction in this paper.

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