THE MECHANISM OF END BREAKAGE IN RING SPINNING: A STATISTICAL MODEL TO PREDICT THE END BREAK IN RING SPINNING

Anindya Ghosh, Sayied Ishtiaque, Seenivasan Rengasamy, Asis Patnaik

Department of Textile Technology
Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India
e-mail: anindya_textile@yahoo.com

Abstract

The mechanism of end breakage in ring spinning is a complex phenomenon, and is entirely different from the yarn failure mechanism during a tensile test. In this paper a possible mechanism of end breakage is reported. A statistical model is developed for predicting the likely end breakage rate in ring spinning. The important factors in governing end breaks are the mean yarn strength, yarn strength variation, mean value of the peak spinning tensions and the variation of yarn mass irregularity. Some practical aspects have also been discussed to tackle the problem of when the breakage rate suddenly increases.

Key words:

end breakage rate, links of fibre bundle, spinning tension, yarn mass irregularity, yarn strength

Introduction

One basic way to increase profit and quality in the ring spinning process is to keep the end breakage rate to a minimum level. The end breakage rate is a critical spinning parameter that not only affects the maximum spindle speed but may also indicate the quality of yarn, the mechanical condition of the machine and the quality of raw materials. Therefore, it is an important parameter which determines the overall working of a spinning mill. Any attempt to explain the end breakage mechanism in terms of qualitative approach will provide an aid to understanding the problem and to tackling it to any possible degree .

Substantial research works have been carried out to predict likely end breakage rates in ring spinning [1-5]. Most of these are based on large numbers of simplifying assumptions and complexity of calculations. Moreover, in many cases, they do not reflect the results which are compatible with the actual situation. This paper presents a simple model to predict the likely end breakage rates based on the statistical analysis.

Theory

Yarn breakage mechanism during tensile testing

The yarn may be assumed to be composed of successive links of fibre bundle. The length of any given link is poorly defined, because the elements of fibre bundle are not separate entities but each gradually merges into its neighbour at either end. Nevertheless, an average element length may be considered to exist. It has been reported by Lord [6] that for the carded cotton yarn the average length of the link is approximately around 3 mm. In fact, break occurs at the weakest link of the yarn, and the yarn strength is nothing but the strength of its weakest link [7].

When a yarn is subjected to a tensile test, the tension is generated in the yarn by an applied load, which is opposed by the resistance of the material. As generated tension acts on the helical structure, the yarn is compressed radially and a force normal to the fibre axis is developed. An increment in the normal force between fibre surfaces in the yarn causes an increase of resistance necessary to prevent fibre slippage. During the tensile test, the tension generated by the applied strain continues to increase. The increase in generated tension is limited by the tensile strength of the fibres. Initially, as the extension increases, few weaker fibres with low extension may break at the weakest link of yarn. The structure is readjusted, and some of these broken fibres may continue to share the load again if the broken segments are long enough to be gripped again. The load will continue to rise depending upon the load-bearing capacity of surviving fibres. As it is further extended, more fibre rupture at the place of the weakest zone takes place. The load-bearing capacity of the surviving fibres becomes less than previously, and the recorded load starts declining. The stress on the surviving fibres concentrates, causing the rupture to propagate faster across the cross-section. The number of broken fibres becomes large enough to affect the structural integrity to such an extent that the unbroken fibres start slipping as well. The yarn rupture continues in a mixed mode of fibre breakage and slippage until it completely ruptures [8].

End breakage mechanism in ring spinning

The mechanism of end breakage in the ring frame is significantly different from the failure mechanism of yarn in a tensile tester. In ring spinning, the end breakage occurs due to the imbalance in the tension imposed on the yarn and the yarn strength at the weakest portion. It is an observed fact that almost all end breaks in the ring frame take place just after the delivery from the front nip in the spinning zone, i.e., between the front rollers' nip and the thread guide. Therefore, an end will break when the spinning tension exceeds the strength of the weakest portion of the yarn in the spinning zone [9]. The end breakage phenomenon in ring spinning is absolutely slippage-dominated, i.e., there is no evidence of fibre breakage. The strength of yarn at the spinning zone is significantly less than the yarn strength obtained by a tensile tester. In general, the spinning tension is considerably greater than one-third of the single thread strength [1]. In fact, a very thin portion of yarn just after the delivery from the front nip causes an end breakage in ring spinning.

Assumptions

In order to derive a mathematical equation to predict the end breakage rate in ring spinning, the following assumptions have been made:

I. The yarn is composed of a successive chain of links with different lengths, and the average length of links is $\bar{l}_h$. For carded cotton yarn, $\bar{l}_h$ = 3 mm.

II. An end break occurs when the spinning tension exceeds the strength of the yarn in the spinning zone.

III. The strengths of the links of fibre bundle just issuing from the front rollers are independent variables and follow a normal distribution, i.e., a link of high strength may immediately follow one of low strength. The strength is constant within a link but varies from link to link. The strength of a link depends on the number of fibres in the link and the coefficient of variation of the strength of all the links. The coefficient of variation of the strength of the links is equal to the coefficient of variation of mass per 8 mm length of the yarn (Uster CV%). This is based on the fact that the variance-length curves of fibre assemblies run practically horizontal for cut lengths between 1 and 10 mm [10].

IV. The strength of the yarn in the spinning zone is about one-third of the mean strength of the yarn.

Derivation of end breakage rates

The frequency (f), i.e. the number of the fibre bundle links emerging per minute from the nip of the front rollers, can be expressed as

$$f = \frac{S}{\bar{l}_h} \times 10^3 \ , \tag{1}$$

where:

S = the front roller delivery speed in m/min, and

$\bar{l}_h$ = the average length of the links of fibre bundles in mm.

Therefore, the total number of links moving past from the nip of the front rollers per 1000 spindles per hour (L) can be represented by

$$L = \frac{S}{\bar{l}_h} \times 60 \times 10^6 \ , \tag{2}$$

Let P be the probability of the number of weak links just emerging from the front rollers' nip causing an end to break. Thus, the number of end breaks per 1000 spindles per hour (B) is given by the following equation:

$$B = LP \ , \tag{3}$$

Now, the strengths (x) of the fibre bundle links just issuing from the front rollers follow a normal distribution N (μ, σ^2) with mean μ and variance σ^2 (Figure 1). The standard deviation of the strength of the links σ can be obtained from the following relationship:

$$\sigma = \frac{V\mu}{100} \ , \tag{4}$$

where V = the coefficient of variation of mass per unit length of yarn.

The variations of spinning tension in ring spinning are mainly caused by the irregularities in the rotation of the traveller around the ring. It is an established fact that in each rotation of the traveller there are five peak spinning tensions [1]. For an end to break, the peak of spinning tensions is a more decisive factor than the average value. Let the mean of the peak values of spinning tensions be T. The average time taken in milliseconds to pass a link through the nip of the front rollers can be calculated as

$$t_1 = \frac{\bar{l}_h}{S} \times 60 \ , \tag{5}$$

In a ring- frame, at a normal rate of production, it has been observed that the average time in milliseconds of a rotation of the traveller $t_2 < t_1$. Thus, each link will undergo at least several peak spinning tensions. An end will break when T > the strength of a link just passing from the front roller. Therefore, the strength of the links which are lower than T would lie at a distance of Zσ from the left side of μ in the normal distribution curve, where Z = standard normal deviation. A linear transformation of normal distribution N (μ, σ^2) into the standard normal distribution N (0,1) is obtained by

$$z = \frac{x - \mu}{\sigma} \ , \tag{6}$$

The probability when T > the strength of the links just passing from the front rollers' nip can be found by the relationship

$$P = 1 - \Phi(Z) \ , \tag{7}$$

where $\Phi(Z)$ can be expressed as,

$$\Phi(Z) = \frac{1}{\sqrt{2\pi}} \int_{-Z}^{\infty} e^{-\frac{z^2}{2}} dz \ , \tag{8}$$

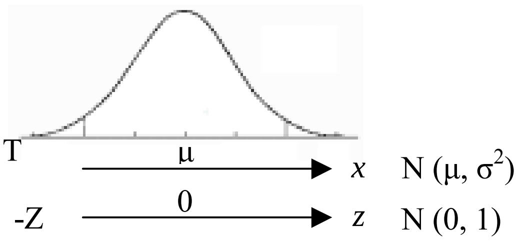

Figure 1. The normal and standard normal distributions of the strength of the links of fibre bundle

Materials and Methods

For the experiments, 30 Tex carded cotton yarn was spun at a spindle speed of 16500 rpm. The spinning tension was measured using a Rothschild tensiometer-2000. This instrument works on the principle of the differential capacitor. Two fixed pins of the tension probe were removed while measuring the spinning tension to avoid twist blockage and consequently yarn breaks. The tension probe was positioned between the front rollers and the yarn thread guide. When the yarn passes over the movable pin, the pressure applied by the yarn causes a change in the voltage which is proportional to the yarn tension. The instrument was interfaced with a computer. The output from the transducer was amplified and processed by the computer using software. A response time (the time interval between successive signals) of 1 ms was selected. Thus it was possible to observe the variation of spinning tension in one revolution of the traveller. The mean breaking force of the yarn was measured using a standard tensile tester. The CV% of the yarn mass was tested with a Uster Evenness tester II. Using the tension measuring system, the tension parametersregarding the average spinning tension & its CV% and the mean value of peak spinning tensions were obtained. The parameters for predicting end breakage rates in ring spinning are given in Table 1.

Table 1. Parameters used for calculating end breakage rates

Parameters, (symbols), units	**value**
Yarn delivery speed, (S), m/min	20
Average length of the links of fibre bundles ($\bar{l}_h$), mm	3
Average time taken to pass a link through the front rollers (t_1), milliseconds	9
Average time required for each rotation of traveller, (t_2), milliseconds	4
Mean breaking force of yarn, cN	375
The coefficient of variation of mass per unit length of yarn, (V), percentage	13.1
Average spinning tension, cN	32
The coefficient of variation of spinning tension, percentage	12.8
Mean value of the peak spinning tension, (T), cN	40

Results and Discussion

Earlier it was shown that each rotation of the traveller introduces five peaks to the spinning tension. But in the present study it was possible to obtain only one peak for each rotation of traveller due to the limitation of the measuring system's response time. It is visible in Table 1 that the average time taken to pass a link through the front rollers is greater than the average time required for each rotation of the traveller. Therefore, each link while passing through the front rollers undergoes at least some peak tensions. From our assumption, the mean breaking force of the link just issuing from the front rollers, which is equal to one-third of the single yarn strength, is of the order of 125 cN. Taking the strengths of these links to follow a normal distribution, using Equation 4, the standard deviation (σ) value would be 16.34 cN. For a break to occur, the strength of the links, which are lower than the value of the peak spinning tension, the standard normal deviation(Z) would come to 5.2. Therefore, to fulfil the condition of end breaks, the strength of the links which are lower than the value of the peak spinning tension would lie at a distance of 5.2σ from the left side of the mean (μ) in the normal distribution curve (Figure

1). Thus using Equations 7 and 8, the probability (P) of the strength of the links lower than the mean value of the peak tension can be solved, which gives the value of P = 1×10^{-7}. This would mean that while passing through the front rollers' nip, one link out of 10^{7} links is the weakest one that causes an end to break. In other words, for every spindle, a break would repeat after a delivery of 30,000 m length of yarn, i.e., after 25 hours excluding stoppage time. Using Equations 2 and 3, the predicted values of end breakage rates per 1000 spindle/h would work out to 40. This predicted value of end breakage rates is approximately the standard norm of the end breaks per 1000 spindle per hour for 30 Tex carded cotton yarn under the machine's normal running conditions.

Possibilities of reducing end breaks in ring spinning

To reduce end breaks, the following aspects should be taken into consideration:

I. Since end breakage in ring spinning is related to slippage of fibres at the spinning triangle as a result of peaks occurring in the spinning tension fibre, the grip at the front drafting rollers should be increased by having a higher top roller pressure. The use of softer cots also enhances the grip at the front rollers. If the total pressure on the rollers cannot be increased, the grip at the front rollers' nip can be improved by reducing the width of the cots.

II. A reduction in friction between ring and traveller could reduce the peak tension during the rotation of the traveller.

III. Measures should be taken to reduce the mass irregularity of yarn straight after carding.

IV. The width of the drafted ribbon at the front roller nip should be reduced.

Conclusions

A simple statistical model has been developed to predict the end breakage rates in ring spinning. Using this model, it is possible to predict the approximate value of the end breakage rate. However, further investigations should be carried out to predict the end breakage rate for different yarn counts, fibre types and blends. The end breaks are very sensitive to the mean yarn strength, yarn strength variation, mean value of the peak spinning tensions and the variation in irregularity of mass per unit length of yarn. Some practical aspects have been considered to tackle the problem of when the breakage rate suddenly shoots up.

References

1. *DeBarr, A. E. and Catling, H. 'The Principals and Theory of Ring Spinning'. P. 149, The Textile Institute, Butterworths, 1965.*
2. *Huang, X. C., and Oxenham, W., 'Predicting end breakage rates in worsted spinning, Part I: Measuring Dynamic yarn strength and Tension', Text. Res. J., 64 (11), 619-626, 1994.*
3. *Huang, X. C., Oxenham, W., and Grosberg, P., 'Predicting end breakage rates in worsted spinning, Part I: A new model for end break prediction', Text. Res. J., 64 (12), 717-722, 1994.*
4. *Hori, Y., 'A Statistical Analysis of Yarn Breakage Rates on a Spinning Frame, J. Textile Mach. Soc. Jpn. 8 (2), 54-59, 1955.*
5. *Kawakami, J., and Hashimoto, M., 'Theoretical Estimation of End Breakage Rate in Spinning, J. Textile Mach. Soc. Jpn. 27 (1), 1-7, 1955.*
6. *Lord, E. "The Characteristics of Raw Cotton, Manual of Cotton Spinning – Volume II, Part- I", P. 232, The Textile Institute, Manchester 1961.*
7. *Peirce, F. T., 'Tensile Tests for Cotton Yarns, Part V: The Weakest Link Theorems on the Strength of Long and Composite Specimens', J. Text. Inst. 17, T355-T368, 1926.*
8. *Broughton, M., Mogahzy, Y. E., and Hall, D. M., 'Mechanism of Yarn Failure', Text. Res. J., 62, 131-134, 1992.*
9. *Salhotra, K. R., 'Mechanism of End Breakage in Ring Spinning'. P. 294, Advances in Technology of Yarn Production, Edited by R. Chattopadhay, NCUTE, IIT Delhi.*

10. *Martindale, J. G., A New Method of Measuring the Irregularity of Yarns with Some Observations on the Origin of Irregularities in Worsted Slivers and Yarns, J. Text. Inst., 36, T35-T47, 1945.*

Acknowledgement

The investigation was carried out at The Department of Textile Technology, Indian Institute of Technology, Delhi, and we are indebted to Dr. K. R. Salhotra for helpful discussions.