END BREAKAGE IN ROTOR SPINNING: EFFECT OF DIFFERENT VARIABLES ON COTTON YARN END BREAKAGE

Apurba Das and Saiyed Muzaffar Ishtiaque

Department of Textile Technology, Indian Institute of Technology,
New Delhi-110 016, India
E-mail: apurba@textile.iitd.ernet.in, ishtiaque@textile.iitd.ernet.in

Abstract

The end breakage in rotor spinning not only reduces the running efficiency of the process, but also deteriorates the quality of the yarn in terms of presence of piecing slubs. A new system has been proposed to classify the end breaks in rotor spinning broadly into seven groups, depending on the configuration of broken ends. By examining the broken end, the probable causes of breakage can be predicted and necessary preventive action can be taken. The rate of end breakage and the proportion of different types of breakages vary with different process variables like yarn count, rotor speed, opening roller speed and residual trash content in draw frame sliver.

Key words:

broken end, end breakage rate, opening roller speed, residual trash content, rotor speed

Introduction

Although rotor spinning is now a well-established manufacturing process, there are problems that must be solved if the full potential of this method of spinning is to be exploited. For example, rotor-spun yarns have low tensile strengths due to their structure, and successful rotor spinning is still restricted to the coarse-and medium-count range. In addition to the yarn values, running behaviour is of great importance for very high-speed rotor spinning, playing a main role in its evaluation. The flow of fibres is interrupted by the process of fibre separation, but the fibres are recollected on the so-called collecting surface of the rotor as a ribbon, which is then converted into yarn by means of the rotating open yarn end. All the foreign bodies in the fibrous assembly, such as neps, bolls, dusts, human hair, plastics etc., are also deposited and pressed by centrifugal force against the collecting surface of the rotor. The density of these impurities is often greater than that of the fibres; it happens that they stay on the collecting surface after the ribbon of fibres has been withdrawn by the open yarn end. By the effect of centrifugal force, the increased mass of the impurity cannot be overcome by the torque of the rotating yarn end, the continuity of fibre flow is interrupted and so the yarn breaks. If the impurity is of small size as compared to that of the fibre assembly, i.e. in case of coarser count, the yarn torque overcomes the increased mass of the impurity, and at the same time the impurity may also be accommodated inside the yarn structure; thus the process of yarn formation continues.

In the rotor spinning, the end breakages are broadly classified into three main groups [1]: tension yarn breaks, spinning yarn breaks and yarn breaks in consequence of sliver breaks, or breaks due to similar interference factors outside the spinning box. The tension yarn breaks are found in the already spun yarn, normally in between the take-off nozzle and take-up rollers. The yarn ends on the yarn package have a blunt appearance, and short broken yarn ends are in general found in the rotor groove. On the other hand, the spinning yarn breaks occurs in the yarn peel-off zone in the rotor groove when continuous fibre spin-in is interrupted. The end breakage due to sliver breaks or other interference factors outside the spinning box can be easily controlled by proper maintenance and good work practice.

In the present paper, a new 7-flod-classification method has been developed to classify the broken ends in rotor spinning. The classification has been done on the basis of broken ends collected from the yarn package, and also by observing the rotor groove after end breakage. We have classified the broken ends simply by observing the tips of the ends collected from the yarn packages, and not on the basis of particle size distribution of the foreign materials. We have also reported the effect of different factors, such as residual trash in draw frame sliver, rotor speed, opening roller speed and yarn count on the end breakage rate and proportion of different types of breakage.

Materials and Methods

A medium grade cotton was used in the study. The cotton fibres were processed through a blow room, carding and two passages of draw frame. The specification of the cotton which was used in the study is as follows:

2.5% S.L	-	24.25 mm
50% S.L	-	11.60 mm
Bundle Strength (g/tex)	-	20.2
Micronaire	-	4.1

For all the samples, the finisher draw frame sliver linear density is kept at 5.37 ktex. The yarn samples are prepared in a rotor spinning machine (Rieter M2/1) with a rotor diameter of 45 mm and a pin type of opening roller.

The yarn samples are prepared by varying rotor speed, opening roller speed, the residual trash content of draw-frame slivers and the yarn count. In order to obtain finisher draw frame slivers with the same fibre properties but different levels of residual trash content, we selected cotton fibre lots from the same variety with similar physical properties but showing variation in trash content. Also, the level of trash extraction in the blow room and the flat speed of card is varied to obtain the draw frame sliver with a wide range of residual trash content. The detail of samples is given in Table 1.

Table 1. Details of samples

Sample code	Yarn count, tex	Rotor speed, rpm	Opening roller speed, rpm	Residual trash content in draw frame sliver, %
BC1	**59.0**	50,000	7500	0.51
BC2	**38.9**	50,000	7500	0.51
BC3	**29.5**	50,000	7500	0.51
BRS1	59.0	**45,000**	7500	0.51
BRS2	59.0	**50,000**	7500	0.51
BRS3	59.0	**55,000**	7500	0.51
BOS1	59.0	50,000	**7000**	0.51
BOS2	59.0	50,000	**7500**	0.51
BOS3	59.0	50,000	**8000**	0.51
BT1	59.0	50,000	7500	**0.28**
BT2	59.0	50,000	7500	**0.51**
BT3	59.0	50,000	7500	**0.76**

Note:

i) Sample codes BC, BRS, BOS and BT are the breakage studies carried out by changing yarn count, rotor speed, opening roller speed and residual trash in draw frame sliver respectively.

ii) Bold letters indicate the variable parameters, other parameters being kept constant.

The method of collecting the broken ends and their classification will be discussed later. A large number of broken ends are collected for classification in different groups. The end breakage rate is studied on the full machine, i.e. for 220 rotors. The study is carried out for four hours continuously, and the total number of ends down is observed during the study. The same study is repeated for ten times, so the total study time per sample is forty hours. The total number of end breaks is then converted into end breakage per 100 rotors per hour. The breakages due to package doffing are not taken into account. The values of end breakage rate and proportions of different classes of end breakages are given in Table 2.

Table 2. Effect of different variables on end breakage rate and proportion of types of breakage

Sample code	Total end breakage per machine in 40 hrs	End breakage rate bks/100 rotors/hr	Proportion of different types of breaks %						
			Type 'A'	Type 'B'	Type 'C'	Type 'D'	Type 'E'	Type 'F'	Type 'G'
BC1	724	8.23	10.6	16.8	6.2	5.4	35.9	12.2	12.9
BC2	1264	14.36	18.1	16.0	6.2	2.2	32.7	11.6	13.2
BC3	2612	29.68	28.3	14.5	8.6	2.0	29.8	6.4	10.4
BRS1	674	7.66	9.2	15.8	10.5	2.4	33.8	11.0	17.3
BRS2	724	8.23	10.6	16.8	6.2	5.4	35.9	12.2	12.9
BRS3	1009	11.47	9.7	16.0	9.8	6.2	29.3	16.3	12.7
BOS1	610	6.93	9.7	11.7	9.0	3.1	39.5	13.3	13.7
BOS2	724	8.23	10.6	16.8	6.2	5.4	35.9	12.2	12.9
BOS3	1107	12.58	9.9	19.8	4.6	6.6	33.6	12.9	12.6
BT1	467	5.31	5.7	19.6	4.2	2.3	41.2	12.9	14.1
BT2	724	8.23	10.6	16.8	6.2	5.4	35.9	12.2	12.9
BT3	1433	16.28	12.4	16.4	9.6	6.5	35.3	10.2	9.6

Note:
A = Broken end with foreign material embedded end; B = Broken end with unopened fibrous end;
C = Broken end with seed coat embedded end; D = Broken end with trash particle embedded end;
E = Broken end with tapered end; F = Broken end with blunt end;
G = Miscellaneous type of breaks.

Proposed Mechanism of End-breakage and their Classification

The broken ends are collected by unwinding approximately fifteen to twenty inches of yarn from the yarn packages. First of all, the rotors are properly cleaned and allowed to run after piecing. During the running of the machine, the rotor heads are identified where the end breakages occur, and the broken ends are then collected immediately from the yarn package. After collecting the broken ends, the left-over deposition inside the rotor and the condition of the suction tube are also examined to assess the probable causes of end breakage. The broken ends are differentiated by both their formation and nature, and different terms can be given for different types of broken ends. The types of end breakages are broadly classified into the following seven different groups, on the basis of their configurations.

Foreign Material Embedded End

These types of foreign materials are generally much coarser than normal cotton fibres, and normally separated out during blow-room and carding. The long and strong fibrous materials, which still remain in the sliver, pass through opening rollers and transport tube, and are deposited inside the rotor groove. As these foreign materials are coarser in diameter, they have very high flexural rigidity, which prevents them from spinning into yarn along with the normal cotton fibre and causes end breakage. These foreign materials are normally attached to broken ends, and sometime remains inside the rotor surface. Figure 1 shows the photograph of **a** foreign material embedded end.

Unopened Fibrous End

The cluster of fibres is normally like a small thick slub, attached either at the tip of the broken end or near to it, as shown in Figure 2. Because of residual grease or imperfect processing, a few fibres are trapped near the path of fibres, and attract other fibres until a fibre cluster is formed [2]; then they are deposited inside the rotor groove along with the other individualised and combed fibres. Analysis of a broken end by gently pulling the fibres out from the cluster shows that the proportion of very short fibres is high, which may be due to the breakage of entangled fibres by the action of the opening roller [3].

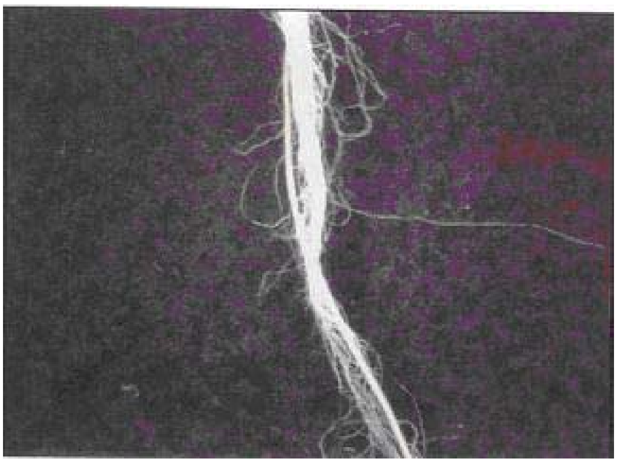

Figure 1. Broken end with foreign material embedded end

Seed Coat Embedded End

This type of end breakage occurs when a large trash particle, such as a larger seed coat, comes along with the cotton fibres and is positioned on the surface of the fibrous ribbon on the rotor's collecting surface, as depicted in Figure 3. The presence of a large-size piece of hard material in the rotor groove causes disturbance at the peel-off zone in the rotor, and causes breakage in the yarn. If in some of the broken yarn ends no such type of large trash particles are present, but such particles are found to be present in the rotor groove, then thise end breakages are also classified to the same category.

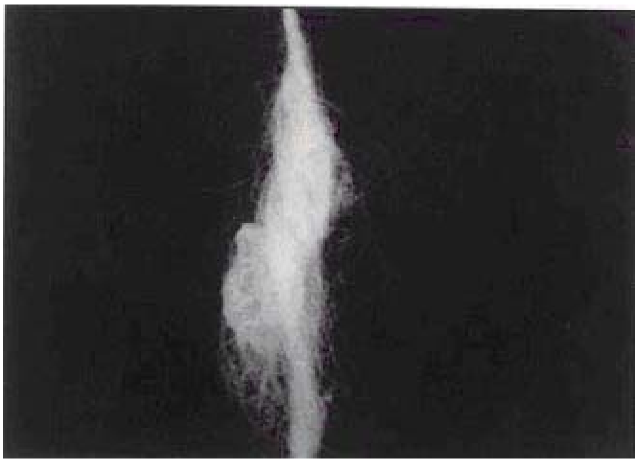

Figure 2. Broken end with unopened fibrous end

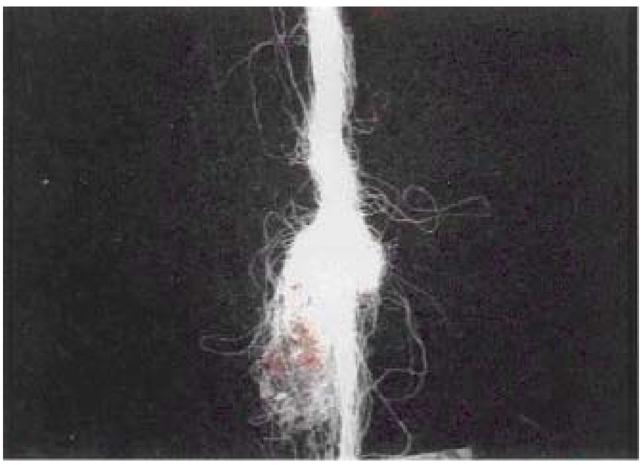

Figure 3. Broken end with seed coat embedded end

Trash Particle Embedded End

This type of yarn breakage occurs mainly for two reasons; when there is blockage or improper suction in the suction tube, or in the case of very light trashy materials such as very small cotton leaves present in large quantity in the feed sliver. When there is any blockage in the suction tube, or the suction pressure is very low, the small trash particles follow the path of the fibres and are deposited inside the rotor groove instead of going to the waste chamber. Very light trash particles also follow the path of the fibres and are deposited inside the rotor groove. Because they are comparatively heavier than cotton fibres, these small trash particles go on accumulating in the rotor groove, and after certain time these particles come out of the rotor groove along with the fibre ribbon and cause yarn breakage. Figure 4 shows the photograph of one such broken end.

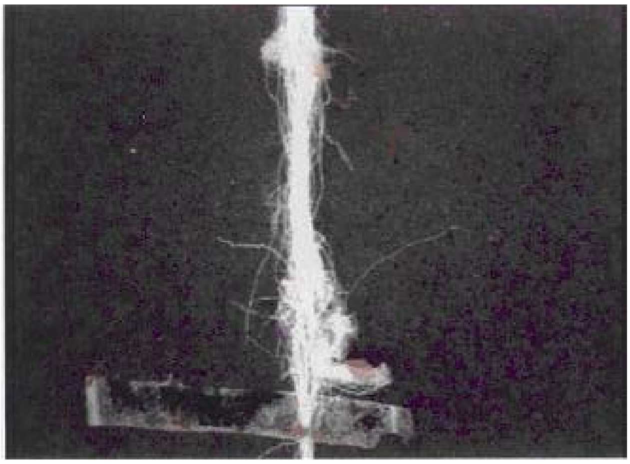

Figure 4. Broken end with trash particle embedded end

Tapered End

In this type of yarn breakage, the tail ends of the yarn are tapered, i.e. the diameter of the yarn gradually reduces towards a pointed tip, as shown in Figure 5. This type of break occurs in the yarn peel-off zone in the rotor, because two forces, i.e. centrifugal force and spinning tension, act in opposite directions. Due to a low twist in the fibre band at the rotor surface, fibre slippage occurs and causes yarn break. In this type of break, the tapered end remains with the package, and the thicker part of the end with the rotor surface.

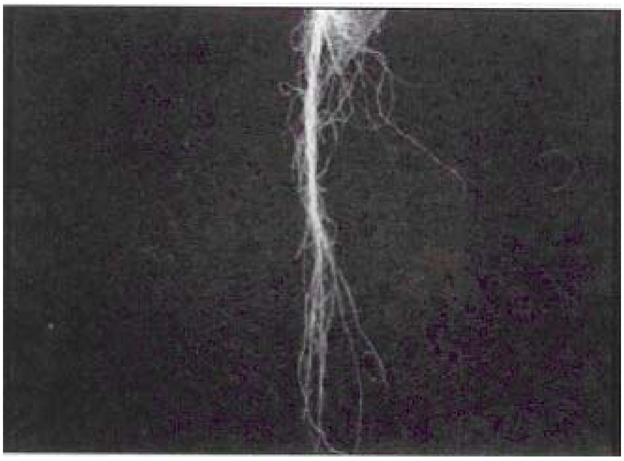

Figure 5. Broken end with tapered end

Blunt End

This type of broken end, when collected from the yarn package, has a tip with a blunt appearance, as if it has been cut or stretch-broken, which is clear from Figure 6. The reason for this type of end breakage is excessive spinning tension, which causes higher tension between the delivery and the winding zone, and causes the breakage in the yarn at its weakest place. In almost all the cases, short broken yarn ends are found in the rotor grooves, which shows that the yarn breakages might have taken place in the zone between the take-off nozzle and the take-up rollers.

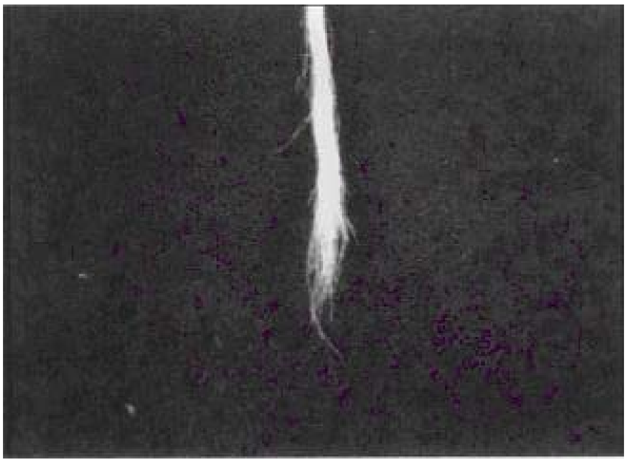

Figure 6. Broken end with blunt end

Miscellaneous Type

This type of end breakage does not fall in any of the above categories. There are various reasons for this type of end breakage. These breakages can occur due to any faulty machine parts like the rotor, because of vibration in any machine components, or any other external interference.

Results and Discussion

Effect of Yarn Count on End Breakage

Table 2 shows that as the count of yarn become finer, the end breakage rate increases drastically. As the count of the yarn becomes finer for a particular fibre fineness, there will be a lower number of fibres in the yarn cross section reaching closer to the spinning limit, which causes an increase in end breakage.

It is also clear from Table 2 that there is a consistent increase in the proportion of breaks with foreign fibre embedded ends as the yarn count becomes finer. In the finer yarn, the number of fibres in the cross-section is low, so the presence of a coarse foreign material creates more interference at the peel-off point than in the case of coarser yarn. On the other hand, the break with an unopened fibrous end reduces marginally as the yarn count becomes finer. This is due to improper individualisation at the opening roller zone due to higher feed rate in case of coarser counts. The proportion of breaks with a seed coat embedded end shows a tendency to increase as the count of yarn becomes finer, which is due to greater interference of large trash particles in the yarn cross-section of finer yarn. A yarn break with a trash particle embedded end increases in the case of coarse yarn, because the high feed rate of fibre at the rotor groove causes the flow of trash particles to accelerate; thus, the chances of the suction tube chocking will be higher, and this will allow trash particles to go along with the fibre on the rotor surface, causing high end breakage. As the count of yarn becomes finer, the break with the tapered end decreases. This is mainly due to a higher centrifugal force and spinning tension for coarser counts, which cause fibre slippage at peeling-off point due to low level of twist at that particular point. As the yarn count becomes finer, the break with blunt end decreases, because in the case of finer yarn, the winding tension reduces and will be responsible for lower end breakage. No specific trend is observed in the case of miscellaneous type break as the yarn count changes.

Effect of Rotor Speed on End Breakage

It is clear from Table 2 that with the increase in rotor speed, the yarn breakage rate increases. A higher rotor speed causes powerful centrifugal forces on the fibres in the rotor groove [4], resulting in poor spinning stability and an increase in yarn tension, which in turn causes high yarn breakage.

Table 2 also shows that no clear trend is observed for breakages with a foreign matter embedded end, with an unopened fibrous end, with a seed coat embedded end or with a tapered end with the increase in rotor speed. It is also observed that the proportion of type of breaks with a tapered end is very high, which shows that a large number of yarn breaks occur due to disturbance in the fibrous strand inside the rotor groove. With the increase in rotor speed, the breaks with a trash particle embedded end and the breaks with a blunt end increase consistently. At lower rotor speed, the small trash particles are constantly taken away by the yarn, due to the comparatively low centrifugal force acted on these trash particles, and become entrapped within the yarn structure, causing less breakage. But at higher rotor speed, these small trash particles continue to be deposited and accumulated inside the rotor groove due to higher centrifugal force, and after saturation point all these accumulated trash particles inside the rotor groove try to come out along with the fibrous strand, causing yarn breakage. So far as the breaks with a blunt end are concerned, with the increase in rotor speed the spinning tension also increases, due to increase in centrifugal force on the fibre stand and yarn winding speed, resulting in an increase in this type of breakage.

Effect of Opening Roller Speed on End Breakage

It is evident from Table 2 that with the increase in opening roller speed the end breakage rate increases. As the opening roller speed increases, the carrying factor (i.e. the effective number of wire points per unit time) increases, which in turn increases the opening efficiency of the opening roller [5]. Owing to the better opening of fibres, it can be expected that the fibre tufts of smaller size and uniform dimensions are fed into the transport tube and thus into the rotor groove. But at the same time, too high an opening roller speed results in higher rotor deposition [6,7], and fibre orientation inside the transport tube also deteriorates drastically [8], which causes higher end breakage.

It is also evident from Table 2 that the proportions of foreign matter which is embedded in the broken ends and blunt broken ends do not show any specific trend with the increase of opening roller speed. The proportion of breaks with unopened fibrous ends increases with the increase in opening roller speed. This can be explained on the basis of higher rotor deposition and deterioration of fibre orientation (clustering) inside the transport tube. Seed coat embedded broken end shows a decreasing trend with the increase in opening roller speed. This is mainly due to better separation of seed coats from the fibre, which thus reduces the deposition of such seed coat particles on the rotor groove. But the breaks due to a trash particle embedded end shows an increasing trend with the increase in opening roller speed. This is mainly due to better separation of trash particles, and thus a higher deposition of trash particles on the rotor groove. Table 2 further shows that the maximum proportion of broken ends belongs to the tapered end category, and shows a decreasing trend with the increase in opening roller speed. However, the miscellaneous type of break shows a marginally decreasing trend with the increase in opening roller speed.

Effect of Residual Trash Content in Draw Frame Sliver

Table 2 also shows that with the increase in residual trash content in draw frame sliver, the end breakage rate increases, which is due to deposition of more micro-dust and trash particles inside the rotor groove. A similar trend was also observed by earlier researchers [9, 10].

The proportion of breakages with a foreign material embedded end, a seed coat embedded end and a trash particle embedded end are found to be increased when the residual trash content in the draw frame sliver increases. All of the above three types of breakages are related to the presence of foreign matter in the sliver, so more trash particles in the cotton fibre means more interference and thus more breakages. But breakages due to a seed coat embedded end and a trash particle embedded end are mainly due to the entrapment of seed coats or trash particles with fibres. The proportion of the remaining types of breaks shows a decreasing trend with the increase in the residual trash content of draw frame sliver.

Conclusions

The type of end breakage can be broadly classified into seven different groups based on the configuration of the broken ends, and the probable reasons of the yarn breakage can be predicted by observing the broken ends.

Keeping all other parameters the same, when yarn count becomes finer, the end breakage rate increases. The proportion of end breakage due to the interference of fibrous materials increases drastically in the case of finer yarn, whereas breakages due to the cluster of small trash particles lessen. With the increase in rotor speed, the end breakage rate increases consistently. As the rotor speed increases, the proportion of end breakages with a trash particle embedded end and with a blunt end increases.

With the increase in opening roller speed, the end breakage rate increases. The end breakages due to a seed coat embedded end reduces with the increase in opening roller speed, whereas the breakages due to small trash particles embedded end increases.

Residual trash content in draw frame sliver has a significant effect on the end breakage rate, and the end breakage rate increases with the increase of residual trash content in draw frame sliver. Also the breakages with a foreign material embedded end, with a seed coat embedded end and a trash particle embedded end, which are related with the foreign particles present in the cotton fibres, increase with the increase in residual trash content in draw frame sliver.

References

1. *Trommer G, 'Rotor Spinning', Deutscher Fachverlang, Frankfurt/Main, Germany, 1995.*
2. *Cizek L, Supervision of the BD 200 Spinning machine, cited in "Open-end spinning" (Elsevier scientific publishing company, New York) 1975, 319*
3. *Saxena A K, Internal and surface structure of rotor-spun yarn, Ph.D. thesis, IIT –Delhi, 1991.*
4. *Ishtiaqe S M & Saxena A K, Indian J Fibre Text Res, 23 (1998) 209.*
5. *Ishtiaque S M & Saxena A K, Indian J Fibre Text Res, 23(1998) 141*
6. *Lawrence C A & Tahiroghi S, Indian J Fibre Text Res, 15 (1990) 108.*
7. *Simpson J & Murray M F, Text Res J, 49(1979) 506.*
8. *Harlock S C, An investigation into feed mechanisms for open-end spinning machines, Ph.D thesis, The university of Leeds, 1977.*
9. *Krishnan K B, Pillay K R P & Balasundaram D, The effect of trash content in draw frame slivers on open end spinning performance and yarn quality, paper presented at the 28th Joint Technological Conference of ATIRA, BTRA, SITRA and NITRA, (SITRA, Coimbatore), February 1987, 6.1.*
10. *Sood M C & Khurana S K, Some studies on rotor spinning, paper presented at the Seminar on Rotor Spinning, IIT Delhi, September 1981, 104.*

∇∆