ANALYSIS OF THE MECHANISM OF FIBRE LAPPING ON RING SPINNING MACHINE

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ABSTRACT

Ring spinning is the most popular method for the production of the cotton and synthetic staple fibers and their blends. The end breakage during the production is rather rare event, but the repair increases labor load and raw material waste. The fibre lapping on the drafting system rollers makes this problem more acquit. The mechanism of fibre lapping as well as the methods for its reduction are given.

Keyword: Ring spinning, Drafting system, Fibre lapping, End breaks.

1. INTRODUCTION

On ring spinning machine the end breaks are a known phenomena that affects both the cost and quality of the produced yarn. Several investigators indicated the effect of the end breaks on the yarn cost [1], [2]. On the other hand, the causes of the end breaks have been studied [3]. Shiffler [1] shows that the end is expected to remain in the broken end collector until it is repaired. However, a fibre occasionally sticks by the top roller or the bottom roller continuously capturing more fibers to form fibre lapping. Since the repair of such case will take longer time than it is usually required this will be a significant cost factor [4]. The incremental cost per 1000 spindle hour is found to increase as a function of the end breaks and warp frequency [1]. The effect of some fibre parameters as well as spinning frame variables are investigated by Shiffler [4]. Soliman [5] studied the effect of the relative humidity and temperature on the fibre lapping for polyester and cotton blends. He mentioned that the lapping is less at low values of the relative humidity.

Nevertheless, the mechanism of the fibre lapping on ring spinning machine still requires further investigation to introduce the possibilities for its control, and this is the aim of the present work.

2. MECHANISM OF FIBRE LAPPING

When an end break happens on ring spinning machine, the fibre bundle comes out- side of the nip point and usually is directed to the nozzles of the broken end collector. The broken ends are easily sucked in the collector at the ends of the machine. Also there is a cleaning system represented by the top roller clearer that rotates by the friction with the top roller.

However, for some reason or another, the fibers will collect on the surface of the top or bottom roller.. Consequently, the following are the possibilities for the movement of the amount of fibers when the fibre breakage occurs:

- Q_1 mass of the fibers lapped on the top roller clearer
- Q_2 mass of the fibers lapped on the top roller
- Q_3 mass of the fibers moving into the direction of the aspiration system
- Q_4 mass of the fibers lapped on the bottom roller

Figure (1) represents a schematic of possible fibre movement after the end breakage.

Since at any moment the total number of fibers coming out of the drafting system is Q then:

$$Q = Q_1 + Q_2 + Q_3 + Q_4 \qquad (1)$$

Generally the fibers will tend to move down towards the aspiration system.

Assume:

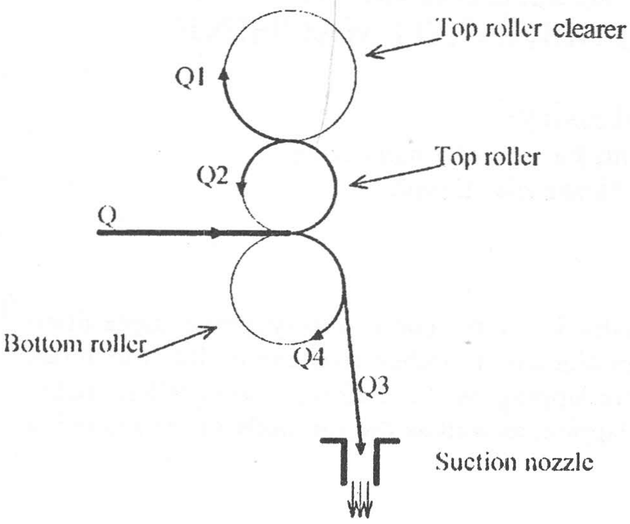

Figure 1. Standard arrangement of top roller clearer.

$$Q_1 = r_1 Q_2 \qquad (2)$$

$$Q_3 + Q_4 = KQ \qquad (3)$$

$$Q_4 = r_2 Q_3 \qquad (4)$$

where:

K is a portion of fibers sucked by the aspiration system
r_1 is a clearing factor of the top roller
r_2 is a transfer factor of the bottom roller

Then the values of the amount of fibers on each part of the front pair will be:

$$Q_1 = Q_1 (1\text{-}K) \left(\frac{r_1}{1+r_1}\right) \qquad (5)$$

$$Q_2 = Q \left(\frac{1-K}{1+r_1}\right) \qquad (6)$$

$$Q_3 = Q \left(\frac{K}{1+r_2}\right) \qquad (7)$$

$$Q_4 = Q \times K \left(\frac{r_2}{1+r_2}\right) \qquad (8)$$

The values of Q_1, Q_2, Q_3, Q_4 as a function of K are given in Figure (2) for the case when $r_1 = r_2 = 100$. For K =1 most of the fibers will be lapped on the bottom roller. No fibers will be directed to the top roller. But at
K= zero all the fibers will be transferred to the top roller and due to the high value of r_1 most of the fibers will be cleared out. No fibre wrapping on the top roller. For the values of $0 \leq K \leq 1$ the values of Q_1, Q_2, Q_3, Q_4 will vary as a function of K. Figures from (3) to (5) show the change of Q_1, Q_2, Q_3, Q_4 for the different values of r_1 and r_2 which are the real cases which usually occur during spinning. Even in most cases after the end breakage when the fibers are sucked into the nozzle of the broken end collector, for some reason or another, a fibre will change its direction and some fibers may wrap on the top or bottom roller. Thus, K will continuously change with the time as well as r_1 and r_2. In all cases the acceleration of fibre lapping mechanism can be based on the assumption that at any moment a ring of fibers on the top or bottom roller creates a sufficient friction force between it and the ribbon of the drafted fibers which will lead to more fibre lapping on the roller due to the cohesion force. This will accelerate building of another layer and ending by lapping of all the fibers coming out from the drafting system. For lapping on the top roller both K and r_1 are reduced with time, while in the case of the bottom roller lapping r_2 increases as well as K. The condition for lapping on the top roller clearer when K= 0 is $(1/r_1)=0$.

3. EXPERIMENTAL INVESTIGATION OF THE MODEL OF LAPPING.

In order to verify the above model, several mills at Alexandria area, Egypt, were investigated to determine the number of lapping during the period of time equal to the patrol time (30 min.). The number of the end breaks as well as the lapping occurrence was determined. Table (1) shows the average number of fibre lapping and its location as a function of the time for different mills. In most cases when the ends break, the fibre bundle is sucked into the nozzles of the broken end collector system while the next frequent occurrence is of fibre lapping on the top roller followed by the top roller clearer. However, the analysis of the individual results show that the most significant parameters affecting fibre lapping on the top roller are:

- value of the negative pressure
- design of the nozzles
- type of raw material (cotton, polyester, and their blends)
- different spinning machine parameters.

Therefore, there is a necessity to investigate how to increase the value of factor K through the study of the efficiency of the broken end collector system or to increase factor r_1, i.e. to increase the efficiency of the top roller clearer.

Table 1. The percentage of fibre distribution on the different elements of the drafting system as a function of time.

Position	Time (min.)					
	5	10	1	20	25	30
Suction system	40	45	42	40	42	40
Top roller	21	20	25	27	26	25
Top roller clearer	21	20	21	22	20	20
Bottom roller	18	15	12	11	12	15

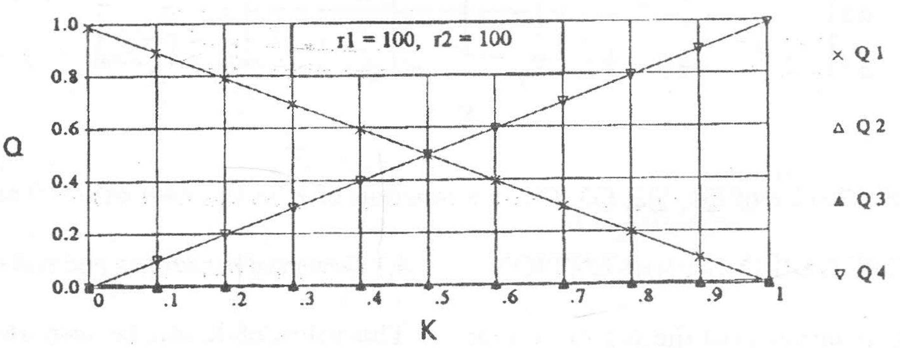

Figure 2. Change of Q1, Q2, Q3, Q4 as a function of K in the case of r1=100 and r2=100.

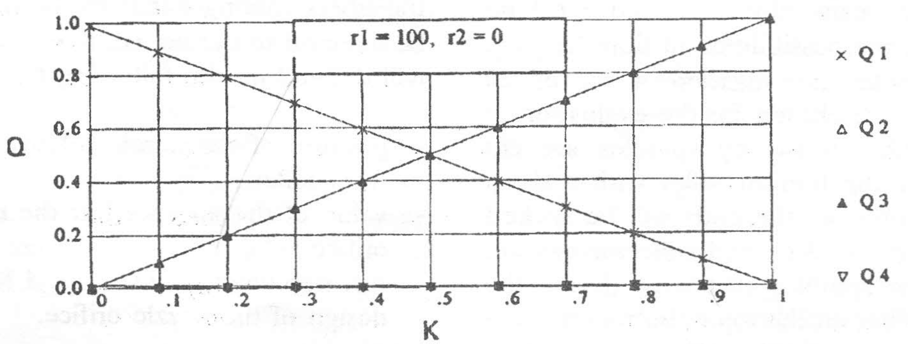

Figure 3. Change of Q1, Q2, Q3, Q4 as a function of K in the case of r1=100 and r2=0.

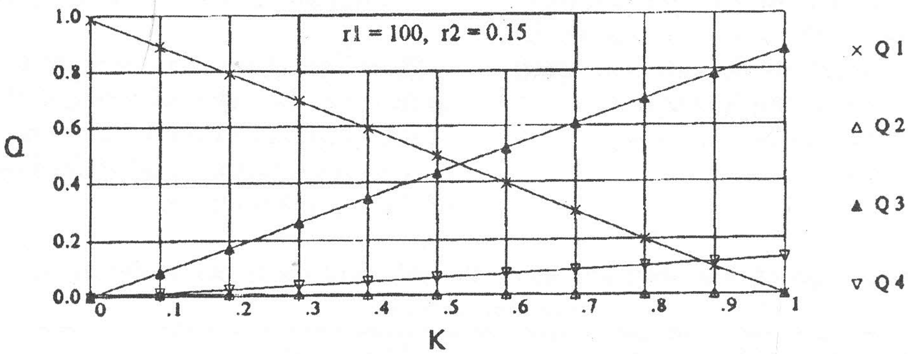

Figure 4. Change of Q1, Q2, Q3, Q4 as a function of K in the case of r1=100 and r2=0.15

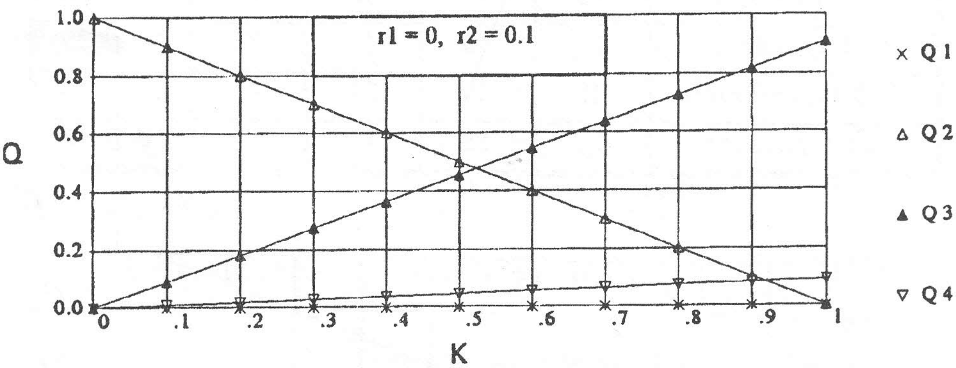

Figure 5. Change of Q1, Q2, Q3, Q4 as a function of K in the case of r1=0 and r2=0.1

4. MEASURES FOR LAPPING PREVENTION

Lapping of the fibers either over the top or bottom roller can increase the time for the repair of the end breaks to even more than 10 - 20 times. Consequently, the main object of the machine design is to reduce the possibilities of fibre lapping. For the experimental investigation a set of 20 adjacent spindles were chosen for the evaluation of the rate of lapping. All twenty spindles are cut immediately under the bottom roller with a sharp scissors. Consequently, all the ends will be sucked by the nozzles of the broken end collector system. The number of the spindles that wrap during the proceeding time either on the top or bottom roller is recorded. According to Shiffler [2] the procedure should be repeated three times.

4.1 *Design of the broken end collector for less lapping:*

The value of K can be increased through a better design of the nozzles of the pneumatic broken end collector so that in the case of the end breakage all the fibers coming out from the drafting system will be directed to the no, i.e. $K = 1$ and R_2 = zero. This will depend on the following factors:

- position of the nozzle relative to the nip of the front roller
- value of the air speed at the entrance of nozzle orifice
- tuft size (yarn count)
- design of the nozzle orifice.

Besides the design of the broken end collector, the most important parameters are the type of the nozzle system and its cross-section area shape as well as nozzle location relative to the nip point of the drafting system. The nozzle system can be divided into individual or flutes [5]. Figure (6) gives the classification of nozzle location relative to the front roller. The efficiency of the broken end collector depends on the value of the maximum speed at the nozzle orifice and also on the position of the nozzle relative to the front pair of rollers. The value of the axial air velocity profile for a circular cross-section nozzle depends on the distance from the nozzle orifice, an example is given in Figure (7). Consequently, the location of the nozzle should be so that its axis coincides with the direction of tangent to the bottom roller (a-b). Any inclination requires a higher air velocity value V_o at the nozzle orifice and leads to an increase in the suction power for the effective suction of the broken ends. The value of the air draft force acting on the fibrous tuft coming out of the delivery rollers varies according to the value of the negative pressure ΔP and type of the nozzles. Figure (8) illustrates the value of the air draft force acting on the fibre tuft as a function of the negative pressure used. For a different nozzle shape there is a minimum value of the negative pressure ΔP_{min} which is sufficient to suck the fibers to the broken end collector when the end breakage occurs. This indicates the performance of the different designs of the broken end collector systems. The experimental investigation of the factors affecting the minimum value of the negative pressure at the nozzle of the broken end collector is found to be a function of the delivery speed. Figure (9) shows the change of the relation between ΔP_{min} and the delivery speed for several usually used types of nozzles. This points out that the increase in the delivery speed should be followed by an increase in the air speed value at the orifice of the nozzle, i.e. increasing the suction almost proportional to the delivery speed of the front roller. Thus, the value of negative pressure should be more than ΔP_{min} to ensure the value of K = 1.

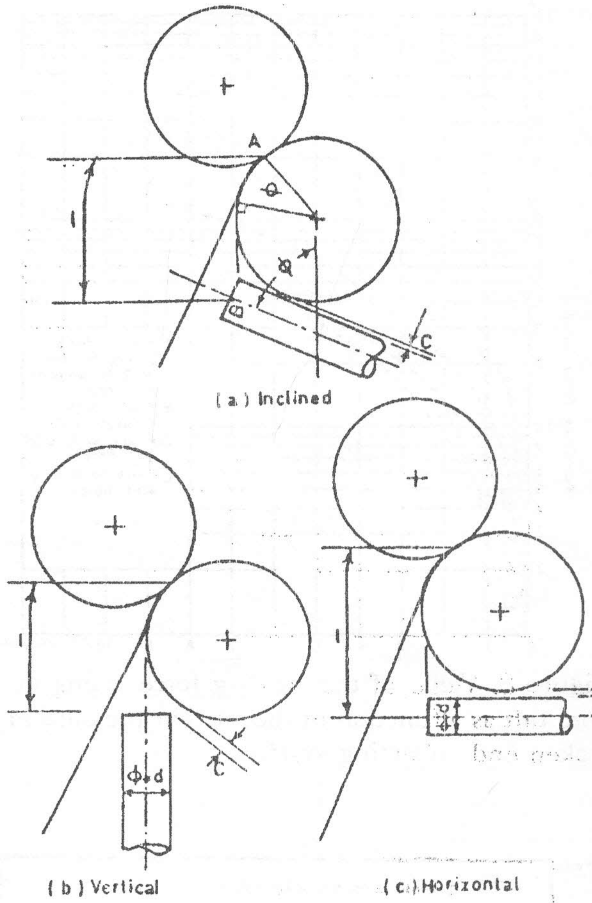

Figure 6. Classification of the different positions of the suction nozzles.

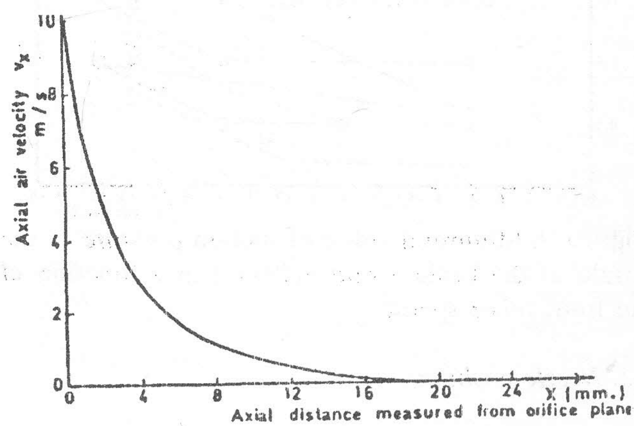

Figure 7. Relation between the axial air velocity and the distance from the orifice of the suction nozzle.

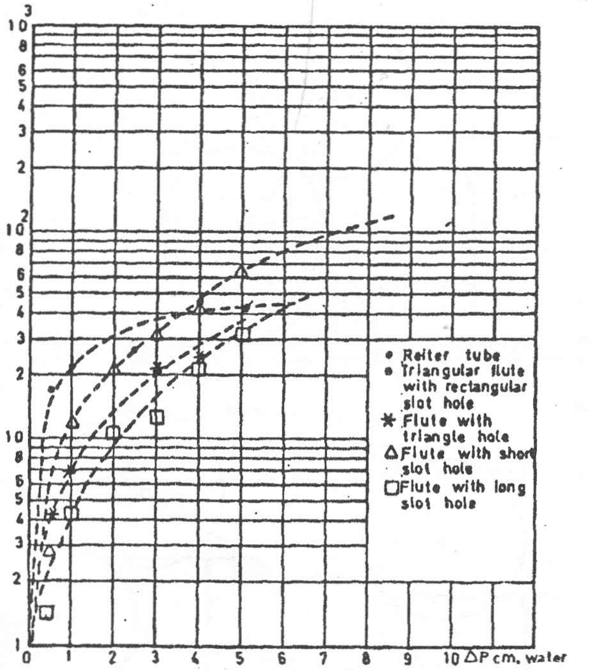

Figure 8. Value of the air drag force acting on the fibre tuft as a function of the suction pressure in the broken end collecting system.

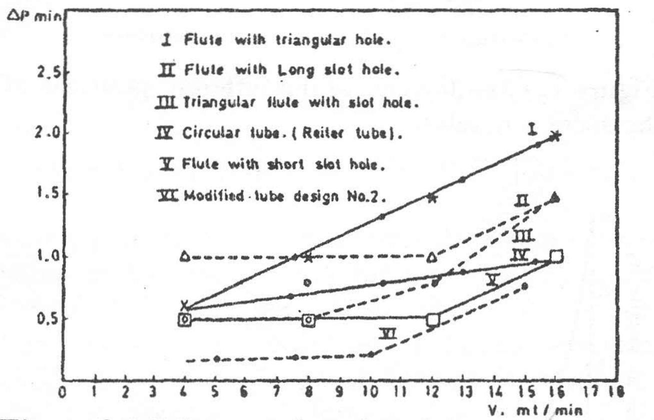

Figure 9. Minimum value of suction pressure in the nozzle of the broken end collector as a function of the front roller speed.

4.2. *Nozzle position:*

The experimental investigation indicates that in all cases nozzle orifice axial line should be located tangential to the bottom line as near as possible to the nip of the front rollers. Higher negative pressure is required upon the deviation from this position on inclination for the successful suction of the fibers at the breaks. Otherwise K will be of a small value and the possibility of top roller lapping increases. Figure (10) gives the effect of the vertical location of the nozzle which suggests that higher negative pressure is required when the nozzle is moved away from the nip points. Thus, ΔP_{min} is directly proportional to the distance Y.

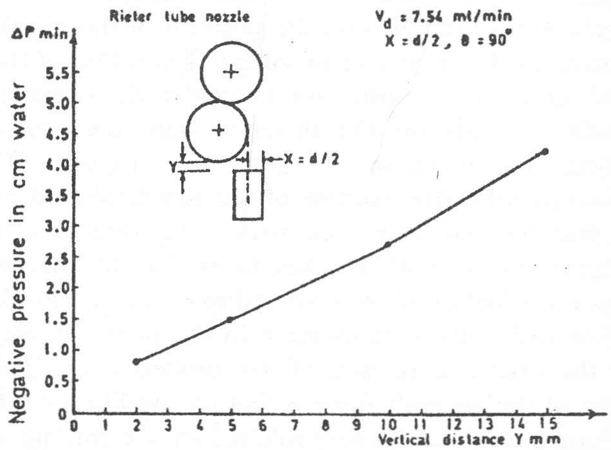

Figure 10. Minimum value of suction pressure in the nozzle of the broken end collector as a function of vertical distance from its orifice.

4.3. *Top roller clearer design for less lapping:*

As mentioned in the case of small values of K, most of the fibers will move with the surface of the top roller and some of them will be cleared with the top roller clearer by wrapping on it. The remained fibers will lap on the top roller and come to the nip of the bottom roller. Then it will collect more fibers, and rapid change of number of fibers on the top roller results in complete lapping on the top roller. The process of lapping on the top roller occurs in this case ($K = 0$, $r_2 = 0$, r_1 is of small value). Thus, it is required to increase the value of r_1 to prevent top roller lapping when the broken end collector system fails to suck all the fibers. Some suggestions were tried to solve this problem:

i- *increasing the contact area between the top roller and clearer roller.*

This can be obtained by using cushion of soft synthetic rubber to cover the top roller clearer under a woven fabric. The suggested design of the top roller is shown in Figure (11). This will increase the contact area between the top roller and its clearer roller leading to better transfer of the fibers to the surface of the top clearer roller due to the high coefficient of friction of a woven fabric. The protruding fibers on the surface of the clearer roller will help in brushing the fibers from the top roller surface and take them away with the moving surface of the top roller clearer. Thus, the percentage of the lapping on the top roller will be reduced keeping most of the fibers to be sucked by the broken end collector system. Table (2) shows the change of the percentage of the ends sucked by the nozzles on ring spinning machine when the end beaks occur as a function of the time using a normal top roller clearer and the suggested design of the top roller clearer. From the results it is clear that during the patrol time (30 min.) about 90% of the broken ends are successfully sucked by the broken end collector system using a new top roller clearer design against only 60% using for the normal cleaners.

Table 2. The percentage of spindles having lapping on the top roller or sucked in the suction system as a function of time.

Time	Old Design		New Design	
(min.)	Top roller	Suction System	Top Roller	Suction System
0	-	100	-	100
5	15	85	-	-
10	15	85	-	95
20	20	67	5	90
30	30	60	10	90
50	40	55	-	-
75	50	40	25	70
100	55	35	-	-

The above results verify that a suggested top roller clearer will reduce the possibility of the top roller lapping through better removal of the fibers at the point of contact preventing the mechanism of lapping to start pulling more fibers from the coming bundle at the nip area.

ii - *eccentric top roller*

In order to improve the efficiency of the top roller clearer to transfer the fibers from the top roller surface to its surface, an eccentric top roller clearer is used This will give a variable rotating speed of the top roller clearer changing the pressure between the top roller clearer and the top roller at the point of their contact. Consequently, the friction between the fibers will vary increasing the probability for the fibre to be cleared. Table (3) gives the percentage of the ends sucked by the nozzles and that lapped on the top roller as a function of time in the case of using the eccentric clearer roller compared with a normal one. The use of the eccentric top roller clearer gives better results since it reduces a possibility of lapping during the patrol time (30 min.).

Table 3. The percentage of the spindles having lapping on the top roller and sucked in the suction system as a function of time.

Time	Old Design		New Design	
(min.)	Top roller	Suction System	Top Roller	Suction System
0	-	100	-	100
5	0.5	95	-	-
20	20	80	-	-
30	20	75	-	95
60	40	57	20	80
75	55	40	20	80
100	60	35	20	75

iii- *Belt driven top roller clearer*

In the case of processing the polyester, the lapping on the top roller can hardly be removed, and damage of the cots usually happens. Besides, more time is necessary to repair the broken ends. The suggested design is to make the removal of PES fibre more easier from the top roller. This is obtained by driving the top roller clearer in the opposite direction of that of the top roller by using an elastic belt on both sides of the top roller and its clearer as illustrated in Figure (12). In this case the fibers coming with the top roller will be transferred totally to the surface of the top roller clearer and come back to the surface of the top roller moving towards the nipping area between the top and bottom roller and bringing all the fibers in the same path as discussed above. This will prevent the top roller lapping and forming a cake of fibers around the top roller and its clearer. The experimental verification of the above design indicates its validity. Figure (12) shows also a photo of the cake formed after the end breakage which can be easily removed.

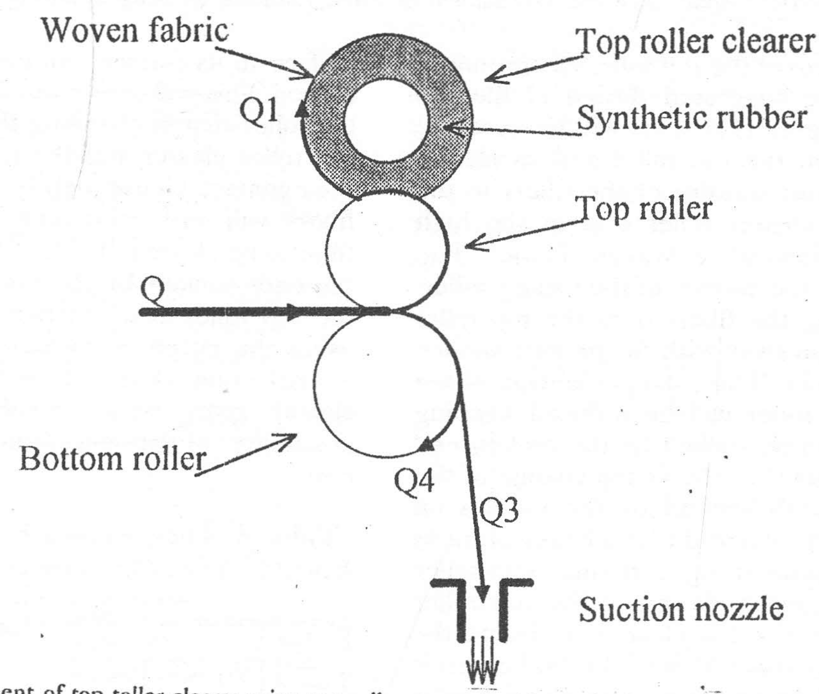

Figure 11. Arrangement of top toller clearer using top roller covered with synthetic rubber layer under the woven fabric.

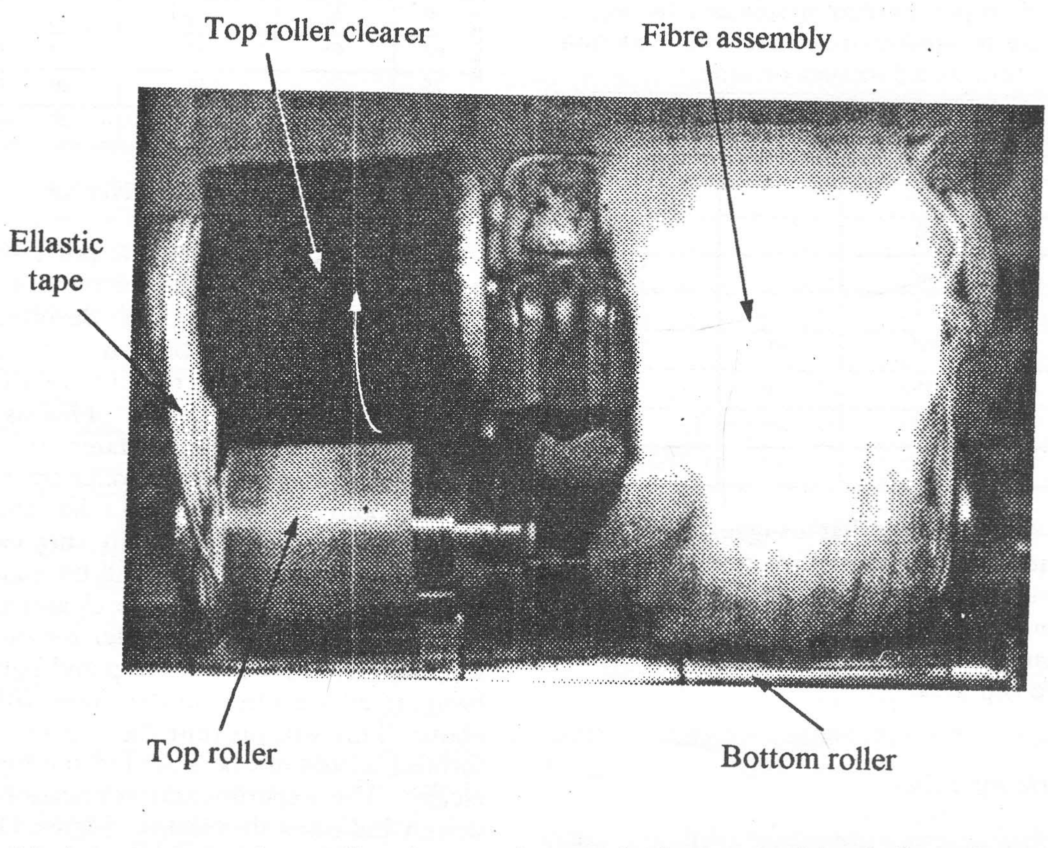

Figure 12. Arrangement of top toller clearer using an elastic tape to drive it from the top toller

5. CONCLUSION

The problem of top roller lapping is investigated to indicate the mechanism of fibre lapping on ring spinning machine as it is an inherent phenomena in such spinning system. Some measures are given to reduce the roller lapping. These are summarized into the following points:

1. better design of the broken end collector system
2. choice of the suitable value of negative pressure at the nozzle sufficient to collect the fibers when the end break occurs
3. modification of the top roller clearer design. The above suggestions help to reduce the possibility for fibre lapping on ring spinning machines when the end breaks occur.

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