THE ABRASION CHARACTERISTICS OF COTTON YARNS

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Abstract

There is a general opinion that open end spun cotton yarns are more abrasive than their ring spun counterparts. The major "evidence" for the differences between the two yarn types is the greater attrition suffered by machinery parts (such as knitting needles) when processing rotor yarns. While these opinions are founded on the claims from the industry, there is little published data to support these views.

The paper describes an investigation into the role of spinning technique on the abrasiveness of yarns. Open-end yarns produced at different production speeds were compared with the equivalent ring spun yarns using a Lawson-Hemphill CTT tester. The abrasiveness was assessed by running the yarn over a wire and determining the length of yarn needed to break the wire.

The role of fiber type, machine type, production speed, and twist level are assessed and the results from the tests are collated with data obtained from tests on "commercial" yarns, which were obtained from the industry.

Introduction

The Constant Tension Transport (CTT), developed by Lawson-Hemphill, is a versatile machine that allows a variety of yarn tests to be run just by utilizing different "attachments". With these additions, the CTT is able to run the following tests:

- Yarn-to-yarn friction;
- Yarn-to-metal friction;
- Yarn on metal abrasion;
- Lint generation; and
- Breaking strength.

The above list only names a few of the CTT's capabilities. The machine is also unique because of its ability to keep the input tension constant throughout a particular test. The input tension can be set to the desired tension, in grams, and a lever arm adjusts/corrects for any changes in tension as the yarn is removed from the package. The test speed and the percent elongation imposed on the yarn are also adjustable.

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For this research, the attachment for testing yarn on metal abrasion was used. This attachment allows the yarn to pass over a copper wire and the machine measures the meters of yarn needed to break the wire. A weight is used to keep a preset tension on the copper wire. Photo 1 is a photograph of the CTT with the yarn abrasion attachment connected. Photo 2 is a close up of the abrasion attachment.

The attachment to the right of the abrasion attachment is a tensiometer, which can be used to measure the output tension of the yarn. Figure 1 is a diagram of the abrasion attachment. The yarn comes in under *Tension 1*, which is held constant by the CTT, then passes under the first frictionless pulley. From that point, the yarn runs across the copper wire and then under the second pulley. The yarn leaves the attachment under *Tension 2*, which is then measured by the tensiometer.

Experimental Design

In order to set up a "standard" with which to compare ring and rotor yarns, a series of trials were run with different yarns. Possible variables for the testing procedure were 1) yarn speed, 2) yarn tension, and 3) weight on the copper wire. During the preliminary trials one variable was changed while the other two were kept constant. This was done in order to achieve a "standard" which takes a "reasonable" time but is not too lengthy. The conditions also had to be acceptable for all yarns.

For the first set of tests, the yarn tension was changed, and the yarn speed and weight on the copper wire were kept constant. Yarns were tested at tensions from 40 grams to 70 grams in 10-gram increments. During the second set of tests, the weight applied to the copper wire was changed and the speed and input tension were kept constant. The weight on the wire was changed between 100 and 300 grams. The final tests kept the input tension and the wire weight constant and changed the yarn/test speed. The three test speeds used were 180, 270, and 360 meters/minute.

From considerations of the time required for testing and the ability of all yarns to be tested under these "standard" conditions, the following conditions were adopted for all future comparison trials:

- Test Speed 360 m/min
- Input Tension 60 grams
- Weight on Wire 200 grams

Yarn Production

The yarns used for testing the effects of spinning system, yarn structure, wax, and twist were produced in the Short Staple Spinning Lab at the College of Textiles. Only new, 100% cotton was used to produce the sliver for the rotor yarns, as well as the roving for the ring yarns. For the open-end yarns, several different rotor speeds were used on both the Rieter R1 and Schlafhorst SE9 spinning frames. The Schlafhorst yarns were spun using five different rotor speeds. The slowest was 80K and the speeds were increased by 10K up to the fastest of 120K. The Rieter yarns had rotor speeds of 60K, 72K, 80K, 92K, 102.8K, 110K, and 122K. The same rotor size was used on both machines, and ring spun yarns of the same count were produced for comparison. A Saco-Lowell Spinomatic with SKF draft change over was used to spin the ring spun yarns. All yarns had an approximate linear density of 20/1 Ne.

Yarn Structure

Samples of open-end spun yarns produced using different rotor speeds were examined under microscope to access the extent of belts. This was done by counting the number and size of belts in 1 cm of yarn. The schematic in Fig. 2 below shows how the belt extent was calculated.

Measuring the extent of the belts allows that part of the yarn structure to be compared to and associated with the abrasiveness of the yarn.

CTT Test Results

Influence of Spinning System on Abrasiveness

Using the "standard" conditions discussed previously, tests were performed that would access the effects of:

- Spinning system;
- Spinning speed;
- Belts; and
- Twist.

Figure 3 shows the average abrasion length associated with yarns produced at different rotor speeds by both the Rieter and Schlafhorst spinning frames. The single point in the bottom left corner is an average of all the ring spun yarns tested. It can be seen that rotor speed has a variable effect on abrasiveness. The Rieter yarns show a slight trend of increased abrasiveness as rotor speed increases, however, this cannot be said for the Schlafhorst yarns due to the R^2 value of 0.089. It can, on the other hand, be said that the Schlafhorst yarns were the least abrasive, and that both sets of rotor yarns (with the exception of the Rieter yarns above 102K) were better than the comparable ring spun yarns.

A t-test was completed to compare the means of the Schlafhorst and Rieter yarns and determine whether the means were significantly different. Because different rotor speeds were used, only the yarns with comparable rotor speeds were used for the t-test. The three sets of means used were the 80K from both Rieter and Schlafhorst, 100K from Schlafhorst and 102.8K from Rieter, and 120K from Schlafhorst and 122K from Rieter. The analysis shows that *the null hypothesis: mu1-mu2=0* <u>cannot be rejected</u> in favor of the *alternative hypothesis: means not equal*, at a 95% confidence interval for the Rieter and Schlafhorst yarns produced with a rotor speed of 80K. However, the null hypothesis <u>was rejected</u> for the other two sets of mean abrasion lengths. This shows that the means were not significantly different at a rotor speed of 80K but were significantly different at 100K and 120K, which is clearly evident from the figure. A t-test was also done on the averages of all the Schlafhorst yarns tested and all the Rieter yarns tested, ignoring rotor speed. With this test, the null hypothesis <u>was rejected</u> showing that there was a significant difference between the means at a 95% confidence interval.

Another t-test was completed to test whether the difference between the abrasion lengths of the ring spun yarns and the rotor spun yarns were significantly different. With this t-test, the null hypothesis <u>was rejected</u> in favor of the alt. hypothesis, which shows that there is a significant difference between the means at a 95% confidence interval.

The graph labeled as Figure 4 shows the relationship between belt extent and rotor speed. There is a noticeable trend in the Rieter yarns that shows an increase in the extent of belts as the rotor speed increases. This trend cannot be generalized, however, since the same trend is not seen in the Schlafhorst yarns.

Figure 5 relates abrading length and belt extent. The abrading lengths of the yarns from the two spinning systems are fairly close but the Rieter yarns again seem to show a trend that is not evident in the Schlafhorst yarns. As the extent of the belts increases, the Rieter yarns became more abrasive, i.e. the abrading length decreased. This is strengthened by the R^2 value of 0.6399. The Schlafhorst yarns showed no trend; therefore this phenomenon cannot be generalized for all yarns. The dotted line is a trend based on the combined data from the Rieter and Schlafhorst yarns as related to abrading length and belt extent. From these tests, there is no evidence to support the general belief that wrapper fibers make the yarn more abrasive.

Effect of Twist in Ring Spun Yarns

Figure 6, shows the effect twist has on the abrasiveness of ring spun yarns. The yarns used were produced with six levels of twist (15.5, 16.9, 18.0, 19.2, 21.3, and 22.0 tpi), and all had an approximate yarn count of 20/1 Ne.

The graph shows that for the range of twists utilized, there appears to be a general trend that as the twist increases the abrasion length increases. In other words, the yarns become less abrasive as the twist per inch increases. This trend was not expected due to the "harsh hand" normally associated with higher twists. On explanation may be that the higher twist compacted the fibers and created a smoother surface also making the yarn less hairy. This presumption of a smoother surface and decreased hairiness may then lead to decreased abrasiveness, but further work is needed to support this hypothesis.

Waxed vs. Unwaxed and Friction

In order to note the effect wax has on the abrasiveness of the yarn, several packages of Rieter yarns were back-wound, half of the yarns were waxed and the other half were unwaxed. The yarns selected were spun at three rotor speeds (72K, 92K, and 122K) and by back-winding all the packages it was also possible to note any directional effects as related to yarn structure. Figure 7 relates abrasion length and rotor speed of the waxed and unwaxed yarns[1]. The line labeled as normal is the average abrasion length of the yarns before back-winding and before any wax application. There seems to be very little difference between the waxed and unwaxed yarns but there is a slight difference between the normal yarn before back-winding and the unwaxed yarn. All three, however, show an increase in abrasiveness as the rotor speed increases, except for a single point on the waxed line. It can also be seen that the waxed yarns were more abrasive than the unwaxed yarns, i.e., it took fewer meters of yarn to break the copper wire. Back-winding, though, does several things to the yarn, including changing the hairiness of the yarn. Further studies are needed in which hairiness of back-wound yarns is measured. This was not possible in the present study because of limited sample size.

The friction tests used the same yarns from the waxed and unwaxed trials. Each yarn was run through a yarn-on-metal friction meter produced by Lawson-Hemphill for 1 minute. Readings were taken at random during that time. Figure 8 shows the results of these tests. There is virtually no difference in friction for yarns produced at different rotor speeds. The only difference is between the waxed and unwaxed yarn's level of friction. The waxed yarns produced less friction than the unwaxed yarns, as would be expected.

The most interesting information collected from these trials was that even though the waxed yarns created less friction, they ended up being more abrasive than the unwaxed yarns. The wax has a positive effect by reducing friction during knitting but it also has a detrimental effect of increasing yarn abrasiveness, at least according to these trials. These results just go to show that further work is need in this area to possibly find answers to this phenomenon.

"Dirty" Cotton

The yarns used in these trials were produced in the Short Staple Lab at N.C. State's College of Textiles. The sliver used to produce the rotor yarns and the roving for the ring spun yarns was made up of 50% "new" cotton and 50% reclaimed cotton. The rotor spun yarns were produced using a Schlafhorst SE9 spinning frame running with a rotor speed of 80K and a 124 m/min take-up. The resultant yarn had a TM of 4.6 and a linear density of approximately 12/1 Ne. The ring spun yarns were produced on a Saco-Lowell Spinomatic with SKF draft change over spinning frame and the resultant yarn was also approximately 12/1 Ne with a TM of 4.6. The comparison of these two yarns is therefore justified due to their likeness in linear density and twist multiples.

The rotor spun yarns had an average abrasion length of 17, 739 meters and the ring spun yarns had an average abrasion length of 8,670 meters. The rotor yarn needed over double the amount of yarn than was needed by the ring spun yarn to abrade the exact same copper wire. This goes to show that in these particular tests, the ring spun yarns were much more abrasive than the rotor spun yarns. A t-test confirms that there is definitely a difference between the two means at a 95% confidence level.

"Fall-out" Tests

The same yarns from the "dirty" cotton trials were used for the "fall-out" tests. The reason for this experiment is that trash on the latch of the needle may be a problem and could be related to "fall-out." Trials were carried out with "dirty" cotton because the excess trash in the yarns would give an idea of the amount of "fall-out" that would occur during knitting, and allow it to be seen after a shorter time span. It had been supposed that this was worse for rotor because of greater "fall-out" of particles from the yarn due to the yarn's passage through the needle. Each yarn was run on the CTT for 10 minutes at 360 m/min, which is equivalent to 3600 meters of yarn. There was a considerable difference between the amount of "fall-out" created by each type of yarn. This can be seen from the following photos take before and after each run.

Photo 3 is the before picture of the CTT. A black cloth was placed over the machine so that the "fall-out" from the yarn could be seen. Photos 4 & 5 show close-ups of the black cloth before testing the yarn. Photos 6 & 7 & 8 show the "fall-out" from the ring yarn after the 10-minute run. Photos 9 & 10 show the "fall-out" from the rotor spun yarn, again after a 10-minute run. The pictures were taken from the same spot for each yarn in order to facilitate a valid comparison.

The pictures speak for themselves and this was the reason why a quantitative comparison of the amount of "fall-out" from each yarn was not done. It can clearly be seen that the "fall-out" from the ring spun yarn greatly exceeds the amount produced from the rotor spun yarn. This goes against some of the reasoning for needle wear from rotor yarns. If you go by the shear amount of "fall-out" produced, the ring spun yarn would seem to wear-out the pivot point of a latch needle much quicker than a rotor spun yarn of the same linear density and TM.

Commercial Yarns

The following is a list of the commercial yarns that were tested:

- 8/1 OE 100% cotton, 3.4 TM
- 8/1 OE 100% cotton, 4.85 TM
- 26/1 OE 65/35% P/C, 3.7 TM
- 25/1 Ring 65/35% P/C, 3.8 TM
- 15/1 OE 65/35% P/C, 3.8 TM
- 16/1 Ring 65/35% P/C, 4.2 TM

Figure 9 shows a comparison of the average abrasion lengths, based on results from the CTT, from all the commercial yarns tested. The first four columns present the open-end yarns and the last two depict the ring spun yarns.

Analysis of the results presented is complicated by the fact that since the samples are commercial yarns they range in fiber type, count, twist and spinning system. It is however possible to draw several general conclusions from the data:

- Yarn count appears to play an important role with finer yarns being more abrasive than coarser yarns (cf. #3 & #4, #5 & #6);
- Lower twist yarns seem to be less abrasive than those with higher twist (cf. #1 & #2); this is different from earlier results, but earlier results were for ring spun yarns and same fiber (cf. 6);
- OE yarns seem less abrasive than ring spun yarns (cf. #3 & #5, although this comparison may be influenced by slight differences in twist).

It is evident from these results, especially when taken in the light of earlier findings, that there seems to be no clearly identifiable factors to which abrasiveness can be absolutely attributed. However, from all the data gathered to date, there appears to be no evidence to support the hypothesis that open-end yarns are more abrasive than ring spun yarns (indeed most of the evidence seems to indicate that open-end is slightly better in this respect).

Conclusions and Discussion

The investigation into the abrasion characteristics of open-end yarns has revealed several inconsistencies with popular beliefs about the behavior of ring and rotor yarns. In summary these are:

- Rotor spun yarns are less abrasive than ring spun yarns;
- Systematic differences exist between machines from different manufacturers;
- The magnitude of the differences in abrasiveness between ring and rotor yarns depends on fiber quality;
- There is no general correlation between yarn structure and abrasiveness;
- Higher twist, which is normally associated with harsher properties, does not lead to an increase in abrasiveness;
- Finer yarns seem to be more abrasive;
- Wax changes the friction of the yarn but is not reflected in the abrasiveness;
- Ring spun yarns produce significantly more “fall-out” during attrition.

It is apparent from the data presented that the two rotor spinning machines produce yarns with different properties and while one may exhibit a trend, this cannot be generally accepted as being true for all rotor yarns. The different trends exhibited by the different spinning machines are not totally unexpected but at this stage no satisfactory explanation can be proposed.

The results acquired from all the tests are essential in the ongoing analysis of the abrasion characteristics of cotton yarns. The role of twist seems to have an effect on ring spun as well as open-end yarns. The abrasion tests on the commercial yarns showed that a change in TM of an open-end yarn does affect its abrasiveness. It was found that increased twist in a ring spun yarn created less abrasion. With these tests with different twist levels, the increased twist caused the open-end yarn to become more abrasive (however, these yarns may also be produced from different cottons). It is unknown at this time what causes these differences between open-end and ring spun yarns when twist is increased or decreased.

The role of yarn count seems quite obvious as far as the abrasion tests on the commercial yarns are concerned. As the yarn diameter increased, the area of copper wire that the yarn passed over, increased. It would make sense that the yarn would take longer to break the copper wire since more of it had to be abraded. The smaller diameter yarns have less copper to wear away, therefore taking less time/length to break the wire.

The results for the “dirty” cotton and the “fall-out” tests give even more interesting results. By using 50% re-claimed cotton and 50% “new” cotton to create the sliver, trash content increased, the amount short fibers increased, and the hairiness of the yarn increased. When the “clean” cotton trials were completed, there was not an extremely large difference between the ring and rotor spun yarn’s mean abrasion lengths. It is not valid to compare the “clean” and “dirty” cotton yarns due to the differences in twist, yarn count, and cotton used, however, several observations can be made. If the role of yarn count is as it is supposed above, then the increased diameter of the “dirty” cotton would be one cause for the increased abrasion length of the rotor yarns, but this was not the case for the ring yarns. There was a considerable difference between the ring and rotor yarns, something that was not seen with the "clean" cotton yarns.

The "fall-out" tests also showed a significant difference between the ring and rotor yarns used for these tests. While the comparison was only qualitative, the photos show there is a clear distinction in the amount of "fall-out" produced by the two yarn types. It is unknown whether this is caused by structural features of the yarn or the shear amount of trash left in the yarn after production. Either way, the ring spun yarns in these tests were considerably more abrasive than the rotor spun yarns.

Acknowledgements

We wish to recognize the financial sponsorship afforded by Cotton Incorporated to support this research.

Notes

[1]It should be emphasized that the behavior of the Rieter open-end yarn was slightly different from Schlafhorst-in particular with regard to its response to different rotor speeds.

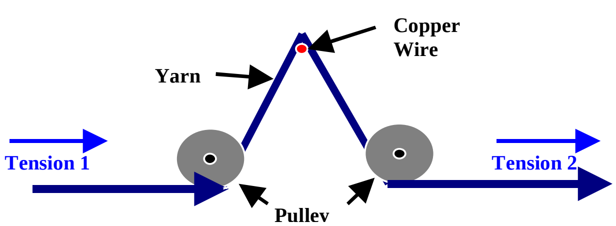

Figure 1

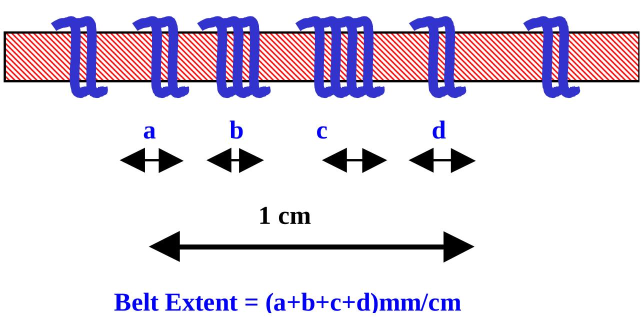

Figure 2

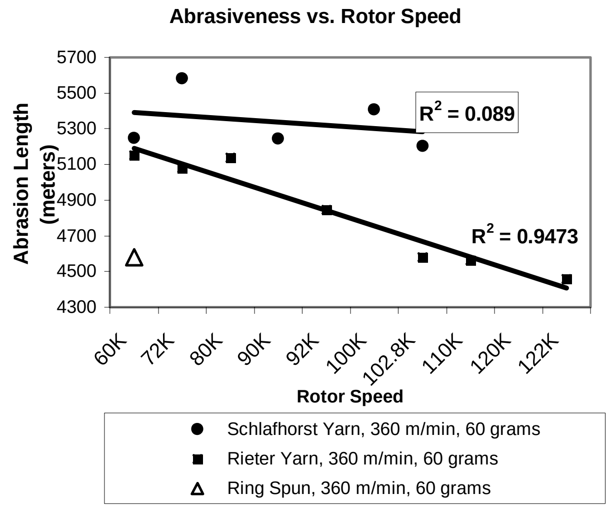

Figure 3

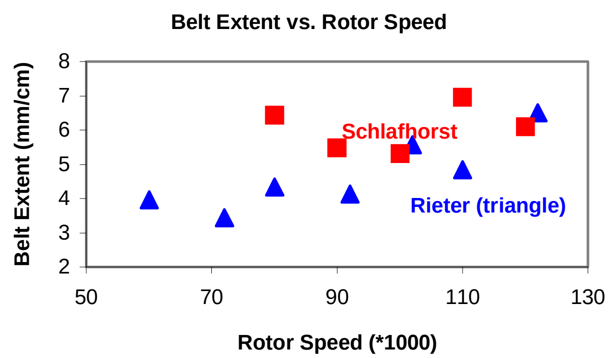

Figure 4

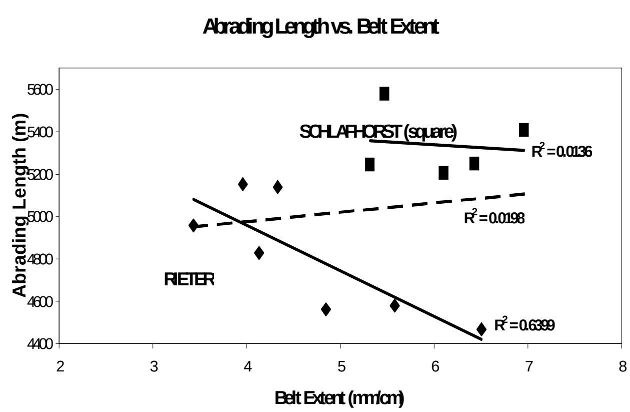

Figure 5

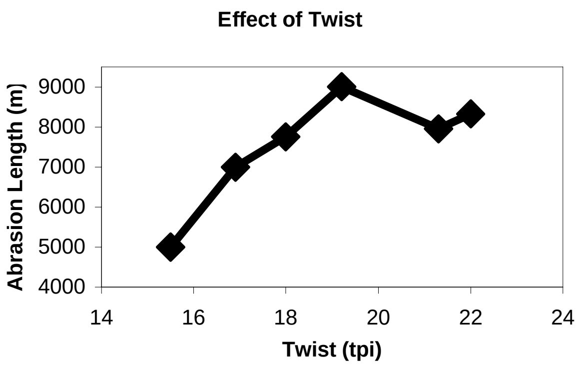

Figure 6

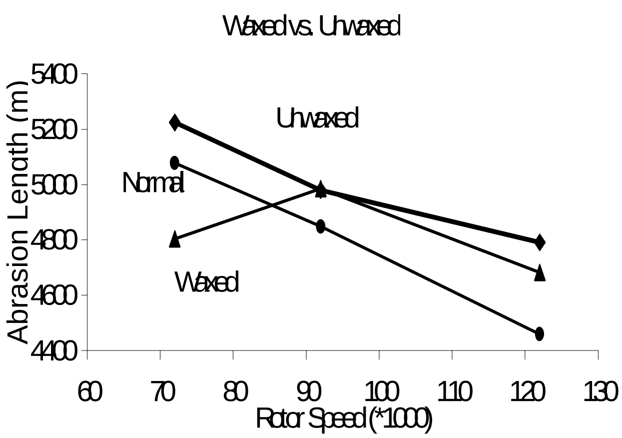

Figure 7

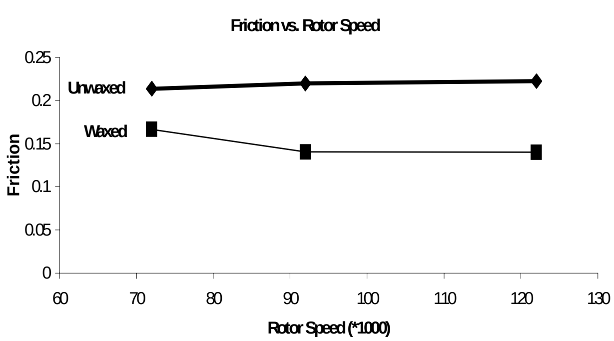

Figure 8

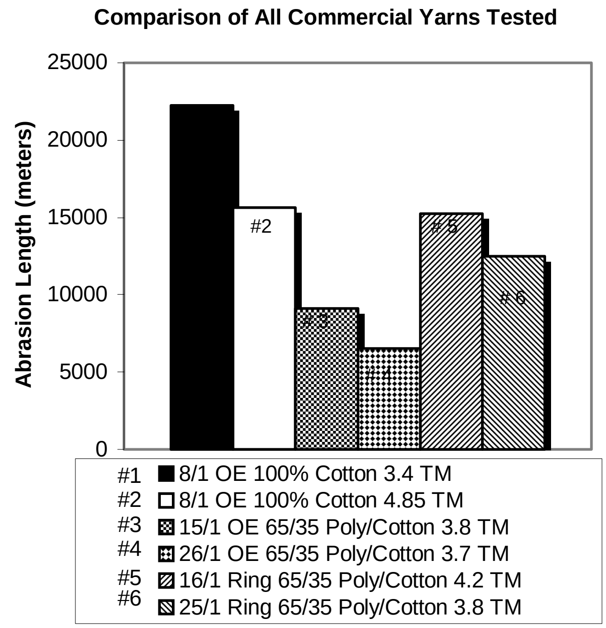

Figure 9

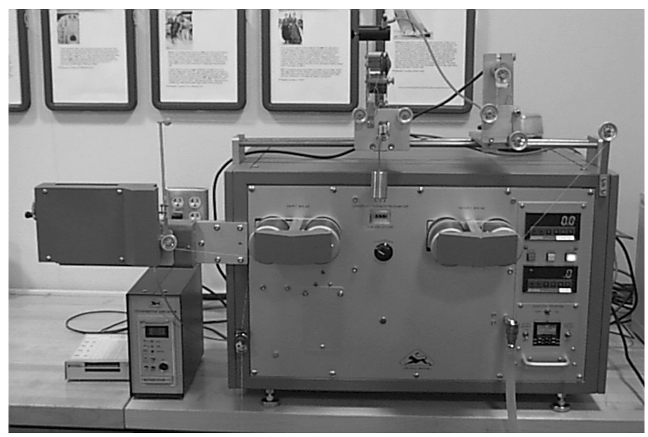

Photo 1. CTT with abrasion attachment.

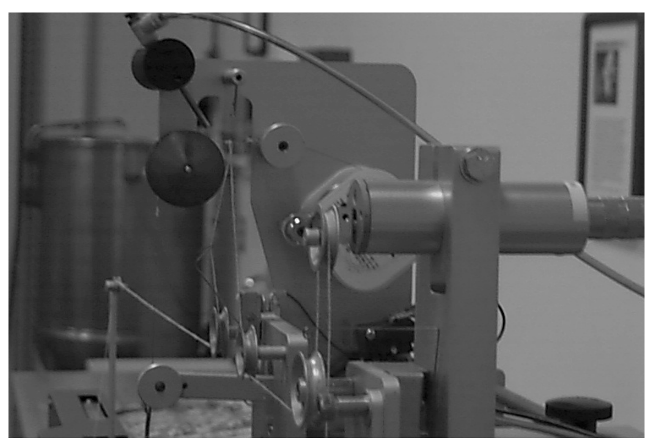

Photo 2. Abrasion attachment

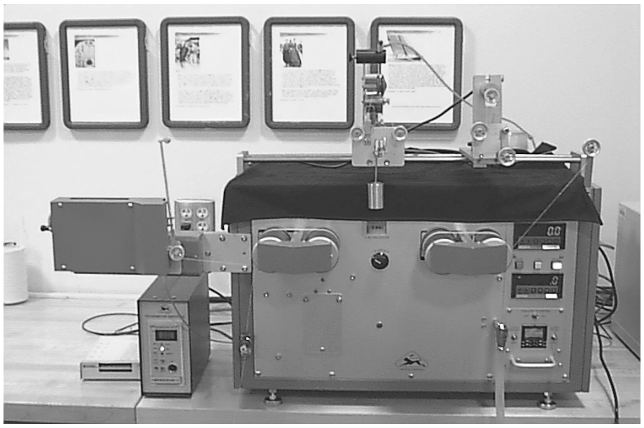

Photo 3

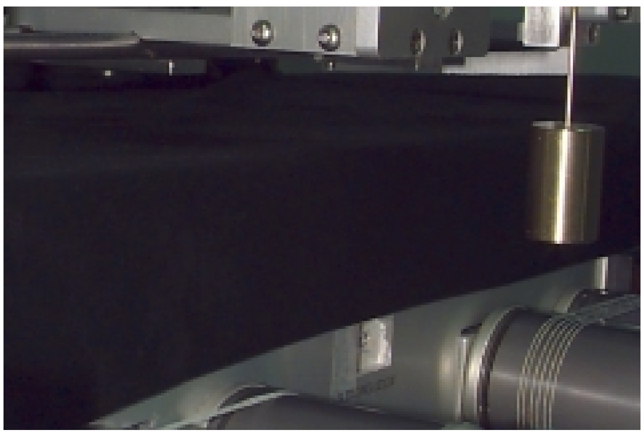

Photo 4

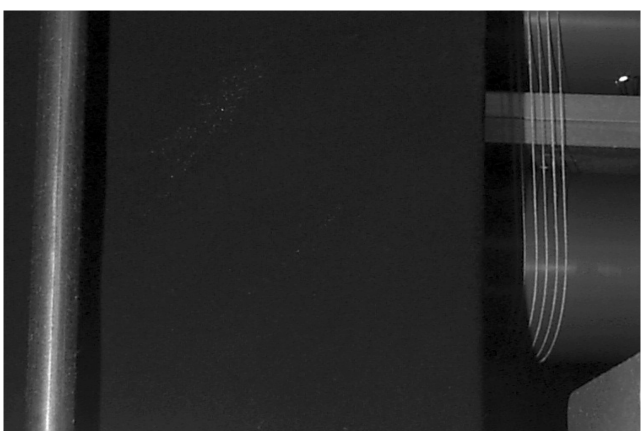

Photo 5

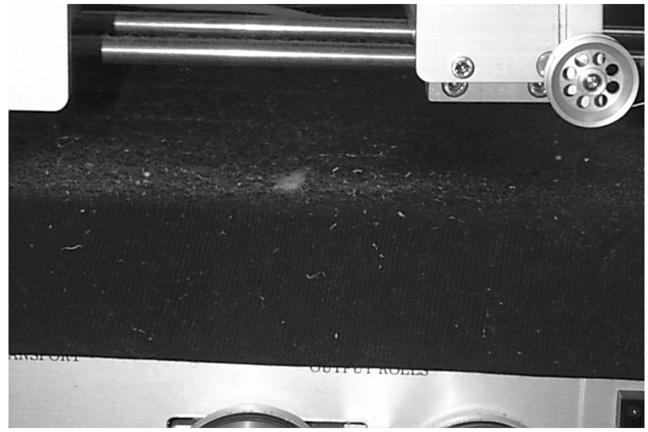

Photo 6. Ring Yarn

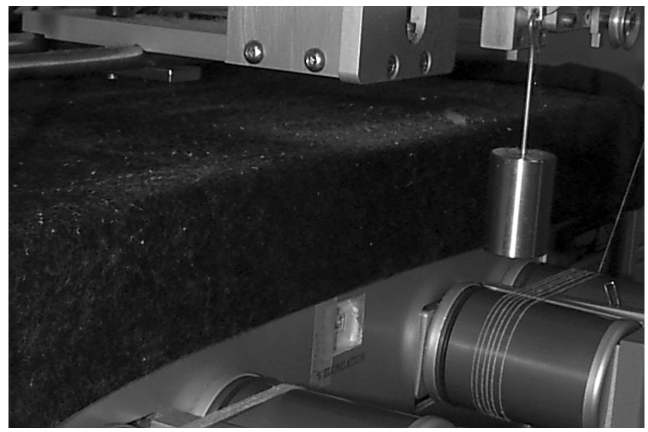

Photo 7. Ring Yarn

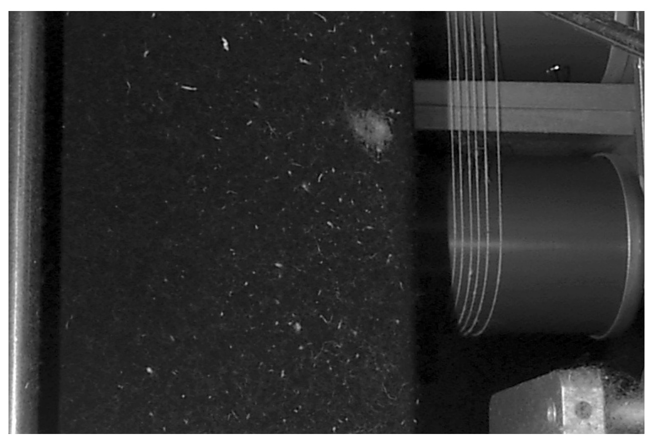

Photo 8. Ring Yarn

Photo 9. Rotor Yarn

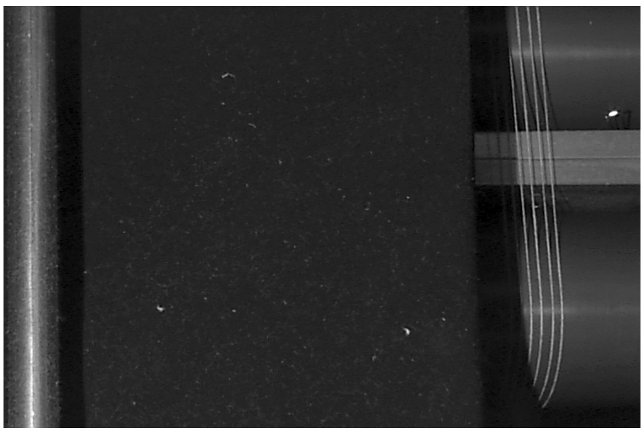

Photo 10. Rotor Yarn