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Bending Behavior of Coated Yarns

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Abstract: Cotton yarns were coated with a polymer solution to hold surface fibers to the yarn body, which caused fiber-fly generation during knitting process. The physical property of the coated yarn, especially a bending rigidity was investigated in order to evaluate the performance of the coated yarn during knitting. SEM images showing the surface condition of the coated yarn demonstrated that the thickness of a coating material increased as the concentration of the coating solution increased. The results of the bending rigidity measured using KES-FB2 system showed that the bending rigidity of the coated yarn increased as the concentration of the coating solution increased. The results also revealed the possibility that yarn coated with a low amount of coating material should be employed for further research of reducing fiber-fly generation during knitting process.

Keywords: Knittibility, Coating, Bending rigidity, Cotton yarn

Introduction

The knittibility of yarns is one of the important factors to produce knitted fabrics with good quality. Knittibility is affected by a number of yarn properties such as strength, elongation at break, yarn frictional properties and bending characteristics. The bending property is especially important mechanical property because it contributes significantly to the draping, wrinkling and hand of fabrics. The bending property of a yarn is again affected by many factors including fiber properties, yarn twist, fiber friction and so on.

During stitch formation, a yarn is bent into the shape of a loop, which forms the fundamental yarn-binding element of a knitted structure. Therefore, the bending rigidity of a yarn influences its knittibility and is closely related with the quality of final knitted products. Many researches[1-8] showed the bending property of a yarn significantly affects the characteristic of woven and knitted fabrics including drape, handle, etc. Other studies[9-12] also revealed that the fiber property and structure influence the bending behavior of a yarn and then a fabric.

During the circular knitting, yarns should contact with many elements on the machine on the way to the knitting zone. Specially, yarns have a great number of bending stresses on the way of feeding due to the complicated machine components and structure. Particularly, yarns have a host of bending stresses on the knitting zone because of consecutive needle movements. Therefore, yarns using on the circular knitting should have not only the bending rigidity but also enough tensile and flexible properties.

Causes of fiber-fly generation of cotton yarns and a possible method during the circular knitting process were studied, and a new way of yarn coating to reduce the fiber-fly shedding was suggested in previous researches[13,14]. However, the new method of yarn coating should take into account the characteristics of knitting process before applying because it could significantly affect the final products.

As addressed in the former study[13], a thin polymer film is formed around the yarn surface and such the layer of polymer film could influence the properties of yarn such as the bending rigidity. Therefore, this research is to investigate the influence of the coating material to the bending property of yarn for further knitting process. A series of tests were carried out with the KES-FB2 (Kwabata Evaluation System) and SEM (Scanning Electric Microscope) for this purpose.

Experimental

Several tests were carried out to check bending property of cotton yarn by applying different amount of coating materials. All yarns used in the analysis were American combed ring-spun yarns of 20 tex, 16.8 tpi and the draft ration of 30.5. The yarns were conditioned in a standard atmosphere of 65±2% R.H. and a temperature of 20±2°C during test.

First of all, the yarn was coated by a machine consisting of two padder rollers, whose speed and compressing pressure can be controlled. The coating is proceeded by the dipping method with solutions of a coating material, which is mainly made from polyethylene. In order to test variation of bending rigidity of the cotton yarn with different amount of coating, coating solutions were prepared and used in different concentrations by applying water to the coating material.

In order to measure the bending rigidity, the Kawabata Pure Bending Tester, KES-FB2 was used[15]. In general, a particular difficulty for bending measurements has been the maintenance of an even curvature during testing. However, the Kawabata Pure Bending Tester was reported to apply a pure bending motion to a specimen and thus reduces much of the error. In case of a thread sample, yarn threads should

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be arranged parallel to each other thus, twenty fibers attached in a parallel fashion to paper strips were mounted for testing by placing the paper strips in the chucks of the instrument. A sample size of 20 cm×20 cm was prepared for the test. Samples were conditioned in the conditioning room to control moisture before undergoing the experiment. Yarn sample for measuring the bending rigidity with this machine was made as shown in Figure 1.

The method of yarn sample making is that a paper having 1.1×2.5 cm rectangular hole is cut from a piece of paper and a both side adhesive plastic tape is used to place yarn threads in parallel with equal tension. After that, the paper at the both sides (dotted line in Figure 2) is removed. 20 yarn ends were used for the test because the number was maximum in the sample size with 1 mm distance between the yarns. The 1 mm distance provided enough space to the yarns not to touch each other during the test. By increasing the number of yarn ends, one can get better results of the test, which are similar with those obtained using a fabric or film. The surface of the coated yarn was studied using SEM images.

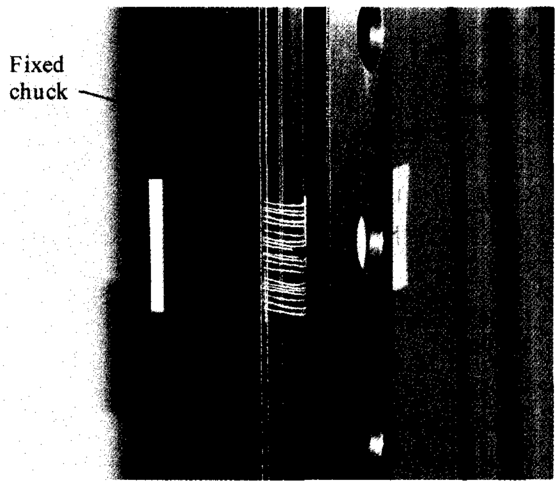

Figure 1. The bending state of the tested yarn.

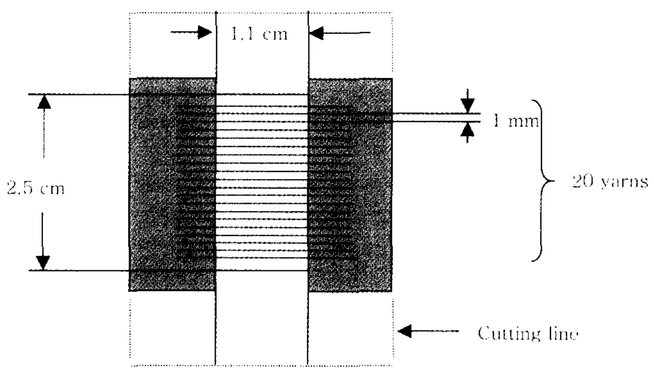

Figure 2. Yarn sample for measuring bending rigidity.

$$\text{Bending (flexural) rigidity} = \frac{1}{4\pi} = \frac{\eta E T^2}{\rho} \qquad (1)$$

where

η: Shape factor
E: Tensile modulus
ρ: Linear density
T: Thickness

As described in equation (1), the bending property of a fiber depends on its shape, its tensile modulus, its density and, most of all, its thickness. Hence, the bending rigidity of the coated yarn is expected to increase as the thickness of yarn increased by coating.

SEM test was performed to observe the variation of surface state of yarns by applying different amount of coating material. A coating material (CM1) used in the previous study[13] was used again for this research because it showed positive effect to reduce the fiber fly generation.

During the test, the bending rigidity of uncoated yarn was examined to compare with its of the coated yarn. The variation of bending rigidity of the uncoated yarn was also tested by changing the number of yarns. However, as comparing the property of bending, the number of yarn ends was set to 20 in both of the uncoated and coated yarn which is recommended by the machine manufacturer of KES-FB2 system to get similar results of bending with fabric. Tests were carried out ten times in each condition.

Results and Discussions

SEM Images of the Coated Yarn

In coating, a thin polymer film is built around the yarn surface. The thickness and the uniformity of the polymer film influence the effectiveness of the coated yarn during knitting. A 100% uniform polymer film should cause all surface fiber that stands out of the yarn surface to bend back and remain on to the yarn surface, i.e. give zero yarn hairiness.

The thickness of the polymer film will also influence the bending characteristics of the yarn. In practice, it was extremely difficult to determine the thickness of the coated polymer film because the film was coated on the uneven surface of spun yarn. However, the uniformity of the polymer film was easily observed using SEM images of the yarn. Magnification of the SEM with ×50 and ×350 was used for the uncoated and coated yarn with CM1 in this study. As can be seen from Figure 3, there are many fibers (hairs) standing out from the yarn surface of the uncoated cotton yarn. These fibers are the cause of fiber-fly shedding during the knitting process. The images in Figures 3 to 8 showed the effect of the concentration of the coating solution in comparison to the images of the uncoated cotton yarns in Figure 3. More residues of the coating materials were found on the surface of coated yarn as the concentration of the coating solution was increased. Furthermore, the majority of hairs were stuck down to the surface of the yarn as the

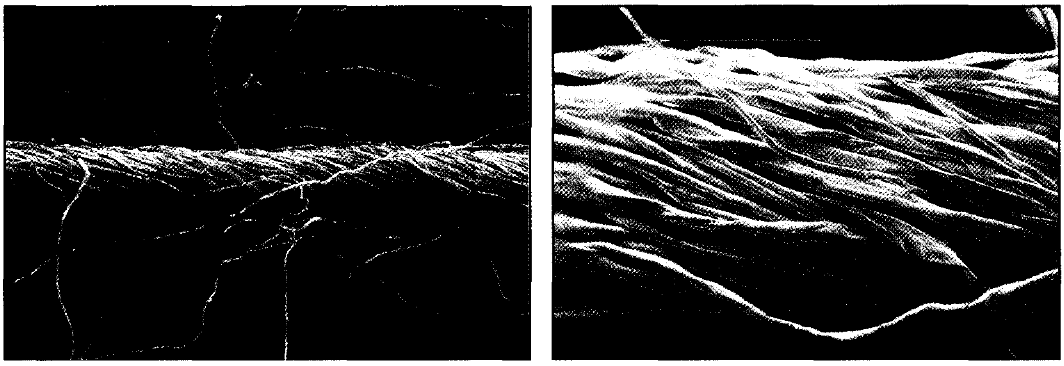

Figure 3. SEM images of uncoated yarn.

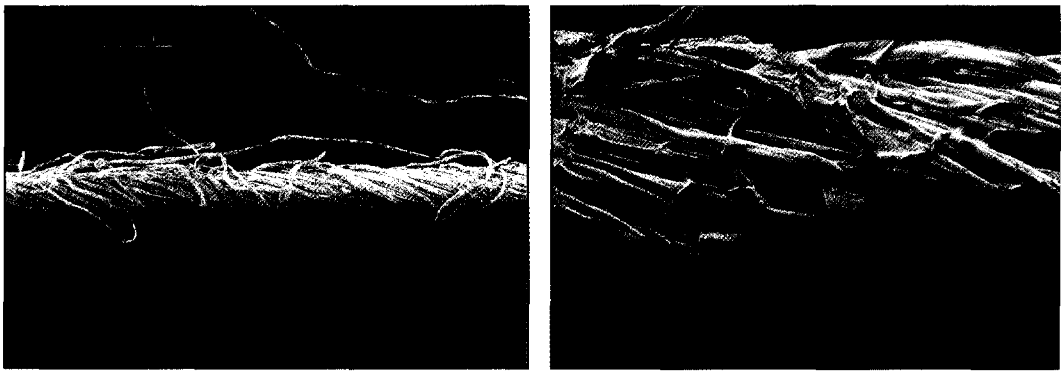

Figure 4. SEM images of coated yarn (20%).

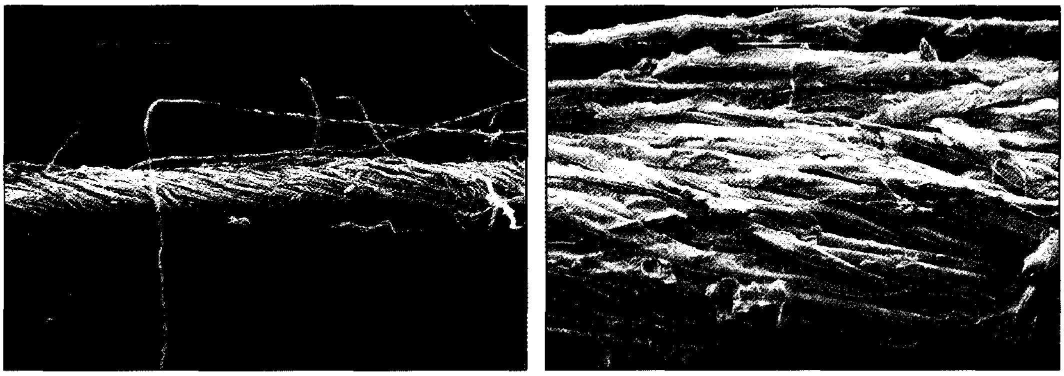

Figure 5. SEM images of coated yarn (40%).

concentration of the coating solution was increased. The amount of coating material with the concentration of 100% seems to be very high on the surface of yarn.

As can be seen from the images, high concentration of coating solution contributed thickness of coated layer on the surface of yarn. This thickness of coated layer is thought to be from high viscosity of the coating solution as the concentration of coating solution gets increased. Therefore, weight of coating materials on the yarn seemed to depend on the concentration of coating solution. It was also expected that the yarn coated with high concentration of coating solution had high bending rigidity due to the increased thickness of yarn, which is expected to increase the tensile modulus of coated yarn.

Bending Rigidity

First of all, the bending rigidity was measured by increasing the number of yarn ends with an uncoated yarn by way of a standard for future tests on coated yarn, as shown in Figure 9. This was also designed to check if the bending tester was working properly by increasing the number of yarns in which the friction can be different by air dragging

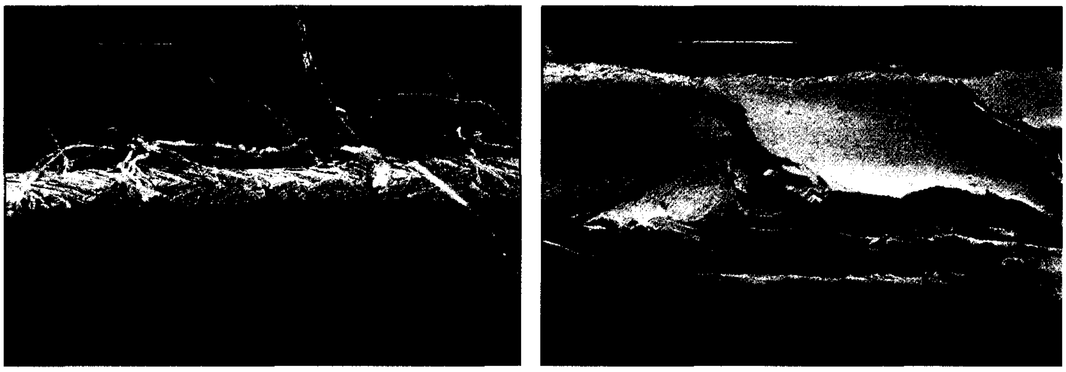

Figure 6. SEM images of coated yarn (60%).

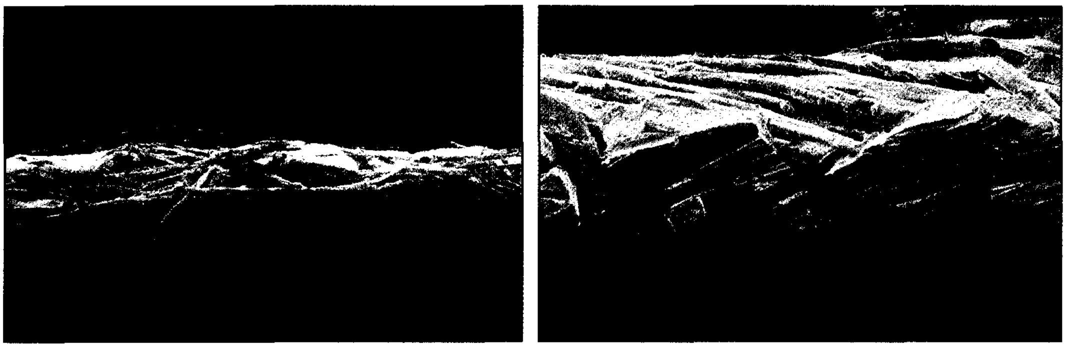

Figure 7. SEM images of coated yarn (80%).

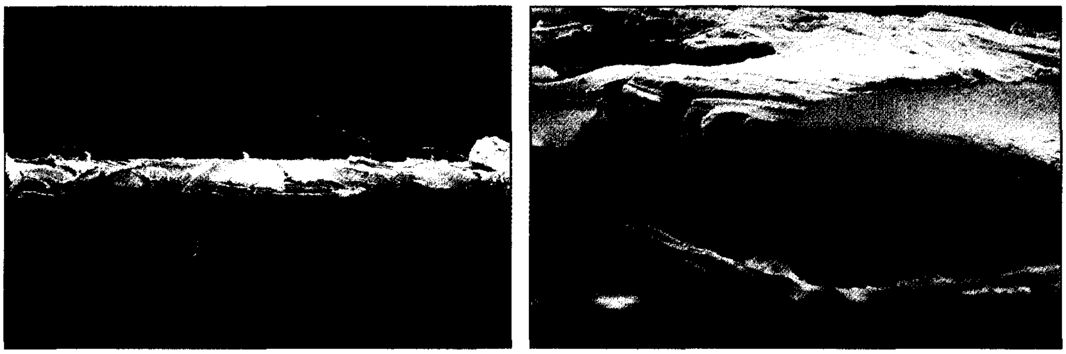

Figure 8. SEM images of coated yarn (100%).

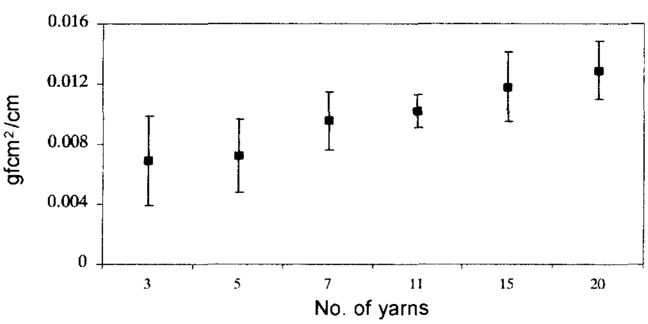

Figure 9. The bending rigidity of an uncoated yarn.

on the yarn. It was difficult to find significant differences but the bending rigidity was increased slightly as the number of yarn ends increased. This means that the resistance of bending on the yarn was increased as the number of yarns increased to a certain extent, 20 of yarn ends as recommended from the machine manufacturer.

The bending rigidity tests were carried out with yarn coated with CM1 at several concentrations and the results were compared with those of the uncoated yarn. This is aimed to check the influence of the coating to the bending property of yarn. As shown in Figure 10, the bending rigidity of the yarn increased as the concentration of coating solution

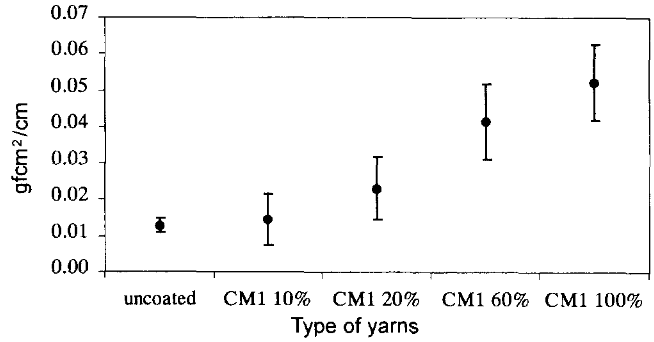

Figure 10. The bending rigidity of coated yarns.

increased. The bending rigidity of the yarn coated with CM1-10% was slightly higher than uncoated yarn at around 0.002 $gfcm^2/cm$. However, the bending rigidity increased higher from the 20% of concentration to about 0.01 $gfcm^2/cm$ and then it was increased significantly to 0.029 $gfcm^2/cm$ at 60% and 0.04 $gfcm^2/cm$ at 100% of the concentration of coating.

This result means that the yarn gets stiffer by increasing the coating concentration and loses its pliability. This may be accounted for by the fact that as mentioned in previous results[13], the coated yarn loses its elongation and gets stiffer as the extent of coating increased. As a result, the coated yarn at increasing concentrations is not suitable for knitting and it can make the processibility of the knitting machine worse. However, the bending rigidity of the yarn coated with 10% concentration of coating solution was not increased significantly. A knittibility test of the coated yarn, which is not mentioned in this study, also proved that this concentration could be used in the knitting process.

Conclusion

The bending property and the surface state of coated cotton yarn were investigated in order to check the influence of coating solution to cotton yarn. In order to reduce fiber-fly generation during knitting process, the coating of cotton yarn was suggested. However, yarn should have enough pliability during the process, so it is important to consider whether this coating also affects yarn property, especially bending behavior of yarn, which is critical in determining fabric mechanical properties.

As shown in the results, one could see the thickness of the coated yarn and the bending rigidity were increased as the concentration of the coating solution was increased. However, there are some reasons that higher concentration of coating is not helpful to reduce the fiber-fly generation. Firstly, coated yarn with high viscosity of the coating solution lost their flexibility due to the yarn stiffness, then the yarn would not be used to any textile processing including knitting. Secondly, polymer particles on the yarn coated with high concentration should be come out during knitting by friction with needle, and then the residue of coating polymer possibly contaminates a knitting machine more seriously than fiber-fly. Lastly, it costs more to use higher concentration of coating solution to industry. Hence, choosing the best concentration of coating solution is as important as to select the best coating material.

Fortunately, the yarn coated with the concentration of 10% of the coating solution (CM1) showed that tiny increase of the bending rigidity. It showed a possibility to carry out the coating method for reducing fiber-fly shedding in a low amount of usage. In conclusion, the coating method to reduce fiber-fly generation should be applied to yarn in an extent not to impinge upon the pliability of yarn.

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