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〈研究論文(學術)〉

니팅공정중에 발생하는 fly 제거를 위한 새로운 기술

구영석

부산대학교 공과대학 섬유공학과
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A New Technology to Remove Fly on the Knitting Process

Young-Seok Koo

Department of Textile Engineering, Pusan National University, Busan 609-735, Korea
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Abstract—The problematic effects of fly creation on circular knitting machines during the knitting process were investigated in order to develop a new method for tackling the problem. A new idea, i.e. coating the yarn surface with a polymer film, was studied. Important physical properties of the coated yarn were studied and compared with normal yarn. A new test-rig was designed to measure the coefficient of friction and the degree of shedding of yarn. Yarns were coated with seven polymer materials and the performance of the coated yarns was tested and the results are discussed.

1. Introduction

Currently a significant quantity of cotton and cotton blended yarn is proceeded on circular knitting machines for use in underwear, outwear, sportswear and in leisure wear applications. During processing, the short fibres in these yarns are liberated from the yarn surface, which is called fibre-fly (fluff, lint). This fly generation causes several serious problems, including yarn breakages due to blocked yarn guides and feeders, fabric faults, such as holes and thick places and occasional mechanical defects like broken needles resulting production losses. Furthermore, although it seems to be generally accepted that there is no health hazard from the dust of processed natural textile staple fibre, it may be unpleasant to work in an atmosphere overburdened with fly. Specifically, dry cotton is so brittle that it is more prone to the creation of fly.

Fly (fluff, lint) is loose fibre that is detached from the yarn surface during processing and is accumulated on many critical parts of the knitting machine [1]. Generally, this fly occurs where the moving yarn comes into contact with yarn guides, feeding devices and knitting elements. Most of the fly is generated due to the composing fibre being pulled out or sheared off from the yarn body at various points along the yarn path when the yarn comes into contact with yarn guides and knitting elements.

This fly problem has resulted in the development of new techniques such as the enclosure of yarn creels, the lint blower systems and covering a section of the knitting machine with polyethylene sheets and so forth. It is also reported that [2] this problem can reduce the machine efficiency by 15-20%. However, this only moves the airborne particles to an adjoining knitting machine, causing further contamination.

Another possible solution, yarn coating [5,6,7] to reduce fly shedding during knitting has been investigated. The proposed solution is based on the idea that if a yarn surface is covered with a thin polymer film capable of holding loose fibres on to the yarn body, the fly shedding may be reduced during the knitting process.

The main aim of the project was to coat a yarn with a suitable polymer material in order to improve the adhesion of surface fibres on to the yarn body. As it has been demonstrated by numerous researchers, yarn friction [8,9,10] is one of important factors affecting fly shedding. Therefore another aim were to reduce the frictional properties of a coated yarn, and if possible to improve yarn pliability. Accordingly, in this study suitable coating materials, and their concentrations for application had to be studied. The material should not affect the cotton yarn properties and should be easily removable during the dyeing and finishing processes.

For the purpose of this study, a yarn coating is defined as a thin film, which is applied to the yarn surface in order to protect or reinforce it during knitting. The coating is also likely to partially encapsulate the yarn surface and shield defects such as weak spots.

2. Experimental

2.1 Introduction

Several tests carried out to check the yarn properties and the amount of fly before and after coating. All yarns used in the analysis were produced in the spinning and non-woven laboratory at UMIST. An American combed ring-spun yarn of 20 tex, 16.8 tpi of twist and 30.5 of draft ratio was used in the study. The yarn was conditioned in a standard atmosphere of 65 ± 2% relative humidity and a temperature of 20 ± 2 ℃ prior to all testing for 1 day.

The yarn was treated on a coating machine consisting of two padder rollers, whose speed and compressing pressure can be controlled. To study the fly shedding, a test rig (referred to as the fly collector thereafter) was designed and constructed. The Shirley friction and hairiness tester (SDL 96/8) was used to measure the yarn friction and the yarn hairiness. The surface of the coated yarn was studied using Scanning Electron Microscopy (SEM) images. Yarn tenacity and elongation tests were carried out with Yarn Tensile Tester, USTER TENSORAPID. Seven coating materials were selected for the study. The experimental procedure is described in the block diagram below(Fig.1). The properties of the yarn (uncoated) used in the study are also given below in Table1.

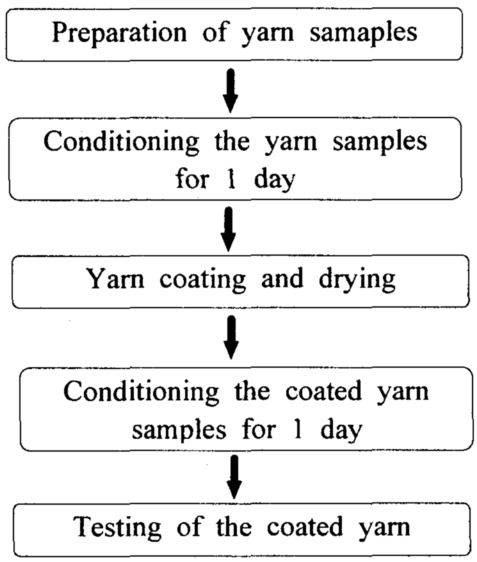

Fig. 1. Block diagram of the experimental procedure.

Table 1. Properties of tested yarn

Fiber type	American cotton	Tenacity(cN/tex)	12.25
Spinning method	Ring spinning	Elongation at break(%)	4.05
Yarn twist(tpi)	16.8	Yarn coefficient of friction(unwaxed)	0.245
Draft ratio	30.5	Hairiness(>3mm)	3.88

2.2 Yarn coating

The coating was carried out at a speed of 10 m/min with 0.3 bar of pressure between the padder rollers. A yarn tensioner was used to achieve an uniform coating of the yarn and to feed the yarn without vibration into the coating machine. A constant pressure on the yarn was maintained by the two padder rollers, in order to achieve an uniform coating of the yarn. The dipping coating method was used for coating.

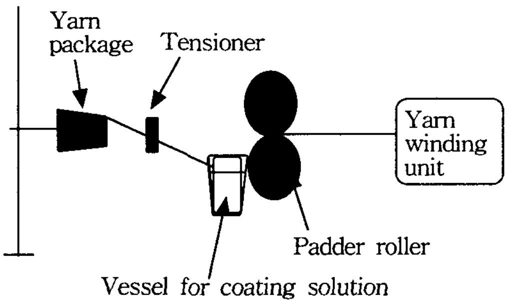

Fig. 2. Schematic diagram representing the coating process.

The coated yarn was wound on to a package by using a variable speed yarn winding unit. After coating, the quantity of coating on the coated yarn was measured by means of a weight difference before and after coating.

Seven Coating Materials (CM) having different chemical compositions were selected. These were all provided by a company that is keen to improve the yarn processing quality in order to improve the efficiency of the fabric production. For physical properties tests were carried out 10 times before and after coating in each concentration of CMs. Table 2 also shows some properties of the tested coating materials.

Table 2. Properties of the coating materials used in the study

Name	Ionic character	Physical form	Composition
CM1	Nonionic	Emusion	Polyethylene
CM2	Cationic	Emulsion	Blending softener & lubricant
CM3	Cationic	Emulsion	Paraffin wax
CM4	Nonionic	Emulsion	Paraffin wax
CM5	Anionic	Powder	Acrylic copolymer
CM6	Nonionic	Pellets	Sizing wax
CM7	Nonionic	Pellets	Hydrocarbon

2.3 Fly collector

Usually, during knitting, loose fibres are released from the yarn surface due to friction between the yarn and the contact surfaces. There is a body of research [1,2,3,4], which measured the amount of fly accumulated in various parts of the knitting machine like the yarn creel, positive feed units, etc. However, it is quite difficult to determine the amount of fibres collected at the knitting zone of the machine. In order to determine the shedding of fly at the knitting needle a test rig, namely, the fly collector was developed (Fig. 3.).

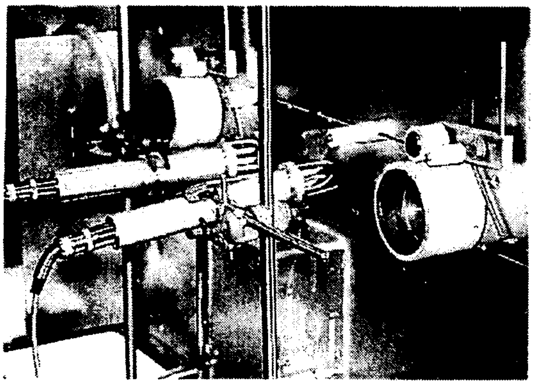

Fig. 3. Fiber fly collector.

The testing rig consisted of an enclosed area, in which a knitting needle was mounted. The test yarn was threaded through the needle hook, and the yarn movement was controlled with two pairs of rollers, that were driven separately by two stepper motors. In order to monitor the yarn tension, two tension measuring heads were also integrated into the yarn path (as shown in Fig.3). Two adjustable yarn guides were also included in the design in order to facilitate the change of yarn contact angle in the needle hook. Hardware and software were created to drive the yarn through the enclosed area under pre-determined tensions and yarn speeds. The fly shed in the needle hook area was collected onto a filter paper by creating a lower atmospheric pressure in the enclosed area with a suction unit. The amount of fly shed during the test was determined by weighing the filter paper before and after testing after conditioning.

The yarn speed could be varied up to 400 m/min from software. By operating the two rollers at different speeds a pre-determined tension created was in the yarn. The yarn passing through the enclosed area can be seen through the transparent box. The fly accumulated in the filter paper was kept in a condition room for 1 day before the measurement. In addition, the total amount of fly was determined by measuring the weight of the yarn before and after testing with the following equations:

Total amount of fly and polymer residue

$$(W_{F.T}\%) = \frac{W_o - W_t}{W_o} \times 100 \text{ -----------(1)}$$

Where

W_o: original yarn weight; W_t: yarn weight after testing.

Fly amount from the collecting box (W_t%) =

$$\frac{N}{W_o} \times 100 \text{ ------------------------(2)}$$

Where

N: weight of the amount of fly shed at the needle.

3. Results and discussion

3.1 Variation of yarn weight

The coating material was mixed with water to form the coating solution. However, it was difficult to make a coating solution with each coating material because of their chemical composition. Specially, it was difficult to make a coating solution with CM5, CM6 and CM7 even with low concentrations. Therefore these three materials were not included in this study.

First of all, five concentrations ranging from 20 to 100% in steps of 20 were made, and yarn was coated. The coating was repeated 10 times with 1 km length of yarn for each concentration of coating material. The Fig. 4 shows the variation of yarn weight for different concentration of coating solutions.

The results indicate that more coating material becomes attached to the surface of the yarn as the concentration of coating solution increases. Whats more, there are differences in the amount of coated material that has attached to the surface of yarn. This may due to the difference of viscosity in each coating polymer solution. That is, each coating polymer has dif-

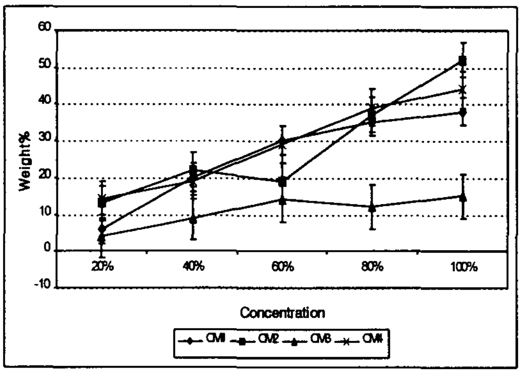

Fig. 4. Increase of yarn weight due to coating.

ferent polymer composition, which may make the viscosity of the coating solution different and changed the attached amount of coating polymer to the yarn surface as well.

However, at higher concentrations some undesirable effects were observed. Firstly, the coated yarn became stiff and lost its flexibility. Secondly, the coated yarn was stuck together and it made the yarn hard to unwind from a package. Therefore, the study was limited to coating solutions with low concentrations. At low concentrations the increase of yarn weight was not significant. The pliability of coated yarn with low concentration was also much better than those coated with high concentrations. Stiffness of the yarns coated with low concentration solutions was also less than that of yarn coated with higher concentrations. All the above properties may be due to the viscosity of the coating solution. A higher viscosity coating solution would form a stiffer polymer film around the yarn surface causing the yarn stiffer and less pliable. The preliminary investigations showed that the flexibility, pliability and stiffness of yarn were compromised with increasing concentration of coating material in the coating solution. Consequently, further tests were continued with yarn coated with low concentration of under 20% of coating solution.

3.2 SEM images

Due to coating a thin polymer film will be built around the yarn surface. The thickness and the uniformity of the polymer film will influence the effectiveness of the coated yarn during knitting. A 100% uniform polymers film will cause all surface fibre, which stand out of the yarn surface to bend back on to the yarn surface, i.e. zero yarn hairiness. The thickness of the polymer film will influence the bending characteristic of the yarn. It was extremely difficult to determine the thickness of the coated polymer film. However, the uniformity of the polymer film was studied using SEM images of the yarn surfaces.

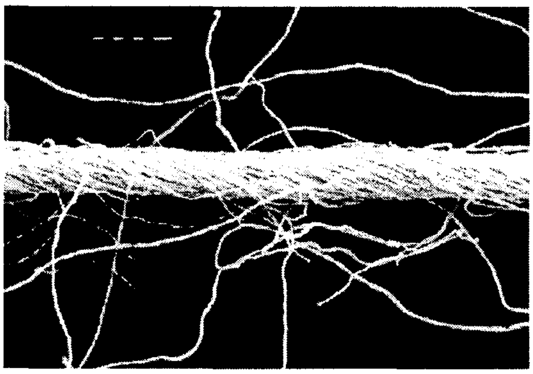

Fig. 5. SEM image of an uncoated yarn.

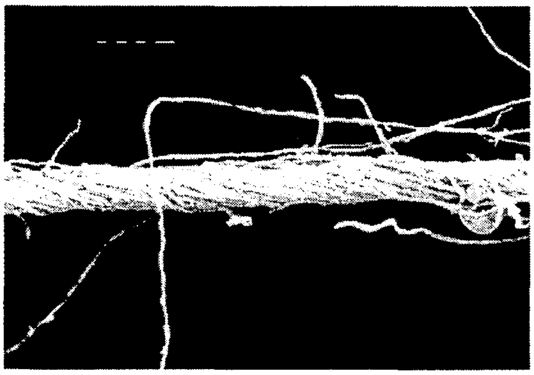

Fig. 6. SEM image of a yarn coated using coating material CM1,40% concentration.

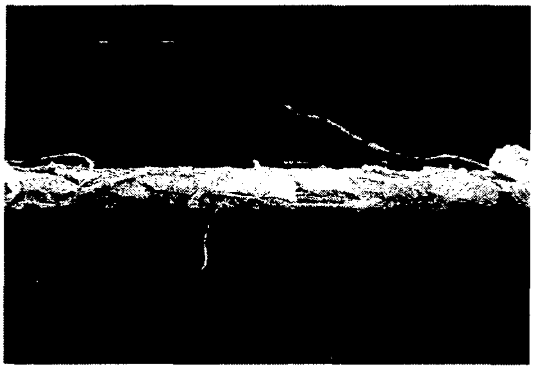

Fig. 7. SEM image of a yarn coated using coating material CM1,100% concentration.

As can be seen in Fig. 5, which is an image of the uncoated cotton yarn, there are many fibres (hairs) erecting from the yarn surface. These fibres are the cause of fly shedding during the knitting processing.

From the images in Fig.s 5-7 the effect of the concentration of the coating solution can be clearly seen. The majority of hairs were stuck down to the surface of the yarn, as the concentration of the coating solution was increased. Furthermore, the amount of coating material on the yarn surface seems to be very high on the yarn coated with 100% coating solution. However, a higher amount of coating is not necessarily desirable, as the coated yarn may cause difficulties during knitting due to its poor bending characteristics. Whats more, the polymer material on the surface of the coated yarn can shear off during knitting, which could block yarn guides resulting in yarn breakages.

3.3 Influence of coating on yarn strength

The breaking-strength of normal (uncoated) and coated yarns were determined. Only yarn coated with CM1, CM2 and CM3 were tested as yarn coated with CM4 caused difficulties unwinding the yarn from the packages. A similar problem was observed with yarn coated with CM1 in concentrations over 60%.

As can be seen from Fig.8, yarn coated with CM1 and CM2 showed slightly higher breaking-strength than normal yarn. A possible explanation is that the coating material contributes to the yarn strength by covering the thin places of the spun yarn. The results also show that the breaking-strength of the yarn coated with CM2 increases with increasing coating bath concentration. This may be due to more coating material being deposited on to the yarn surface.

The polymer coating material contributed to the yarn strength, thus increasing the breaking-strength. However, a slight increase in the breaking-strength of the yarn coated with CM1 was found. In contrast, the breaking strength of yarn coated with CM3 was lower than the normal yarn. A possible reason for this is likely to be that the coating material weakened the strength of the cotton fibres due to its chemical composition. The above results show that the coating material can influence the breaking strength of the normal cotton yarn due to coating, and therefore, the coating polymer material have to be selected carefully.

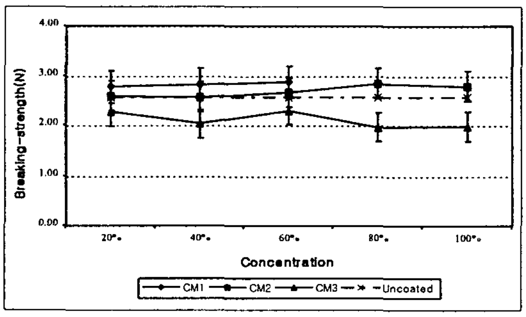

Fig. 8. Influence of coating on yarn breaking-strength.

3.4 Influence of coating on yarn elongation

The results of the elongation at break are given in Fig.9. The result showed that the elongation at break decreases due to coating. The possible reason for less elongation of the coated yarn may be due to the film of coating material on the yarn surface influencing the yarn elongation. A significant reduction in elongation at break was observed for yarn coated with CM3. However, the reduction in elongation at break of yarn coated with CM1 and CM2 is insignificant as the bandwidth of the error bars of the results lies within the elongation values measured for normal yarn.

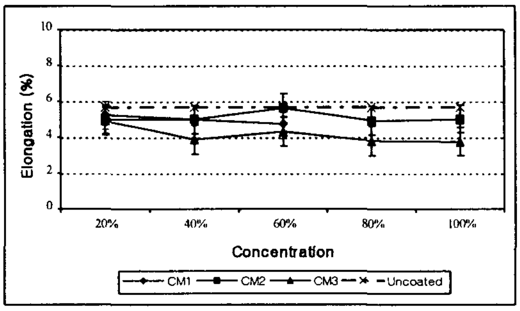

Fig. 9. Elongation test of various types of yarns.

3.5 Friction test

Yarn friction is considered the main cause of fly shedding during the knitting process. Yarn comes into contact with many stationary surfaces along its path from yarn creel to the knitting point. Due to coating one could expect reduced fly, as the coating material can not only hold loose fibres on to the yarn surface, but can also reduce the friction between the yarn and contact surfaces.

Fig.10 shows the results of friction tests. These test results are from the SDL friction/ hairiness machine. Unfortunately, friction of some yarns coated with CM3 and CM4 could not be measured, due to problems such as yarn slippage on the rollers of the testing machine and poor yarn unwinding from the cone. As can be seen from the results, the friction of the coated yarn is higher than the normal yarn. Usually, yarn comes into contact with smooth surfaces such as a highly polished metal or porcelain. Considering the test results, as the concentration increases, the more coating polymer seems to cover the uneven places on the surface of a normal yarn making the surface of the coated yarn smoother. As a result, the contact surface areas between the coated yarn and the yarn contact surfaces could increase causing a higher frictional drag.

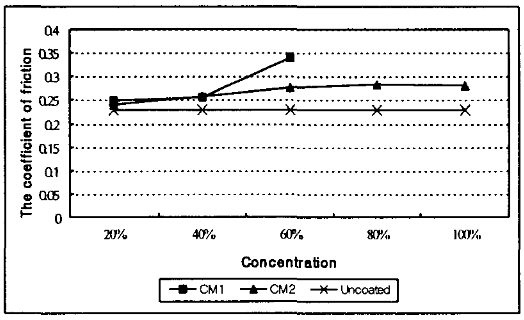

Fig. 10. Comparison of friction between uncoated yarn and yarn coated with CM1 and CM2.

3.6 Hairiness test

One important factor of fly shedding is the hairiness of a yarn, which is distributed on the surface of spun yarns. Short hairs on the surface of the yarn are the main cause for the fly shedding. Therefore, the number of hairs on the surface of the yarn before and after coating was studied. Before testing the hairiness of coated yarn, the average number of hairs over 3mm length of a normal cotton yarn was measured at different yarn speeds. The results showed that short fibres are not detected accurately at higher yarn speeds. Therefore, all the tests were carried out at a yarn speed of 60 m/min, which is also recommended as the most reliable testing speed by the equipment manufacturer. Fig. 11 shows the distribution of the hairiness of uncoated yarn.

The test results show that the hairiness of the yarn is influenced mostly by 2~3 mm length yarns (hairs). If the proportion of short fibres in component yarn is high, fly shedding becomes high during the knitting process. The main objective of coating yarn is to fix the short fibres (hairs) on to the surface of the yarn making them secure for knitting.

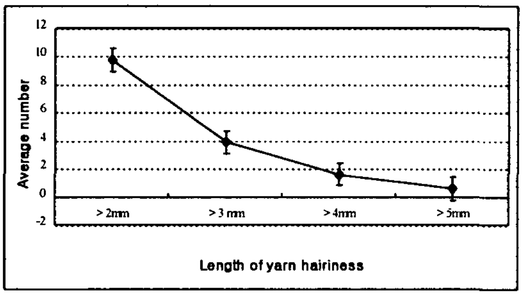

Fig. 11. Variation of mean number in different measuring length of hairiness.

Fig. 12 shows the test results on hairiness for some coated yarns. Some yarn coated with high concentration solutions could not be tested because of unwinding problems of the coated yarn. The average number of hairs on coated yarn was slightly lower than for normal cotton. Whats more, the amount of hairiness was decreased slightly by increasing concentrations of the coating solution. Therefore, the hairs can be anchored down on to the yarn surface by coating.

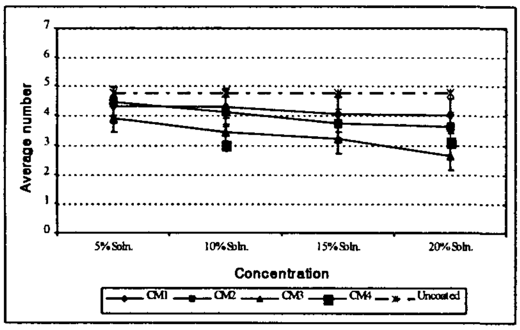

Fig. 12. The number of hairs on various coated yarns.

3.7 The amount of fiber fly

Tests for the amount of fly were carried out with several coating materials at low input tension of 3 cN in the testing rig described earlier. The test results are given in Fig. 13, which showed an increase in the amount of fly at higher concentrations of coating solution. This was accounted for by some of the coating materials showing a higher adhesion even in low concentrations, and difficulties were encountered when unwinding such yarn from the package. Furthermore, at higher concentrations, coated polymer particles were observed on the surface of the yarn after drying. During the fly test such polymer particles may have detached from the yarn surface, thus increasing the amount of fly measured.

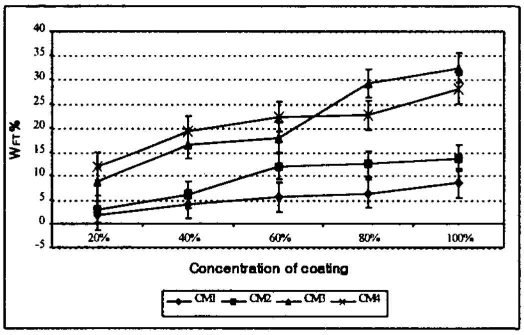

Fig. 13. The amount of fly shed from coated yarns.

Therefore, it can be concluded that yarn should be coated with low concentration coating solutions so that the knitting process will not be adversely affected. As shown in Fig.13, yarn coated with CM1 and CM2 shed low amount of fly although it was insignificant when coated with low concentration solution. Consequently, this study continued to find out the best low concentration of coating solution with CM1 and CM2 in slightly higher input tension of 10 cN in order to study the effect of yarn tension on fly shedding.

The tests were carried out with yarn coated with low concentration solutions at different yarn speeds. The fly shedding was checked with two categories, namely, a total amount of fly and a fly amount from around the needle. There were several contact points on the test-rig such as yarn guides, rollers and tension heads. Hence the total amount of fly was measured in order to evaluate fly shedding on the parts. The total amount of fly was calculated by weight difference before and after testing with the equation 1 and the amount of fly from around needle with equation 2. The results are represented graphically in Fig. 14 and Fig. 15.

As can be seen from Fig. 14, all of the coated yarns (except CM1-10%) show a higher total amount of fly compared to normal yarn. Even though there isnt a significant difference between the normal and CM1-10% coated yarn in the amount of fly, CM1-10% coated yarn seemed to have the aimed properties, namely, holding surface fibre on to the yarn body. Fig. 15 shows the variation of fly amount collected from around the needle. CM1-10% coated yarn showed less fly compared to yarn coated at other concentrations. This also could be accounted for by the good holding effect to prevent the fly shedding on the needle hook.

Furthermore, it can be said from the results that yarn coated with polymer CM2 generates more fly than the normal yarn. This may be due to poor adhesion of surface fibre on to the yarn body by polymer CM2. An increase in fly amount could also be due to the shedding of the polymer coating in the form of fine polymer particles (coated material). A fine white powder could be observed in the fly collected in the test rig. It was extremely difficult to separate the fly and the polymer residue to determine the true fibre content. Therefore, all the results of fly amount represented in this paper include both the weight of the fibres shed and fine polymer residue.

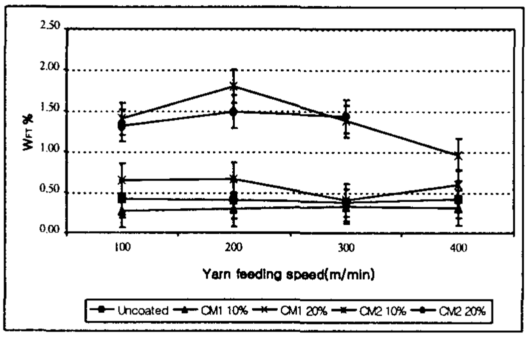

Fig. 14. Total amount of fly with yarn coated with CM1 and CM2.

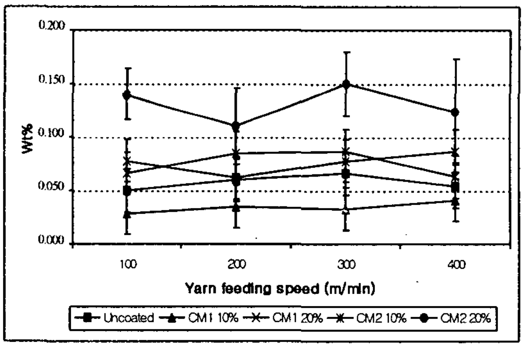

Fig. 15. The amount of fly collected around the needle with yarn coated with CM1 and CM2.

Fig. 16 shows an image of the yarn surface coated with CM1-10% coated yarn. It showed the surface fibres could be stuck down to the yarn body even with low concentration of coating solution.

The investigation so far showed that CM1 with 10% concentration has an effect in reducing the amount of fly. In order to investigate the effect of other concentrations, further analysis was carried out with 5% and 15% concentration. As shown in Fig.17, all yarns coated with 5%, 10% and 15% concentrations of coating solutions seemed to have an effect in reducing total fly amount. However, Fig. 18 shows that the amount of fly in the needle hook has a slightly different result than the total amount of fly. This may be accounted for by the following reasons. First of all, some polymer residue was found in the accumulated fibre-fly on the filter paper during testing with the yarn coated with 15% concentration. This may be due to an excess coating so the polymer particles were shed from the surface of the coated yarn. Otherwise, 5% concentration was likely to have less influence from the polymer residue, however the results suggested that this concentration may not be sufficient to anchor the loose fibre on to the yarn body during testing.

Fig. 16. Image of the yarn surface coated with 10% of CM1.

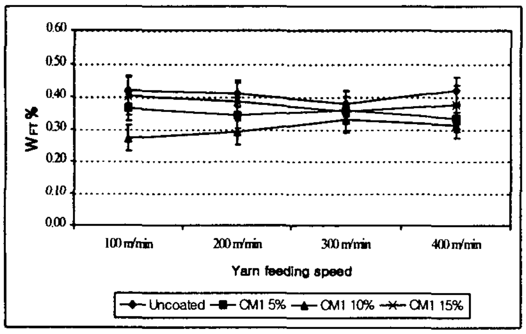

Fig. 17. Variation of total fly amount from yarns coated with 5%, 10%, 15% of concentration.

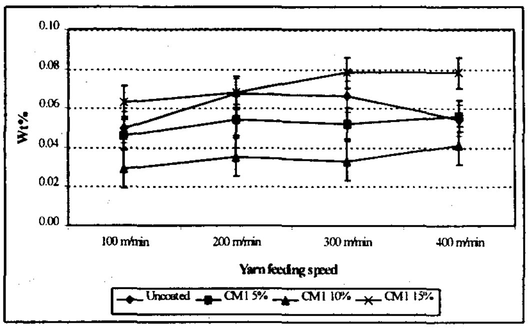

Fig. 18. Variation of fly amount around needle hook from yarns coated with 5%, 10%, 15% of concentrations.

4. Conclusions and discussion

Throughout the research, many causes of fibre-fly creation during knitting have been investigated. Reducing the amount of fly during knitting have been studied with a new trial of yarn coating and tested against some factors that influence fly shedding. Various coating materials and concentrations were studied in the research. Properties of the coated yarn were tested and compared with a normal yarn. The coating had an insignificant influence on properties such as the elongation at break and the breaking strength of yarn at low concentrations. The coating polymer should be selected carefully so as to prevent any detrimental effect to the yarn. A decrease in the number of the surface fibres (hairiness) was observed in the coated yarn. The most important function expected from coating is the holding effect of the surface fibres on to the yarn body, especially when the yarn is moving over guides, feeding devices and knitting elements during the knitting process.

First of all, a study to find suitable polymer materials were carried out and seven coating materials (CM) were chosen. Among the selected seven coating materials from CM1 to CM7, three of them CM5, CM6 and CM7 were decided unsuitable due to their high viscosity. The other coating materials from CM1 to CM4 were tested by coating yarn with different concentrations of coating solution. Yarn coated with CM3 and CM4 showed an increase amount of fly than the normal yarn even with a low amount of coating during testing. Yarn coated with CM1 and CM2 also showed an increase amount of fly with higher concentrations of the coating solution but a reduction of it with low concentrations under 20% was also found.

Secondly, polymer particles were found in the collected fly from yarn coated even in the low concentration of coating material from the needle hook. From this result, it is believed that the increased amount of fly from the coated yarn was caused by the fibre-fly and polymer particles shed together from the surface of the coated yarn during testing. This is because the frictional forces at needle and a bending of the yarn due to a sharp radius of the needle hook may have damaged the coated surface of the yarn. As a result, some coating polymers may have detached from the surface of the coated yarn. This is an important concern because a different type of contamination from the coating polymer may result due to this polymer residue. Further tests were carried out with yarn coated with CM1 and CM2 with low concentrations. From the results of the amount of fly with 10 cN input tension on the test-rig, yarn coated with CM2 showed an increase amount of fly than for normal yarn even with low concentrations. This may be due to the polymer film being damaged. The study of frictional properties of the yarn coated with CM2 showed a slightly lower value than for normal yarn, but with the respect of reducing the fly, the results showed that CM1 was better than CM2.

Out of the seven coating polymers analysed in the study only one polymer coating material, CM1, is suitable for coating yarn to reduce the fly shedding during knitting. The test results also demonstrated that 10% of the coating solution could be considered as the most suitable for reducing fly during knitting. Consequently, this research has demonstrated that the method of coating yarn with a suitable polymer is a viable option for reducing the fibre fly shedding during knitting.

REFERENCES

1. W. R. Evans, *Knitting International*, May, 41(1983).
2. G. BÜhler, O. Riederer, W. Haussler, and G. Egbers, *Knitting technique*, **10**, 163(1988).
3. B. Edberg, *Knitting Times yearbook*, p88 (1985).
4. Alan Shelton Ltd., *Textile Month*, July, 20(1982).
5. A Barella, J. Torn, and J. P. Vigo, *Textile Research Journal*, **41**, 126(1971).
6. J. A Chapman, M. W. Pascoe, and D. Tabor, *Journal of Textile Institute*, **46**(1955).
7. H.G. Howell, K. W. Mieszkis, and D. Tabor, *Friction in textiles* , London Butter worths Science Publications, p32(1959).
8. Taylor Marjorie A, *Technology of textile properties* , unknown(1974).
9. J. J. F. Knapton, *Textile Institute and Industry*, 23(1963).
10. D. J. Spencer, *Knitting Technology* , Pergamon press, p67(1989).