기술논문

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Causes of Fly Generation during Knitting Process

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1. Introduction

The problem of fly generation on circular knitting machines has become more serious over the last few years. The clothing industry requires more goods made from natural fibres. These are mostly liable to create fibre fly. Another contribution to the problem comes from the increasing speed of knitting machines, which makes loose fibres separate from the main body of the yarn due to increase in yarn tension and frictional forces. One serious problem caused by the generation of fibre fly is the decrease in working efficiency of the machine caused by yarn breakage. For instance, loose fibres will not accumulate at the hook of a latch because of the self-cleaning effect of the latch needle in stitch formation. However, the loose fibres may get into the cheek of the needle and cause a stiff latch. Furthermore, loose fibres may accumulate on the stationary yarn guides because of the friction generated by the yarn moving over the guides. These accumulated balls of fibre on a yarn guide eventually lose their adhesion and fall onto the yarn and are fed into the knitting points. Alternatively, they can block the yarn guide, eventually leading to yarn breakage. Both will lead to fabric faults or machine stoppage. These faults in knitted fabrics, especially when cotton yarns are knitted on high production circular knitting machine, are frequently due to fibre fly. Many fault analysis projects have shown conclusively that 60~80% of faults are caused by fibre fly [1]. Thus the costs incurred by these faults may be up to 4~6% of the total turnover [2]. The fibre fly [3] can also cause quality, health, fire as well as maintenance of knitting machine problems. The fact that it accounts for 15% of all faults, 15% of downtime for maintenance, and weight losses between 0.5 and 1% of a knitted fabric demonstrates the importance of the fibre fly problem. Therefore, the important fact is that the fibre fly problem influences all aspects of knitting process.

There are many factors that affect fibre fly shedding in circular knitting from the type of yarn, to the contact points on a knitting machine. Synthetic filament yarn does not produce this problem due to its manufacturing characteristics, but spun yarn (especially those made from cotton) displays this problem in all areas of textile processing. As the production speed of knitting machinery increases the structure of spun yarn creates an even more serious fiber fly problem. In particular, the yarn comes into contact with yarn guiding elements and knitting elements, and as yarn speed and the knitting speed increase fiber fly generation also increases. All yarn contact points on a circular knitting machine are potential causes of fiber fly shedding. The object of this research is centered on evaluation of the all possible

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causes of fiber fly shedding in order to study a new method of preventing this liberation of short fibers from the yarn surface during knitting.

2. Parameters Affecting Fiber Fly Shedding

2.1. Fiber Type

Textile fibers are the basic component of any yarn. Natural fibers have a comparatively short length. In order to produce a satisfactory length of yarn of suitable strength, short staple fibers require spinning and twisting together. The characteristic of short fiber length of most natural fibers is of fundamental significance in this study. Most manufactured fibers have indefinite length, which requires combining with other filaments with some twist in order to produce a yarn of sufficient bulk. However, they may also be cut or broken into the staple fiber, from which they are later spun on systems originally developed for natural fibers such as wool or cotton. Due to the inherent characteristic of the long length of this fiber, they are quite free from the fiber fly problem. Evans [4] mentioned that synthetic yarn is rather free from the fiber fly problem because the continuous nature of the synthetic yarn reduces the risk of filament breakage and any broken filament remains attached to the yarn. It also resists well bending strain because of its flexible and elastic property. However, yarn spun from natural fibers is prone to shedding during textile process.

There are many parameters of fibers that influence fiber fly shedding during processing, which are also important to the structure of yarn, the yarn preparation process, the knitting process and so on. The most basic parameters of a fiber are fiber length, fiber fineness and torsional and flexural rigidity.

2.2. Fiber Length

Fibre length is a basic factor in textile processing and is also one of the factors influencing fibre fly shedding. Like all other physical properties of natural textile fibres, fibre length varies considerably within any one sample. Goswami *et al* [5] showed that the variability in terms of the coefficient of variation in fibre length might be as high as 40% for cotton. They also found that man-made staple fibres are generally much more uniform but they may have a coefficient of variation of as much as 10%. This variation is partly caused by faulty stapling and by fibre breakage that occurs during processing.

The average length of the ends and loops of fibres provided from the staple fibre yarn is very small. Ruppenicker and Lofton [6] showed that in the case of cotton, the majority of fibres are less than 30 mm. Fibre lengths greater than 30 mm are also very rare. Brown [7] also found that fibres shorter than about 10 mm tend to have insufficient length to permit them to be twisted into a strand of adequate cohesion, regularity and evenness to make it a useful yarn structure. They said that if the binding fibres were too short, they would very much involve in the creation of fly.

Brown [7] investigated that 90% of the fibres set free in the knitting zone have a length of 9.5 mm at most with the average length being less than 3.5 mm. Ruppenicker and Lofton [6] also found that 30% of fly length is less than 2 mm shed from a yarn package creel. It can therefore be stated that short fibres in yarn are insufficiently bound into the body of the yarn to remain there during knitting.

In order to tackle this problem the mean fibre length of the yarn should be increased. Lawrence *et al* [8] investigated the relation between mean fibre length and fibre fly shedding are found that the amount of fibre

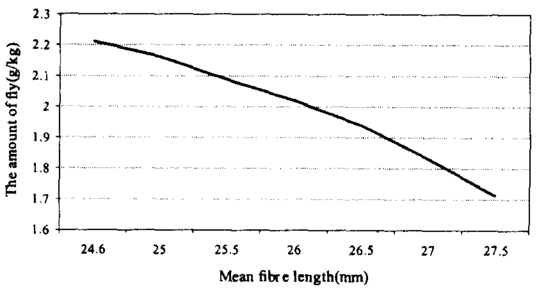

Figure 1. Effect of mean fibre length to fibre fly generation [8].

fly decreased as the mean fibre length was increased (*Figure* 1). By increasing these mean fibre lengths, there would be many finer fibres in the yarn cross section which should increase the friction between the fibres, resulting in better fibre adhesion. Furthermore, with the increased mean lengths, there would be a greater contact length between fibres, thereby reducing the degree of fibre slippage when the yarn is placed under stress.

The number of protruding fibres influencing fibre fly shedding is also affected by the fibre length and flexural rigidity. Pillay [9] found that short fibre percent and torsional rigidity come next in order of importance since the number of fibre ends per unit length of yarn for a particular count is determined by the mean length of the cotton and the fibre weight per unit length.

Gohl and Vilenski [11] found that blending of staple and filament fibres can maximise the distribution of fibre length and reduce the percentage of short fibres in the distribution. In case of cottonpolyester blended yarn, polyester is stronger than cotton fibre, and should therefore better withstand stresses during knitting. They also showed polyester wrapper fibres promote a more compact arrangement of the underlying fibres in the core of the yarn than cotton wrapper fibres would. For example, Ruppenicker and Lofton [6] showed that yarn spun from the shorter staple cotton and cotton blends sheds about 20% more fibre fly than long staple cotton spun yarn. They also said that blending polyester with cotton reduces fibre fly shedding by approximately as much as the amount of polyester added.

When using staple fibre yarns on knitting machines, fibre fly will occur at various points from the yarn package to the knitting point. This is caused by the variation of frictional force in yarn movement. B hler et al [10] found this accumulation of fibres is made up of primarily short fibres or broken pieces of fibre (10 mm). Consequently, a reduction in mean fibre length causes an out-of-proportional rise in the production of fibre fly.

2.3. Fiber Fineness

Fiber size [2] is usually specified in terms of diameter or linear density. Sometimes cross-sectional area and specific surface are used. Textile fibers come in various forms and cross-sectional shapes, whether they are natural or synthetic fibers. Some like wool and synthetics have a circular cross section, whereas others have an irregular shape. Ruppenicker and Lofton [6] investigated that finer yarns shed more fiber fly than coarser yarns, which is accounted for by the fact that the same weight of fabric from finer yarns requires a greater length of yarn, and results in more surfaces coming into contact with the knitting elements. They also added that coarser yarns contain more fibers in the cross section, and so there are greater frictional forces between the fibers in the yarn body to hinder deposition and slippage of the fibers, and accordingly there is reduced fiber fly.

2.4. Yarns

Yarns are the raw materials used in fabric production. The quality of yarn itself is an important factor in the problem of fiber fly. Brown and Evans [4, 8] found that combed cotton yarn sheds fiber fly less than carded yarn, but it costs more. Evans [8] also showed that open-end spun yarn produces about 50% less fiber fly than ring spun. Improved staple quality, greater staple length, finer and less brittle fibers reduce the fiber fly shedding as well, but once again they all cost more. Adding twist to the strand also helps to bind the fibers but alters the yarn stiffness, with consequent deterioration of knitting characteristics.

2.5. Yarn Twist

Fibers are usually twisted together by the process of spinning to produce a yarn. The purpose of twist in staple yarn is to generate lateral pressure and thus help in firmly gripping the fibers together. Lawrence et al [8] showed that the greater the twist, the higher the lateral pressure and the more closely the fibers are held. If longer fibers are used in the production of yarns, they will have a large surface area of contact (overlaps), over which the fibers can be made to cohere by means of twist. The degree of twist given to a yarn affects a number of aspects of its appearance, behavior, durability and fiber fly.

Twist plays an important role in affecting the arrangement of fibers or filaments in the yarn cross section. Gohl and Vilenski [11] showed that as the twist increases, the surface fibers could be a series of ridges inclined at an increasing angle of steepness to the direction of movement by their helical orientation to the yarn axis. These ridges support the yarn and have only a small area of contact with the machine elements. This reduces the frictional force acting at the interface of the yarn and the machine element, and consequently decreases the amount of fiber fly generated.

Klen *et al* [12] found that as the twist gradually increases there is a decrease in the number of protruding fiber ends and loops. Twist in yarn will run closer to the nip of the front rollers for higher twist, resulting in an improved control over the emerging fibers. Thus longer length fibers will have a greater chance of being bound up into the body of the yarn and shorter lengths will be more apt to protrude outside. As the result of fiber entanglement with the twist, the opportunity of fiber fly shedding also decreases.

In terms of reducing fiber fly, high twist yarns are more beneficial as mentioned before. However, processing properties like strength and pliability of the highly twisted yarn during knitting can be worse than with an optimally twisted yarn. Therefore, yarn twist should not be increased for only the purpose of reducing fiber fly.

2.6. Hairiness

As yarns are spun faster than ever before, the increasing speeds of rotating put the yarn under greater stress whether it is open-end or ring spun. A side effect of these increased speeds is a tendency to spin hairier yarn. Hairiness is an undesirable property in a yarn if it leads to an increase in surface friction and then fiber fly generation.

Lee *et al* [14] defined yarn hairiness as the fibers in the outer layer of the yarn where cohesion to the core of the yarn is small. A certain number of fiber ends rooted in the core of the yarn are entangled with other fibers, whereas the other end protrudes as a consequence of the mechanical properties of the fiber (rigidity, section et). Yarn hairiness affects the appearance, handle, and appeal characteristics of yarns, and fiber fly shedding as well. Pillay [9] showed that the hairiness of yarn seems to fall into two methods. One is the quantitative assessment of hairiness and the other is the influence of yarn structure and processing factors on the length, numbers, and distribution of protruding fibres.

Among the several factors, fiber length has more effect on yarn hairiness than either fiber fineness or fiber strength. For example, Ruppenicker and Lofton [6] found that cotton/polyester blend yarns are less hairy than 100% cotton yarns. They mentioned that part of the reduction in fiber fly shedding of the blend could probably be attributed to the strength and toughness of the polyester fiber. They also assumed that fiber fly shedding is related to yarn hairiness with good correlation that may be caused from the effect of the level of inserted twist.

2.7. The Moisture Content in Yarns

Fibers vary significantly in the quantity of moisture they absorb. Some fiber properties as well as yarn properties are altered by their ability to absorb moisture. As far as the production of fiber fly is concerned, swelling and surface moisture on the yarn may have a particular influence in this matter. Bühler investigated [2] that when yarn moisture content of a cotton/viscose mixture yarn was raised by 130%, there was a reduction in the amount of fiber fly shed of about 20% (see in *Figure* 2). This can be accounted for by the fact that the moisture absorbed by the yarn causes swelling and results in a substantial raising of the tenacity of the yarn and yarn extensibility. He and his colleague [2] also studied that both carded and combed cotton ring spun yarn shed more fiber fly in a dry state. They also said the fact that the high degree of swelling and suction ability of cotton and viscose makes the pulling out of fibers from the yarn structure much more difficult.

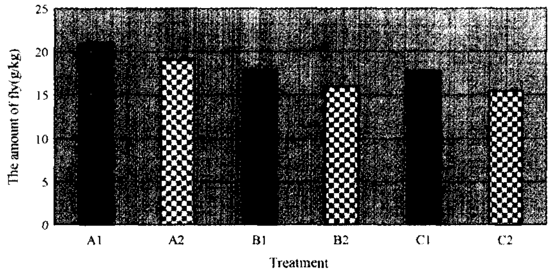

Figure 2. Effect of moisture content on the fiber fly shedding [2].

Ruppenicker and Lofton [6] showed that when in their oven-dry state, both carded and combed cotton yarns showed an increase in fiber fly shedding of 8% or 9%. There was a reduction in the production of fiber fly when the yarns had moisture content of 6.9%. This reduction in the case of the carded cotton yarn only amounted to 2% but in the case of the combed cotton yarn it amounted to 12%. They also mentioned that a change in the moisture content of the yarn had a much stronger effect upon the fiber fly generation or rather a reduction of it. That is to say, the combed cotton yarn has a much better fiber orientation than the carded cotton yarn and this together with the swelling effect causes the fibers to adhere more closely to the body of the yarn.

2.8. Yarn Preparation

Spinning is the final process in the production of single yarn. Staple fibers have a very wide range of physical properties and many of these have some effect on the methods used in processing them into yarn. Spun yarns are those produced from staple fibers and the length of the staple fiber is critical in determining the spinning process that will be used and on the properties of the yarn.

Tortora *et al* [13] found that different spinning systems orientate the fibers differently, especially on the surface of the yarn and also bind them differently into the yarn structure. It is therefore possible to assume that a high fiber orientation will give the fibers fewer opportunities to tear themselves away from the yarn body along the yarn surface structure. However, a good orientation of the fibers does not mean that either one or both fibers ends are firmly anchored in the body of the yarn and therefore, the importance of the inner yarn structure should be considered.

Furthermore, B hler *et al* [2] showed that generally, ring spun yarns that are usually in the lower twist range display a proportionally greater increase in fibre fly with a decrease in twist per unit length. This effect tends to become more pronounced when more short staple cotton is used to spin the yarn. Carded ring spun yarns in particular display a high fibre fly shedding when the twist in the yarn is low.

The staple length of the fibers forming the yarn is known to be the main parameter affecting the tendency of cotton yarn to shed fly. Carded yarns contain fewer aligned fibers in their body, so fine fibers can be removed from the yarn body more easily than coarse fibers during knitting.

Figure 3 shows that the knitting zone has short fibres in the fibre fly than the fibre fly collected from the yarn guide area. This may be accounted for by the more severe frictional forces on the yarn at the knitting zone, so the surface fibres may be cut and shed during the knitting.

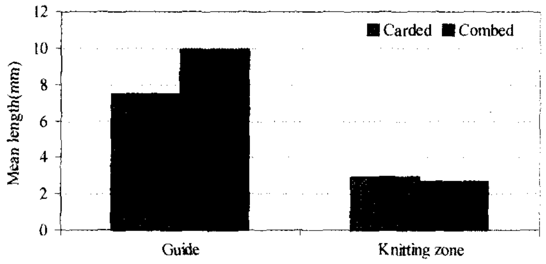

Figure 3. Mean fiber length of carded and combed yarn collected from different areas of the circular knitting machine [4].

Several studies [6, 12] show yarns spun at a higher spindle speed consistently shed less fibre fly during knitting. Lofton [6] showed that yarns spun at a low spindle speed involving a sliver carded at a high carding rate shed substantially more fibre fly than yarns spun at a high spindle speed with a sliver carded at a low carding rate. He accounted for that because although higher carding rates can increase the yarn strength due to better fibre orientation, high carding rates also may damage the fibres. After all, a change in carding rate could increase the short fibre content in the sliver and result in an overall increase in fiber fly shedding.

3. Circular Knitting Machines

Among the various developments in circular knitting machines over recent years, attempts to increase the productive capacity of the machines have been very successful. A number of innovations have been introduced to increase the speed of knitting. These include improvements in the design of knitting machine needles, as well as an increase in the number of knitting points. However, in the

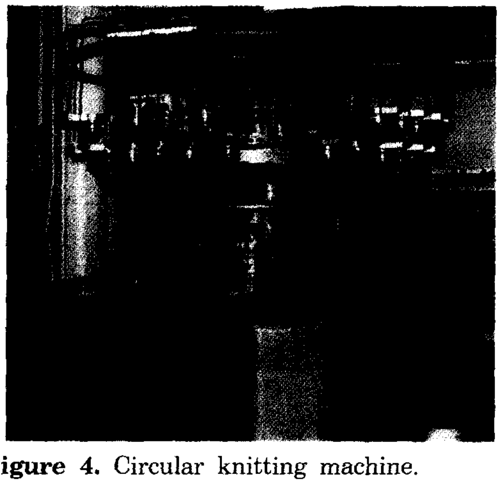

Figure 4. Circular knitting machine.

effort to improve knitting machine productivity, the fibre fly problem was exacerbated as well. Furthermore, the number of feeders around the cylinder of the circular knitting and the knitting speed of these machines is directly connected with the creation of fibre fly.

The distribution of fiber fly generation has been investigated on many areas of the circular knitting machine [1, 8]. This distribution seems to be connected to the length of fiber fly and the sector of the machine where the fiber fly is collected. The mechanisms of fiber fly liberation may have been the cause of the difference in the length distribution between the sectors of the machine. Most of the fiber fly is shed from the yarn body along the yarn guides and the knitting zone. The main reason for fibre fly shedding on all points of the knitting machine is friction.

B hler *et al* [10] found that contact friction that is encountered frequently on knitting machines increase as yarn tension increases. Based on these considerations it is possible to count on an increase in fibre fly values when the forces upon the yarn rise. fiber fly shedding increases rapidly and at an almost linear rate with an increase in yarn tension. Ruppenicker and Lofton [6] showed the positive feed mechanisms in reducing fibre fly shedding is important by continuously maintaining low and uniform yarn tension. Increasing take-up tension causes more yarn-to-yarn and yarn-to-metal friction.

There are three main areas of fibre shedding on high production circular knitting machines processing spun yarn. These are free standing creels, positive storage feeders and the knitting area.

3.1. Yarn Creel

The yarn creel is a specially designed compartment to store the yarn for the circular knitting machine (*Figure* 5). The yarn creel is seriously affected by fiber fly because of its design. Lee and Ruppenicker [14] found that approximately half of the total weights of the fiber fly is released during unwinding of the yarn from the yarn packages. Lawrence et al [1, 8] also studied that a third of all fiber fly was found in this creel section. The vast majority of all the short fibers are also released at this stage.

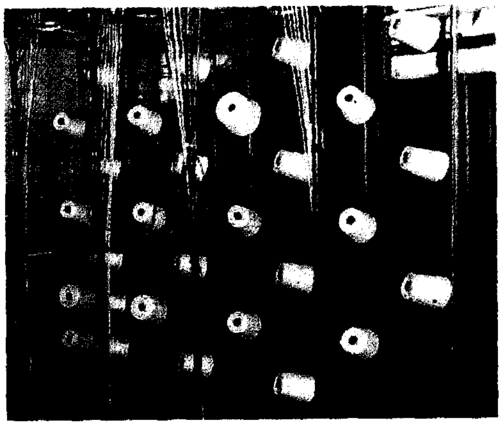

Figure 5. Yarn creel section.

In the yarn creel section, fibre shedding is caused by the release of short fibres (under 10 mm in length) that are loosely held in the yarn structure. Normally, these are shed during yarn unwinding from the package. Subsequently, long and loose fibres that initially reside in the yarn surface can be ejected by the ballooning forces of the yarn. These fibres may be quickly recaptured by the moving yarn while it whirls as a balloon. There is also mechanical interlocking of protruding fibres from different yarn layers, which may be broken resulting in fibre fly during unwinding from the package.

3.2. Positive Storage Feeder

In order to produce fabrics of uniform quality it is absolutely essential to maintain a uniform stitch length. However, although the feeders do produce great technological results,

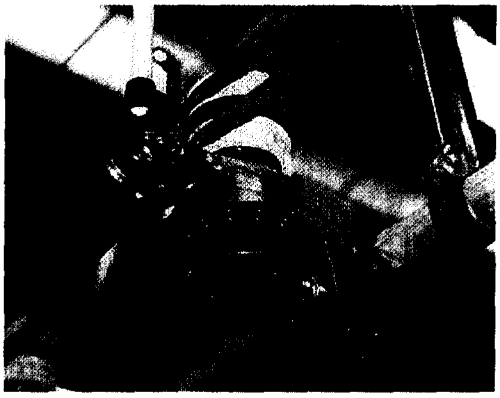

Figure 6. Positive feeder device.

they are considered a major source of fibre fly. Here, the yarn comes into contact with several elements as shown in *Figure* 6, such as a yarn-tension, a knot-catcher and a stop motion. Yarn must contact all of the elements that divert it.

Spencer [1] showed that in the yarn stop motion of the feeder; the wire-bracket that rests upon the yarn by its own weight is caused to vibrate by the running yarn. The resulting non-stationary load conditions upon the yarn make a contribution towards the formation of fibre fly.

In addition, the yarn should be in a severe centrifugal force as the feeder rotates very fast for feeding of the yarn. As a result of the centrifugal force, fibres which are not securely held in the yarn structure point readily outwards away from the yarn coil. Whats more, the high rotation speed of the yarn-feeding drum produces additional substantial air resistance forces. Hence, the surface fibres unanchored firmly on the yarn body can be pulled out. Fibre fly distribution on a circular knitting machine that is equipped with positive feeders is given in *Figure* 7.

3.3. Knitting Zone

The yarn is converted into knitted loops at the knitting position on the knitting machine. In order to achieve this, it is necessary to deliver the yarn with great precision to the latch needles by means of a yarn feeder. The individual parts of a yarn feeder on a circular knitting machine are the yarn-guides and the pot-eyes.

B hler *et al* [10] demonstrated that the yarn feeder fitted on circular knitting machines has two tasks; one of these is to prevent the needle latches closing the needle-hooks, when the needles are rising and before any new yarn has been fed into the needle-hooks. The second task requires the yarn feeder to guide the yarn with great precision into the needle hooks. However, Lawrence *et al* [8] reported that the knitting point represents a typical example of fibre fly being created because of

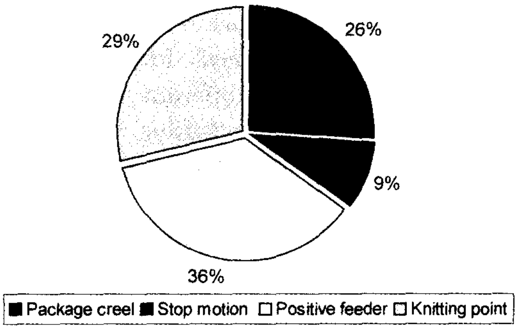

Figure 7. Fiber fly distribution on a circular knitting machine with positive feeders (wt%) [8].

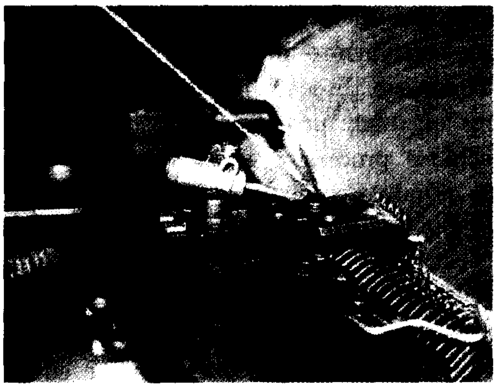

Figure 8. Knitting points.

extreme yarn diversions, i.e. narrow radii points of friction and drastically increased yarn stresses produce ideal conditions for the accumulation of fibre fly impurities.

During the stitch formation cycle, the yarn is subjected to high tension, frictional forces between yarn and knitting elements, and bending stresses. On these machines, the yarn is delivered to the yarn guide readily. After the yarn guide the yarn is delivered tangentially to the needles. This sudden change of yarn feed angle results in fiber fly shedding. Besides the yarn is forced to bend to a great degree by the tiny radius of the hook of the needles, and the stress between the yarn and the knitting elements causes the yarn to deform in cross section. This, in turn, results in a momentary localized twist change in the yarn. This may well increase the frictional forces between the yarn and the knitting elements and between fibers themselves, substantially contributing to fiber fly generation.

Evans also showed [4] that most of the fibre fly shed in the knitting zone is sheared from the yarn by the knitting elements, and the more loosely held longer fibres are pulled from the yarn as it passes through the guides. Specifically, the greatest amount of fibre fly at the knitting point occurs during the interlooping of loops when the needles are in their lowest position.

4. Processing Parameters

Lawrence *et al* [8] showed that the effect of changing the input tension gives rises to changes in two factors; the area of the contact region and the pressure over the contact surface. As input tension during knitting increases, the pressure between the yarn and knitting elements increases, and the yarn lies in a flattened state in the needle hook. The shearing forces acting on the yarn therefore increases.

B hler *et al* [10] also found that fibre fly shedding increased rapidly and at almost a linear rate with an increase in yarn tension. Hence, it illustrates the importance of the positive feed mechanisms in reducing fibre fly shedding by continuously maintaining low and uniform yarn tension.

The conicity of the yarn package also impinges on fibre fly shedding because the yarn can always be dragged between the moving yarn and the package surface. Therefore, it is desirable to decrease the conicity of the cone to reduce the abrasion between yarn to yarn and yarn to package surfaces.

Yarn feeding speed is also another factor affecting shed fibre fly during processing. Fibre fly shedding increased as yarn speed increased, probably because of the greater shearing force at the high speeds. Movements, especially when they are very fast, produce shearing forces on contact surface. Such movements may cause fibres to become detached form fast moving yarn-surfaces. The yarn speed increases in proportion to the knitting speed. Consequently, the lower yarn speed is concerned only very small increases the amount of fibre fly. Otherwise, high yarn speed increases the amount of fibre fly shedding.

5. Conclusions

Four major parameters affect the amount and kind of fiber fly shedding during knitting. These parameters are;

- Fibers
- Yarns
- Yarn processing
- Circular knitting machines.

Some properties of the fiber and yarn have been investigated to establish a theory of the mechanism of fiber fly shedding. A staple yarn will produce more fiber fly than a filament fiber. Shorter staple yarn will produce more fiber fly than longer staple fibers. A finer yarn will produce more fiber fly than a coarse yarn. A yarn with more twist will shed less fiber fly than a yarn with less twist. These properties can be moderated to some extent in the yarn preparation process, although this may well add to the manufacturing cost. These manufacturing costs must be measured against the cost of fabric faults.

There are three main areas where fiber fly is generated on a circular knitting machine. Each area has its own cause of fiber fly generation. However, the main cause of the problem at each area is related to the increase in yarn input tension caused by higher frictional forces generated by increased machine speed. It shows the relationship between the frictional forces in knitting and the generation of fiber fly. There is a clear correlation between increase in frictional forces and an increase in fiber fly.

Many methods have been tested for solving the problem of fiber fly generation, and some of these are currently used in the knitting sector. Thanks to the closed side creel, a third of the fiber fly generated in the knitting process has been contained in it. However, most of these methods have their own disadvantages and have not given a clear solution of the problem, which has at best only been partly addressed in terms of problem management and not problem solution.

The object of this study is to investigate a new method of reducing fiber fly generation on circular knitting machines from a new and comprehensive approach to the problem. In order to achieve a new solution to the problem all the properties mentioned so far including the desired fabric properties for the end use must take into account in the future development.

References

1. G. Bühler, O. Riederer, W. Haussler, and G. Egbers, *Knitting Technique*, **10**, 163(1988).
2. G. Bühler, O. Riederer, W. Haussler, and G. Egbers, *Knitting Technique*, **12**, 208(1990).
3. B. Edberg, "Knitting Times Yearbook", pp.88-89, 1985.
4. W. R. Evans, "Knitting International", May, pp.41-43, 1983.
5. B. C. Goswami, J. G. Martindale, and F. L. Scardino, "Textile Yarns, Technology, Structure and Applications", 1977.
6. G. F. Ruppenicker and J. T. Lofton, *Textile Research Institute*, **49**, 681(1979).
7. P. Brown, *Text. Res. J.*, **48**, 162(1978).
8. C. A. Lawrence and S. A. Mohamed, *Text. Res. J.*, **66**, 694 (1996).
9. K. P. R. Pillay, *Text. Res. J.*, **34**, 663(1964).
10. G. Bühler, O. Riederer, W. Haussler, and G. Egbers, *Knitting Technique*, **9**, 250(1987).
11. E. P. G. Gohl and L. D. Vilensky, "Textile Science", Longman Cheshire, 1983.
12. N. N. Klen, Maschinengerechtes und flusenfreie Garnveraveitung, *Textilbetrieb*, **101**, 1/31(1983).
13. P. G. Tortora and B. J. Collier, "Understanding Textiles", Macmillan Publishing Company, 1997.
14. J. R. Lee and G. F. Ruppenicker, *Text. Res. J.*, **48**, 27(1978).