Role of Yarn Hairiness in Knitting Process and its Impact on Knitting Room's Environment

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Abstract: Cotton fibre fly generated in knitting process due to interactions of frictional surfaces with the hairiness of ring spun yarn. This fibre fly creates a serious indoor pollution. The working personnel suffer from acute and chronic respiratory problem after inhaling cotton dust particles and fibre fly. Experimental results show that most of the fibre fly are shorter in nature compared to virgin cottons. The knitting performance is badly affected by its deposition at different places and responsible to produce poor quality fabric. The mechanical means to remove fibre fly from indoor atmosphere do not provide any cost- effective way to control it. Search for an alternative solution to control the fibre shedding problem, researchers have found the level of yarn hairiness is one of the major contributors amongst other parameters. However, our study shows the length distribution of protruding hairs from yarn surface is directly responsible to shed fly in knitting process mainly in cone unwinding zone.

Key- words*: Fibre fly, Cotton dust, Bysinosis, Ring -spun yarn, Knitting*

1 Introduction

The manufacture of textiles from raw materials or its blends involves a wide variety of physical and chemical processes, depending on the fibre type and the specifications of the fabric produce for use in clothing, furnishings or for industrial applications .Key processes include the conversion of fibre into yarn by spinning and twisting and the conversion of yarn into fabric by weaving or knitting. The principal raw materials used in textile manufacture are the natural fibres wool, cotton and silk and man-made fibres. During conversion of cotton fibres into fabrics, a significant amount of fibre fly along with cotton dust particles are released into the working atmosphere .However, persons exposed to cotton dust particles during processing of textile fibres may develop a series of acute and chronic symptoms, commonly referred to as Bysinosis[1] . The problem of Bysinosis has plagued cotton textile mills for hundreds of years, and cotton fibre fly and its dust are undoubtedly the most serious problem facing the textile industries today. The problem associated with fibre fly generation along with cotton dust is severe when ring spun cotton yarn is converted into knitted fabric on high speed knitting machine. The environmental risks associated with the manufacture of cotton knitted fabrics not only create problem of health hazards to the working personnel but also affect the machine performance as well as the quality of the product. The fact of fibre shedding was relatively unknown for the knitting industry when polyester filament was used in the knitted fabric production during its boom period some time before 1979 [2]. But when the cotton knitwear was back in great demand in global fashion, then the manufactures were put into a great trouble due to the problem of fibre shedding. An investigation was carried out in Sweden about the problems caused by generation of fibre fly and reported in December 1979. The problem was taken up at International Exhibition of Textile Machinery (ITMA) 1979 to discover what remedies were being offered. Various types of lint blowers succeeded in removing the fly from the machine into the atmosphere, but the lint suckers were relatively ineffective. Ventilation systems encountered filtration problems and heat losses. Air conditioning with floor extraction, at least in theory gave some promise. But the Swedish researchers come to the conclusion that there was nothing new on the 'fly' front at ITMA 1979. Since then, the researchers are trying to find ways of dealing with these problems from every aspect to control it in the knitting process as the demand of cotton knitted fabrics is growing day by day. Some investigations have been carried out on fibre shedding behaviour of staple-spun yarn by considering fibre, yarn and knitting parameters along with finishing treatments on cotton spun yarn [3, 4, 5, 6, 7, 8, 9]. Most of the investigators concluded that fibre fly generation is caused by the fibre properties of the yarn where the level of yarn hairiness is playing a major role. In addition to these findings, researchers observed that some knitting parameters have a direct involvement to shed fibre fly in the production of fabric. However, some of these studies reported interesting facts about fibre shedding, whereas some others are contradictory in nature. As yet little was known of the root causes of this problem, the study of the mechanism of fibre shedding behaviour at the different sectors of knitting machine may bring any partial or comprehensive solution to the present crisis of the knitting industry. Therefore, the present paper highlights the severity of problem of fibre shedding on human health as well as its impact on knitting performance and quality of fabric, physical and chemical characteristics of fibre particles and existing atmospheric pollution control in knitting room. Finally, we have reported the mechanism of fly generation in cone winding zone of knitting process and its sources as we observed an higher amount of fibre fly is deposited in this zone that have the same opinion with other researchers [3, 5].

2 Air pollution in knitting room and its sources

On the knitting machine, the fiber fly from cotton yarn generates at various en route from the yarn package to the knitting points caused by intensive friction and flexing at guides, feeders, over and under sinkers and needles and other outer interferences. The outer interferences come through longitudinal and traverse vibrations, yarn to yarn interaction, and centrifugal force due to rotational movement of the yarn after withdrawal from the cone package. As a result, short fibers or broken fiber pieces (shown in Figure1) are detached from cotton yarn structure along with invisible cotton dust and fine fibre particles as by-products. These are deposited at different sectors of knitting machine namely cone unwinding zone, guide area and knitting zone. Besides, cotton dust and small fine short particles escaped in atmosphere. They capable of temporary suspension in air, they settle under the influence of gravity with time.

3 Nature of fibre fly and chemical composition of cotton dust

From our experimental studies[10] on carded cotton yarn, it was observed that deposition of fibre fly more in cone unwinding zone and knitting zone compare to other areas in knitting machine. Accordingly, fibre fly was collected from these zones to study their length characteristics and some important fibre parameters like maturity, fineness etc. The length characteristics of fibre fly of these zones are shown in Figure 2 and corresponding fibre properties in Table 1. The data analysis of individual samples showed that total short fibres present in respective zones 97.6% and 98.9 %. And both the cases, fibre fineness of fibre fly was found finer side followed by uncommon immature fibres as compared to virgin cotton fibres. In cotton dust samples, as per the reports of the different researchers [11] to investigate the causative agent(s) and physiological mechanism of byssinosis: they observed that silicon, calcium, potassium, and aluminum were present in relatively high concentrations (1-4%) in the dust fractions. The ash content of the dust fractions increased as the fraction particle size decreased. Proximate analyses demonstrate that "noncellulosic organics" are the major class of constituents (35-45%) in cotton dust. Cellulose comprises only 10-15% of the dust, while water-extractable materials comprise approximately 20% of the dust including the presence of phosphate, malate, arabitol, citrate, fructose, glucose, and mannitol.

4 Effect of fibre fly on human health

At high concentrations, suspended particulate matter of cotton dust and fibre fly poses health hazards to humans, particularly those susceptible to respiratory illness [12]. The nature and extent of the ill effects that may be linked to suspended particulates depend upon the concentration of particulates, the presence of other atmospheric contaminants, and the length of exposure. The human respiratory defense mechanism defends itself against the invasion of foreign substances that depends on Particulate sizes (over10 μm - less than 2 μm). The success or failure of the respiratory defense systems depends, in part, upon the size of the particulates inhaled and the depth of their penetration into the respiratory tract. Approximately 40 percent of the particles between 1 and 2 µm in size are retained in the bronchioles and alveoli in lungs. Particles ranging in size from 0.25 to 1 µm show a decrease in retention, because many particles in this range are breathed in and out again. However, particles below 0.25 µm show another increase in retention because of Brownian motion, which results in impingement.

5 Adverse effects on the machine performance, fabric quality and other environmental impacts

The performance of knitting machine as well as the quality of knitted fabric is solely depend of quality of feed yarn and right choice of machine and process parameters. However, the accumulation of fibre fly in different sectors of the knitting machine creates a severe problem [2]. When fiber fly or large accumulation of fiber fly is carried with the yarn that creates problem in smooth knitting, produce hole in knitted fabric due to yarn breakage, thick place as a blemish in knitted fabric. Sometimes, bending of the needle head, shearing of needle head in extreme cases produces fabric faults like needles stripping or dropped stitches. In addition to this, there will be machine downtimes and time consuming search for defective needles, along with increased needle costs and more cleaning which reflects on the overall machine efficiency 70-80%. One fourth of fabric faults occur during the knitting process can be traced directly back to the incident of fiber fly excluding needles stripes and dropped stitches. Fiber shedding is also responsible to reduce the fabric weight at the order of 0.5% to 1%. On the other hand, high levels of fly and dust within buildings, if uncontrolled, may cause litter and nuisance problems outside the building. If not properly cleaned, build up of fly on machines and ceiling can ignite and cause fires.

6 Atmospheric cleaning processes for indoor pollution control

The initial studies [2, 3] have usually been concerned with the mechanical removal of fly from the knitting machine, with redesign of knitting equipment to minimize the effect of fly. With the application of various treatments, usually lubricants, to reduce fly production [2, 3, 7]. The use of lint blowers was made to keep the fly air borne in the sensitive areas, with the hope that the fibre fly will eventually end up on the floor. Various attempts have been made to use the vacuum cleaner principle for automatic fly and dust removal, including arrangements which combine both sucking and blowing. These have proved relatively ineffective. Once the fibre fly and cotton dust have settled on the machine the only remedy is the time-honoured blow gun. But this method demands some essential requirements to improve ventilation and extraction systems to remove cotton dust and fly from indoor atmosphere. This may have health and safety benefits as well as reducing the potential risk of fires. Potential environmental improvements may include regular cleaning and sweeping of dust and fly and extraction and ventilation system to ensure dust/fly is controlled. The environmental action plans should focus on means to minimize the generation of dust/fly to a great extent, and the adequacy of ventilation and extraction systems where and when it is generated.

7 Mechanism of fibre fly liberation in cone unwinding zone

When cotton fibres are processed in spinning process, the edge fibres are abraded with different parts of the machineries from raw material stage to cop formation (ring yarn package). As a result, these fibres become finer in diameter along with poor strength than virgin fibres (shown in Table 1). These edge fibres produce hairiness in yarn that originates from spinning triangle zone in ring spinning machine, as shown in Figure 3. The amount of hairiness further increases in cone winding process[13]. The increase in yarn hairiness level over ring cop and corresponding fibre shedding values are shown in Table 2.However, the amount of average fibre shedding in knitting process and level of hairiness in yarn have no correlation as per our findings [14],as shown in Figure 4. In cone unwinding zone of the knitting process, fibre fly usually generated from two sources. Due to interaction of protruding long hairs of the withdrawal yarn and the surrounding hairs embedded on cone surface with the formation of a triangle zone[14] at the yarn withdrawal point(Figure 5). And secondly from the yarn ballooning zone between yarn withdrawal point on cone package to yarn guide (Figure 5). It has been observed that majority of fibre fly shorter in length due to breakage of long fibres along with some long fibres liberated at cone unwinding zone. The phenomenon of fibre breakage occurs as the protruding fibres from the withdrawal yarn and the adjacent hairs from cone surface mesh together in triangle zone before leaving the package. As these fibres are weaker in strength, they easily break at this zone when yarn is pulled. Some long fibres simply come out from yarn structure due to their higher breaking strength than usual. Some broken fibres along with long fibres may carry with the yarn, they further escaped from yarn surface in yarn ballooning zone due to centrifugal force. However, the mechanisms of fibre liberation from yarn guide area and knitting zone are under proposed plan for further work.

8 Conclusions

Generation of cotton fibre fly in knitting process not only creates health hazards to the working personnel but also affects the fabric quality and smooth performance of the knitting machine. Mechanical removal of fibre fly and cotton dust from source points are not the complete solution to this problem, often some are ineffective. Improvement in atmospheric cleaning process by different means no doubt will bring a substantial change inside the knitting room but they demand high initial cost as well as running cost. However, in depth study of raw material properties, individual processes from raw material stage to fabric formation and careful investigation of mechanism of fibre shedding at different stages of knitting process may bring reduction of this problem to a great extent.

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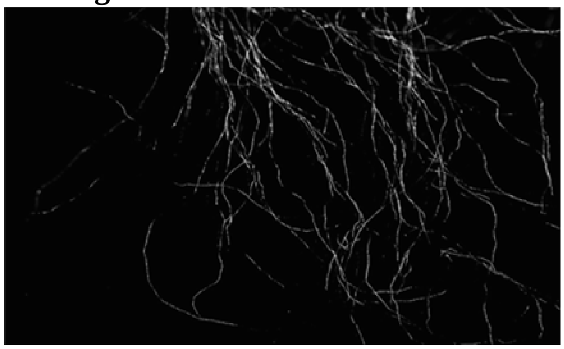
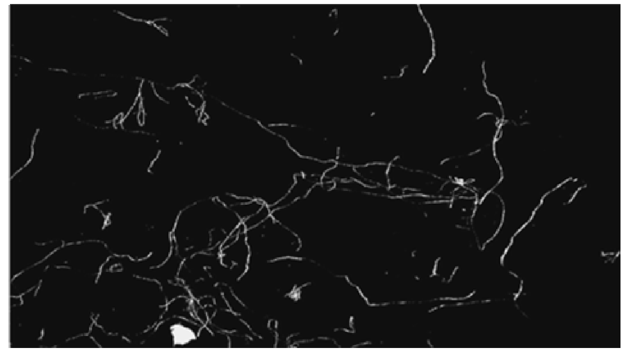
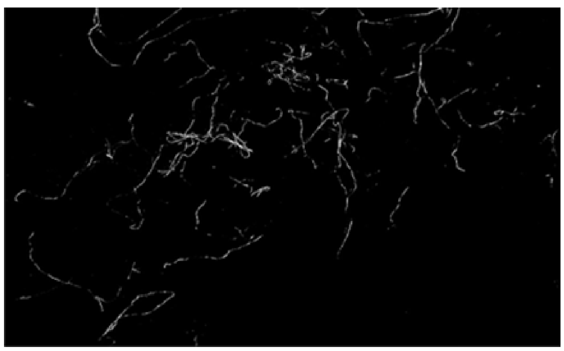
Figure 1 **Nature of virgin cottons and deposited fibre fly at different sectors of knitting machine.**



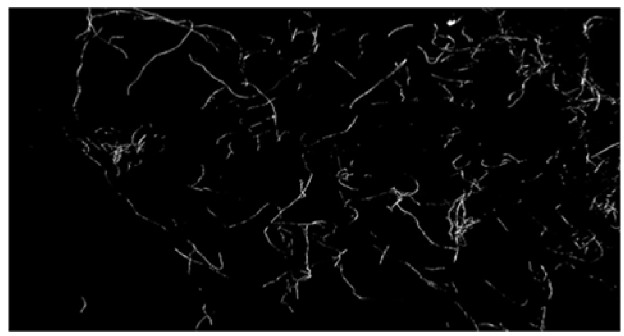
Virgin cotton fibres



Fibre fly at cone unwinding zone



Fibre fly at guide zone



Fibre fly at knitting zone

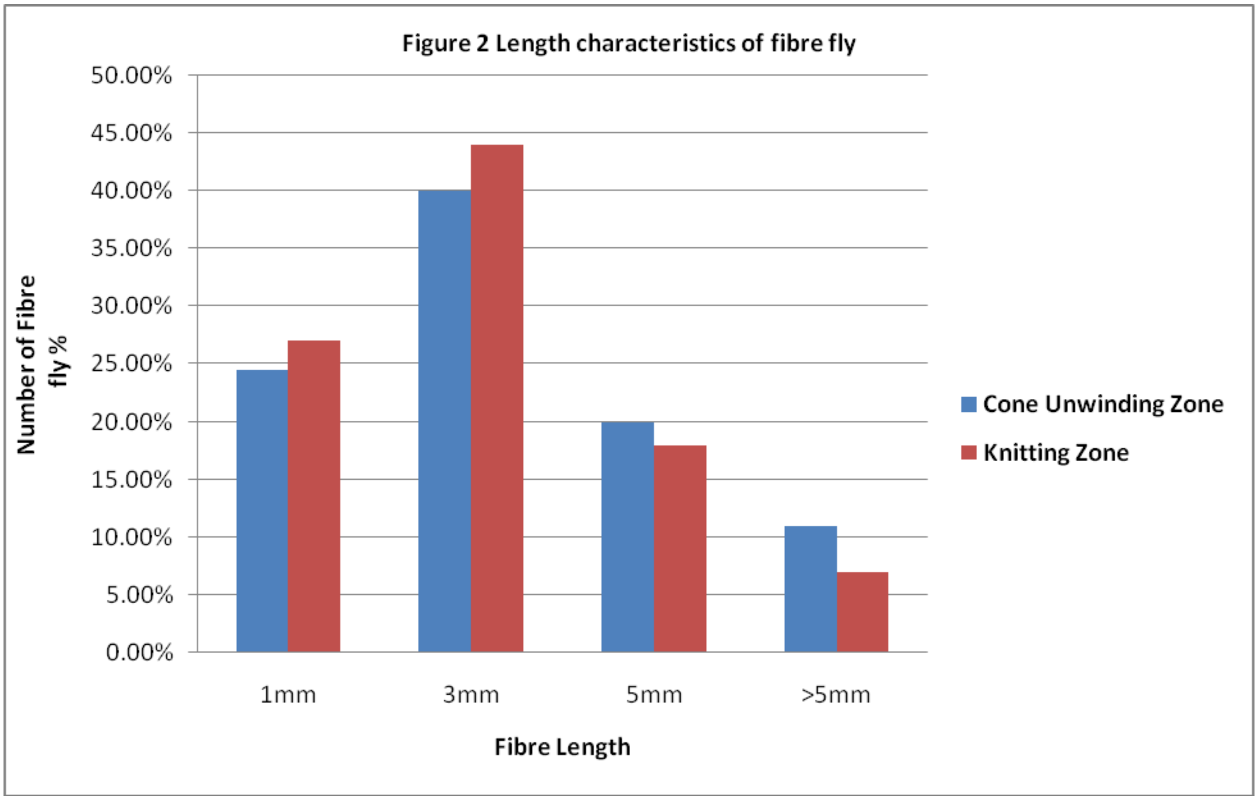
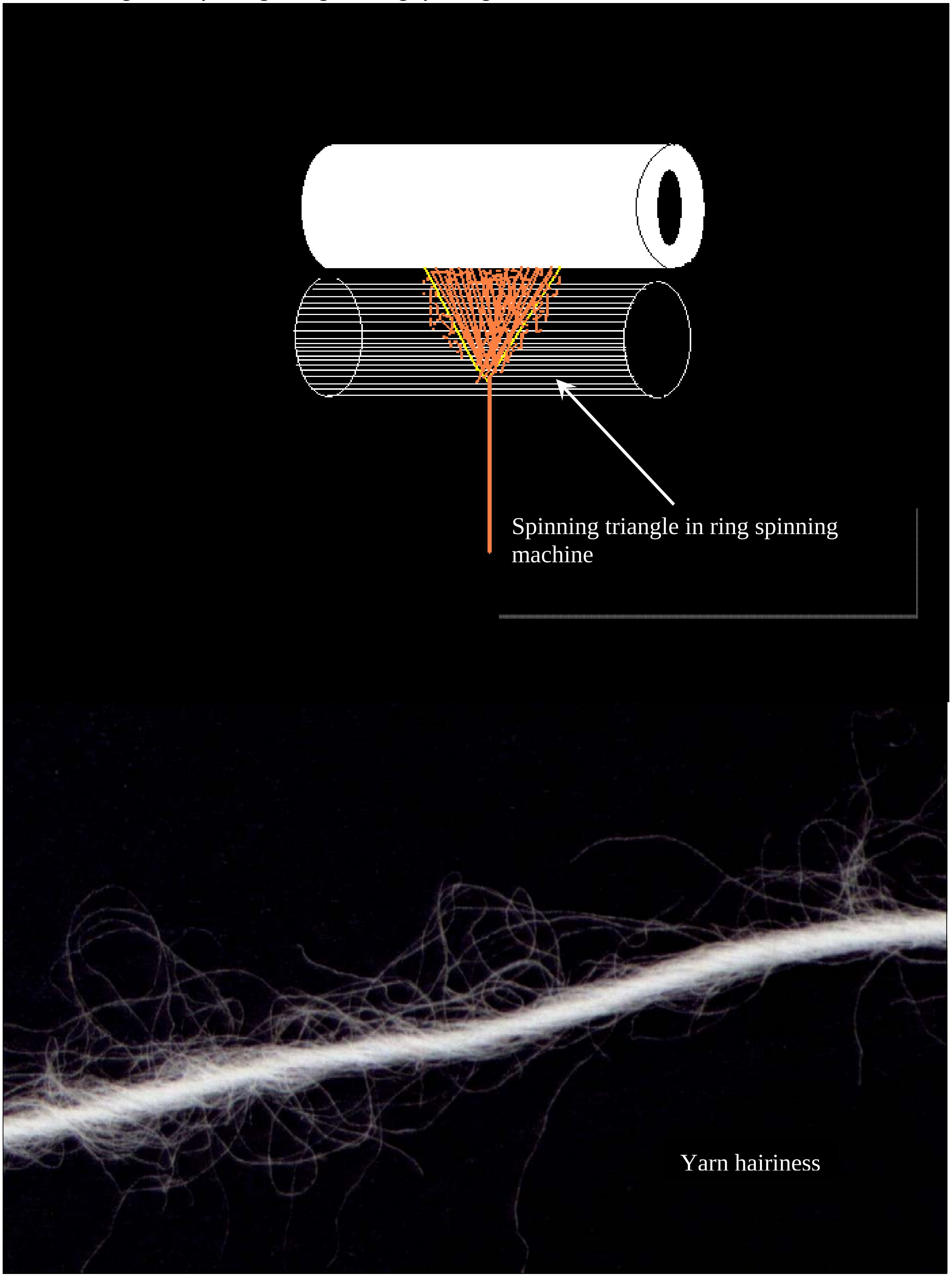


Figure 2 Length characteristics of fibre fly
Number of Fibre fly %
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1mm
3mm
5mm
>5mm
Fibre Length
Cone Unwinding Zone
Knitting Zone

Figure 3: Spinning triangle in ring spinning machine and Yarn hairiness.



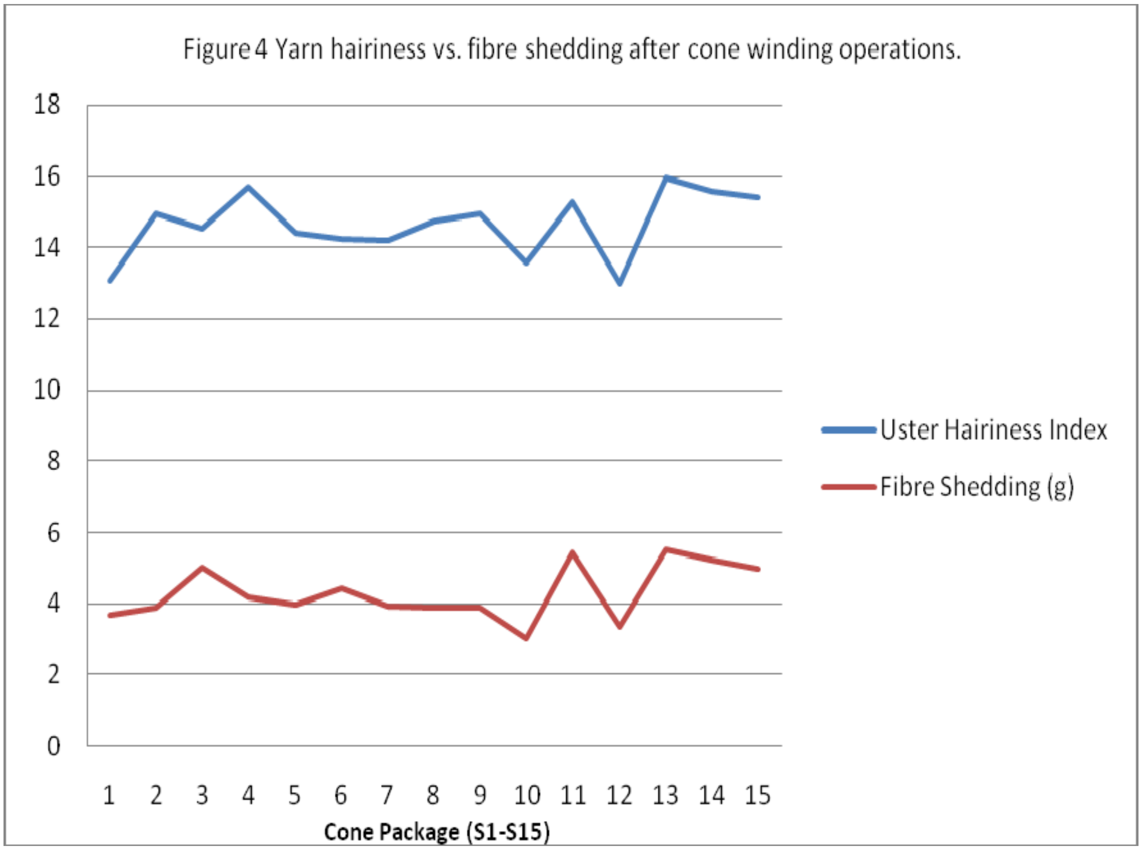


Figure 4 Yarn hairiness vs. fibre shedding after cone winding operations.
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Cone Package (S1-S15)
Uster Hairiness Index
Fibre Shedding (g)

Figure 5 Triangle zone in cone surface and yarn ballooning zone.

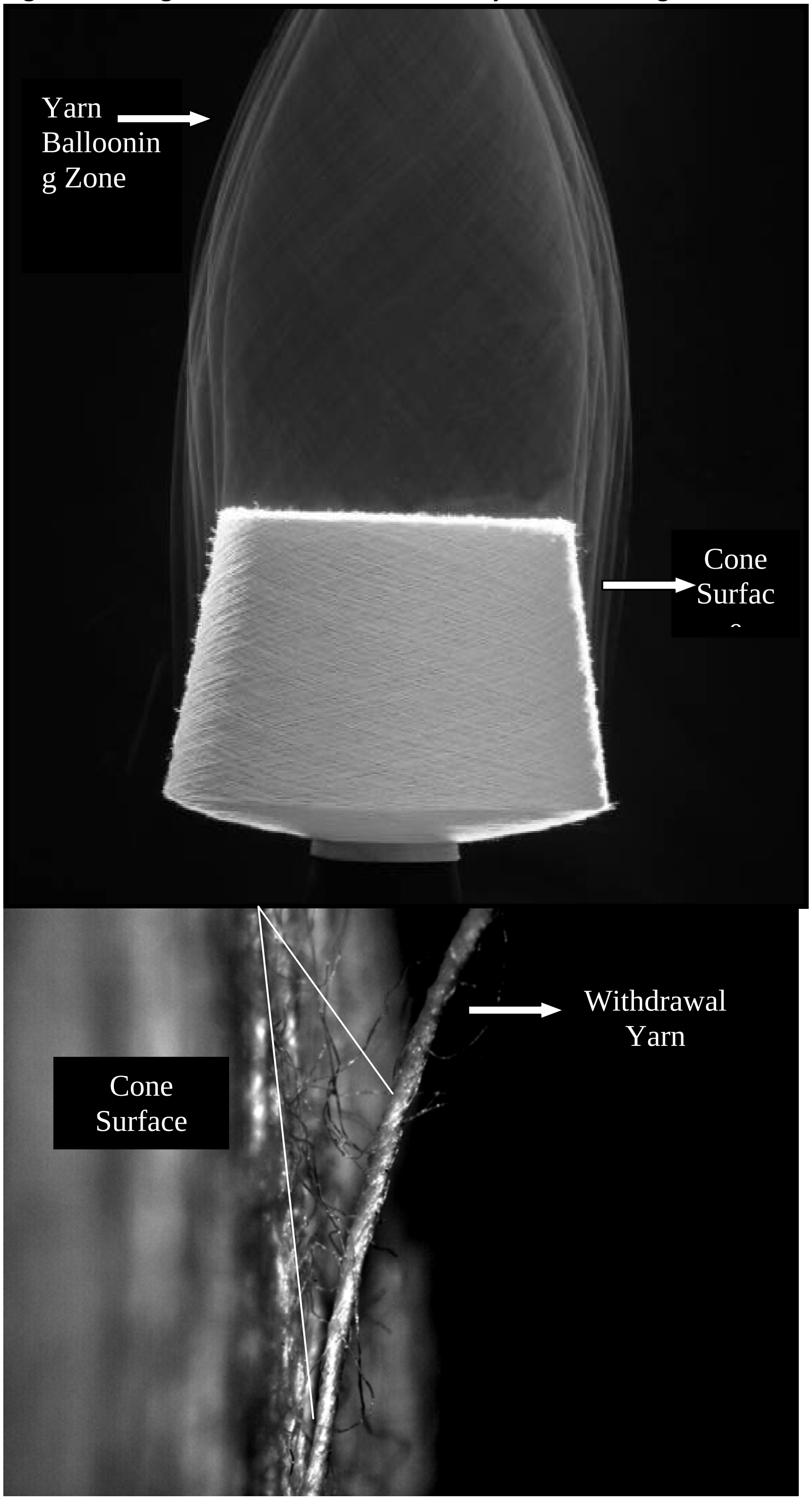


Table 1 Comparison of virgin fibre properties with fibre fly.

Fibre properties	Parent fibres	Fibre fly
Fibre fineness (mtex)	**160**	**134**
Immature fibre content (%)	**006**	**17.3**
Fibre maturity (Maturity ratio)	**0.91**	**0.64**

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Table 2 Fibre shedding vs. yarn parameter before & after cone winding operation.

Samples	Winding variables			Per kg of yarn fed	Yarn Parameter
	Tension	Speed	Contact Pressure	Fibre Shedding (g)	Hairiness Index
Ring yarn				3.26	8.63
Cone Package					
S1	3.5	600	Medium	3.67	9.39
S2	3.5	1400	Medium	3.88	11.05
S3	1.5	600	Medium	5.01	9.51
S4	1.5	1400	Medium	4.16	11.53
S5	3.5	1000	Low	3.96	10.46
S6	3.5	1000	High	4.41	9.85
S7	1.5	1000	Low	3.92	10.26
S8	1.5	1000	High	3.86	10.88
S9	2.5	1400	Low	3.85	11.11
S10	2.5	1400	High	2.98	10.61
S11	2.5	600	Low	5.45	9.85
S12	2.5	600	High	3.30	9.69
S13	2.5	1000	Medium	5.52	10.43
S14	2.5	1000	Medium	5.24	10.35
S15	2.5	1000	Medium	4.95	10.44