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Dynamic Friction of Polyester Air-jet Textured Yarns

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Abstract: In this paper, friction of air-jet textured yarns is investigated. Using a friction measuring apparatus fabricated in-house, dynamic friction forces of the yarns under yarn-to-metal (YM) and yarn-to-yarn (YY) rubbing modes are measured. The influence of processing variables of air-jet texturing viz., overfeed, air pressure, dry/wet texturing and normal/core-and-effect texturing on dynamic friction is analysed. The results indicate that friction force increases with increasing rubbing speeds and yarn input tension. YM dynamic friction decreases initially and then starts to increase at higher overfeeds. YY dynamic friction increases with increasing overfeed. YM dynamic friction decreases with an increase in air pressure while an opposite trend is observed for YY friction. Wet textured yarns have higher friction than dry textured yarns. Core wetted core-and-effect textured yarns have higher friction than normal textured yarns.

Keywords: Yarn-to-yarn friction, Yarn-to-metal friction, Overfeed, Air pressure, Core-and-effect

Introduction

During processing yarns encounter friction in a variety of ways, either between themselves or against other surfaces. With ever increasing speeds during processing of yarns, yarns friction become critical in process ability of the yarns. General frictional behaviour of liquid-lubricated textile yarns is described [1]. The mechanism of lubrication in low speed/high pressure region is boundary lubrication and is typically found at the range of speeds from just above 0 to 0.1 m/min. Hydrodynamic lubrication is believed to be the controlling mechanism in the high speed/low pressure range, typically above 4 m/min [2]. Olsen has listed important factors that influence boundary and hydrodynamic friction of yarns [3]. Smooth continuous filaments were found to show low friction at low speeds and high friction at high speeds while the opposite is the case with rough (textured) yarns [1]. Friction increases significantly with increase in yarn denier, which can be attributed again to an increase in area of contact at the yarn/metal interface [4,5]. All workers have observed that the yarn to metal friction increases with increasing speeds. Roder [6] suggested that at high speeds the lubrication film is destroyed and the friction approaches that of the un-lubricated fiber. Lyne [7] has suggested that the fiber becomes warm and softens, so giving an increased area of contact.

According to Olsen [3], an increase in the roughness of a guide surface can be considered analogous to an increase in the pressure between the yarn and guide as a result of the decrease in yarn to metal surface contact area. This result in a shift towards semi boundary region with consequent lowering of the friction from the high values observed on polished guide surfaces. In contrast, at low speeds or in other words in the boundary and semi boundary region, the exactly opposite phenomenon observed, namely, friction increases with increasing surface roughness. This is attributed to an increased wear of the yarn surface on the rough guide surface.

Air-jet texturing converts feeder filament yarn into an entangled structure with many loops on the yarn surface, consequently a bulk yarn. The surface loops give clinging tendency, 'Velcro-effect' to the yarn while rewinding it. The type of texturing, viz., dry, wet, normal and core-and-effect results in different yarn structure and properties [8,9]. Though the wet texturing improves the entanglements of filaments, it removes most of the spin finishes from feed yarns, necessitating re-application of lubricants to yarns after texturing. Air-jet textured yarns are known to give problems during rewinding operations due to their looped-surface structure. Study of friction of air-jet textured yarns with varying process conditions is significant in understanding the role of surface structure of the yarns in friction. So far no study has been reported in this area. In the present study, YM and YY dynamic frictions of air-jet textured yarns produced under different process conditions are investigated and reported.

Experimental

Production of Textured Yarns

A fully drawn polyester yarn of 75 denier having 36 filaments was used as feeder yarn in this study. The tenacity and extension at break of this yarn were 34.3 cN/tex and 32.1 % respectively. Texturing was carried out on Eltex AT/HS air-jet texturing machine using two ends of this yarn. Details of textured yarns with codes and deniers are given in Table 1. To study the effect of overfeed, normal wet textured yarns (O2, O3, O4 and O6) were produced at 20, 30, 40 and 60 % overfeeds at a constant air pressure of 7 bar (gauge). For air pressure series, normal wet textured yarns (P5, P7 and P9) were produced at 5, 7 and 9 bar air pressures (gauge) at a constant overfeed of 30 %. To study the effect of dry and wet texturing, normal textured yarns (D and W) were produced at overfeed of 30 % and air pressure of 7 bar (gauge). To compare the effect of normal texturing and core-and-effect

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Table 1. Yarn codes with deniers

Particulars	Code	Denier
Two ends of feeder yarn	F	150
Textured yarns:		
Overfeed 20 %	O2	168
Overfeed 30 %	O3	182
Overfeed 40 %	O4	196
Overfeed 60 %	O6	224
Air pressure-5 bar	P5	182
Air pressure-7 bar	P7	182
Air pressure-9 bar	P9	182
Dry textured	D	181
Wet textured	W	181
Normal mode with overfeeds of 25 % for each end	N 25/25	175
CE mode with overfeeds of 15 % for core & 35 % for effect	CW15/35	175
CE mode with overfeeds of 10 % for core & 40 % for effect	CW10/40	175

texturing, wet textured yarns were produced at a constant air pressure of 7 bar with an average overfeed of 25 %. In the case of core-and-effect texturing, core end was wetted. The combination of overfeed % for core and effect components was 15/35 and 10/40 for the yarns CW15/35 and CW10/40 respectively. For normal wet texturing (N25/25) both ends of the polyester yarns were wetted. The overfeed % employed for both the ends were 25. The texturing was done using a nozzle, HemaJet Core S315 at a speed of 300 m/min. After texturing yarns were stretched to 4.7 % in the mechanical stabilizing zone and then heat set at 180 °C before being wound.

Measurement of Friction of Yarns

A laboratory set up was used to measure dynamic friction of yarns. This consists of three units, viz., yarn driving, tension measuring and data processing. The driving arrangements for yarn to metal (YM) and yarn-to-yarn friction (YY) testing are shown in Figures 1 and 2 respectively.

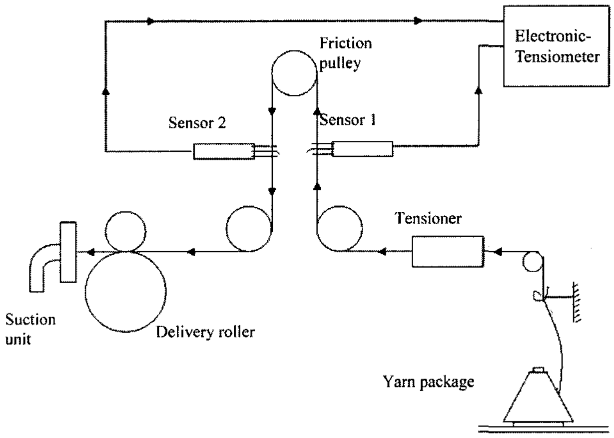

Figure 1. Schematic diagram for the measurement of YM friction.

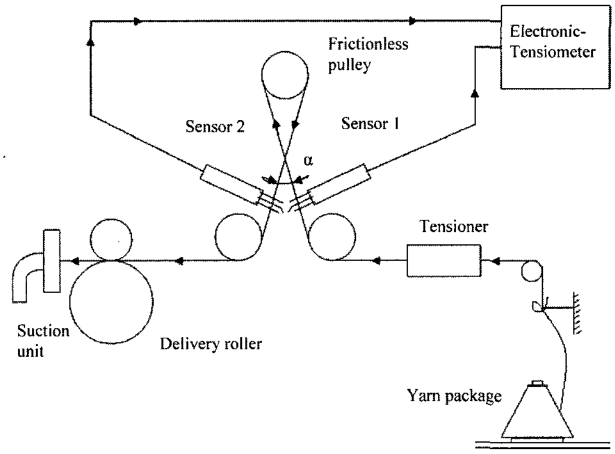

Figure 2. Schematic diagram for the measurement of YY friction.

Yarn from a supply package was pulled by a pair of delivery rollers during friction measurement. The speed of the delivery rollers was adjusted to get the required rubbing speeds of 100 and 200 m/min. The pressure between delivery rollers was adjusted such that yarn was not slipping from delivery rollers. Input and output tensions were measured simultaneously from sensors 1 and 2 respectively using Rothschild electronic tensiometer. Input tension levels of 5 and 10 cN were selected in this study. In the case of YY friction testing, incoming and outgoing yarns are twisted by one turn with a separating angle of 14 ° (α in Figure 2). To avoid yarn wrapping over the delivery rollers, yarn was given a slight suction by a nozzle placed after the delivery rollers. The nozzle was operated at 0.5 bar (gauge) pressure. Since there was no slippage between the yarn and delivery rollers, the drag forces acting on the yarn by the suction of the nozzle would not influence the output tension. Using a software package, 'Rothschild ETR 2000' tension data was transmitted to a computer for analysis. Yarn friction force is calculated as the difference between output tension and input tension on the yarn.

Results and Discussion

Effect of Overfeed on Friction

The effect of overfeeds on YM dynamic friction force is shown in Figure 3. It is evident that when the overfeed increases; the friction force decreases first and then increases. As the feeder yarn is textured, smooth yarn surface is converted into a rough surface because of the formation of loops. As overfeed increases, yarn surface roughness increases initially, a further increase of overfeed results in more and

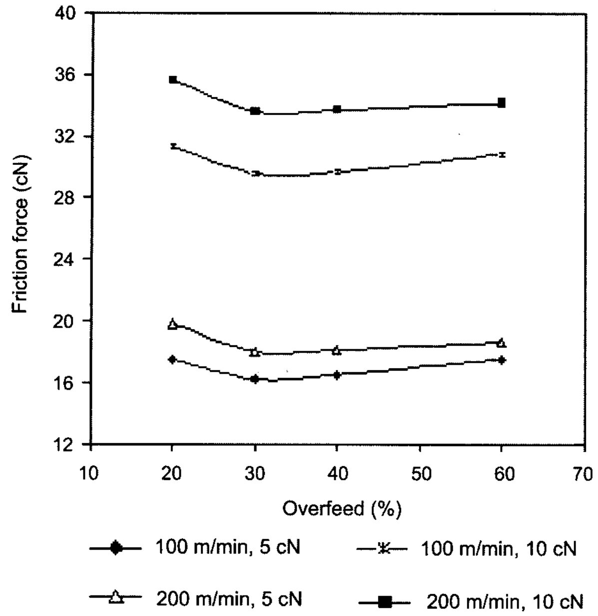

Figure 3. Effect of overfeed on YM dynamic friction.

more loops on the yarn surface, which makes the yarn surface rather smooth. At 30 % overfeed, friction force is found to be minimum for both the input tension levels used in this study. This can be attributed to more roughness of yarn at this overfeed level in comparison with the yarn textured with 20 % overfeed. The higher friction force for yarns textured at overfeeds of 40 % and 60 % may be due to more number of slack and large loops per unit length on these yarns [10]. These protruding loops can easily fold back on yarn surface during rubbing over metal surface which in turn makes the yarn smoother, consequently, increases the area of contact between the yarn metal during rubbing. A significant increase in the yarn denier is also observed at higher overfeeds (Table 1), which leads to higher friction because of increased area of contact between yarn and metal.

The influence of overfeeds on YY dynamic friction is shown in Figure 4. From the graph, it is clear that, the friction force increases as the overfeed increases. This is due to the increased area of contact between the rubbing yarns as a result of higher yarn deniers. Further, the increase in number of loops on the textured yarn surface as a result of higher overfeeds, increases the clinging tendency of loops from one yarn to another rubbing yarn. Higher pretension in the yarn further aggravates this tendency.

Effect of Air Pressure on Friction

When the air pressure is increased from 5 to 9 bar, a reduction in YM dynamic friction force is observed at all speeds and input tension levels as shown in Figure 5. This trend can be explained on the basis of the following facts:

1. Yarns produced at lower air pressure have less number of loops [10]. Velocity of air currents inside the texturing jet is low at low air pressures [11]. Low degree of entanglements of filament at low air pressure lead to fewer large sized loops on textured yarn surface. These loops can easily fold and further the easy displacement of filaments during bending and rubbing over a hard metal surface increase the area of contact between yarn and metal roller and hence a high friction for yarns textured at low air pressure.

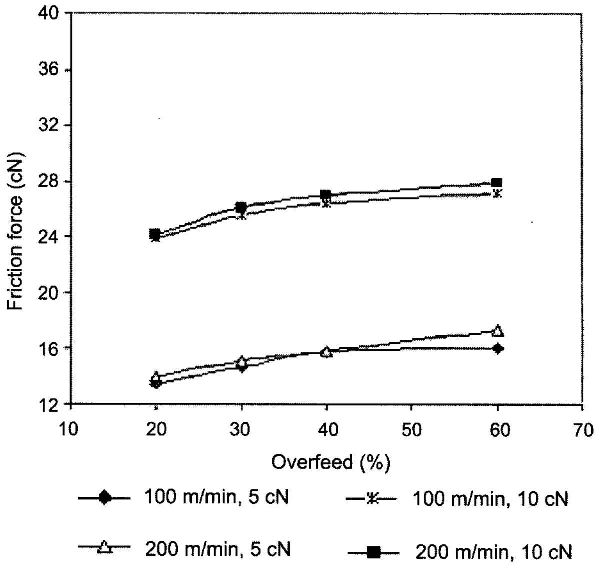

Figure 4. Effect of overfeed on YY dynamic friction.

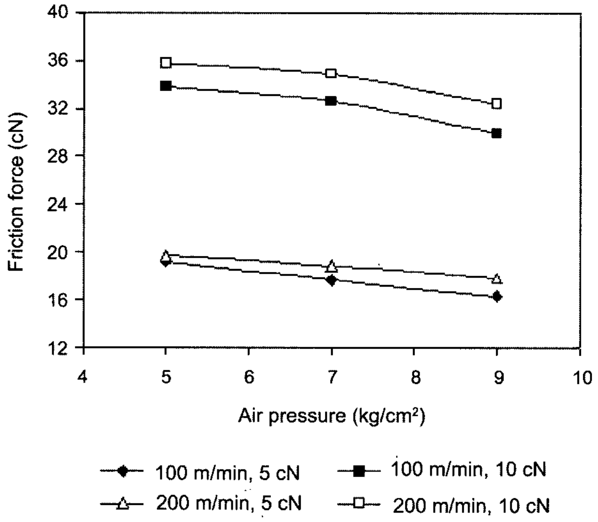

Figure 5. Effect of air pressure on YM dynamic friction.

2. Flat knitted fabrics produced from yarns textured at higher air pressure of 9 bar has more thickness, 0.73 mm than the one made from yarn textured at low air pressure of 5 bar (0.62 mm). This is due to more number of smaller loops for yarns produced at higher air pressures. This gives a high cushioning effect of the yarn over hard metal surface during rubbing, reduces the real area of contact between metal and yarn. Hence, the yarns textured at higher air pressures exhibit

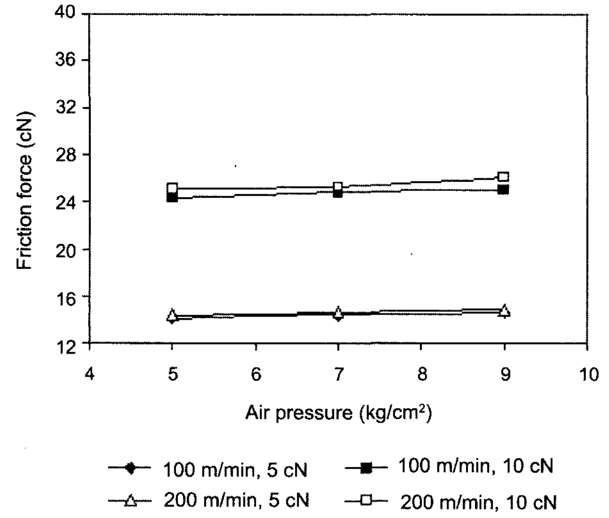

Figure 6. Effect of air pressure on YY dynamic friction.

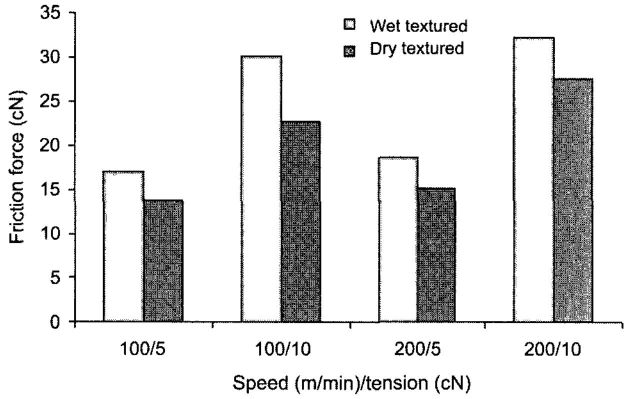

Figure 7. YM dynamic friction of dry and wet textured yarns.

low friction forces.

Figure 6 shows that YY dynamic friction increases with an increase in air pressure. The formation of large number of smaller loops on yarn surface when yarns are textured at higher air pressures increases clinging tendency of these loops from one yarn to the other rubbing yarn. This increases the YY friction force.

Friction of Dry and Wet Textured Yarns

Wet textured yarns shows higher friction than the dry textured yarns in both yarn to metal and yarn to yarn testing as shown in Figures 7 and 8. From the structure of wet textured yarns, one can expect that wet textured yarn will show less YM friction compared to that of dry ones, as it contains many surface loops. Higher friction for wet textured yarns compared to dry textured yarns is attributed to the washing and blowing out of spin finishes during wet texturing. From the analysis of spin finish content using Soxhlet apparatus, it was found that, nearly 61 % of spin finish gets removed during wet texturing whereas in dry texturing there is only 19 % loss of finish.

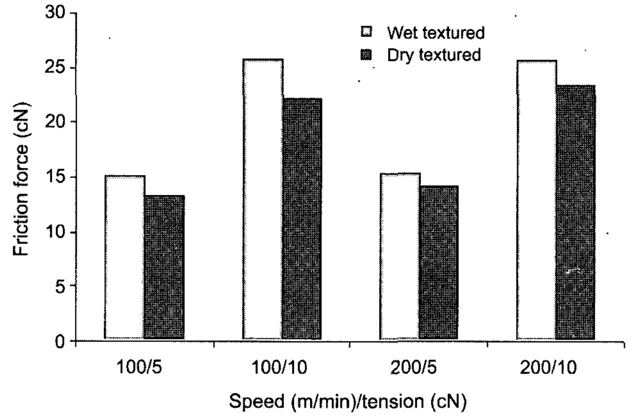

Figure 8. YY dynamic friction of dry and wet textured yarns.

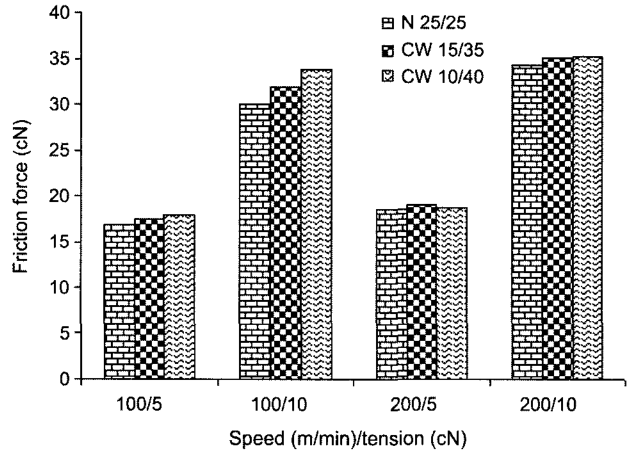

Figure 9. YM dynamic friction of normal and core wetted core-and-effect yarns.

Effect of Normal and Core-and-effect Texturing on Friction

YM dynamic friction forces of normal and core-and-effect textured yarns are shown in Figure 9. It can be seen that core wetted core-and-effect textured yarns have slightly higher YM friction than normal textured yarns. This is attributable to higher bulk of the core-and-effect yarns than the normal yarns textured at the same average overfeed and air-pressure levels. Knitted fabrics made from yarns N25/25, C15/35 and C10/40 have thicknesses of 0.71, 0.74 and 0.77 mm respectively. However, the difference between the friction forces of the yarns textured at different modes is not significant. Similar is the trend observed for YY friction.

Conclusions

Friction forces increase with increasing testing speed and pretension. For textured yarns, YM dynamic friction declines initially and then starts to increase at higher overfeeds. Yarns textured with overfeed of 30 % exhibit lowest friction. Further increase in overfeed increases the YM friction. YY dynamic friction increases with increasing overfeed. YM dynamic friction of textured yarn decreases with an increase in air pressure, while the YY friction shows opposite trend. Wet textured yarns have higher friction than dry textured yarns. Core wetted core-and-effect textured yarns have higher friction than normal textured yarns.

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