Nonlinear Dynamics of High Speed Transport for Staple Yarns

Goals : The primary objective of this project is to develop and experimentally validate computer models of high-speed textile systems that transports non-uniform yarns. Applications include winding and unwinding of staple fiber yarns. The present study will focus on yarns with significant non-uniformity (e.g. staple fiber yarn) considering the various yarn structures made on different systems (e.g. ring, open-end, and vortex spinning technologies).

Successful completion of this project will provide accurate, experimentally verified computer models for high-speed yarn transport systems. The computer models will enable textile engineers to use computer-aided design to optimize the quality and productivity of high-speed yarn transport systems.

Abstract : During this year, our research group had worked on redesigning the yarn-package friction tester, an offline-measuring instrument similar to the one reported by Yu, Goswami and Rahn [5]. Several experiments were carried out in determining the yarn-package friction coefficient at different radial positions in packages wound at different tension levels. Friction tests are being carried out for non-uniform yarns differing in hairiness, imperfections and linear density.

Introduction :Winding and unwinding of yarns are omnipresent in the textile industry. They are the fundamental processes in converting yarns to woven or knitted fabric in the textile industry and in the transportation of yarns, cords and ropes for varied applications. It becomes essential to study the dynamic behavior of yarn during winding or unwinding to increase the process efficiency and product quality.

The dynamic behavior was found to be nonlinear since it depends on many factors like yarn tension, frictional drag, air drag, transport speed and Coriolis force. Optimized unwinding performance is achieved by reduced and consistent unwinding tension. The yarn package friction was found to be one of the important parameters, which determines the dynamics of unwinding tension [1,2].

Experimental work : Previously we had developed a mechatronic setup to study the tension, thread line dynamics of the yarn and yarn-package friction coefficient during unwinding of fully drawn and textured yarns from cylindrical packages [5]. Now we have constructed an offline-measuring instrument, which is used to measure the yarn-package friction coefficient using Instron tensile tester. Though the measured frictional coefficient was found to be higher than that found indirectly from the unwinding analyzer, however there is approximately close correspondence between the values obtained by the two techniques [4].

Experiments will be designed:

1. To qualitatively investigate the friction coefficient of staple yarns in the package at different radial positions.
2. To study the effect of winding tension on the friction coefficient of yarn package.
3. To study the effect of yarn hairiness, imperfections and linear density on the yarn package friction coefficient for staple yarns.

Instron based yarn –package Friction Tester : The friction between yarn and the package is difficult to measure and estimate [6]. We have constructed standard laboratory equipment as an alternative to the complex unwinding analyzer. A test yarn is stretched at the required tension between the two ends of the carrier that is pivoted on a slide with a low friction guide bush. The carrier weight provides the normal force between the test yarn and a cylindrical package of the same material. The cross head of the Instron tensile tester pulls the carrier across the package surface with the help of an inextensible string and it also measures the tension force required to pull the carrier (See Figure 1).

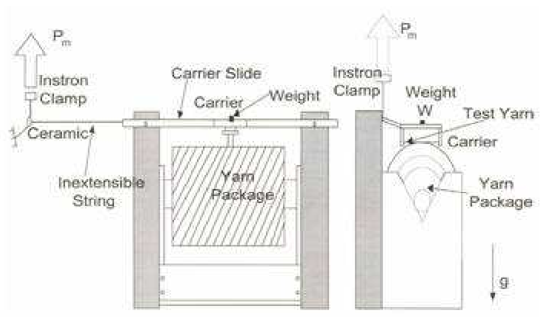

Figure 1

Friction coefficient can then be calculated as: $\mu_1 = \dfrac{P_m}{W}$, where P_m is the string tension minus the base-line eyelet and carrier/slide friction, and W is the total weight of the carrier and the test yarn. The frictional coefficient values are significantly larger from those values derived from unwinding analyzer. This is probably due to the large stick-slip force associated with the package and the carrier [4].

Results and Discussions

Material Parameters:

Type	Polypropylene
Denier	235
No.of.Filaments	27
Circumference of the package	35 cm
Circumference of the tube	27 cm
Winding tension	10, 15, 18 and 20 Grams.
Winding speed	460 m/min.

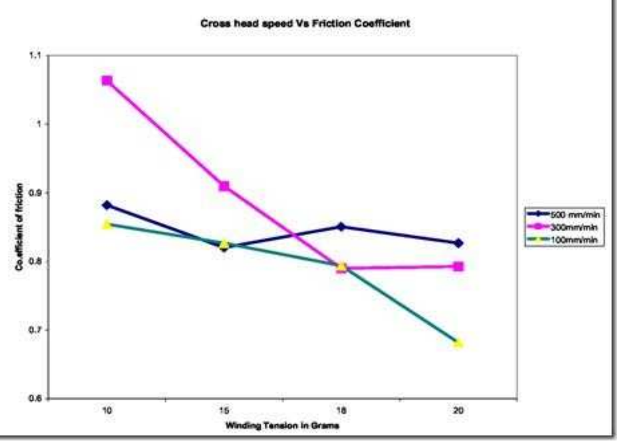

Figure 2 shows the relationship between cross head speed of the Instron tester and the friction coefficient. From the graph it can be seen that the crosshead speed has significant effect on the friction coefficient. It may be surmised that the winding tension of the package does not have a pronounced effect on the friction coefficient when the unwinding speed is increased.

From Figure 3, it can be seen that the friction coefficient of the yarns at lower tension levels is higher for the yarns located at the intermediate position of the package circumference. This can be conveniently related to the residual tension in the yarns. From Huang and Goswami [3], it is concluded that the residual tension in the yarn are is lower which eventually leading to higher friction coefficient since the diameters of

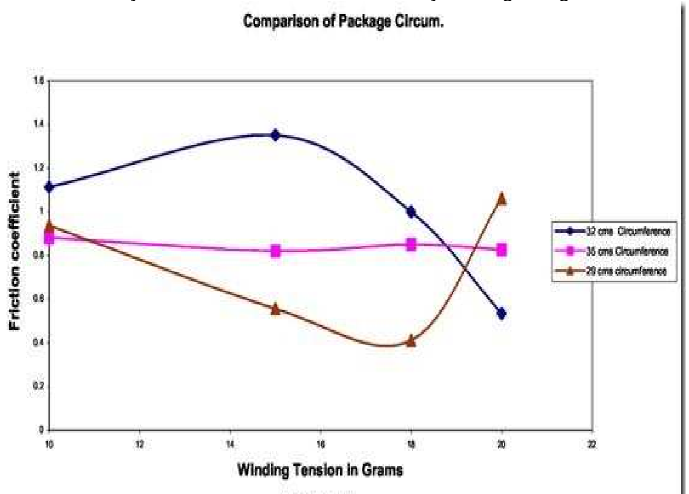

Figure 3

the yarns are relatively greater and the filaments are spread at the center than that of the yarns at the core or surface increasing the stick-slip force between the yarn and the package. The frictional values for the packages produced with 20 grams, as winding tension, does not agree with the other three tension levels.

Figure 4 shows the results of the frictional coefficients determined at three different normal forces of 3.6 grams, 4.1 grams and 4.6 grams for the polypropylene material

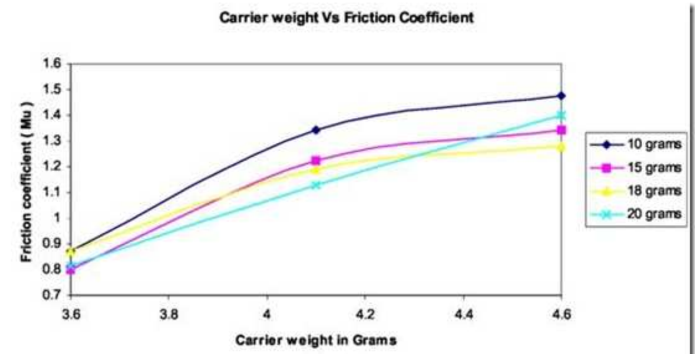

Figure 4

described earlier. The frictional coefficient increases with the increase in normal force. The results are unexpected because; according to the frictional law the frictional coefficient should remain the same irrespective of the normal force. The increase is perhaps due to the increase in the stick slip force between the yarns and the packages as the normal force is increased.

At present the works are being conducted to study the effect of yarn hairiness, imperfections and structure of staple yarns on friction coefficient. In addition, the unwinding analyzer is being assembled that will also have sensors that will determine the evenness and hairiness of staple yarns online. A modified unwinding nonlinear dynamic unwinding model to analyze the behavior of ballooning staple yarn that will include yarn hairiness and yarn evenness is also being developed.