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The Effect of Fine Denier Polyester Fibre Fineness on Dynamic Cohesion Force

Abstract
This study aims to explain the effects of fibre fineness on dynamic cohesion force at different delivery speeds. In order to monitor the effect of fineness, we produced polyethylene terephthalate (PET) fibres and slivers which were almost identical except for fineness, of 0.88, 1.11 and 1.33 dtex. In this study, the dynamic cohesion force of a single card sliver at different roller speeds (15, 30 and 60 m/min) were measured by using a Rothschild Cohesion Meter. The cohesion force of 1.11 and 1.33 dtex card slivers increased with increasing delivery speed, while the cohesion force of microfibres had a decreasing trend at the same delivery speeds. Sliver irregularity was positively correlated with variation in cohesion, while a negative correlation was detected between sliver irregularity and cohesion force and between sliver irregularity and fineness. Therefore, the slightest change in fibre fineness can cause dramatic changes in the drafting process and sliver irregularity.

Key words: *polyester, dynamic cohesion, sliver irregularity, fineness, microfibres.*

Introduction

One of the most important parameters regarding the processibility of a synthetic fibre is the level of inter-fibre friction, which determines the drafting force or cohesive force dependent on such factors as surface conditions, crimping and lubricant deposit on the fibres [1-3]. Staple length and crimp are highly significant factors affecting the cohesion values [4]. Experiments conducted on cotton fibres revealed that there was a positive correlation between 2.5% span length and variation in cohesion force, which affected ends down in spinning. Doraiswamy et al. [5] reported that the fibres with smoother surfaces had greater cohesion than fibres with geometrically rough surfaces. Crimp drastically influences the cohesive force by changing the surface roughness and the cross-sectional shape of fibres. Chellamani et al. [6] studied the cohesive force and its influence on yarn quality, and their results indicated a strong interaction between the variability in drafting force and the variability in the single yarn strength.

The inter-fibre friction affects the drafting force which has to be overcome in every drawing section of production. Therefore, this force has to be controlled in order to reduce any drafting problems. Although many studies have been conducted to determine the effect of fibre properties on drafting force, there is very little published information available on the effect of fibre fineness. In this study, the effect of fineness on the dynamic cohesion and its interaction with sliver irregularity were investigated.

Material and Method

Material

The polyethylene terephthalate (PET) fibres used in the experiment were supplied by Wellman Inc., Charlotte, NC, USA. There were three groups of material, all of which had the same fibre properties apart from fibre fineness. The manufacturing company used the same processing procedure to manufacture fibres of 0.88, 1.11 and 1.33 dtex, all having the same length (38 mm). The advantage of using PET is to eliminate the length effect by reducing variations in length. The fibres were in the card sliver form which was prepared in the same manufacturing process, and the sliver weight was 5 ktex.

Method

The Cohesion-Meter R-2020 was used for the dynamic cohesion testing. Two drawing rollers, mounted on the machine, provided the draft. When the material was passed through a drawing frame-like device, the sliver was exposed to a draft and its resistance to drawing was electronically measured by the electronic measuring head of the Rothschild Electronic Tensiometer. The testing time was 1 minute with a 50 reading per second rate, and the machine setting was 90 mm long.

The test was run at three different speeds, 15, 30, and 60 m/min, and the draft ratio was maintained at a constant of 1.25:1. There were two factors: fibre fineness (0.88, 1.11 and 1.33 dtex) and delivery speeds (15, 30 and 60 m/min). After each test, irregularity was measured by using a Keisoke Evenness Testing device. The data was tested by analysis of variance (ANOVA), and the relative importance of each source of variation in the ANOVA (including fibre fineness and speed) was determined by partitioning the total sum of squares for treatments into main and interaction effects, and expressing the individual contributions to variation as a percentage of the total sum of squares for the model. The data for drafting force was regressed, and correlated with fibre fineness and speed to determine the strength of relationships and test if the F test was significant at p=0.05.

Result and Discussion

The main effect of fibre fineness accounted for 76% of total variation in dynamic cohesion force (Table 1). The delivery speed by itself was not a major factor, contributing to only 5% of total variation. The fibre fineness did interact

Table 1. *Sources of variation in the analysis of variance (ANOVA) for the effect of fibre fineness and delivery speed on cohesion and sliver irregularity.*

Parameter	Cohesion		CV% of cohesion		CV% of evenness	
	P value	% contribution	P value	% contribution	P value	% contribution
Fineness	<0.001	76	<0.001	62	0.001	74
Speed	0.002	5	0.008	13	0.430	4
Fineness x Speed	<0.001	13	0.016	10	0.355	10
Error	-	5	-	15	-	12
Total	-	100	-	100	-	100

with delivery speed, accounting for 13% of the total variation in cohesion. A regression analysis was run for each fibre fineness value to uncover the relationship between fineness and cohesion force. There was a curvilinear relationship between fibre fineness and cohesion, and the cohesion increased as the fineness increased from 0.88 dtex to 1.11 dtex, after which it levelled off at all delivery speeds (Figure 1). On the other hand, delivery speed interacted differently with the cohesion force for each one of the fibre finenesses. The cohesion force of microfibre sliver decreased linearly with increasing delivery speed, whereas for slivers of 1.11 dtex and 1.33 dtex, cohesion force increased linearly with an increase in delivery speed from 15 to 60 m/min (Figure 2). These findings indicated that the sliver structure of microfibres might differ from that of the other two fibres. Previously, Lawson et al. [7] reported a similar significant relationship between cotton micronaire and cohesion force. They postulated that the greater surface area per unit weight for fibres increases the number of possible contact points. Although the fibre properties of cotton are very difficult to control, their results emphasised the importance of fineness.

In this experiment, all other fibre properties were the same apart from fibre fineness. Even a small change in fibre fineness altered the drafting behaviour drastically due to cluster formation or fibre grouping. Cluster formation mainly depends on the number of fibres in a cross-section and the bending rigidity of the fibre [8]. Microfibres have a high

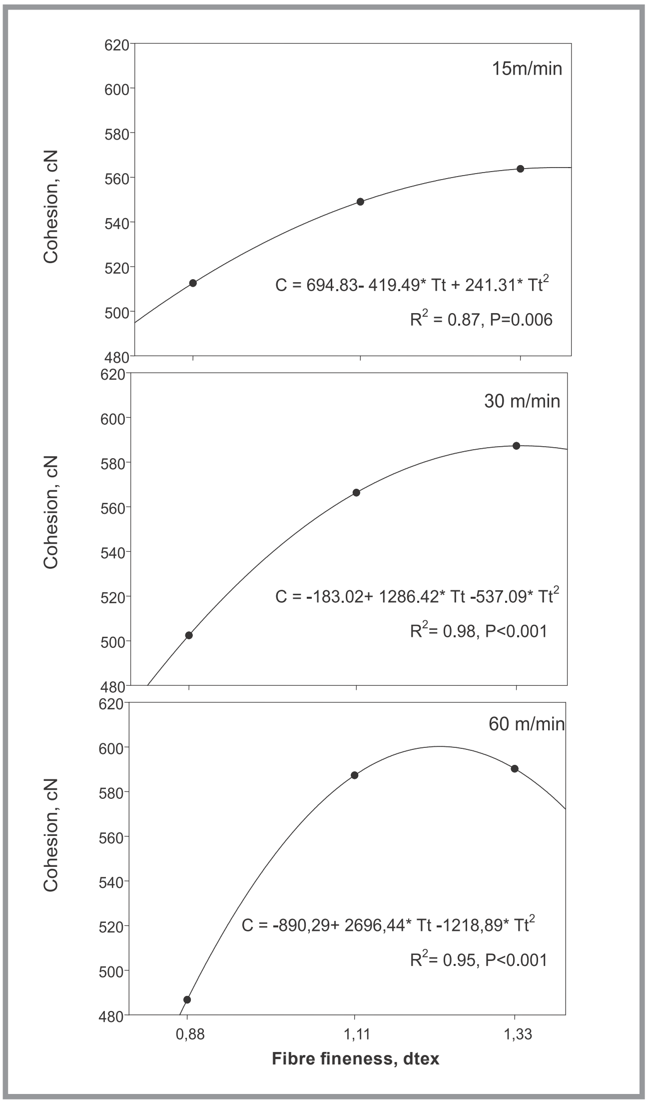

Figure 1. *The regression analysis of fibre fineness at different delivery speeds on the dynamic cohesion force (C - cohesion, Tt - fibre linear density).*

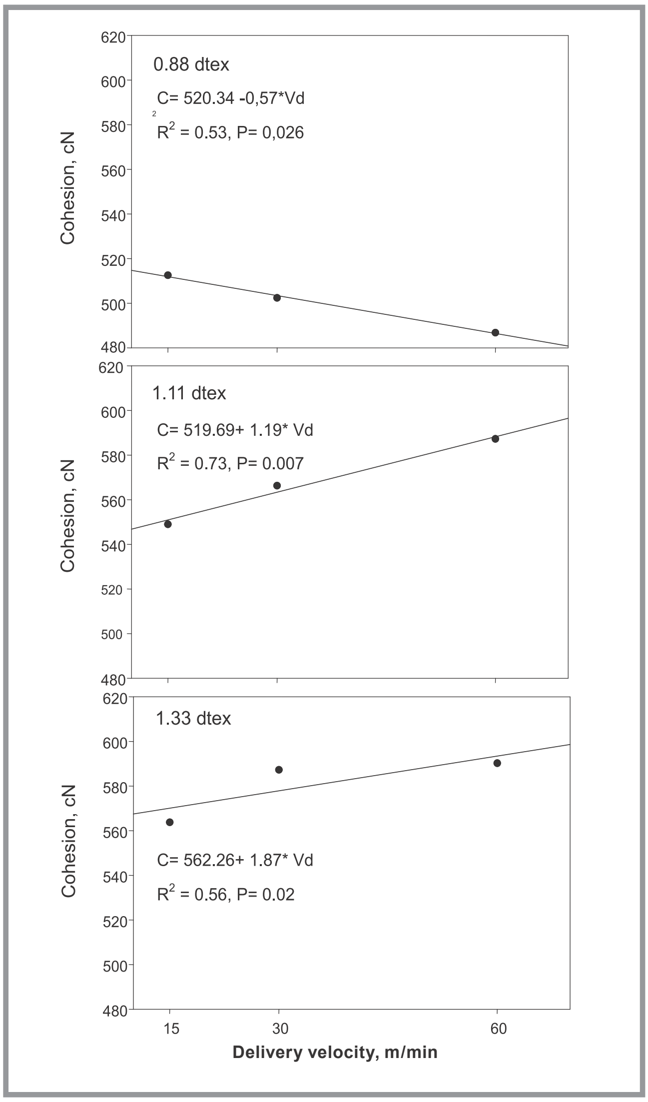

Figure 2. *The regression analysis of delivery speed at different fibre fineness on the dynamic cohesion force (C - cohesion, Vd - delivery speed)*

number of fibres in a cross-section but lower bending rigidity values, which results in more compact clustering or grouping of fibres in the sliver and higher number of fibre contact points.

The other important point is the magnitude and characteristics of friction force which depends on the drafting ratio. According to Korkmaz and Behery [9], there is a curvilinear relationship between drafting force and the break draft ratio. At lower drafting ratios, where the static friction is almost dominant, the drafting force increases with draft ratio up to a maximum; after this critical point, force decreases with an increase in draft ratios where the dynamic friction becomes dominant. During the drafting process, the entangled fibres in clusters start to straighten and change their orientations between roller sets by forcing clusters to break down into smaller groups and reducing entanglements. However, in this experiment the setting was twice as large (90 mm) as the regular drafting roller, and the draft ratio of 1.25 was much lower than the critical draft ratio. Therefore, the large setting and the low draft ratio caused clusters to move almost without changing their structures due to minimal restrictions. For 1.11 and 1.33 dtex, the cohesion force which was linearly increased with speed suggests that static friction was a dominant force between individual fibres or clusters during attenuation. In the case of microfibres, cohesion force decreased with an increase in speed. The compact structure of microfibre clusters could not be attenuated uniformly, since they were floating freely between back and delivery roller sets because of the large roller spacing and low drafting ratio. Since any further increase in delivery speed will speed up the sliver breakage, microfibres are very susceptible to change in drafting conditions.

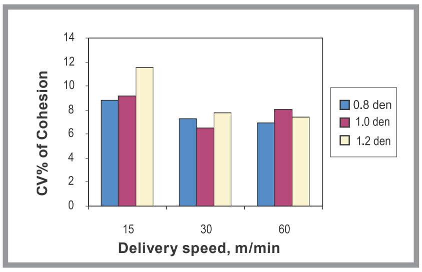

Figure 3. *Relationship between delivery speed and CV% of cohesion at different fibre finenesses.*

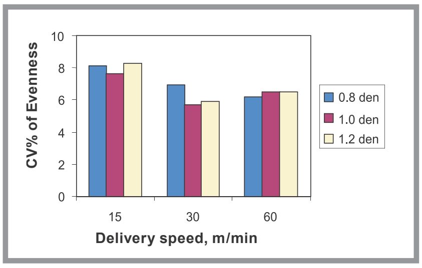

Figure 4. *Relationship between delivery speed and sliver evenness at different fibre finenesses.*

Table 2. *Correlation analysis for the effect of fibre fineness and delivery speed on cohesion and sliver irregularity.*

Parameter	**Cohesion**		**CV% of cohesion**		**CV% of evenness**	
	P value	**r**	**P value**	**r**	**P value**	**r**
Fineness	<0.001	0.84	<0.001	0.62	0.001	-0.73
Speed	0.386	-	0.091	-	0.806	-
Cohesion			0.001	-0.65	0.004	-0.81
CV% of cohesion					<0.001	0.86

The CV of cohesion was highly dependent on fibre fineness as well. The greatest portion of variation in CV of cohesion was attributable to the main effects of fibre fineness, reaching 62% (Table 1). The main effects of speed and the interaction between fibre fineness and speed accounted for 13% and 10% of the variation in CV of cohesion respectively. After measuring the cohesion force of each treatment, sliver evenness was measured. The main effect of fibre fineness contributed significantly to total variation in sliver evenness with 74% (Table 1). The variation in cohesion force and sliver irregularity was the highest at a delivery speed of 15 m/min (Figures 3, 4). Irregularity of micro fibre slivers decreased with increasing delivery speed, whereas for 1.11 and 1.33 dtex slivers irregularity was the lowest at 30 m/min speed, and then increased at 60 m/min speed (Figure 4).

According to the correlation analysis, the evenness was negatively correlated with fibre fineness and cohesion (Table 2). Sliver evenness worsened with a decrease in the fibre fineness and cohesion force. The evenness of sliver was highly correlated with CV% of cohesion (r=0.86), and similar results were obtained on jute fibres by Sanyal and Mukhopadhyay [10]. Higher variation in cohesion force frequently generated higher irregularity in the linear density of the sliver. This correlation between sliver irregularity and variation in cohesion implies that the drafting process should be monitored in order to achieve better sliver quality.

Conclusion

In this research, the effect of fibre fineness on cohesion was investigated. Fibre fineness was a very important fibre property affecting the cohesion force and sliver irregularity. The dynamic cohesion force decreased with the increase in delivery speed for microfibres. However, the cohesion force of 1.11 and 1.33 dtex slivers increased with the increase in delivery speed. The irregularity of outgoing slivers negatively correlated with cohesion force and fibre fineness, while a positive correlation was detected with a variation in cohesion force. Drafting conditions should be carefully set in order to allow the fibres to be uniformly attenuated.

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