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Effect of blend composition on tensile properties of blended Dref-III yarns

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Blended Dref-III yarns have been prepared by using same stock of blended materials (polyester-viscose) both in core and sheath. Stress-strain curves of both fibre and yarn (100% polyester and viscose) have been used for the prediction of both ring and Dref-III spun blended yarn strength. Hamburger model using yarn stress-strain curves for blended ring-spun yarn has been found suitable to predict the tensile strength of blended Dref-III yarns for different core-sheath ratios separately. From this observation, an equation has also been derived to predict the strength of blended Dref-III yarn for all types of combinations of core and sheath components as well as blend composition.

Keywords: Blend ratio, Blended yarn, Core–sheath ratio, Dref-III yarn, Hamburger model, Polyester fibres, Ring yarn, Stress-strain curve, Tenacity, Viscose fibres

1 Introduction

Typical core-sheath structure of Dref-III yarns has been exploited by using different fibres in core and sheath for making blended yarns and the characteristics of such yarns have been studied. But, such blended yarns suffer from the limitations of lack of blend homogeneity, which is the basic requirement of blended yarn structure. Moreover, blend percentage could not be controlled independently and may be decided by the core-sheath ratio. There is no model established so far to predict the blended yarn tenacity of Dref-III yarns. Hamburger model[1] is well established to predict the blended yarn strength of ring-spun yarn only. It is essential to study the suitability of Hamburger model to predict the strength of blended Dref-III yarn as well as similar ring-spun yarn.

In the present study, efforts have been made to use blended stock of materials, i.e. polyester and viscose in both core and sheath to make the blend percentage independent of core-sheath ratio and to have proper blend homogeneity. Tensile characteristics of the yarns have been thoroughly studied.

Blended ring-spun yarns have also been prepared with different blend proportions as like as Dref-III yarns. Attempts have been made to study the suitability of Hamburger model[1] to predict the strength of blended Dref-III as well as ring-spun yarns. Stress-strain curves of both fibre and yarn (100% polyester and viscose) have been considered for the purpose of prediction. Attempt has also been made to derive an equation to predict the blended yarn strength of Dref-III yarn with a given input of blend percentage and core contents.

2 Materials and Methods

2.1 Materials

1.2 denier × 44mm polyester and 1.5 denier × 44mm viscose fibres were used to prepare the blended Dref-III yarns. The physical properties of the fibres used here are listed in Table 1. The stress-strain diagrams of polyester and viscose fibres are shown in Fig. 1.

2.2 Methods

Sliver Preparation

Polyester and viscose fibres were opened and mixed manually with different proportions such as 80:20, 70:30, 60:40, 50:50, 40:60, 30:70 and 20:80 (wt/wt) respectively. Sliver of 100% polyester and viscose fibres and the different blended stocks were processed separately.

The fibres were processed twice through miniature card (Platt Saco Lowell). The lap thus produced was processed through the miniature draw frame (Platt Saco Lowell) and obtained a sliver of desired linear

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Table 1—Tensile properties of polyester and viscose fibres.

Fibre	Staple length mm	Linear density den	Tenacity cN/tex	Strength CV%	Breaking extension %	Extension CV%	Initial Modulus cN/tex	Modulus CV%
Polyester	44	1.2	30.25	6.79	14.66	14	750	9.42
Viscose	44	1.5	9.25	14.52	11	22	195	10.96

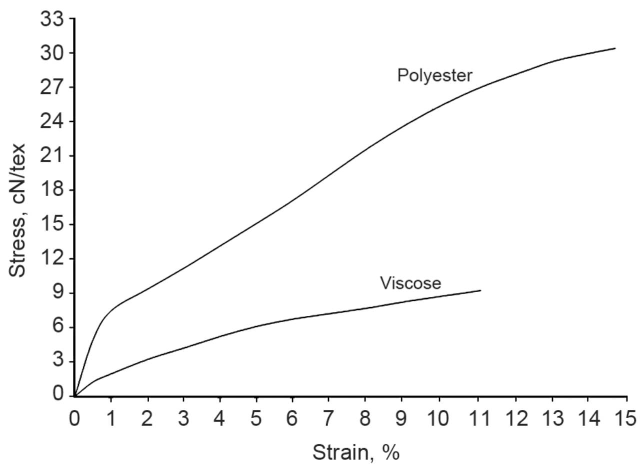

Fig. 1—Stress-strain curve of polyester and viscose fibres

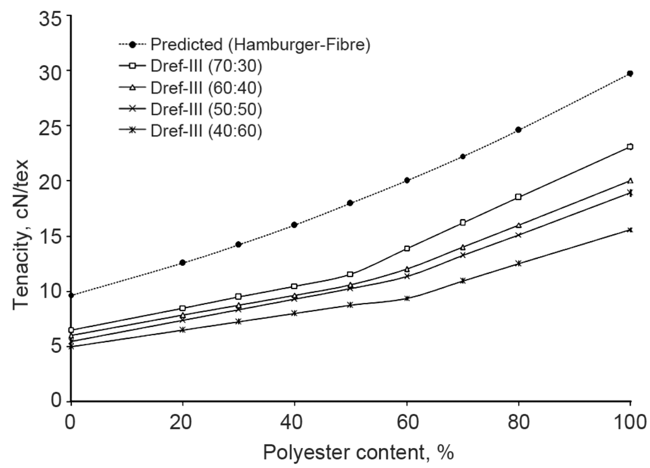

Fig. 2—Comparison of yarn strength predicted by Hamburger model and actual strength of different Dref-III yarns at different polyester contents

density. The sliver thus produced was further processed through the same miniature drawing frame with six folding of sliver. The linear density of the sliver was maintained at 3.6 K tex and then used as the feed material to Dref-III machine.

To get the homogeneous blend, additional two passages of drawing operation were carried out with six draft and six folding. The linear density of the sliver was maintained as 3.6 K tex and used as feed material to Dref-III machine.

Yarn Preparation

Dref-III spinning machine was used to prepare yarn sample from the above nine types of drawn slivers for four different core-sheath ratios (70:30, 60:40, 50:50 and 40:60) with a constant delivery rate of 100m/min; 35mbar nip pressure and 3800 rpm drum speed.

Ring spinning frame (model G 5/1 of LMW Ltd.) was used to prepare 100% polyester and viscose ring yarns as well as polyester/viscose blended ring yarns with blend ratios similar to that used in case of Dref-III yarns with 23.7 tpi at a spindle speed 15000 rpm.

Evaluation of Tensile Properties

Instron universal tensile tester (model 4411) was used for evaluation of tensile properties as per the prescribed method[2], maintaining test length 50 cm and test speed 100mm/min. The stress-strain curves of different 100% polyester and 100% viscose Dref-III yarns having different core-sheath ratios have been utilised to derive Hamburger model for the prediction of tenacity of blended Dref-III yarn (Fig. 2). The stress-strain curves of 100% polyester and 100% viscose ring-spun yarns have been utilised to derive Hamburger model for prediction of tenacity of ring yarn (Fig. 3).

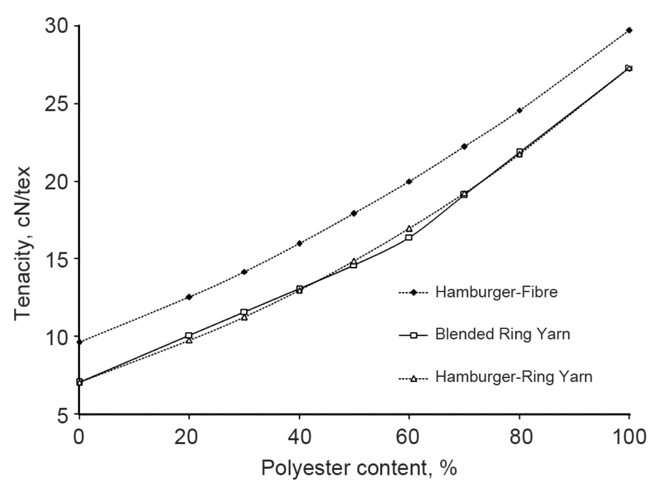

Fig. 3—Tenacity curve of blended ring yarn and Hamburger models at different polyester contents

3 Results and Discussion

3.1 Effect of Core-sheath Ratio on Tensile Strength

It is observed from Table 2 that the tenacity of Dref-III yarns increases with the increase in core content for 100% polyester yarns, viscose yarns and other yarns with different proportions of polyester and viscose contents in blend. Regression equations of tenacity and core content at different blend levels are exhibited in Table 3 and they represent best fitted curves. As core fibres are load bearing fibres, the increase in core content results in increase in load bearing capacity of Dref-III yarns.

Table 2—Tensile properties of Dref-III and ring yarns with the variation of blended core composition and core-sheath ratio

Sample No	Blend proportion (P:V)	Core-sheath ratio in Dref-III yarn	Tenacity cN/tex		Breaking extension %		Initial modulus cN/tex	
			Dref-III	Ring	Dref-III	Ring	Dref-III	Ring
B1	100:0	70:30	23.125	27.32	20	22.5	154.40	221.7
		60:40	20		19.6		151.6	
		50:50	18.9		20		150.4	
		40:60	15.6		18.5		149.46	
B2	0: 100	70:30	6.49	7.08	15	17.5	104.24	89.80
		60:40	6.0		13		102.6	
		50:50	5.46		14.2		100.1	
		40:60	4.96		12.24		98.7	
B3	80:20	70:30	18.5	21.856	19.6	21.6	148.06	184.58
		60:40	16		19.8		147.42	
		50:50	15.12		17.4		146.25	
		40:60	12.48		16.3		145.6	
B4	70:30	70:30	16.19	19.124	19.1	20.19	146.06	156.2
		60:40	14		19.6		145.36	
		50:50	13.23		19.6		145.1	
		40:60	10.92		18.54		144.26	
B5	60:40	70:30	13.88	16.392	18.7	22.17	144.09	141.36
		60:40	12		16.24		143.2	
		50:50	11.34		17.2		142.78	
		40:60	9.36		16.59		142.32	
B6	50:50	70:30	11.56	14.63	18.1	21.36	142.06	132.5
		60:40	10.56		16.8		141.2	
		50:50	10.23		17.32		140.6	
		40:60	8.73		16.35		139.7	
B7	40:60	70:30	10.46	13.12	17.7	14.56	134.56	121.37
		60:40	9.65		17.5		133.56	
		50:50	9.28		18.2		132.4	
		40:60	7.98		16.8		133.6	
B8	30:70	70:30	9.47	11.61	17.2	19.87	126.53	109.2
		60:40	8.74		17.1		120.5	
		50:50	8.32		17.6		119.4	
		40:60	7.22		17.3		118.2	
B9	20:80	70:30	8.47	10.1	16.1	16.24	116.79	94.67
		60:40	7.83		17.1		115.45	
		50:50	7.37		14.9		114.98	
		40:60	6.47		13.5		112.73	

3.2 Effect of Blend Proportion on Tensile Strength

The tenacity of Dref-III yarns have been found to increase with the increase in polyester content in the blend as shown in Table 4. Regression equations of tenacity and blend proportion at different core content levels are exhibited in Table 5, where '*X*' and '*Y*' are polyester content (%) in the blend and tenacity respectively. Polyester fibre has higher tenacity as compared to viscose fibre. Hence, increase in proportion of high tenacity polyester fibres in the core results in more load bearing capacity of Dref-III yarn.

3.3 Prediction of Blended Yarn Tenacity using Hamburger Model

Dref-III Yarn Tenacity using Stress-Strain Curve of Fibres

Tenacity of blended Dref-III yarns has been predicted using Hamburger model for yarns with different blend levels using fibre stress-strain curves (Fig. 1). Predicted and actual curves are compared in Fig. 2. Wide differences are observed between the predicted and the actual tenacity values for yarns of all core-sheath ratios. In fact, in all the cases the actual tenacity values are much lower than the values obtained from Hamburger model (Fig. 2). This may be due to the reason that in case of prediction, failure of yarn has been assumed due to failure of fibres. But in the actual case failure of yarn is predominantly due to slippage of fibres. It is noticeable from Fig. 2 that the difference in respective tenacity value has gradually reduced with the increase in core content in Dref-III yarn. This is due to the presence of more load bearing component fibres in the yarn.

Dref-III Yarn Tenacity using Stress-Strain Curve of Yarn

Stress-strain curves of 100% polyester and 100% viscose Dref-III yarns are shown in Fig. 2. The blended yarn tenacity, predicted from Hamburger model derived from each stress-strain curve having different core-sheath ratios (70:30, 60:30, 50:50 and 40:60), is compared with actual value of each yarn for different blend proportions. Each predicted curve shows very good similarity with the actual curve for all types of yarn.

Regression equations have been developed to predict the tenacity of blended Dref-III yarn, for different core-sheath contents and different blend ratio of Dref-III yarns (Table 3). The difference in actual tenacities of Dref-III yarn and predicted yarn strength from Hamburger model (derived from stress-

Table 3—Regression equations relating tenacity and core-sheath ratio at different blend proportions of Dref-III yarn

Blend proportion (P:V)	Regression equation	Correlation coefficient
100:0	$Y = -4.375X^2 + 28.487X + 5.1163$	0.969
80:20	$Y = -3.5X^2 + 22.79X + 4.093$	0.969
70:30	$Y = -3X^2 + 19.88X + 5.1163$	0.969
60:40	$Y = -2.5X^2 + 16.97X + 3.099$	0.969
50:50	$Y = -12.5X^2 + 22.57X + 1.794$	0.9589
40:60	$Y = -12.25X^2 + 21.285X + 1.4945$	0.9589
30:70	$Y = -9.25X^2 + 17.345X + 1.8115$	0.9815
20:80	$Y = -6.5X^2 + 13.617X + 2.097$	0.983
0:100	$Y = -0.25X^2 + 5.405X + 2.8335$	0.9997

X – Core-sheath ratio and *Y* – Tenacity, cN/tex.

Table 4—Comparison of blended yarn tenacity of Hamburger model derived from yarns stress-strain curve with actual tenacity of Dref-III yarn

Polyester content in blended yarn, %	Core-sheath ratio in Dref-III yarn	Tenacity[a] cN/tex	Difference[b]
80	70:30	18.039	0.461
	60:40	15.8302	0.1698
	50:50	15.284	-0.164
	40:60	12.1775	0.3025
70	70:30	15.841	0.3465
	60:40	13.9992	0.0008
	50:50	13.526	-0.296
	40:60	10.8865	0.0335
60	70:30	13.823	0.052
	60:40	12.3482	-0.3482
	50:50	11.928	-0.588
	40:60	9.7155	-0.3555
50	70:30	12.105	-0.5425
	60:40	10.8772	-0.3172
	50:50	10.49	-0.26
	40:60	8.6645	0.0655
40	70:30	10.567	-0.109
	60:40	9.5862	0.0638
	50:50	9.212	0.064
	40:60	7.7335	0.2425
30	70:30	9.2489	0.2171
	60:40	8.475	0.265
	50:50	8.094	0.228
	40:60	6.9225	0.2975
20	70:30	8.1509	0.3231
	60:40	7.5442	0.2858
	50:50	7.136	0.234
	40:60	6.2315	0.2365

[a]Tenacity of Hamburger model of blended yarn derived from stress-strain curve of Dref-III yarn. [b]Difference between actual and Hamburger model.

strain curve of 100% Dref-III yarns) for different blends are shown in Table 4. The regression equations have also been developed to predict the tenacity of blended Dref-III yarn for different polyester content and different core-sheath ratio of yarn (Table 5).

Ring Yarn Tenacity using Stress-Strain Curves of Fibres

The tenacity of blended ring yarn is predicted from Hamburger model of blended yarn tenacity, derived from stress-strain curve (Fig. 1) of polyester and viscose fibres. Tenacity value as obtained from experiment and Hamburger model for different polyester contents in blended ring yarn is shown in Tables 2 and 6 respectively. Notable difference has been observed between the actual and the predicted curves for different polyester contents (Fig. 2).

It is understood that Hamburger model of blended yarn tenacity can be utilised successfully for the prediction of yarn tenacity of blended Dref-III yarns with little difference in results.

Ring Yarn Tenacity using Stress-Strain Curves of Yarns

Stress-strain curves of ring-spun 100% polyester and 100% viscose yarns have been utilised to derive Hamburger model of blended yarn tenacity for ring yarn. Comparison of actual blended yarn tenacity with blended yarn tenacity obtained from Hamburger model have shown notable similarity, as may be observed from the actual and predicted tenacity-polyester content curves (Fig.3).

It is observed from Tables 4 and 6 that the magnitude of difference in tenacity between actual and predicted tenacity values is less in case of prediction based on stress-strain curves of 100% polyester and viscose yarns than those of polyester and viscose fibres.

Dref-III Yarns using Equation Derived from Hamburger Model for different Core-Sheath Contents

The regression equations for blended yarn tenacity (as derived from stress-strain curves of Dref-III yarns) for different core contents have been utilised to form an equation to predict the tenacity of polyester-viscose blended Dref-III yarn at different core contents and for any polyester content in yarn. The general form of equation to predict the blended yarn tenacity of Dref-III yarns is represented as:

$$Y = 3.0135 — 0.6862X_1 + 5.3528X_2 + 3.1827X_1^2 – 3.6101X_2^2 + 19.8997X_1X_2 \text{ (Correl-0.9924).}$$

where Y is the tenacity of blended Dref-III yarn in cN/tex; X_1 , the polyester content (%) in the blend; and X_2, the core-sheath ratio of blended Dref-III yarn.

It is evident from the equation that the tenacity of blended Dref-III yarn depends upon the value of polyester content (X_1%) and core content (X_2%) in blended yarn. The comparison of the actual values of blended yarn tenacity and values obtained from the general equation and their differences are shown in Table 7. Very small and insignificant difference in all

Table 5—Regression equations relating tenacity and blend ratio at different core-sheath ratio of Dref-III yarn

Core-sheath ratio	Regression equation	Correlation coefficient
70:30	$Y = 0.0011X^2 + 0.0549X + 6.6135$	0.998
60:40	$Y = 0.0009X^2 + 0.0481X + 6.2222$	0.998
50:50	$Y = 0.0008^2 + 0.0558X + 5.6998$	0.998
40:60	$Y = 0.0006X^2 + 0.0391X + 5.2102$	0.997

X – Polyester content (%) in the blend and Y – Tenacity (cN/tex).

Table 6—Comparison of blended yarn tenacity between Ring yarn and Hamburger model derived from stress- strain curves of polyester and viscose fibres and yarns

Polyester content in blend yarn, %	Tenacity of blended yarn of Hamburger model[a], cN/tex	Difference of tenacity between ring yarn[b] and Hamburger model	Hamburger model of blended yarn tenacity[c] cN/tex	Difference of tenacity between ring yarn[b] and Hamburger model
0	9.65	-2.57	7.08	0
20	12.54	-2.44	9.78	0.3216
30	14.199	-2.589	11.27	0.3346
40	15.966	-2.846	12.97	0.1476
50	17.933	-3.303	14.87	-0.2394
60	20.01	-3.618	16.97	-0.5744
70	22.23	-3.106	19.26	-0.1394
80	22.584	-0.728	21.76	0.0956
100	29.72	-2.4	27.32	0

[a]Derived from stress-strain curve of fibres .
[b] Actual tenacity of ring yarn.
[c]Derived from stress-strain curve of 100% ring yarns.

Table 7—Comparison of blended yarn tenacity of Hamburger model derived from stress-strain curve of Dref-III yarns with tenacity obtained from general equation for different core-sheath ratio and polyester content

Polyester content in blended yarn, %	Core-sheath ratio in Dref-III yarn	Tenacity of Dref-III yarn obtained from general equation, cN/tex	Hamburger model of blended yarn tenacity[a], cN/tex	Difference of tenacity between Hamburger model and general equation
80	70:30	17.6234	18.039	0.4156
	60:40	15.9654	15.8302	-0.135
	50:50	14.2353	15.284	1.0487
	40:60	12.433	12.178	-0.255
70	70:30	15.8216	15.841	0.0194
	60:40	14.3627	13.9992	-0.3635
	50:50	12.8315	13.526	0.6945
	40:60	11.2282	10.8865	-0.3417
60	70:30	14.0835	13.823	-0.2605
	60:40	12.8236	12.3482	-0.4753
	50:50	11.4914	11.928	0.4366
	40:60	10.0870	9.7155	-0.3715
50	70:30	12.4090	12.105	-0.304
	60:40	11.3481	10.8772	-0.4709
	50:50	10.2149	10.49	0.2751
	40:60	9.0096	8.6645	-0.3451
40	70:30	10.7982	10.567	-0.2312
	60:40	9.9363	9.5862	-0.3501
	50:50	9.0021	9.212	0.2099
	40:60	7.9957	7.7335	-0.2622
30	70:30	9.2511	9.2489	-0.0022
	60:40	8.5881	8.475	-0.1131
	50:50	7.8529	8.094	0.2411
	40:60	7.0456	6.9225	-0.1231
20	70:30	7.7676	8.1509	0.3833
	60:40	7.3036	7.5442	0.2406
	50:50	6.7674	7.136	0.3686
	40:60	6.1591	6.2315	0.0724

[a]Derived from stress-strain curve of Dref-III yarn.

the cases confirms the validity of the general equation for prediction of blended yarn tenacity of Dref-III yarns at any core-sheath ratio.

3.4 Effect of Core-Sheath Ratio and Blend Proportion on Breaking Extension of Dref-III Yarn

The breaking extension values of Dref-III yarns with different core-sheath ratios at different blend proportions are shown in Table 2. Breaking extension is gradually increased with the increase in polyester content for different core-sheath yarns. There is no definite trend observed for all types of yarn with the change in core-sheath ratio and polyester content in the blended yarn. Increase in breaking extension of yarn takes place because of high extensible polyester fibre content in yarn.

3.5 Effect of Core-sheath Ratio and Blend Proportion on Initial Modulus of Dref-III Yarn

The initial modulus of Dref-III yarns for different core-sheath ratios and different blend proportions are shown in Table 2. Initial modulus increases with the increase in polyester content in the different core-sheath yarn and also with the increase in core content of the yarn which may be attributed to the higher modulus polyester fibres. Ring-spun yarn follows a similar trend in initial modulus with change in blend proportion (Table 2). 100% ring-spun polyester yarn gives maximum modulus value. Increase in low modulus viscose fibres in polyester-viscose blend results in reduction in initial modulus of ring yarn.

4 Conclusion

4.1 The tenacity, breaking extension and initial modulus of both Dref-III and ring-spun polyester-viscose blended yarns increase with the increase in polyester content in yarn.

4.2 Hamburger model for prediction of tenacity of blended yarn, derived from stress-strain diagram of fibres and that of yarns is used to predict the blended yarn tenacity of ring and Dref-III yarns. The prediction level of blended yarn tenacity for both the yarns has found to be poor while using the model derived from the stress-strain curve of fibres.

4.3 The prediction of tenacity of blended Dref-III and ring-spun yarns respectively with high level of accuracy has been established while using the Hamburger model derived from the stress-strain diagram of the yarns.

4.4 An equation has been formulated to predict the tenacity of polyester-viscose blended Dref-III yarn for different core contents and also for different blend proportions of blend constituents. High level of accuracy has been observed for prediction of blended yarn tenacity for Dref-III yarns.

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