Bharani and Mahendra Gowda, J Textile Sci Eng 2012, 2:5
DOI: 10.4172/2165-8064.1000118

Journal of Textile Science & Engineering

Research Article Open Access

A Study on Effect of Strain Rate on Tensile Behavior of Inherent Flame Retardant Trevira CS Airjet Spun Yarns

Bharani M[1]* and Mahendra Gowda RVM[2]

[1]Department of Fashion Technology, Bannari Amman Institute of Technology, Sathyamangalam, Tamil Nadu, India
[2]VSB College of Engineering, Karur, Coimbatore, India

Abstract

It is well known that the tensile behaviour of a spun yarn depends largely on the characteristics and structural arrangements of its constituent fibres. An air-jet spun yarn consisting of a core of parallel fibres wrapped by sheath fibres, exhibits a fasciated yarn structure. Therefore, due to the marked structural differences, the responses to the tensile forces of these yarns are expected to be different. Further, the theoretical analysis of the tensile behaviour of a staple-fibre spun yarn is highly complex, mainly because of discontinuities at fibre ends. For instance, during the insertion of weft, whether by projectile or air jet, the yarn has to withstand accelerations of many thousands of times greater than that due to gravity. Hence it becomes important to understand the stress-strain responses of yarns under non-standard loading conditions vary over a range of strain rates. Hence the present paper is designed to understand the how the (Trevira CS) inherently flame retardant fibres were successfully processed on air-jet spinning system to produce 20 Ne & 30 Ne yarns. As regards the influence of high strain rate on yarn tensile characteristics, it is found that an increase in strain rate from 5 m/min to 400 m/min considerably increases the yarn tenacity but decreases the yarn breaking extension. The reduction in tenacity is significant at the 95% level of confidence in case 30 Ne pure Trevira-spun and its blended yarns. This paper is written to understand the effect of strain rate on the tensile behaviour of Trevira CS fibre.

Keywords: Trevira CS; Tensile behavior; Strain rate; Tenacity; Breaking extension

Introduction

The increase in strain-rate, the tenacity was initially found to increase up to 10 mm/sec for both ring spun and air-jet spun yarns, this followed by a sharp reduction [1]. The increase is more for air-jet spun yarn than for ring spun yarn. For both ring spun and air-jet spun yarns, sharp and sudden fall in load value is observed as the yarn fails after attaining its peak load when the test is conducted at low strain-rate because of the possibilities of readjustment with the adequate time that enable almost all fibres in the structure to participate in breakage reaching their breaking extension levels together. At high strain-rate, after attaining maximum value the load falls off slowly with increasing strain, giving the peak a rounded-off shape, which was observed in both the yarns. Owing to the high rate of extension, the fibres in the failure region have hardly any chance of readjustment or realignment and start breaking in a locked-in configuration in the structure as and when the local strain level reaches their own breaking strain. The process continues until sufficient fibres break to bring down the load to zero. For air-jet-spun yarn at a low strain rate of 0.1mm/s, the load-extension curve shows a definite phenomenon in the recorded values with an increase in extension, which is not observed at high strain rate. It was attributed to the fact that as the yarn is slowly extended, uncrimping of the core and occasional slippage of core fibres are likely to take place either because the surface fibres are not wrapped under uniform tension or slippage of wrapped fibre ends from the body of the yarn occurs because of not being integrated properly.

The effect of rate of extension of the tensile properties of a spun yarn was investigated by Radhakrishnaiah and Huang [2]. Cotton yarns of 18s Ne were spun on ring, rotor and friction spinning systems. Similarly, cotton/polyester (50:50) yarns of the same count were produced on ring, rotor, friction and air-jet spinning systems. These yarns were tested at gauge lengths of 45 mm and 500 mm and at test speeds varying from 15 mm/min to 2000 mm/min. Based upon the analysis of failure modes of the yarns, it was concluded that there are major differences in stress-strain behaviours of cotton yarns representing the three spinning systems. The average stress-strain curves of the cotton/polyester yarns representing the three spinning systems were found to be somewhat similar up to the yield point. The traverse rate appears to have a similar effect on the stress-strain responses of three cotton yarns. The polyester/cotton yarns representing the three different spinning systems, however, fail to show a similar change in stress-strain responses with the change in traverse rate. Further, all six experimental yarns show catastrophic failure at 500 mm gauge length. At 45 mm gauge length, ring spun yarns show most catastrophic failures while the rotor, air-jet and friction spun yarns show mostly non-catastrophic failure.

The effect on heat of textile materials can produce physical as well as chemical changes in them. In thermoplastic fibres, the physical changes can occur at second order transition (Tg) and Melting Temperature (Tm), while chemical changes takes place at a Pyrolysis Temperature (Tp), at which the thermal degradation occurs as in case of natural fibres. Textile combustion is a complex process that involves heating, decomposition leading to gasification (fuel generation), ignition and flame propagation [3].

***Corresponding author:** Bharani M, Department of Fashion Technology, Bannari Amman Institute of Technology, Sathyamangalam, Tamil Nadu, India, Tel: 919585636161, 04295-226072; E-mail: mbharan79@gmail.com

Received July 04, 2012; **Accepted** August 30, 2012; **Published** September 08, 2012

Citation: Bharani M, Mahendra Gowda RVM (2012) A Study on Effect of Strain Rate on Tensile Behavior of Inherent Flame Retardant Trevira CS Airjet Spun Yarns. J Textile Sci Eng 2:118. doi:10.4172/2165-8064.1000118

Although few researchers [4-6] have reported recent developments in tensile characteristics of yarns, the tensile behaviour of yarns cannot be generalized as the properties of every new fibre developed from time to time vary and these fibres when spun into yarn at varying speeds and processing conditions, and these yarns in turn when converted into fabrics will have unique characteristics. About the tensile properties and performance aspects of yarns representing the new yarn structures, the conclusions drawn from the studies of these researchers were restricted to only low strain rates, say up to 2000 mm/min. Now-a-days, in spinning mills, yarns are being tested at high strain rates of up to 400 m/min. Therefore, it becomes essential to understand the tensile behaviour of these yarns at very high strain rate as well as varying gauge lengths. These aspects have also been considered in the present research work, where all the yarns produced were characterized for tensile properties at high strain rate and varying gauge lengths.

Meridith [7] tested yarns over a million-fold range of rates of extension and found that the relation between yarn breaking load and rate of extension was approximately linear (actually slightly concave to the breaking load-axis) for most fibres. He also observed that the strength of cotton yarn decreases by approximately 9% for a 10-fold increase in time to break.

Deluca and Thibodeaux [8] reported that tenacity of the 49.2 Tex cotton yarns increases linearly with the logarithm of rate of extension from 10 to 100 mm/min. At 200 mm/min, yarn tenacity increases slightly, and at 5000 mm/min it decreases abruptly. The 16.4 Tex cotton yarn data showed a similar increase in yarn tenacity from 100 to 2000 mm/min as found for the 49.2 Tex yarn tenacity over the range 100 to 500 mm/min. However, yarn tenacity for the 16.4 Tex yarn was constant from 100 to 5000 mm/min.

Oxenham and Lee [9] compared the tenacity and elongation of different blended yarns tested at Tensojet (400m/min) and Tensorapid (5m/min). They found that the tenacity values of ring, rotor and air-jet spun yarns tested at Tensojet are higher than those from the Tensorapid. However, in case of air-jet yarns the tenacity values measured in Tensojet and Tensorapid showed the least difference than those in ring and rotor spun yarns. Also, the difference between the Tensojet and the Tensorapid is not significant for 50/50 poly/cot blend. They also found that the yarn tenacity for 100% cotton and 50/50 poly/cot blend the yarn tenacity shows a continuous increase with the logarithm of the testing speed in both Tensorapid and Tensojet.

Ghosh et al. [10] found that yarn tenacity increases continuously with the extension-rates for all spinning systems. The increase in tenacity with the increase in the extension-rate is due to the consequent increase in the proportion of fibre breakage, as depicted in Figure 1. The effect of impact loading at high strain rate is responsible for more fibre breakage. On the contrary, at a slow strain rate the mechanism of yarn failure is slippage dominated, as more time is available for yarn to cause rupture.

Experimental Procedure

Materials

As the present work is focused on development of flame retardant apparels on the economic scale, Trevira CS flame retardant fibres were procured from Rajasthan Spinning and Weaving Mills Ltd. Also, Cotton (DCH 32), Modal and Acrylic fibres were collected from nearby Spinning Mills to produce Trevira blended yarns.

Measurement of fibre characteristics

The conditioned DCH 32 Cotton fibres were tested on High Volume Instrument for micronaire, length, strength and extension characteristics. All other man-made fibres chosen as above were tested on Lenzing Technik instruments for single fibre fineness, crimp, and tensile characteristics. The single fibre fineness and length characteristics were measured as per the International Bureau of Standardization of Man-Made Fibres 1998 test method. The crimp and tensile characteristics of single fibres were measured using the procedures described in ASTM D 3937-01 and D 3800-01 test methods respectively.

Preparation of yarn samples

Yarn samples of 20 Ne and 30 Ne were spun from pure Trevira CS fibres in Air-jet spinning to observe the process performance of Trevira CS fibres as well as to investigate the influence of these yarn structures on flammability of fabrics produced from them. Air-jet-spun yarns of 20 Ne and 30 Ne were spun from pure Trevira CS fibres on a laboratory model Air-jet spinning machine MJS 802.The yarn spinning plan and the process parameters used are given in Table 1.

Tensile characteristics

The conditioned yarn samples were tested on Tensomaxx 7000 and Tensojet 4 for tensile characteristics, like breaking force, tenacity, breaking extension, breaking work, and secant modulus between 1% and 5% extension levels. The yarn samples were tested at two different gauge lengths, viz. 200 mm and 500 mm at a constant strain rate of 5m/min on Tensomaxx 7000 tensile tester. Yarns were also tested at two different strain rates of 5 m/min and 400 m/min using a constant gauge length of 500 mm on Tensojet 4 tensile tester. The strain rates of 5 m/min & 400 m/min and gauge lengths of 200 mm & 500 mm are chosen as these are the commercially practiced test conditions in most of the spinning mills and conform to most test standards.

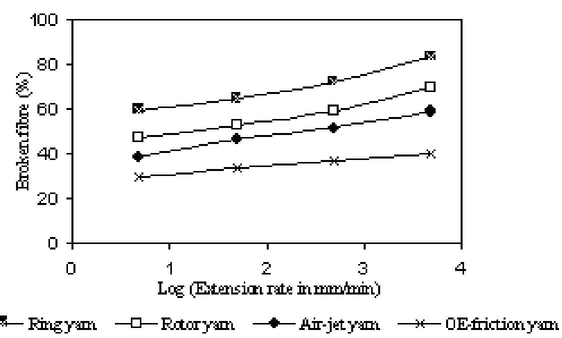

Figure 1: Effect of Extension Rate on broken fibre percentage [10].

Ring Spun Yarns	Spindle Speed (r/min)	Break Draft	Twist Multiplier	Traveller
Air-jet Spun Yarns	N_1 Pressure (kg/cm²)	N_2 Pressure (kg/cm²)	Delivery Speed (m/min)	Total Draft
20 Ne Trevira CS	2.5	4.0	180	114.7
30 Ne Trevira CS	2.5	4.0	180	171.4

T/A : Trevira / Acrylic; T/C : Trevira / Cotton; T / M : Trevira / Modal

Table 1: Particulars of Yarn Sample Preparation.

The secant modulus of the yarn can be determined with respect to its completeness or a selected elongation range. It provides information about the elasticity of the yarn between the two points in a selected extension range, when the material is subjected to such loading conditions during any subsequent process. In the present study, two elongation values on the load-elongation curve, say 1% & 5% are chosen as they form the most common range of elongation to which any yarn is subjected during various processes before it ruptures. The force values of these elongation values are determined to compute the secant modulus as given below [11]:

Secant modulus = $[\{(F5-F1)/(E5-E1)\}/tex] \times 100$

For each sample, 50 tests were conducted and the average values of breaking force, tenacity, breaking elongation, breaking work, and secant modulus is computed.

Result and Discussion

Characteristics of fibres

The characteristics of Trevira CS, Acrylic, Modal, and Cotton fibres used for manufacturing yarns are given in Tables 2 and 3.

It can be observed from Table 2 that Trevira CS fibre exhibits high tenacity and good extension-at-break, whereas the acrylic fibres exhibit moderate tenacity but high extension. Modal fibres have good tenacity and moderate extension-at-break. The DCH 32 cotton fibres are relatively longer with moderate strength and good extension values Table 3.

Tensile characteristics of yarns

The tensile characteristics of all the yarns are analysed with respect to strain rate and gauge length. The changes in tensile properties of yarns caused due to increase in strain rate as well as gauge length are subjected to tests of significance at 95% confidence level and inferences are drawn.

Influence of strain rate

It can be seen from Table 4 that an increase in strain rate from 5 m/min to 400 m/min considerably increases the yarn tenacity but decreases the yarn breaking extension. At a very high strain rate of 400 m/min, the loading of yarn resembles an impact test wherein due to the absence of an appreciable time for relaxation; the fibres are subjected to an instantaneous force, which results in catastrophic breakage of very large proportions of fibres in the yarn and thus recording a higher tenacity. The lack of an appreciable time for relaxation of stress by fibres and the absence of realignment causes a reduction in breaking extension of the yarn. This trend is exhibited by these two of the yarns as depicted in (Figures 2-4). The 20sNe yarn is showing higher tenacity, extension%, breaking work. This is due to the higher contribution of wrapper fibres which act as belts to hold the core fibres and make the yarn to depict higher in yarn tenacity, extension%, breaking work.

Further, it is clear from Table 4 that the increase in yarn tenacity due to increase in strain rate from 5 m/min to 400 m/min increase is not statistically significant at the 95% level of confidence but it is appreciable and of practical importance.

Conclusions

The increase in strain rate from 5 m/min to 400 m/min initially increases the tenacity of air-jet spun yarns and then decreases. The maximum tenacity was recorded at around 100 m/min. The initial increase in the tenacity with an increase in strain rate is definitely due to breakage number of fibres in the yarn. The reduction in yarn tenacity and extension of high strain rate (400 m/min) may be due to instantaneous extension of core fibres followed by loosening of wrapper fibres and the consequent slippage of core fibres. The present

Fibre	Titre (den)	Length (mm)	Tenacity (g/tex)	Tenacity at 10% extn. (g/tex)	Elongation (%)	Crimp (arcs/inch)
Trevira CS	1.5	38	48.7	29.9	20.3	8
Acrylic	1.2	38	27.7	12.8	28.0	8
Modal	1.2	38	31.5	23.0	13.1	6

Table 2: Characteristics of Man-made fibres.

Micronaire	2.5% Span Length (mm)	50% Span Length (mm)	Uniformity Ratio	Tenacity (g/tex)	Elongation (%)
3.5	30.4	13.5	44.5	26.9	6.2

Table 3: Characteristics of DCH 32 Cotton.

Sl. No.	Yarn Description	Strain Rate (m/min)	Breaking Load (gf)	Tenacity (g/tex)	Extension (%)	Breaking Work (kgf-m)
1	20 Ne Trevira Air-jet-spun	5	521.2	17.65	9.78	1289
		400	531.1	17.99	9.14	1227
		% change	1.9	1.9	-6.5	-4.8
2	30 Ne Trevira Air-jet-spun	5	318.9	16.20	8.57	718
		400	344.0	17.51	7.73	752
		% change	7.9	8.1	-9.8	4.7

T/A : Trevira / Acrylic; T/C : Trevira / Cotton; T / M : Trevira / Modal

Table 4: Tensile Characteristics of Yarns measured at Different Strain Rates.

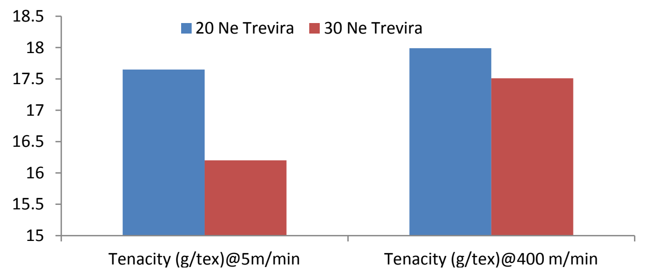

Figure 2: Tenacity of Yarns at Different Strain Rates.

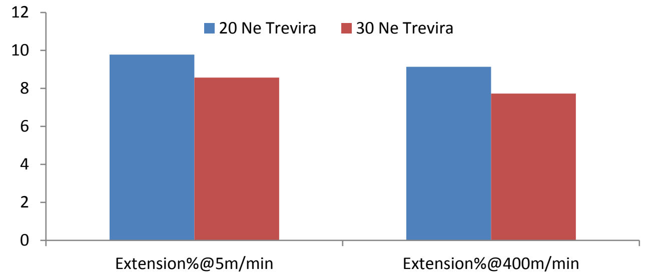

Figure 3: Extension% of Yarns at Different Strain Rates.

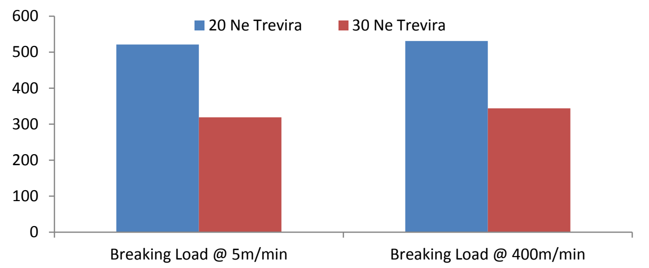

Figure 4: Breaking Load of Yarns at Different Strain Rates.

work will be of great use to the spinners and quality control personnel to select suitable guage lengths and test speeds for different types of yarns to depict high tenacity, extension and breaking work depending upon the application.

Acknowledgement

We would like to acknowledge and extend my heartfelt gratitude to DRDO, New Delhi, for sponsoring this research work to develope flame retardant textile materials.

References

1. Chattopahyay R (1999) The Influence of the Strain Rate on the Characteristics of the Load-Elongation Curves of Ring-Spun and Air-Jet-Spun Yarns. J Text I 90: 268-271.
2. Radhakrishnaiah P, Huang G (1997) The Tensile and Rupture Behavior Of Spun Yarns Representing Different Spinning Systems. School of Textile & Fiber Engineering Atlanta GA 30332-0295.
3. Horrocks AR, Anand SC (2000) Handbook of Technical Textiles. Woodhead Publishing India.
4. Balasubramanian P, Salhotra KR (1985) Effect of Strain Rate on Yarn Tenacity. Text Res J 55: 74-75.
5. Sawhney APS, Ruppenicker GF (1997) Special Purpose fabrics Made with Core-spun Yarns.Indian J Fibre Text Res 22: 246-254.
6. Majumdar A, Sengupta R (2003) Effect of extension rate and specimen length on tenacity and breaking extension of polyester/viscose twin-spun air-jet yarns. Indian J Fibre Text Res 28: 182-184.
7. Meridith R (1950) The Effect of Rate of Extension on the strength and Extension of Cotton Yarn. J Text Inst 41: T199-T224.
8. Deluca LB, Thibodeaux DP (1992) Comparison of Yarn Tenacity Data Obtained using the Uster Tensorapid, Dynamat II, and Scott Skein Testers. Text Res J 62: 175-184.
9. Oxenham W, Lee EK (2003) Proceedings of World Congress on Textile in the Millenium. 225-236. 2003.
10. Ghosh A, Ishtiaque S, Rengasamy RS (2003) Proceeding of 1st International Conference “Baltic Textile & Leather,” 1-6.
11. Further R (1995) Strength and Elongation Testing of Single and Ply Yarns: Experience with Uster Tensile Testing Installations. The Textile Institute Manchester.