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Research Article

Effect of Gauge Length and Speed on Fiber Strength Utilization in Spun Yarns Made from Cellulosic Fibers

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Abstract

In this study the effect of gauge length and test speed on coefficient of fiber strength utilization have been investigated before the process of yarn break. Viscose and cotton yarns produced from ring and rotor technologies were used. The yarns of similar linear densities of viscose (29.5tex) and cotton (73.8tex) were measured for tensile strength at different gauge length. The tensile strength of cotton yarns was also measured at different speeds. It can be inferred that at higher gauge length, all types of viscose and cotton yarns exhibited higher coefficient of fiber strength utilization before the process of yarn break. The test speed has also slight effect, at lower test speed the coefficient of fiber strength utilization is found higher than at the greater speeds. The effect of gauge length on fiber strength utilization has been observed more in all types of ring yarns as compared to the rotor yarns.

Keywords: *Gauge Length; Test Speed; Viscose and Cotton Yarns; Coefficient of Fiber Strength Utilization*

Introduction

The yarn structure and testing conditions (gauge length and test speed) are the most important parameters which can affect the tensile strength of staple spun yarns. Gauge length of 500 mm is used as standard for measurement of yarn tensile strength because the yarn bears stresses at more than 500 mm length on warping, sizing, beaming and weaving. Theoretical analysis of tensile behaviour of staple spun yarns is very complex because of discontinuities at the fiber ends, fibers can slip, break or both phenomena can occur during yarn extension [1].

Das., *et al*. [2] studied the effect of gauge length on yarn tensile strength and developed mathematical model for prediction of yarn strength at different gauge length. They found different empirical relationship among yarn strength and gauge length for different yarns. Ghosh., *et al*. [3] have reported the effect of testing condition on yarn tenacity. They studied that yarn strength is affected prominently by yarn structure, twist and gauge length. It was also revealed that manufacturing techniques have considerable effect in yarn structure. Ring spun yarn possess helical structure, but the core-sheath structure is observed in rotor yarns.

Realff., *et al*. [4] investigated the failure mechanism of yarn for ring, and rotor yarns at different gauge lengths. They established that both slippage and breakage of fibers can affect the yarn failure at longer gauge lengths but at shorter gauge length fiber breakage has more effect than slippage. The balance between fiber slippage and breakage relates with the yarn structure which is finally affected from the spinning technologies and gauge lengths.

Oxenham., *et al*. [5] have studied the effect of gauge length on ring, open-end and friction spun yarns and it was observed that the ring spun yarn exhibited significant drop in tensile strength as the gauge length increased up to 40 mm while strength of the friction spun yarns was considerably reduced as gauge length increased up to 20 mm. The strength of ring spun yarn was found to be fairly constant for a gauge length greater than 40 mm whereas it was reduced as gauge length increased in case of friction spun yarn, reflecting more discontinuities observed in the yarn formation zone in friction spinning.

Zubair., *et al*. [6] validated the mathematical model to predict the coefficient of fiber strength utilization using ring and rotor viscose staple spun yarns. There was good agreement between predicted and experimental coefficient of fiber strength utilization.

There are numerous publications in the branch of evaluation and comparison of tensile properties of spun yarns related with the standard testing condition. But in reality the yarn and fabric undergo tensile forces that are substantially different from those applied in the standard testing condition. Therefore, the results obtained under the standard test method cannot always be expected to fully reflect the end-use performance of the yarns. Moreover, it is a recognized fact that yarn strength at shorter gauge length gives better correlation with the fabric strength as opposed to the standard gauge length. Thus. the study of the tensile properties of spun yarns at different speeds and gauge lengths is certainly important.

In the current study, we have compared experimental coefficient of fiber strength utilization at four different gauge length for cotton and viscose staple spun yarn from ring and rotor spinning technologies. The experimental coefficient of fiber strength utilization for cotton ring and rotor yarns was also compared at different speeds. The similar yarn linear densities for each type of material were used in this study.

Material and Methods

Experiments were carried out to investigate the effect of gauge length and test speed on coefficient of fiber strength utilization in staple spun yarns. Two different types of materials viscose and cotton were used to produce ring and rotor staple spun yarn. Viscose and cotton fiber tensile properties were measured on Lenzing Vibrodyne-400 at gauge length of 10 mm and test speed of 10 mm/min according to the standard test method EN ISO 1973. Fifty specimens for each type of fiber were tested for stress-strain curves. The specifications of the fibers used are shown in table 1.

Parameters	Viscose	Cotton
Fiber length [mm]	38	25
Fineness [dtex]	1.32	1.6
Tenacity [cN/tex]	29.60	30.5
Breaking force [N]	3.81	4.88
Breaking strain [%]	18.04	6.35

Table 1: *Fiber specifications.*

All the yarns were measured on Instron-4411 in accordance with standard test method ISO 2060 for force and elongation at different speeds and gauge length. Fifty samples from each type of yarn were measured for stress-strain curves. Twist per meter were measured on twist testing machine according to standard procedure CSN 80 0701. Yarn diameter was determined by image analysis technique according to the standard test method (Interni norma) C.22.102-01. The yarn linear density was measured from a lea of one hundred meters according to standard test procedure CSN 80 0050. Five samples for each type of yarn were prepared on lea making machine and each sample was weighed in grams on weighing balance and yarn tex was determined from mean of five yarn samples. The physical characteristics of viscose and cotton yarns used are presented in the table 2.

Material	Yarn type	Yarn linear densities (actual)	Twist coefficient	Yarn twist	Yarn dia.	Twist angle
		Tex	[ktex$^{2/3}$]	Z [m^{-1}]	D [mm]	
Viscose	Ring	30.41	50	425	0.22	16.4
			56	470	0.22	18.0
	Rotor	29.76	75	595	0.20	20.5
			84	731	0.19	23.75
Cotton	Ring	72.2	128	493	0.301	25
	Rotor	73.5	123	454	0.380	28.5

Table 2: *Yarn characteristics.*

Results and Discussions

Average fiber and yarn specific stress-strain curves

The individual raw stress-strain curve data for each type of fiber and yarn from fifty specimens was used to obtain average specific stress-strain curve using linear interpolation and Matlab software. The experimental mean specific stress-strain curves at different gauge length for viscose and cotton fiber and also for both type of ring and rotor yarns before the process of break are shown in figure 1 and 2 respectively. It is evident that yarn stress-strain curves are always lying under the fiber stress-strain curves for all types of viscose and cotton yarns. The specific stress-strain curves at higher gauge length are lying at higher positions as compared with the curves obtained at lower gauge lengths for both type of yarns. The yarn twist in viscose yarn has also effect on yarn specific stress-strain curves, higher twist represents higher yarn specific strength in ring and rotor viscose yarns. The difference between specific stress-strain curves is more prominent in ring yarns as compared with rotor yarns due to their structure.

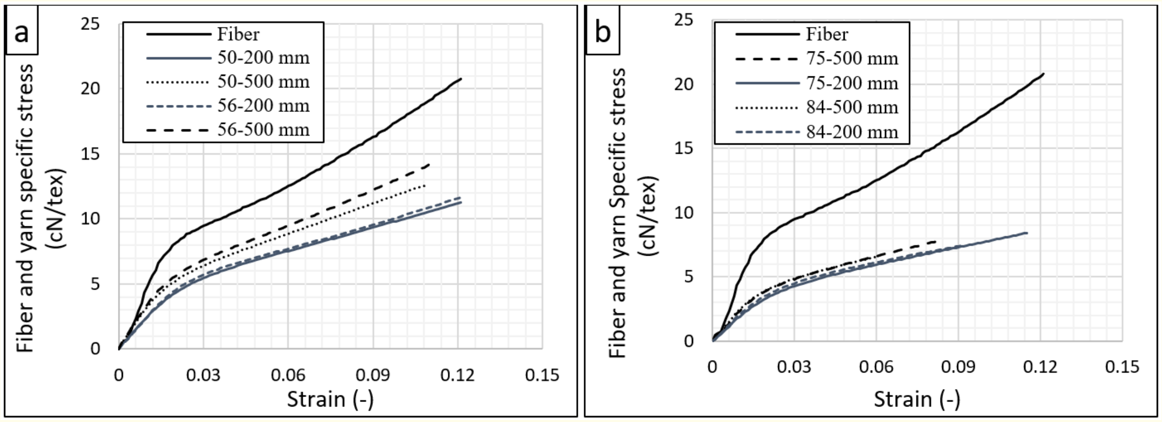

Figure 1: *Viscose fiber and yarn (29.5 tex) specific stress-strain curves at different gauge length a) ring yarns b) rotor yarns.*

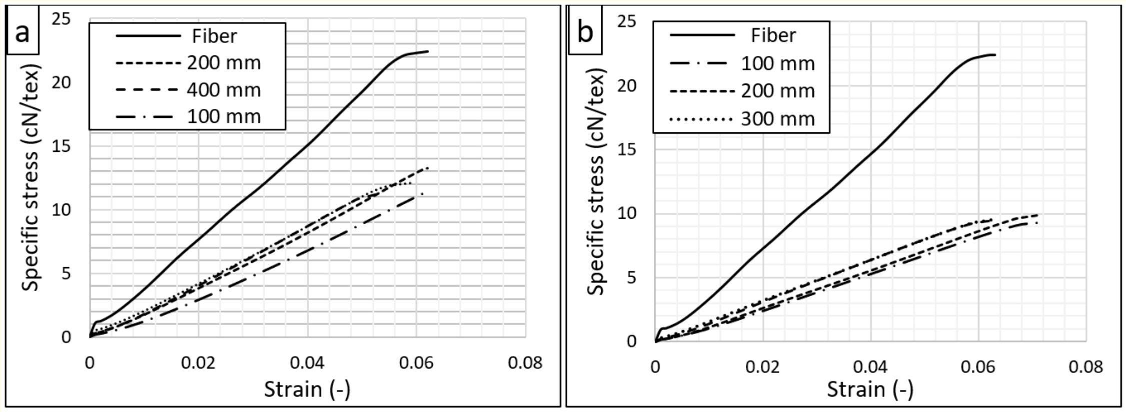

Figure 2: *Cotton fiber and yarn (73.8 tex) specific stress-strain curves at different gauge length a) ring b) rotor.*

The mean curves for cotton fiber and yarns at different test speeds are shown in the figure 3. The difference in the specific stress-strain curves at different speed levels is less. Almost all three curves at speed of 100, 150 and 200 mm/min are lying at same position. The specific stress-strain curves at speed of 100 mm/min is somehow at higher levels as compared with the others.

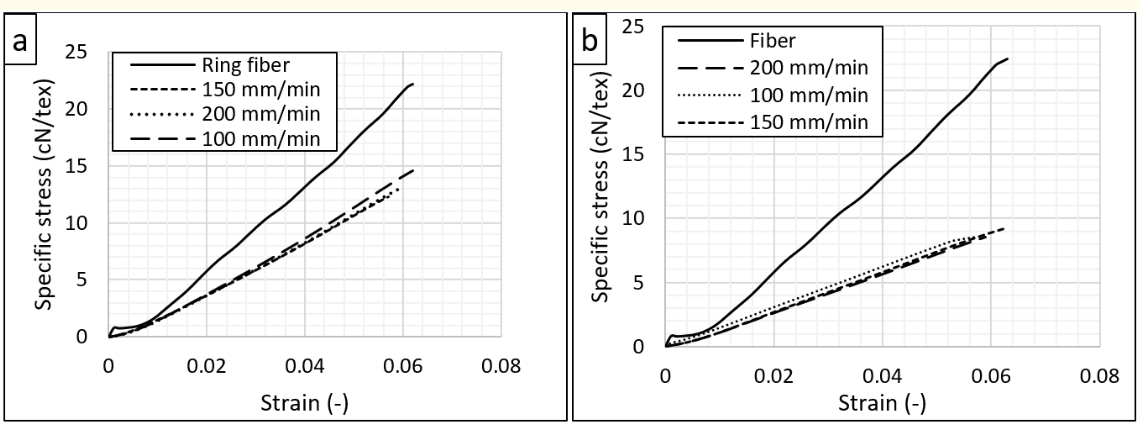

Figure 3: *Cotton fiber and yarn (73.8 tex) specific stress-strain curves at different gauge length a) ring b) rotor.*

Coefficient of fiber strength utilization

The coefficient of fiber strength utilization was determined experimentally which is the ratio of yarn tenacity and mean fiber tenacity and it is an indication of the contribution for mechanical properties of the fiber to mechanical properties of the yarn spun from it. The specific stress in fiber $\sigma_f(\varepsilon_y)$ and specific stress in yarn, $\sigma_y(\varepsilon_y)$ before break were determined experimentally as shown in the figure 1 and were used to evaluate the "coefficient of fiber strength utilization" in the yarn as below:

$$\varphi(\varepsilon_y) = \frac{\sigma_y(\varepsilon_y)}{\sigma_f(\varepsilon_y)} \quad (1)$$

Where $\varphi(\varepsilon_y)$ is coefficient of fiber strength utilization in yarn.

Effect of gauge length

The effect of gauge length on coefficient of fiber strength utilization for viscose and cotton ring and rotor yarns is being explained with the help of graphs. The higher variation in coefficient of fiber strength utilization was found in region of small strain 0.02 due to pre tensioned and crimp in fiber and yarn, so we will not study this small region due to difference in process of measurement. Liu., *et al.* [7] also presented the similar conclusion for fiber and yarn strains. They also studied stress-strain curves beyond the limit of 2%.

Viscose yarns

The experimental coefficient of fiber strength utilization before break of viscose yarn at two levels of gauge lengths were evaluated as function of strain from equation (1) and curves are shown in the figure 4. It is evident that the shape of curves is roughly similar for both viscose ring and rotor yarns. The coefficient of fiber strength utilization is more at higher gauge length (500 mm) as compared with smaller gauge length (200 mm) for both viscose ring and rotor yarns. Higher difference is found in ring yarns as compared with rotor yarns due to their structure. Both the graphs indicate that effect of gauge length on coefficient of fiber strength utilization is more prominent as compared with the twist in both types of ring and rotor viscose yarns.

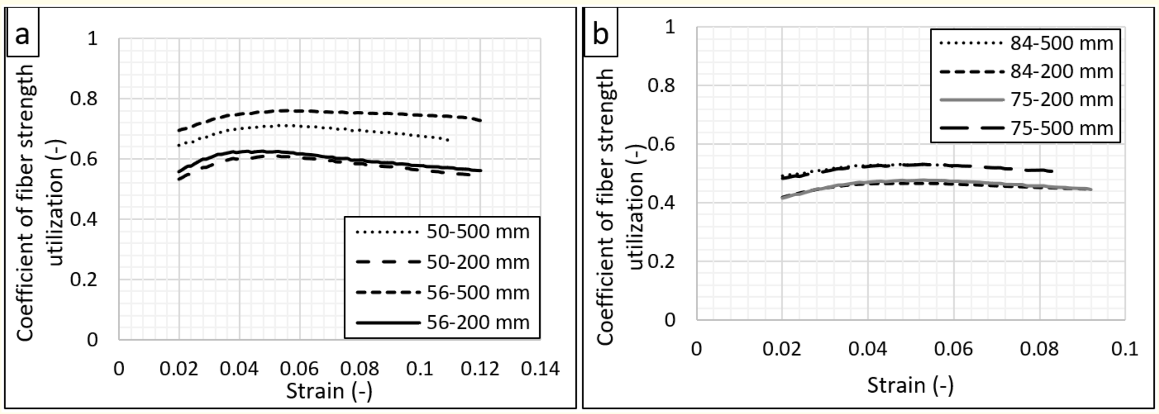

Figure 4: *Effect of gauge length on coefficient of fiber strength utilization for viscose yarns: a) ring b) rotor.*

Cotton yarns

The coefficient of fiber strength utilization determined experimentally at different gauge lengths for 73.8 tex cotton ring and rotor yarns is shown in the figure 5. The higher difference in coefficient of fiber strength utilization was observed between gauge length of 100 mm and other three gauge length (200 mm, 300 mm, 400 mm) for ring yarns and similar behavior was observed for rotor cotton yarn except at 200 mm gauge length the difference was less which might be the result of variation in rotor yarns.

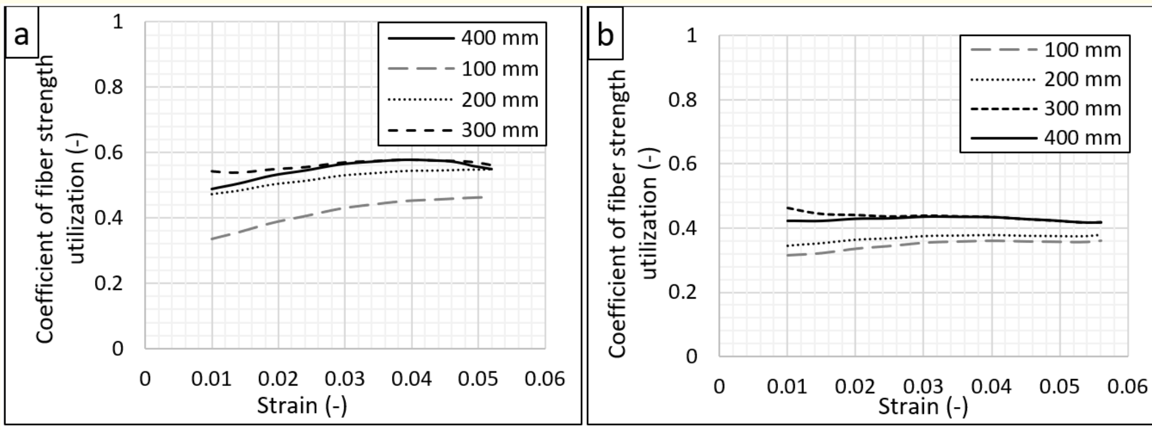

***Figure 5:** Effect of gauge length on coefficient of fiber strength utilization in 73.8 tex cotton yarn a) ring b) rotor.*

Effect of test speed

The same linear densities of cotton yarn produced from ring and rotor technology were measured for yarn coefficient of fiber strength utilization at three levels of test speeds (100, 150 and 200 mm/min). The coefficient of fiber strength utilization evaluated from equation (1) for cotton ring and rotor yarns before break is shown in the figure 6. It can be revealed that effect of test speed on coefficient of fiber strength utilization before the process of yarn break is not prominent. It is evident that the coefficient of fiber strength utilization is observed higher at slow speed as compared with higher test speeds before process of yarn break. At higher test speeds (150 and 200 mm/min) the effect on coefficient of fiber strength utilization is negligible for both ring and rotor cotton spun yarns before the process of yarn break.

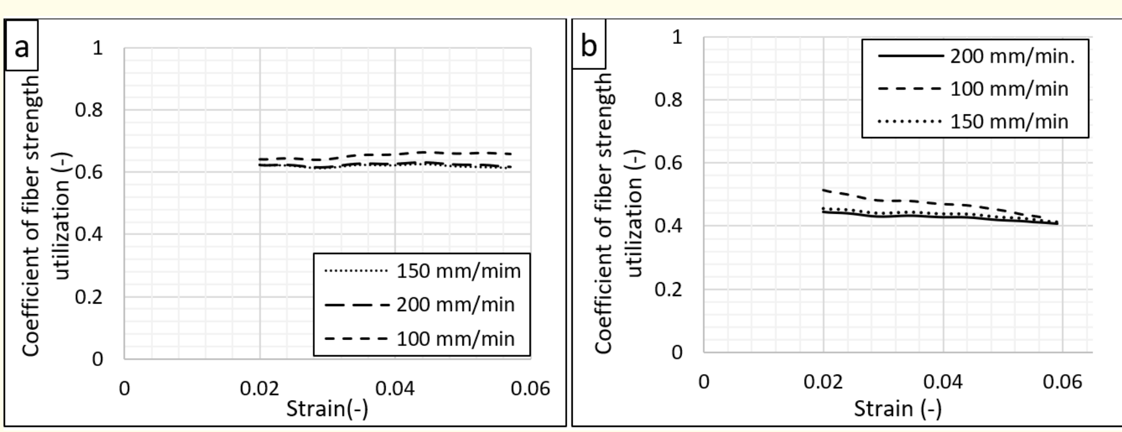

***Figure 6:** Effect of test speed on coefficient of fiber strength utilization in 73.8 tex cotton yarn a) ring b) rotor.*

Conclusion

It can be found from the results as the gauge length is increased the coefficient of fiber strength utilization in staple spun yarns is increased before the process of yarn breakage but this effect is more prominent in ring yarn as compared with rotor yarns in case of viscose and cotton. The difference in coefficient of fiber strength utilization for cotton yarns is higher at lower strains as compared with the higher strains. The coefficient of fiber strength utilization is lower at very small gauge length of 100 mm for both type of yarns studied. The test speed has minor effect on coefficient of fiber strength utilization, at very low test speed (100 mm/min) the coefficient of fiber strength utilization effect is low as compared with the higher speed for both type of ring and rotor cotton yarns.

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