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Spun Yarn Strength as a Function of Gauge Length and Extension rate: A Critical Review

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ABSTRACT

It has been known for many years that the strength of a spun yarn depends on the two important testing parameters, namely, the gauge length and rate of extension. There is no doubt that all studies relating to the influence of gauge length and extension rate on yarn strength are invaluable both in theory and practice. In this article, a critical review of various theoretical and practical aspects of the influence of gauge length and extension rate on yarn strength has been discussed.

Keywords: Yarn Strength, Gauge Length, Extension rate, Weak-Link, Strength distribution

1. Introduction

The standard measurement of yarn strength is executed at 500 mm gauge length and 20 ± 3 sec. However, during the post spinning operations, namely warping and beaming, a longer than 500 mm length of yarn experience stresses. In addition, most recently, researchers [1] have shown that the experimentally determined strength behavior of yarn at short gauge length is more appropriate to simulate the mechanical behavior of fabric than those measured at long gauge length. Therefore the results obtained at standard test methods may not correctly reflect the tensile performance of the yarns. Thus, measurement of yarn strength only at 500 mm gauge length is not sufficient. In fact, it is not also realistic to measure yarn strength at all possible lengths. This can be overcome by using the theoretical relationships of strength and strength variability between long and short specimens. Yarns undergo stress and strains during weaving and other operations that are significantly different from those applied in the standard tensile tests. Therefore the studies of tensile testing of spun yarns at various level of gauge lengths and extension rates on yarn strength are very significant and in this paper a critical review of these aspects has been made.

2. Spun Yarn Strength as a Function of Gauge Length

2.1 Theoretical Consideration

Many researchers attributed that the presence of flaw in the yarn leads to localization of stress in excess of theoretical strength, whereby the rupture process is initiated. It thus follows that the fall in strength of a material with increasing test length is due to the presence of a distribution of flaw of wide ranging magnitude, since the probability of encountering a large fatal flaw increases with test length.

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Peirce [2], after studying strength variability of yarns, proposed the “chain weak link” theory. His theorem has been based on the following assumptions:

- A Yarn of length l may be considered as a chain of m links having the same length l_0, but various resistance of stretch (Figure 1).
- Breaking loads of adjacent links are independent variables, i.e., the link of maximum strength may follow immediately one of minimum strength.

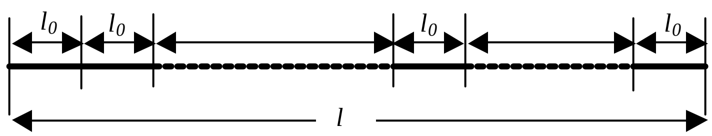

Figure 1. Yarn as a links of twisted fiber bundle.

A simple derivation of Peirce’s theorem of yarn strength is given as follows. Let S_{l_0} be the yarn strength at a gauge length l_0. S_{l_0} is a random variable. Also, suppose that, $f(S_{l_0})$ and $f(S_l)$ are the probability density functions of yarn failure at a gauge length l_0 and l respectively. $F(S_{l_0})$ and $F(S_l)$ are the probability distribution function of yarn failure at a gauge length l_0 and l respectively.

Thus, from the theory of probability, we have:

$$\frac{dF(S_{l_0})}{dS_{l_0}} = f(S_{l_0}) \quad , \tag{1}$$

$$\frac{dF(S_l)}{dS_l} = f(S_l) \quad , \tag{2}$$

Now, to find out the probability of failure of a chain of m links from the probability of failure at any load X applied to a single link of length l_0, it is obvious from the weakest link theory that the chain as a whole fails, if any one of its links fails.

If it is assumed that P (S_{l_0} £ X) is the probability of failure of a specimen of length l_0 at a load X, then

$$P(S_{l_0} \leq X) = F(S_{l_0}), \tag{3}$$

Thus, the probability of non-failure of a specimen of l_0 length at a load X = 1 - $F(S_{l_0})$. Therefore, the probability of simultaneous non-failure of all m links at a load X $= [1 - F(S_{l_0})]^m$. So, the probability of failure at a gauge length l is expressed as

$$F(S_l) = 1 - [1 - F(S_{l_0})]^m \quad , \tag{4}$$

By using this relation, frequency distribution of failure at any gauge length can be worked out. If the form of the function

$f(S_{l_0})$ follows a normal distribution, it gives:

$$f(S_{l_0}) = \frac{1}{\sigma_{l_0}\sqrt{2\pi}} exp\left[-\frac{\left(S_{l_0} - \overline{S}_{l_0}\right)^2}{2\sigma_{l_0}{}^2} \right] \quad , \quad (5)$$

where $\overline{S}_{l_0}$ and s_{l_0} are the mean and standard deviation of S_{l_0} .

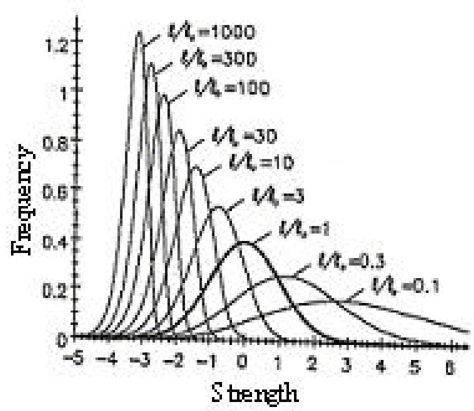

Figure 2. Application of Peirce's theory to a normal distribution. Curves for various test lengths *l*, calculated from the normal distribution at *m* = 1.

The relations of Equations 1 and 5 can be substituted in Equation 4, and new distribution is then defined. Figure 2 shows an example of this. It will be noticed that even though we start with a symmetrical normal distributions, the derived distribution at other lengths are skew. The distribution of $F(S_l)$ is thus known in terms of $\overline{S}_{l_0}$, s_{l_0} , and *m.* Analyzing this expression, and making some mathematical approximation, Peirce obtained Equations giving the mean strength $\overline{S}_l$, and standard deviation s_l , for specimen length *l*. The relations are:

$$\overline{S}_{l_0} - \overline{S}_l = 4.2\left(1 - m^{-\frac{1}{5}}\right) s_{l_0} \quad , \qquad (6)$$

$$\frac{s_l}{s_{l_0}} = m^{-\frac{1}{5}} \quad , \qquad (7)$$

The Equations 6 and 7 are known as the Peirce's Equations of yarn strength. The result of the mathematical approximation is given in the Table 1.

Table I: Experimental and theoretical values obtained from approximate Peirce's Formula

Value of m	Calculated value of $\frac{\overline{S}_{l_0} - \overline{S}_l}{s_{l_0}}$	From Peirce's formula $4.2(1-m^{-\frac{1}{5}})$	Calculated value of $\frac{s_l}{s_{l_0}}$	From Peirce's formula $m^{-\frac{1}{5}}$
1	0	0	1	1
2	0.564	0.543	0.82	0.87
3	0.846	0.829	0.74	0.80
4	1.03	1.02	0.70	0.76
5	1.16	1.16	0.66	0.72
10	1.54	1.55	0.58	0.63
30	2.05	2.07	0.49	0.51
40	2.16	2.20	0.48	0.48
80	2.43	2.45	0.44	0.42
100	2.50	2.53	0.42	0.40
160	2.67	2.67	0.41	0.36
275	2.86	2.83	0.39	0.33
1000	3.25	3.15	0.35	0.25

Zurek et al [3, 4] modified the Equations 6 and 7 after making some empirical correction, which are given by

$$\overline{S}_{l_0} - \overline{S}_l = 3.64\left(1 - m^{-\frac{1}{7}}\right)s_{l_0} \quad , \tag{8}$$

$$\frac{s_l}{s_{l_0}} = m^{-\frac{1}{7}} \quad , \tag{9}$$

Neckar and Das [5] considered yarn strength as a stationary, ergodic, Marcovian, stochastic process, and on the basis of these strength values, the response of yarn strength at any gauge length was simulated. They measured the yarn strength that follows the criteria of a stochastic process i.e. the strength of adjacent yarn sections of a gauge length l_0 was measured in a consecutive manner. They took a long length of yarn, which is divided into m equal sections of length l_0. The strength of the yarn was stochastically measured at a gauge length of 50 mm in the Instron tensile tester attached with a special device for semi-automatic feeding of the yarn in between the jaws of the tensile tester. The autocorrelation function was calculated to analyze the strength values of adjacent yarn sections as a function of yarn length. The correlation coefficients of experimentally measured strengths as a function of the distance along the yarn are shown in Figure 3.

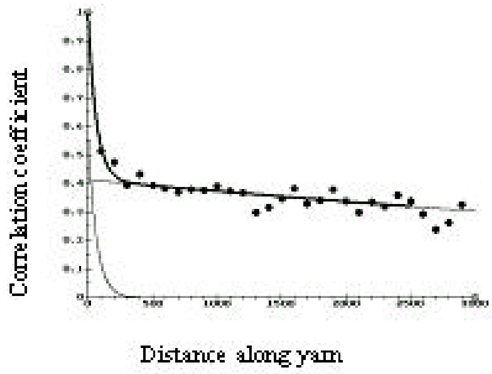

Figure 3. Autocorrelation function of strength of cotton carded rotor-spun yarn (20 tex).

Neckar and Das [5] also obtained the empirical relationships concerning the strength and the strength variability between long and short specimens on the basis of simulated strength data for different gauge lengths by the statistical regression technique. The approximated relationships for 20 tex count cotton carded rotor-spun yarn were found to be as follows:

$$\overline{S}_{l_0} - \overline{S}_l = 6.08\left(1 - m^{-\frac{1}{11.89}}\right) s_{l_0} \quad , \qquad (10)$$

$$\frac{s_l}{s_{l_0}} = m^{-\frac{1}{11.89}} \quad , \qquad (11)$$

If the probability distribution function of failure at a gauge length l_0 follows a two-parameter Weibull distribution [1,6,7], we have:

$$F(S_{l_0}) = 1 - exp\left[-\left(\frac{S_{l_0}}{x_0}\right)^r\right] \quad , \qquad (12)$$

Then the strength distribution $F(S_l)$ at any gauge length l is given by

$$F(S_l) = 1 - exp\left[-\left(\frac{S_{l_0}}{x_\ell}\right)^r\right] \quad , \qquad (13)$$

where x_0 = scale parameter, r = shape parameters, and $x_l = x_0 m^{-1/r}$. The values of x_0 and r are positive. For data following a Weibull distribution with scale parameter x_0 and shape parameter r, the mean, and variance are given by

$$m = x_0 \Gamma(1 + \frac{1}{r}) \quad , \qquad (14)$$

$$\sigma^2 = x_0^2 \left\{ \Gamma(1 + \frac{2}{r}) - \left[\Gamma(1 + \frac{1}{r}) \right]^2 \right\} \quad , \qquad (15)$$

Therefore, the coefficient of variation is

$$CV = \frac{s}{m} = \left[\frac{\Gamma(1+2/r\,)}{\{\Gamma(1+1/r\}^2} - 1 \right]^{1/2} , \qquad (16)$$

where μ, s^2, and CV are the mean, variance, and coefficient of variation (fraction), respectively, and $\Gamma(.)$ is the classical gamma function. The expression of $\Gamma(n)$ is given by

$$\Gamma(n) = \int_0^\infty \exp(-t)t^{n-1}dt \quad , \qquad (17)$$

The scale parameter x_0 is related to the strength of the flaw in a yarn. Typically the scale parameter is numerically close to the mean yarn tenacity. It is noticed from the Equation 16 that the coefficient of variation of yarn tenacity depends only on shape parameter r. Rosen [8] has shown that for $0.05 \leq CV \leq 0.5$, $CV \approx r^{-0.92}$ or $CV \approx 1/r$. In other words, r is an inverse measure of the coefficient of variation. The shape parameter r represents the dispersion of yarn strength per unit length of yarn. More precisely, shape parameter related to the Poisson distribution of flaws per unit length of yarn. A greater value of r indicates a small yarn strength variation. When r ? ∞, there will be no variation of yarn strength and the mean yarn strength will then become independent of gauge length. In general, values of r between 2 and 4 correspond to brittle fiber, whereas a value of 20 is appropriate for a ductile material [9].

If it is assumed with some approximation that the yarn breaking load is proportional to thickness, one arrives to the conclusion that with sections of shorter or equal length to that of drafting wave, Peirce's formula does not hold good. Furthermore, Peirce neglected the fact that the strength of adjacent fracture lengths is related. The relationship between the strength of adjacent fracture zones arises partly because the same long fiber will occur in a number of fracture zones, and partly because of the non-random irregularities introduced into the thickness of the yarn by the spinning machines.

An improvement on Peirce's theory has been worked out and applied to yarns by Spencer-Smith [10]. He suggested quite a different approach to the problem of effects of sample length on the value of breaking load. He also pointed out that the strengths of neighboring fracture zones in yarns are related to one another. According to him, the average yarn strength at any specimen length can be calculated from the average strength, variability, and serial correlogram of the strength of the fracture zones. Spencer-Smith has worked out the theory in detail and obtained the relation:

$$\overline{S}_{l_0} - \overline{S}_l = W(m).F(m).s_{l_0} \quad , \qquad (18)$$

where l_0 is the fracture-zone length, $\overline{S}_{l_0}$ and S_l are the mean values for lengths l_0 and l respectively.

$W(m)$ is a statistical function, tabulated by Tippett [11] for values of m, and $F(m)$ is the serial correlation function, which is expressed as

$$F(m) = \left\{\frac{1}{m^2}\left[m(m-1) - 2(m-1)r_1 - 2(m-2)r_2 ...... - 2(m-n)r_n ....2r_{m-1}\right]\right\}^{\frac{1}{2}}, \quad (19)$$

where r_n = correlation coefficient for the strengths of fracture zones.

In this expression, $W(m)$ is a numerical factor, $F(m)$ is a factor taking account of the correlation of strengths of neighboring zones, and s_{l_0} brings in the variability. The product $W(m). F(m)$ replaces $4.2(1-m^{-1/5})$ in Peirce's expression.

An adequate theory of weak link effect has not yet been worked out, though Peirce's theory is a useful approximation, and Spencer-Smith's relation is open to criticism on the grounds that it must be based on experimental results for the fracture-zone length. Apart from the fact that this length is not known and may be very ill defined, it is very likely that, when jaws are clamped on the specimens at a distance apart equal to the estimated fracture-zone length, the nature of the break will be different from that at much shorter or much longer lengths. When the jaws are closed together, they will restrain deformation of the fiber, and the distribution of the strain, giving rise eventually to rupture, will be different. The effect of changes in the mechanism of breakage cannot be included in any statistical theory, and it seems likely that different relations would apply for lengths much greater than, and much less than, the fracture-zone length. The variations for lengths near the fracture-zone would depend on the particular properties of the fiber.

If $m = \infty$, then from Peirce's Equation 6

$$S_\infty = \bar{S}_{l_0} - 4.2 s_{l_0} , \quad (20)$$

where S_∞ breaking load of infinity long sample.

Therefore, the breaking load of yarn at any gauge length

$$\bar{S}_l = S_\infty + 4.2 s_{l_0} m^{-\frac{1}{5}} , \quad (21)$$

If $\bar{S}_{l_0}$ is the mean breaking load and s_{l_0} standard deviation of breaking loads of samples of 1 mm length, then

$$\bar{S}_l = S_\infty + 4.2 s_{l_0} l^{-\frac{1}{5}} , \quad (22)$$

And after some transformations, above Equation becomes

$$\frac{1}{\bar{S}_l - S_\infty} = \left(\frac{1}{4.2 s_{l_0}}\right) l^{\frac{1}{5}} = b_1 l^{\frac{1}{5}} , \quad (23)$$

where b_1 is a factor which depends on the characteristics of the material. A similar to that of Equation 23, Weibull [12] introduced the relationship of the mean breaking load of yarn at l gauge length as follows

$$\frac{1}{\overline{S}_l - S_\infty} = bl \quad , \tag{24}$$

For $l = 0$ the Equations 23 and 24, of course, lose sense. Consequently, the Equation 24 was modified by introduction of an additional component [12]. Thus the Equation 24 becomes

$$\frac{1}{\overline{S}_l - S_\infty} = a + bl \quad , \tag{25}$$

where a is a constant.

The Equation 25 was worked out as an effect of theoretical considerations. The Equation 25 is also identical with Sipple's [13] expression, which is given as

$$\frac{1}{\overline{S}_l - S_\infty} = \frac{1}{S_0 - S_\infty} + bl \quad , \tag{26}$$

where S_0 = breaking load of a yarn at a gauge length of $l = 0$.

Some workers [14-16] have attempted empirical approaches to understand the nature of strength variation with test length. They found the following logarithmic, exponential, and power law relationships relating yarn tenacity ($\overline{S}_l$) and gauge length (l) as follows

$$\overline{S}_l = c_1 + c_2 \log l \quad , \tag{27}$$

$$\overline{S}_l = c_3 e^{c_4 l} \quad , \tag{28}$$

$$\overline{S}_l = c_5 l^{c_6} \quad , \tag{29}$$

where c_1, c_2 ,.. , and c_6 are constants.

A power law Equation gives rise to singularities at extreme values of l, i.e.; when $l = 0$, tenacity becomes infinity, and when $l = \infty$, tenacity becomes zero, neither of which is actually true.

Hussain et al [17] proposed that yarn tenacity was a modified power law function of gauge length to avoid these singularities:

$$\overline{S}_l = C + \frac{a}{(l + d)^x} \quad , \tag{30}$$

where C is the limiting minimum value of tenacity, a is the difference between the tenacity at gauge length $(1\text{-}d)$ cm and the limiting tenacities, x is a constant.

2.2 Experimental Studies of the relationship between the Yarn Strength and Gauge Length

Hussain et al [17] found a significant difference in the gauge length effect on the strength of ring and rotor spun yarns. The length effect, which they expressed as a ratio between the tenacity of a given gauge and that of a 1 cm length, showed no significant difference between ring versus rotor spun yarns at relatively short lengths. But the differences were statistically significant at long (70 cms) lengths. The extent of decrease is greater for ring spun yarns than for OE yarns, indicating that the rotor yarns are more uniform with respect to the ring yarns.

Table II: Range of failure zone size for different gauge lengths.

Yarn system	**Gauge length, mm**	**Failure zone size*, mm**
Ring spun	127	<3
Ring spun	76.2	2-4
Ring spun	<2	0.5-2
Air jet spun	76.2	3.5-10.5
Air jet spun	12.7	3-8
Air jet spun	<2	0.5-2

*The length of the failure zone to be the length of the region of reduced cross section of one of the failed ends

Realff et al [1] proposed that the mechanism of failure might also change due to a decrease in the test length. They observed the different range of failure zone size for ring-spun and air-jet-spun yarns for different gauge lengths (Table II). According to their observation, as compared to the air-jet spun yarns, ring spun yarns yield higher strength, many broken fibers and a small failure zone size at longer gauge lengths. But, at gauge lengths well below the fiber staple length, air-jet spun yarn shows more strength than ring spun yarn because the difference in surface helix angle (q), since $q > 0$ for ring spun yarn and $q \cong 0$ for the core fibers of air-jet yarn. While comparing the influence of gauge length on yarn failure for ring spun and open-end spun yarn, they found that the ring spun yarns fails by fiber breakage at both long and short gauge lengths. But the open-end yarns show a change in breakage mechanism from a fiber slippage dominant failure at long gauge length (127 mm) to a fiber breakage dominant failure at short gauge lengths (12.7 mm and < 2 mm).

Oxenham et.al [18] compared the effect of gauge length on the strength of ring spun and open end friction spun yarns and found that the strength of the ring spun yarns shows a sharp drop as the gauge length increases from 1 mm to 40 mm (which is approximately the fiber length). The strength of the friction spun yarns also drops sharply as gauge length increases from 1 mm to 20 mm (which is almost equal to the fiber extent in this yarn). For gauge length greater than 40 mm, the strength of ring spun yarns appears to be fairly constant whereas the strength of the friction spun yarn continues to reduce as gauge length increases, reflecting the discontinuities in the yarn formation zone in friction spinning.

Using a Kolmogorov-Smirnov goodness-of-fit at a significance level $a \geq 0.05$, Reallf et al [1] obtained that the tenacity data for ring, air-jet, and open-end spun yarns were fitted to a two-parameters Weibull distribution. From the Weibull distribution parameters of yarn tenacity at a particular gauge length and using the classical weakest-link scaling theorem of Peirce [2], they tried to predict the strength response at other gauge lengths. They found that none of the spun yarns considered in their studies strictly follow the weakest link theory when a Weibull strength distribution is assumed. For all the yarns, they observed that there was a noteworthy change in the Weibull shape parameter as a function of gauge length, indicating a greater variability in strength with decreasing gauge length. Moreover, the

Weibull scale parameter, mean tenacity, and standard deviation were found to be increased with decreasing gauge length in a manner not coincident with the weakest-link scaling theories. From these deviations they concluded that the mechanism of yarn failure changes in going from ‘long’ to ‘short’ gauge lengths.

3. Spun Yarn Strength as a Function of Rate of Extension

Time to break a yarn specimen decreases with the increase of extension rate. Between the time to break and extension rate there is following relationship

$$t = \frac{E.l.60}{100.V} \quad , \qquad (31)$$

where E = breaking elongation of yarn (%), l = test length in mm, t = time to break the specimen in seconds, V = extension rate in mm/min.

The rate of strain during tensile testing influences yarn tenacity. Rapid straining of yarn results in a higher breaking load. Midgley and Peirce [19] were the first to study the effect of strain rate on yarn tenacity and showed that the breaking load of a 36^s sakel cotton ring spun yarn was inversely proportional to the logarithm of the time to break the yarn. This relationship was approximately valid over a range of times from 1/50 second to a month.

Meridith [20] 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 fibers. He established the following empirical Equation for breaking times ranging between a second and an hour

$$F_1 - F_2 = k\, F_1\, log_{10}\left(\frac{t_2}{t_1}\right) \quad , \qquad (32)$$

where F_1 is breaking load at time t_1, F_2 is breaking load in a time t_2, and k is the strength-time co-efficient.

The strength-time co-efficient is the gradient of the average slope of the lines obtained when the breaking loads are plotted against the logarithm of the time to break. He observed that the strength of cotton yarn decreases by approximately 9% for a 10-fold increase in time to break and the value of k is close to 0.09. He also stated that the same formula applies to constant-rate-of-loading and constant-rate-of extension tests.

Balasubramanian and Salhotra [21] failed to observe a steady increase in tenacity with increasing rate of extension. They found that tenacity reaches a peak value around a strain rate of 20 cm/min and thereafter declines gradually (Figure 4). This behavior was found to be true for both ring and rotor yarns, spun from three different cotton varieties, at three twist levels. The authors thus concluded that maximum tenacity occurs not at the maximum rate of extension as observed by Midgley and Pierce [19] but at the optimum extension rate. They attributed these results to the following facts. As the rate of extension increases, the percentage of rupture fibers increases, resulting in a higher breaking strength i.e., a greater number of fibers are contributing to the breaking load. At still larger extension rates (when yarn tenacity decreased), they proposed that the short time available may not be sufficient for the realignment of fibers, this factor could therefore cause a drop in tenacity of individual fibers which is more than what could be offset by the increase in tenacity due to a higher percentage of fiber rupture.

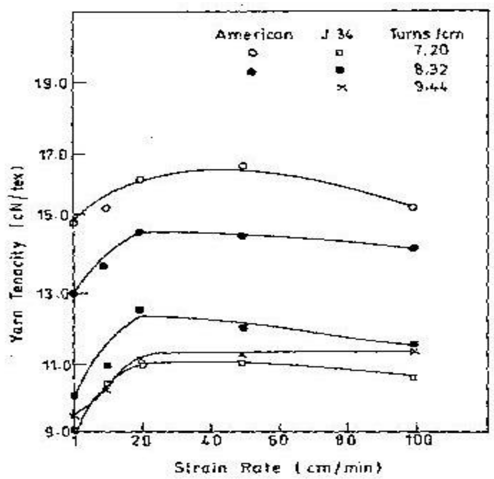

Figure 4. Effect of strain rate on ring yarn tenacity.

Kaushik et al [22] found that as the rate of extension increased, yarn tenacity increased reached a maximum, and then decreased or remained constant for both ring and rotor spun yarn.

Deluca and Thibodeaux [23] were the pioneers to show analytically how low or high speed testing affects yarn tenacity. They studied yarn spun from USDA Acala cotton at testing speeds ranging from 0.1 to 5 m/min. They found that as the rate of extension increased, the yarn tenacity increased linearly with the logarithm of the rate of extension from 0.1 to 1 m/min. At 2 m/min, yarn tenacity increased slightly, reached a maximum, and then at 5 m/min, it decreased.

Chattopadhyay [24] showed that with an increase in the strain rate the tenacity initially increased up to 10 mm/s for both ring-spun and air-jet-spun yarns and then followed by a sharp reduction.

Oxenham et al [25] compared the tenacity and elongation of different blended yarns tested at Tensojet (400 m/min) and Tensorapid (5 m/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 bgarithm of the testing speed in both Tensorapid and Tensojet.

Gulati and Turner [26] found a close relationship between percent fiber rupture and yarn strength. According to their study, the correlation coefficient between the percent fiber rupture and yarn strength were 0.94, 0.97, and 0.99 for 20’s, 30’s, and 40’s count ring yarns. Singh and Sengupta [27] have shown that the increase in tenacity with the increase in strain rate is directly attributable to the increasing incidence of fiber rupture (Table III).

Table III: Effect of strain rate on percentage broken and slipped fibers.

Strain-rates (cm/min)	Yarn strength (gm/tex)	Percentage of fiber breaking (%)	Strength contribution due to fiber breaking (gm/tex)	Strength contribution due to friction of slipping fibers (gm/tex)
0.1	12.7	32.5	8.6	4.1
1.0	14.5	36.8	9.9	4.7
10.0	15.7	41.0	10.9	4.8
100.0	18.3	51.6	13.7	4.6

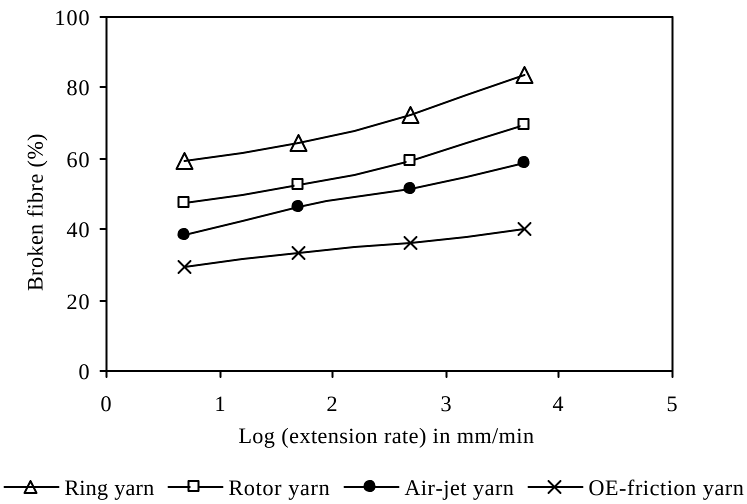

Figure 5. Effect of extension rate on percentage of broken fibers.

Ghosh et al [28] found that yarn tenacity increases continuously with the extension rates for all spinning systems. The increase in tenacity with the increase in extension rate is due to the consequent increase in the proportion of fiber breakage, as depicted in Figure 5. The effect of impact loading at high strain rate is responsible for more fiber breakage. On the contrary, at slow strain rate the mechanism of yarn failure is slippage dominated, as more time is available for yarn to cause rupture.

4. Conclusions

The foregoing discussion gives an overview of the various theoretical and experimental aspects of the influence of gauge length and extension rate that have been reported so far in the literature since the interest of this topic made a beginning. The yarns representing different spinning technologies have also been concerned in this article. Finally, an inference may be drawn that the discussions made in this article is useful for the textile researchers as a tool for further research in the area of yarn strength.

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