

Role of Instrumental Parameters on Yarn Properties

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ABSTRACT: The tensile strength has always been a property that has intrigued research workers; hence also the most investigated one. Tensile instruments working on different principles are available and that tensile results obtained on one are likely to differ from the other. Likewise tensile instruments have parameters; changing which can change the tensile results. Though lot of work has already been reported in this regard especially on constant rate of loading (CRL) and constant rate of extension (CRE) principles, comparison here is made between constant rate of traverse (CRT) and CRE principles. In this paper, study of tensile test has been carried out at different gauge lengths on CRT instruments with pendulum lever but in case of CRE instruments working on strain gauge, test results obtained by varying both the strain rate and gauge length have been discussed. Decreasing the gauge length resulted in an increase in the breaking load recorded in case of pendulum lever instruments. Tensile tests conducted on CRE instruments revealed that shorter gauge length and higher strain rate resulted in higher breaking load. Yarn strength is also dependent on the twist level and any variability in the yarn twist would be reflected in the strength variability. However it is also true that twist found by instruments working on different operating principles may not be same. It was found that when twist measurement was done the turns per inch came out to be more at shorter gauge length but with rise in the coefficient of variation.

KEYWORDS: Tensile instruments, gauge length, strain rate, breaking load, twist measurement

I. INTRODUCTION

Yarn properties that need to be reviewed as a part of routine and research activity include tensile/mechanical, twist, fineness and of course yarn evenness. Several instruments are available in the market to carry out tensile testing that are working on varied principles; most popular being CRL and the CRE. It is known that the working principle of tensile instruments is likely to influence the test results as do some of the instrumental parameters. Tensile behaviour under static conditions on rapid testing instruments like Tensorapid and Tensojet for different instrumental parameters and for yarns spun on different spinning systems has been discussed¹. Similar kind of study has been reported for different blend proportions of worsted yarn². Another study puts forward comparison between static and dynamic test results for different blends for predecided instrumental parameters³. Prediction of yarn strength has been attempted using Weibull distribution⁴. However not much has been reported on the CRT instruments and difference in their test results with other instruments has not been compared. In the present study tensile tests were conducted at different gauge lengths on instruments working on CRT and CRE principle and their results have been evaluated. Study has also been carried out on the instrumental parameter of strain rate/cross-head speed in case of CRE instruments. Twist is another important property which has been analysed with instruments working on different operating principles.

II. PRINCIPLES

CRL indicates that the change/increase in load with respect to time remains the same, while in CRE, the rate of change/increase in extension with time remains unchanged (strain rate is constant). Slight modification of CRE instruments result in instruments working with CRT principle. Each instrument is unique and the results are likely to change as the loading principle change. The instrumental parameters that can affect the test result include gauge length, time to break/rate of loading, capacity of the instrument, previous history and the atmospheric conditions; of these

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

focus here is on gauge length. The time to break on CRL instruments is usually adjusted such that specimen breaks within 20 ± 3 seconds and are unaffected by the gauge length of the instrument. On the contrary the CRE/CRT instruments get influenced by the gauge length as the time to break gets changed. Similarly the extension of specimen can also influence its time to break, hence while using the CRE instruments it is specifically important to jot down these⁵. However it should be noted that if the time to break is less it also implies that the rate of loading will be high.

III. INSTRUMENTAL PARAMETERS AND THEIR IMPLICATIONS

III a. Tensile testing

To understand these and to find time to break, consider the following arbitrary specifications related to a tensile testing instrument with constant traverse rate.

Traverse rate: 12 inches/min, Gauge length: 10 inches and Extension: 10%

In this case the specimen will break when its length is increased by 1 inch; that is 11 inches. For the given traverse rate the specimen will break after 0.9167 minutes or 55 seconds. To see how extension of specimen influences time to break consider extension to be 20%; rest of the parameters remaining same. Here the specimen will break when its length is increased by 2 inches, which is 12 inches. For the traverse rate of 12 inches/min the specimen will break after 1 minute or 60 seconds. So obviously in both the cases the rate of loading and time to break do not remain the same as will be seen in the breaking load recorded. It also implies that the breaking elongation will be different. It should be noted that higher the time to break, lower will be the breaking load. Indirectly it is meant to point out to the fact that if specimen is more extensible then it will take more time to break and hence the breaking load recorded will be lower.

Effect of change in gauge length

Traverse rate: 12 inches/min, Gauge length: 20 inches and Extension: 10%

Here the specimen will break when its length is increased by 2 inches that is 12 inches. For the traverse rate of 12 inches/min the specimen will break after 1 minute or 60 seconds. With this calculation it will be clear that instruments with constant traverse rate get influenced by the changes in gauge length or the specimen extension due to change in the rate of loading. This implies that the breaking load recorded in this case would be lower than that recorded when the gauge length was shorter.

Effect of working principle

It is known that the load-elongation or stress-strain curves of the same material obtained on CRL and CRE principle do not match due to difference in the time spent at different portions of the curve⁶. However no such comparison is made between CRE and CRT instruments. The CRT instruments can be considered as an extended version of CRE instruments. CRT instruments usually make use of a pendulum and lever for recording load; hence are also known as pendulum lever instruments. With CRT instruments it is neither possible to set/maintain the time to break nor achieve constant rate of loading with time⁵.

III b. Twist measurement

Producing 'S' or 'Z' twisted yarn is familiar to spinners; the method of twisting and untwisting being opposite to each other. Various instruments are available for estimating the twist. There are certain instruments that work on fibre parallelization method, some on twist contraction method, some on twist to break method and some may even use the microscope to establish the twist inserted in the yarn; choice of method dependent on yarn type. Usually standard twist multipliers are used as per the count of yarn to achieve the required twist per unit length. It will be observed that for the same yarn if the twist measurement principle and its gauge length are changed then the test results are also likely to be different.

IV. MATERIAL AND METHODS

Tensile tests were carried out on instruments operating on CRT principle using pendulum lever and CRE with strain gauge principle to study the effect of gauge length and strain rate; keeping rest of the instrumental parameters unaltered (ASTM D 2256). The traverse rate in case of CRT instruments was fixed at 12 inches/min for all the tests conducted

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 3, March 2016

and the yarn count was 30's Ne ring spun cotton yarn. The results show an average of 60 readings taken on this instrument. Similar tensile tests were also carried out on CRE instruments for the same yarn except that the strain rate was also varied to find its influence on the test results with an average of 20 readings. The twist measurement (ASTM D 1423) was done on instruments working on different principles namely the fibre parallelization and twist contraction; the average value of turns per inch (TPI) is reported on the basis of 150 and 50 readings respectively.

V. RESULTS AND DISCUSSION

V. a Tensile properties, gauge length and strain rate/traverse speed:

As explained earlier the increase in gauge length causes the time taken to break the specimen to increase; resulting in decreased strength. This trend is also seen in the experimental results shown in fig. 1.

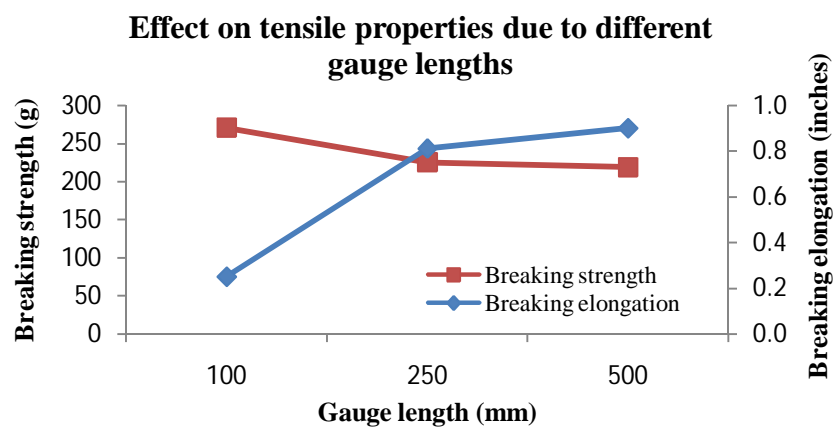


Fig. 1 Change in tensile results with gauge length

It can be seen from the same figure that the breaking strength increases with decrease in gauge length, however the breaking elongation shows exactly the reverse trend which can be attributed to the increase in fibre slippage with increase in gauge length. This could also be the reason why greater variability is observed in the values of breaking strength and elongation at higher gauge length. The tenacity value obtained in case of samples tested at shorter gauge length is highest while that tested at longer gauge length is the least (weak-link effect). CV% of breaking strength as well as breaking elongation showed improvement as the gauge length was increased. There are some very powerful tools to explain influence of the treatment given on the result; here treatment being the change in the gauge length. F test, t test and ANOVA have been applied for thorough understanding. Table 1 shows the computed results of F-test.

	250 mm G.L	500 mm G.L
Mean	0.497 lbs	0.482 lbs
Variance	0.0066	0.0036
Observations	60	60
df	59	59
F	1.85	
P(F<=f) one-tail	0.0099	
F Critical one-tail	1.54	

Since the value of p value is less than 0.05, it indicates that the variances of mean are not equal. Due to a smaller value of p obtained in this case ANOVA was applied to 30 readings and the results of which are shown in table 2.

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Table 2 Summary of ANOVA for single factor

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.203	1	0.203	91.402	1.59828E-13	4.007
Within Groups	0.129	58	0.002			
Total	0.332	59				

Table 2 shows that the value of p as 1. 59828E-13, which is less than 0.05 indicating that the results obtained on changing the gauge length are significant in case of tests conducted on pendulum lever instruments. However such strong correlation was not obtained in case of elongation. The difference in breaking elongation is mainly due to fibre slippage. Application of regression to the data set gave the following equation:

$$Y=0.358 - 0.45X, \tag{Equ. 1}$$

Where Y is the Breaking load in pounds at 250 mm and X is the breaking load in pounds at 500 mm.

Equation 1 shows the relation between the gauge length and breaking strength and can be used to find the breaking strength of yarn sample from a given value of gauge length.

For the given yarn count, if the breaking strength is 230 gm, 210 gm or 190 gm then rating can be good, average or poor respectively while strength CV% should be 14%⁷. The average breaking strength at 250 mm and 500 mm gauge length was found to be 225.44 g and 218.64 g with CV% of 16.36% and 12.41% respectively. The breaking strength obtained at shorter gauge length is higher and is closer to 230 gm so it can be rated as good where as with longer gauge length it can be rated as average. But of course the CV% norms are fulfilled only in case of the longer gauge length. Thus a weak yarn can also be shown to be strong by testing it on shorter gauge length.

In case of CRE instruments the traverse rate and gauge length can be considered as important instrumental parameters. Figure 2 shows the effect of strain rate/traverse rate/cross-head speed when a short gauge length (100 mm) was selected for conducting the tensile tests. It is seen that the trend of breaking strength and breaking elongation is similar to what was seen in case of gauge length. As the strain rate increases the breaking strength is found to increase.

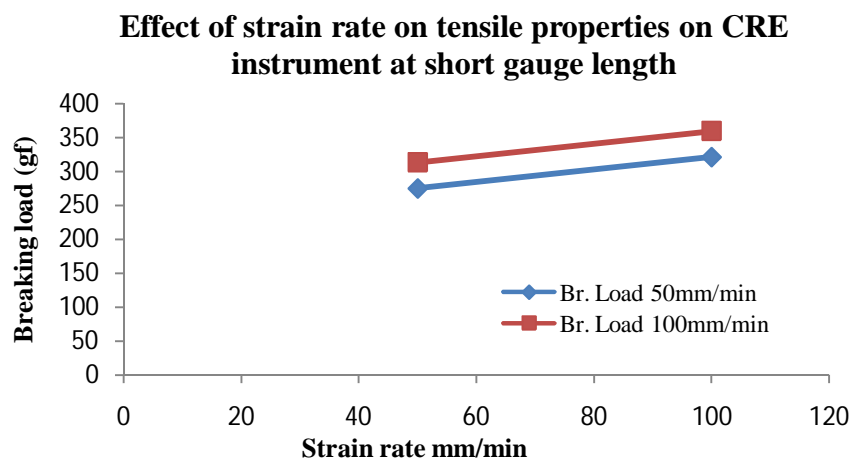


Fig. 2 Influence of strain rate at shorter gauge length

Figure 2 shows that at lower strain rate the breaking load is lower. But as the strain rate increases the breaking load also shows an increase. The CV% of both breaking load as well as breaking elongation shows an increase, with increase in

the strain rate. This could be because of the increased tendency of the fibres to slip past as the strain rate is augmented leading to higher variability in both.

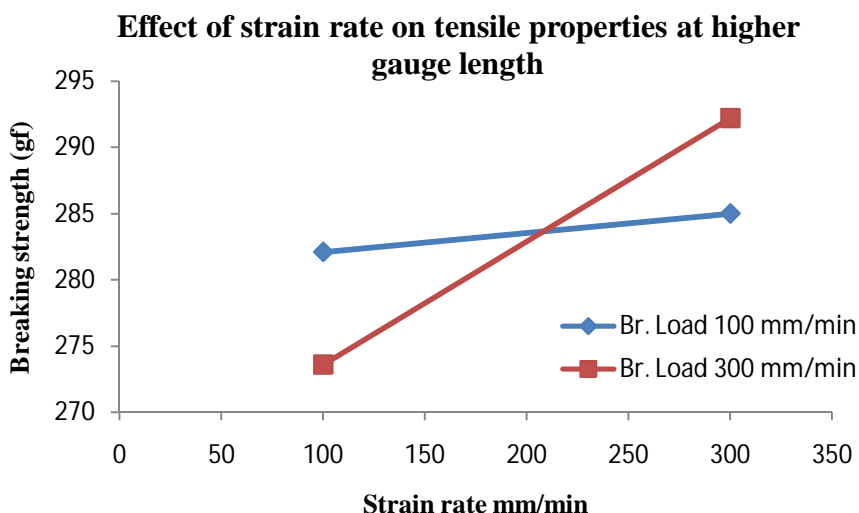


Fig. 3 Influence of strain rate at longer gauge length

Figure 3 is a plot of strain rate and breaking strength but at higher gauge length; trend being preserved. As the strain rate increases the breaking strength also increases. However it needs to be mentioned that when testing was carried out at shorter gauge length with strain rates of 50 and 100 mm/min; percentage increase in breaking load was 5.06%. Whereas when testing was carried out at longer gauge length and strain rates of 100 and 300 mm/min; percentage increase in breaking load was 4.60%. This could also be attributed to the fact that at shorter gauge lengths the variability in twist is more; twist being important in giving strength to yarn, as will be seen in the following section. Hence it can be said that even if the test was performed at higher strain rate that would have further increased the percentage difference at shorter gauge lengths.

It is pointed out that when tensile test is performed on CRE principle instruments the gauge length as well as the strain rate influences the tensile results. The breaking load of sample tested at shorter gauge length is greater than the one tested on longer gauge length reflecting the weak link effect. Thus irrespective of the principle on which tensile instruments (CRE/CRT) operate change in the gauge length and strain rate/cross-head speed affects the breaking load which may be due to change in the failure mechanism. At the same time the variability in elongation is found to increase as the gauge length reduces. It is pointed out that the test results obtained from CRE and CRT principle instruments do not match in spite of maintaining similar instrumental parameters.

V. b Twist and instrumental parameters:

The table 3 is result of F test conducted on test data set and shows that though the yarn under consideration was the same, there is difference in the mean value of turns/inch. The fibre parallelization method recorded higher value of T.P.I, standard deviation and CV%. But when the same yarn was tested using twist contraction principle, it showed lower value of turns/inch, standard deviation and CV%. Higher CV% can be attributed to the difference in the gauge length at which measurement is carried out. Shorter the gauge length higher will be CV%.

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Table 3 F-Test for Variances of twist measured using different principles.

	Fiber para.	Twist cont.
Mean	22.667	21.634
Variance	11.311	2.581
Observations	60	60
df	59	59
F	4.382771	
P(F<=f) one-tail	2.94E-08	
F Critical one-tail	1.534	

The p value of 2.94E-08 in table 3 indicates that the test results are significant and application of t test showed p value (0.035) to be less than 0.05 hence ANOVA was applied and results are tabulated in table 4.

Table 4 ANOVA for yarn twist data

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	31.97	1	31.97	4.603	0.034	3.92
Within Groups	819.62	118	6.95			
Total	851.57	119				

Here also since F value is greater than F critical; implies the sample means are different or in other words the change in gauge length resulted in different values of turns/inch.

VI. CONCLUSION

The study reveals that instruments working on CRE and CRT instruments do not show similar results. The reason could be attributed to the different velocities of the jaws as a result of variability in the extensibility of the specimen. At shorter gauge lengths the variability is higher in case of CRT instruments with pendulum lever. Tensile tests at shorter gauge lengths show higher breaking strength due to weak link effect as do those conducted at higher strain rates. Higher strain rates on CRE instruments reveal that breaking strength also increases that can be attributed to difference in the failure mechanism. At shorter gauge lengths also the same observation is seen but is not proportionate. However the changing gauge length produced significant change in the breaking load and CV% especially for elongation. Similarly the twist variation may also have some bearing on the tensile test results obtained at different gauge lengths. The change in the gauge length on CRT instruments shows that the rating may change due to change in specimen length. The twist measured and the CV% was found to vary significantly due to the gauge length. Thus the instrumental parameter of gauge length is significant and has influence on the results obtained after changing them.

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