Comparative Study of Blended Worsted Yarn Tensile Properties, Measured in Different Principles of Measurement

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Abstract
Tensile property of textile yarns is a prime important parameter in determining the suitability for any particular application. It is therefore of utmost importance to determine this characteristic accurately. There are three basic principles for measuring yarn tensile strength. But for measuring single yarn tensile strength mainly constant rate of extension (CRE) and constant rate of loading (CRL) principles are used. A single yarn shows two different results of breaking load and elongation value in these two methods due to the difference in measuring system. In this article a comparative study is carried out between these two methods.

Key words
Yarn breaking strength, breaking elongation, CRE, CRL, Correlation, Regression

1. Introduction

It is absolutely essential for spinners today to test weaving or knitting yarns properly prior to actual use or further processing. Breaking strength, elongation, elastic modulus, resistance abrasion etc. are some important factors which will represent the performance of the yarn. Among all these measurable tensile properties of spun yarn, considerable attention has been paid on the evaluation of tensile strength and breaking extension, as these properties of the spun yarns influence the efficiency of weaving and knitting machines and the quality of the fabric produced from them. The first theoretical work published concerning the mechanics of blended yarn was by Hamburger. He was concerned with the fact that the blended yarns have breaking strengths lower than those expected from the summation of the proportioned constituent fiber component strengths. [1] However, the tensile strength and breaking extension of the yarns are not the unique functions, but they depend on the rate of extension, gauge length, breaking time and also on the principle of testing machine. [2] According to Midgley & Pierce, rapid test produces a higher breaking load than a slow test and they have also established relationship between the strength values obtained and the breaking time. [3]

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Based on the principle of working, the instruments used for determining the tensile strength are classified into three groups,

1. CRT - Constant rate of traverse
2. CRE - Constant rate of extension
3. CRL - Constant rate of loading

In the instruments of CRE type, the application of load is made in such a way that the rate of elongation of the specimen is kept constant. In the instruments of the CRL type, the application of load is made in such a way that the rate of loading is constant throughout the duration of the test. And in the instrument of CRT type, traverse rate of the gripping jaw is constant. Although now-a-days only two methods are mainly used to measure the tensile properties of textile specimens, 'Constant Rate of Loading' (CRL) and 'Constant Rate of Extension' (CRE). [4] According to Morton and Hearle, if the stress-strain curves of the textile yarns are nonlinear, there will always be a difference between the constant rate of loading (CRL) and constant rate of extension (CRE) tests results due to the different proportions of time spent on different parts of the stress-strain curves. Thus, in studying time effects of yarn breaks, it is important to indicate, whether the tester uses the CRL or CRE method. [5]

The present investigation intends to correlate the yarn tensile properties of blended worsted yarn, obtained from both the CRE and CRL type instruments, with each other to give an idea of the similarities or variations in the result obtained from both the instruments.

2. Materials and methods

2.1. Material

Dyed two ply yarn, which is the final product of the worsted yarn production, is used for this experiment. All the yarns were spun in the same worsted processing system. Three different blends of Polyester – Wool and two different counts of each selected blend, are selected for tensile testing. To reduce the chance of occurrence of within bobbin variation, only one bobbin for one variable was tested. Same bobbin is tested both in CRE and CRL instruments. The details of the tested yarns are given in Table 2.1.

Table 2.1 : Yarns taken for testing

Sample ID	Count (Nm)	Wool %	Polyester %	Wool Micron	Polyester Denier
Sample 1	2/60	45	55	21.5	2.5
Sample 2	2/70	45	55	21.5	2.5
Sample 3	2/60	35	65	22.5	2.5
Sample 4	2/70	35	65	21.5	2.5
Sample 5	2/60	25	75	22.5	2
Sample 6	2/70	25	75	22	2

2.2. Method

Prior to testing all the yarn samples were kept in a standard atmospheric condition (65% ±2 RH and 27ºC ±2) for 4hours and then tested in both CRE and CRL type instruments. SHIMADZU Tensile tester (Model No. AG-X) is used as a CRE type instrument and Zellweger USTER Tensile tester (Type AD) is used as a CRL type instrument in this experiment. All the samples were tested under a standard test method. British Standard EN ISO 2062 (1995) was followed for all the testing. The details of the testing parameters are given bellow.

<u>SHIMADZU</u>
Gauge Length: 500 mm.
Jaw Speed: 500mm/min.
Pre-tension: 0.5 cN/tex.
<u>USTER</u>
Gauge Length: 500mm.
Time to Break: 20±3 Sec.

A minimum of 50 observations were made for each sample in order to obtain a 5% error of estimation. The tenacity and breaking extension values were recorded, and then the average value and standard deviation were calculated. The results were also tested for significance and correlation.

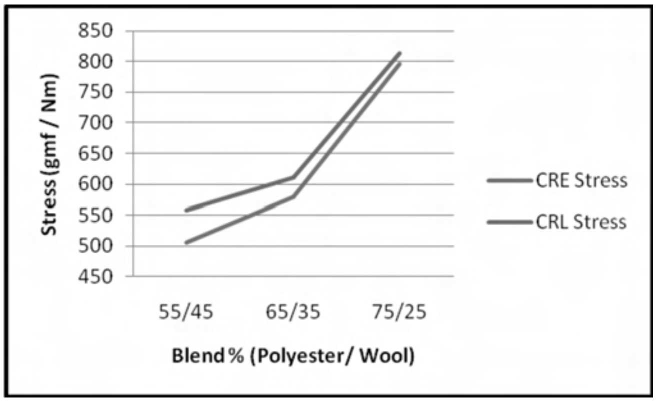
3. Results and Discussions

3.1. Breaking Tenacity

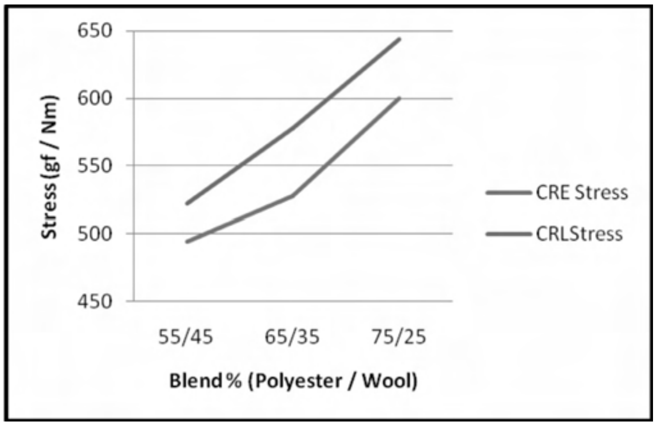
The detail results of the tensile strength, tested by both the principle, are given in Table 3.1. It was observed that in all the cases CRL principle shows higher stress than CRE principle test method. It was also observed from the Graph 3.1 and Graph 3.2 that yarn strength follows the same trend in both the principles and shows higher difference in 2/70 Nm yarns. Yarn strength increases with the increase of the polyester percentage in the blend. 75/25 polyester/wool blended 2/60 Nm yarn shows highest strength between the entire variable. To confirm the presence of real difference between these two method results, significance test for mean and standard deviation was done.

Table 3.1 : Tensile strength tested by both principles

Blend (P/W)	Count in Nm	CRE Stress (gm-f/ Nm)	CRL Stress (gm-f/ Nm)
55/45	60	15.15	16.77
55/45	70	17.28	18.27
65/35	60	17.37	18.34
65/35	70	18.47	20.23
75/25	60	23.86	24.42
75/25	70	21.00	22.54



Graph 3.1 : Strength of 2/60 Nm Yarn



Graph 3.2 : Strength of 2/70 Nm Yarn

The detail results of significant test are given in Table 3.2. Almost in all the cases it was observed that the value of T is greater than 2.58, which implies that the difference between two methods of testing is significant at 99% level of confidence. It was also observed that in all the cases values of F test is much lesser than 1.96 i.e. standard deviations of the strength results, measured in two different methods, is not significantly differ even at 95% level of confidence. In other word it indicates that the differences in mean stress results are not by chance. So the variation in stress value is only for the principle of measurement.

Table 3.2 : Significance test between the two methods

Blend	Count	T Value	F value
55/45	60	9.42	0.55
55/45	70	3.31	0.78
65/35	60	2.83	0.27
65/35	70	3.65	0.45
75/25	60	2.39	0.09
75/25	70	4.45	0.32

In constant rate of extension (CRE) tests, the specimen is extended at a constant rate up to the break and the force is a dependent quantity, whereas in constant rate of loading (CRL) tests, the specimen is loaded at a constant rate up to the break and the elongation is a dependent quantity. For the usual non-linear fibre stress–strain relations, the load–time relation is different in the two procedures (Fig 3.1 and Fig 3.2). So in case of CRE principle, specimen spends the maximum time in higher load region and as a result yarn shows lower value of breaking strength.

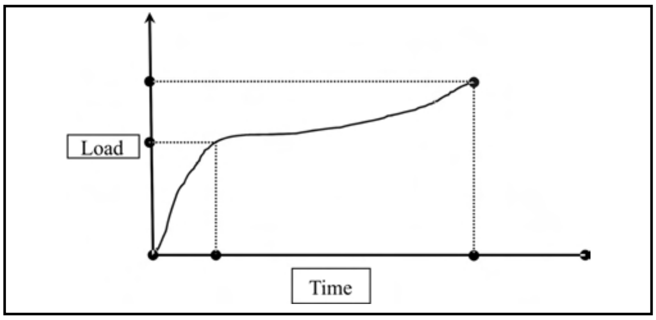


Figure 3.1: Load – Time curve in CRE principle.

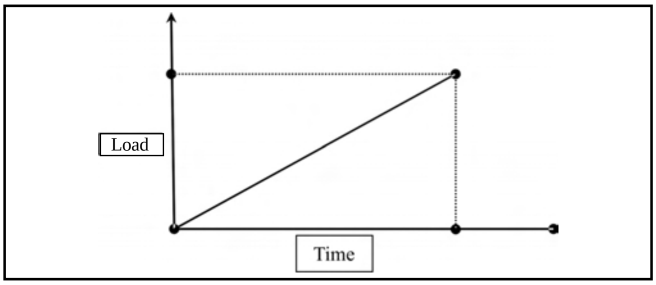


Figure 3.2: Load – Time curve in CRL principle.

Another consequence is that in a constant rate of extension test it is possible for the load to decrease while the elongation increases, but this is not possible in constant rate of loading tests, where the load must increase throughout the test, giving the difference shown in Fig. 3.3.

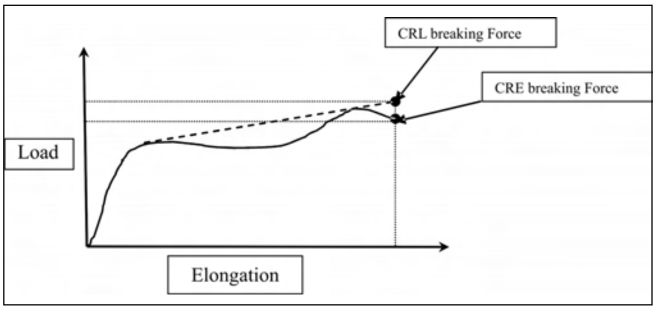


Figure 3.3: Load-Elongation Curve for yarn.

To find out the relation between these two methods, all the stress results are analysed for Correlation and Regression equations in linear, quadratic and cubic model. It was found that yarn stress shows a very good correlation between these two methods in cubic model (The value of R^2= 0.997). It shows the feasibility of predicting the CRE stress from the CRL stress result. The regression equation for these two principles is

CRE = -213.548 + 33.1439(CRL) - 1.60977(CRL)^2 + 2.66E-02(CRL)^3

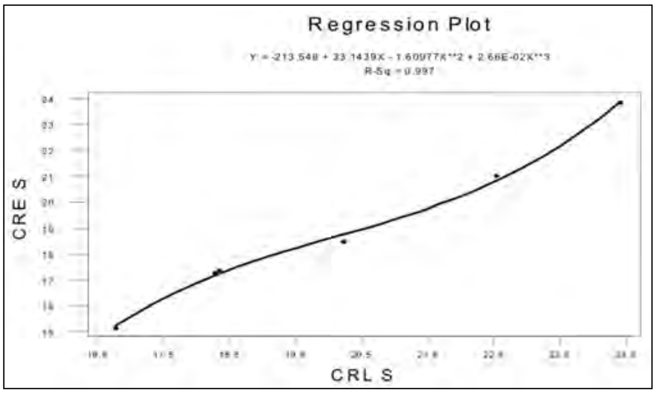


Figure 3.4 Regression plot of CRE and CRL test in cubic model.

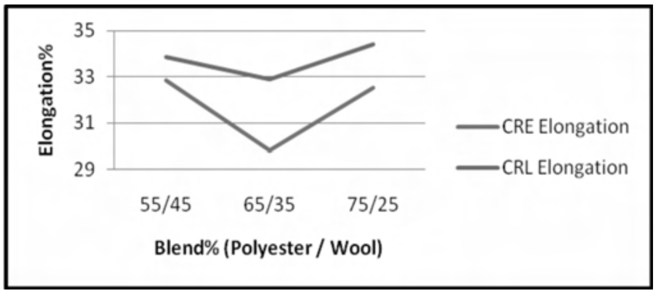
3.2. Breaking Elongation

Table 3.3 : Breaking Elongation tested by both principles

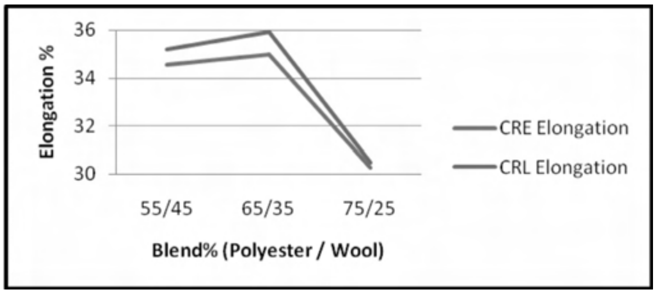
Blend% (P/W)	Count in Nm	CRE Elongation%	CRL Elongation%
55/45	60	32.85	33.88
55/45	70	34.56	35.20
65/35	60	29.81	32.90
65/35	70	34.99	35.90
75/25	60	32.53	34.40
75/25	70	30.27	30.50

It was observed from the Table 3.3, that in case of breaking elongation, the same yarn shows higher elongation at break in CRL principle of measurement.

From the Graph 3.3 and Graph 3.4 it was observed that the trend shown by the different blend and count yarns are same in both the principles. In 2/60 Nm yarn 65/35 (P/W) blend shows the lowest elongation% where as in 2/70 Nm yarn 75/25 blend shows the lowest elongation%. It was also observed that 65/35 polyester /wool blended 2/60Nm yarn shows the highest difference in elongation% between these two methods of measurement.



Graph 3.3: Elongation of 2/60 Nm Yarn



Graph 3.4: Elongation of 2/70 Nm Yarn

No definite trend was also observed in elongation% with the variation in blend ratio in both the principles. 65/ 35 polyester/wool blended 2/70Nm yarn shows the highest elongation% between the entire variable. To confirm the presence of real difference between these two methods result, significance test for mean and standard deviation was done. The detail results of significant test are given in Table 3.4.

Table 3.4 : Significance test for mean & standard deviation

Blend (Polyester/Wool)	Count in Nm	T Value	F value
55/45	60	4.844712	0.649097
55/45	70	4.157298	1.61427
65/35	60	3.005103	0.729394
65/35	70	4.43533	0.678129
75/25	60	5.247438	0.999512
75/25	70	4.007042	0

In all the cases it was observed that the value of T is greater than 2.58, which implies that the difference between two methods of testing is significant at 99% level of confidence. It was also observed that in all the cases values of F test is much lesser than 1.96 i.e. standard deviations of the strength results, measured in two different methods, does not significantly differ even at 95% level of confidence. In other words, it indicates that the differences in mean stress results are not by chance. So the variations in strain values are only for the principle of measurement.

In CRE principle rate of increase in elongation percentage is constant with the time but in CRL principle amount of extension is comparatively lower in the initial portion of the measurement, but in the final position, rate of extension is high (Fig 3.5 and Fig 3.6).

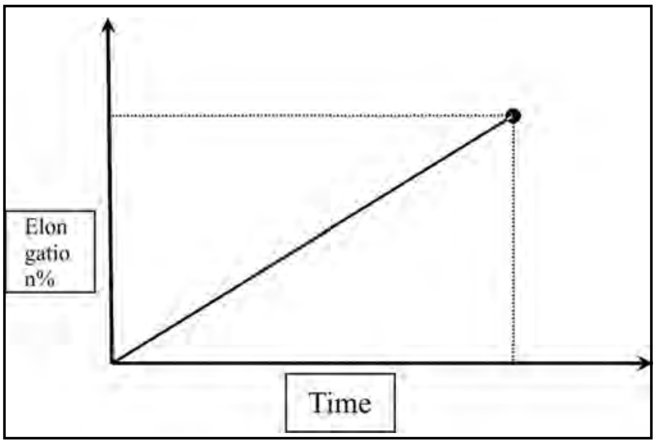


Figure 3.5: Elongation – Time curve in CRE principle.

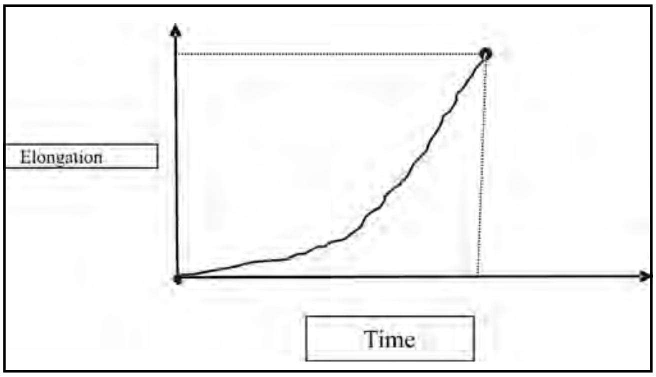


Figure 3.6: Elongation – Time curve in CRL principle.

So in the final phase of CRL principle, yarn sample shown a similar behaviour as a rapid test in CRE principle. Number of ruptured fibre increase in any rapid test method which contribute the maximum fibre elongation in yarn elongation. So yarn sample shows higher strength and elongation in CRL principle.

Strain results are also analysed for Correlation and Regression equations in linear, quadratic and cubic model to find out the relations between these two methods. It was found that yarn elongation shows a poor correlation between these two methods. Only in cubic model it shows some correlation (The value of R^2= 0.534). The regression equation for these two principles in cubic model is

$$\mathbf{CRE = -50951.4 + 4766.15CRL - 148.265CRL^2 + 1.53462CRL^3}$$

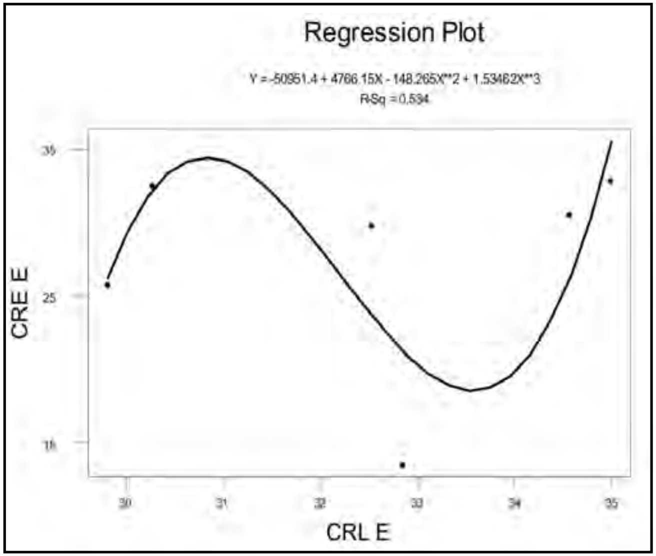


Fig. 3.7 Regression plot of CRE and CRL test for Elongation% in cubic model.

4. Conclusion

From the forgoing discussion it can be now concluded that yarn tensile properties highly depends on principle of measurement. Above experiment shows that CRL principle instrument always shows higher strength and elongation value than the CRE principle instrument. So it is necessary to mention the testing principle at the time of comparing tensile testing results.

From the regression analysis of the two variables, it is observed that breaking stress of one specimen can be predicted in one principle of measurement from another. But yarn breaking elongation cannot be predicted with high accuracy.

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