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THE EFFECT OF GAUGE LENGTH AND RATE OF LOADING ON THE TENSILE PROPERTIES PART 1: COMBED COTTON ROVE

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ABSTRACT

The tensile properties of combed cotton roves under different testing operating conditions had been investigated. Significant regression relations for time of break, break strength and percentage elongation have been detected. Different factors transformation had been tested for the breaking strength, with two types of regression equations. The quadratic relation under logarithm transformation tends to attain the most significant regressions.

NOMENCLATURE

F_1 = Breaking load at t_1 breaking time
F_2 = Breaking load at t_2 breaking time
t_1 = Time of break at first rate of loading
t_2 = Time of break at second rate of loading
x_1 = the rove length
x_2 = the rate of loading
a_0, a_i, a_{ij} parameters of the regression equation.
X_1 = the rove length in cm
X_3 = the rate of loading in cm/min
X_2 = the time of break in seconds.
Z_1, Z_2 are the center of the transfered response.
B_{11}, B_{22} are the coefficients of the conical equation

INTRODUCTION

The tensile properties, tensile strength and elongation and their variations, can be considered as the most important characteristic figures for textile materials. The performance of the textile products in further applications and processing can be estimated knowing the tensile behavior. The tensile response is always used in optimizing the textile outcome in different processing. Meanwhile, the Quality Control and optimization procedure are faced with the time which is needed for testing the yarn tensile strength for attaining a higher precision. For a normal significance of about 95% the standard time can attain a value of four hours for carrying only one trial. Therefore, there is always the tendency to test fewer readings, which can lead to wrong conclusions with respect to the performance of textile material in subsequent process or utilization.

Also due to the high production speed in all textile processes the textile products are hardly ever stressed over the duration of 20 seconds ± 2 seconds.

Therefore the interpretation of results obtained by means of 20 seconds test is not real also the significance of results from such test in experiment such as ends down, productivity, wear, is quite limited.

The effect of rate of loading on cotton yarns has been studied by Meredith [1,2], Mereness [3], Midgley and Pierce [4]. It was shown that the breaking load is inversely proportional to the logarithm of the time to break the yarn. So that higher elongation speeds result in a higher maximum force that can be applied to staple spun yarn. The tensile strength increase to about 15% due to the increase of the rate of loading. An imperical relationship was established to convert results obtained at one arbitrary rate of strain to values at another rate,

$$F_1 = 0.09 F_2 \log_{10} (t_2 / t_1)$$

Such a relation was not attained by Solhotra [5] when working on carded cotton yarns. The effect of Gauge lengthes on tensile strength can be explained by the weak link theory [6], from which the strength is inversely proportional to the Gauge length.

Most of the work carried upon the effect of rate of loading were carried upon the carded cotton yarns. It is important to carry such work on cotton roves which can enable the application of results in both quality control and technological features [7]. The effect of rate of loading and gauge length was carried using different rove count and twist factors.

EXPERIMENTAL PROCEDURE

The Giza 75 cotton fiber was used in this investigation. It was processed through normal cotton fiber processing and was combed at 15%. The obtained sliver was processed and different roves were obtained having the specifications shown in table (1).

Table (1)

The specification of different rove under investigation

Rove Number	1	2	3	4	5	6	7	8
Count	2.75	1.8	1.98	3.2	3.0	2.9	2.6	1.95
T.F.	0.97	1.12	1.11	1.2	0.85	0.75	0.85	0.8

The rove strength was determined on the Instron. The tensile properties were determined by carrying 25 readings for every tested condition.

The experimental conditions for both rate of loading and gauge length are shown in Table (2). Three different experimental designs were applied.

TABLE (2)

DIFFERENT EXPERIMENTAL DESIGNS FOR THE DETERMINATION OF ROVE TENSILE STRENGTH

Exp. set	Rove No.	Exp. No. Factors	1	2	3	4	5	6	7	8	9	10	11	12
I	1, 3	Gauge l. cm	7.5	7.5	5	5	1.5	1.5	3.5	3.5	5.5	-	-	-
	4, 6	S. cm/min	10	30	10	50	20	50	1	100	20	-	-	-
II	2, 7	Gauge l. cm	7.5	7.5	2.5	2.5	1.5	1.5	1.5	5.5	5.5	-	-	-
		S. cm/min	10	50	10	50	1	10	100	1	100	-	-	-
III	5, 8	Gauge l. cm	7.5	7.5	2.5	2.5	1.5	1.5	5.5	5.5	2	2	10	10
		S. cm/min	10	50	10	50	1	100	1	50	50	100	1	100

Gauge l. = Gauge length S. = Speed cm/min

RESULTS AND DISCUSSION

The obtained results were analysed for the determination of the shape of response surface. The regression equations for the effect of Gauge length and rate of loading on different properties were determined and the equation was determined at 95% level of significance.

Due to lack of space the individual results are not included in the paper.

1- The effect of Gauge length and rate of loading

The effect of Gauge length and rate of loading on three rove properties were studied. The following are the results obtained.

1.1 Time of break.

The rove breaking time was determined for every working condition a regression relation of the following form was determined.

$$y = a_0 + \sum_{i=1}^{2} a_i x_i + \sum_{i=1}^{2} \sum_{j \geq i}^{2} a_{ij} x_i x_j \qquad (1)$$

The regression equations for different response surfaces are shown in table (3).

Table (3)

The regression equations for different response surfaces characterizing the dependence of time of break to length & rate of loading

Exp. No.	Rove Count	Rove T.F.	Regression Coefficients						Cor. R^2	Standard Error MSE
			a_0	a_1	a_2	a_{12}	a_{11}	a_{22}		
1	2.75	0.97	29.5	-2.44	-1.5	0.2	-0.31	0.01	0.88	3.77
2	1.8	1.12	250	-112.1	-3.9	-4.51	17.86	0.27	0.64	89.22
3	1.98	1.11	-85.1	60.53	-8.9	1.24	-7.38	-0.04	0.83	16.47
4	3.2	1.2	26.5	-3.93	-0.9	-0.057	0.64	0.01	0.73	8.39
5	3	0.85	11.7	0.10	-0.4	-0.004	0.008	0.003	0.79	4.17
6	2.9	0.75	36	-6.30	-1.3	0.176	0.111	0.005	0.99	0.69
7	2.6	0.85	-35.2	20.87	-0.9	-0.057	-1.94	0.001	0.84	8.49
8	1.95	0.8	-11	10.42	-1.7	-0.03	-0.98	-0.002	0.74	5.07

The coefficients of the equations in the conical form are shown in table (4).

Table (4)

The coefficients of the conical equations, characterizing the dependence of breaking time to Gauge length and rate of loading

Serial No.	Coefficients of Conical Equation					
	Z1	Z2	B10	B11	B22	λ
1	5.51	29.25	27.04	0.035	-0.339	3.45
2	4.93	30.68	119.06	0.337	-12.6	943.78
3	5.81	20.37	-24.6	0.094	-7.431	12.05
4	6.24	70.92	22.6	0.008	0.64	22.11
5	11.19	71.33	11.8	0.003	0.009	2.76
6	5.46	28.91	29.68	0.161	-0.045	0.565
7	5.14	16.54	-14.32	-1.94	0.007	0.015
8	4.07	81.42	119.06	-0.98	0.002	0.015

Where Z_1, Z_2 are the center of the transfered response and B_{11}, B_{22} are the coefficients of the conical equation of the form

$$y = B_0 + B_{11} X_1^2 + B_{22} X_2^2 \qquad (2)$$

While λ is the parameter of the two coordinate axis of the form.

new x_1 axis is $x_2 - \lambda x_1 = 0$

new x_2 axis is $\lambda x_2 + x_1 = 0$

From these tables the following can be attained.

1- The coefficient of correlation for a second degree equation varies from 0,8 to 0,998, which attains a significance
Level more than 95%, this indicate that the relation have to be in a Quadratic form.

2- The effect of lenght on the breaking time is greater than that of the rate of loading.

3- The sign of the coefficients for both Gauge lenght and speed depends on both rove Count and Twist factors.

4- Relations concerning the effect of rove count and twist factors on conical coefficient are shown in table (5).
From table (5) The effect of rove twist factor dominate the coordinate values and attain a ratio varying from 4.3 to 10.2 while the rove count dominate the coefficients of the conical form with a ratio about 2. Also the twist factor have a negative effect on most of conical parameters.

Table (5)

Relations reffering conical coefficients
to rove count and rove twist

Conical Coeff.	Coefficients of Regressions						Cor.	Standard Error
	a0	a1	a2	a12	a11	a22	R2	SE
Z1	-32.1	-51	203.1	-8.53	12.67	-96.75	0.77	1.94
Z2	937.2	-1090.5	1007.6	168	188.9	-808.8	0.948	11.16
B11	1.94	-9.1	19.06	-4.9	2.9	-3.04	0.6	0.914
B22	-29.24	-6.8	79.8	28.8	6.11	2.47	0.982	1.19
λ	93.7	-40.15	-128.6	-2.98	8.96	90.94	0.999	0.622

1.2. **Rove strength.**

Eight linear regressions,were proposed to the obtained data, four of them are straight lines (class A) while the others are Quadratics (class B).

The form of these relations are :

For straight line

$$y = a_0 + \sum_{i=1}^{2} a_i Z_i \qquad (3)$$

While for Quadratic a relation of the form :

$$y = a_0 + \sum_{i=1}^{2} a_i Z_i + \sum_{i=1}^{2} \sum_{j \geq i}^{2} a_{ij} Z_i Z_j \qquad (4)$$

The transformation of X_i to Z_i for the four conditions are of the form:

Type I $\quad Z_1 = X_1 \qquad Z_2 = X_2$

Type II $\quad Z_1 = \ln X_1 \qquad Z_2 = \ln X_3$

Type III $Z_1 = \ln X_1$ $Z_2 = \ln X_2$

Type IV $Z_1 = X_1$ $Z_2 = \ln X_2$

The results obtained are shown in table (6). From table (6) the following can be determined.

The class A regressions (straight line) fails to represent the results in about 45% of the cases. Ranking this failure with report to types, the degree of failure can be classified in the following manner I, II, III, IV. The type IV regression was able of attaining a success in about 75% of the cases. From that it is important to note that the ability of straight line relation for the description of the effect of rate of loading upon the strength depends upon the properties and the method of preparation of rove under study.

The coarse rove with higher twist factor was representative with all the proposed equations while all the equations fail to give representation of fine rove Ne>2.75 and low twist factor <0.85. From that the straight line relation don´t describe to a great extent the effect of Gauge length and rate of loading, while from table (6) the Quadratic regression describe this effect without failure for all type of relations. The conical form of the Quadratic equations are shown in table (7). From this table the value of shows a homogenity for most of the tested rove, this homogenity is greater in type III and IV. For the detection of the greater effect of regression type the multiple rank correlation analysis was applied, the result is shown in table (8).

Table (6)

The regression equations for different response surfaces, characterizing the dependence of rove strength
a- on Gauge length and rate of loading

	Straight line relation					Quadratic relation							
	Coefficients of Regression					Coefficient of regression							
	a0	a1	a2	R2	MSE	a0	a1	a2	a12	a11	a22	R2	MSE
1	14.1	3.2	0.6	0.70	5.0	81.05	-9.9	-37.55	7.4	-0.031	6.06	0.84	5.8
2	181.9	-18.5	0.7	0.35	116	51.33	3.7	6.5	-0.74	-0.418	-0.00	0.85	79.8
3	64.9	-0.8	0.7	0.81	63.3	-176.4	85.6	5.83	-1.11	-7.400	-0.00	0.95	49.4
4	22.5	-2.1	-0.5	0.74	4.0	51.02	-8.1	-10	3.04	0.067	0.25	0.96	2.41
5	27.3	-1.1	1.4	0.34	14.5	8.07	0.6	19.45	-1.14	-0.001	-0.48	0.92	5.96
6	18.3	-0.8	0.4	0.30	5.1	16.02	-10.2	42.1	-7.68	1.820	-0.94	0.97	1.86
7	22.0	2.9	0.2	0.10	27.1	65.05	-45.5	27.3	-1.59	5.160	-0.64	0.95	12.4
8	6.8	4.2	0.9	0.60	12.4	24	-7.7	3.145	1.4	0.964	-0.39	0.88	8.18

b- on Gauge length and rate of loading

	Straight line relation					Quadratic relation							
	Coefficients of Regression					Coefficient of regression							
	a0	a1	a2	R2	MSE	a0	a1	a2	a12	a11	a22	R2	MSE
1	17.4	12.0	-1.3	0.67	5.3	-21.47	46.3	6.78	-10.55	-0.222	1.16	0.84	5.8
2	289.3	-32.5	-51.2	0.70	78.1	237.6	424.3	-148.3	90.6	-253.8	-10.1	0.96	41.0
3	320.5	-6.2	-73.8	0.94	34.0	132.1	140.7	-42.26	-24.15	-28.89	4.16	0.99	10.7
4	14.4	-8.9	2.9	0.78	3.7	40.86	-30.9	-1.81	7.36	-0.567	-1.1	0.89	4.2
5	55.8	-3.5	-7.0	0.47	12.9	121.8	-26.5	-20.42	10.98	-6.850	-1.49	0.99	2.03
6	29.1	-6.0	-1.4	0.40	4.8	123.6	-112	-14.7	10	25.100	-0.01	0.99	1.45
7	49.5	6.2	-7.1	0.34	29.3	89.6	-57.5	18	5.58	15.380	-7.24	0.97	9.3
8	34.1	12.7	-6.5	0.74	10.1	-74.3	81.6	38.7	-14.58	-5.070	-4.64	0.96	4.56

TABLE (6) cont.

c- on Gauge length and breaking time

	Straight line relation					Quadratic relation							
	Coefficients of Regression					Coefficient of regression							
	a0	a1	a2	R2	MSE	a0	a1	a2	a12	a11	a22	R2	MSE
1	9.7	12.7	3.7	0.79	4.2	23.98	11.0	-28.31	18.48	-3.750	2.28	0.84	4.8
2	90.8	-64.8	53.1	0.73	74.3	-356.3	411.7	246.6	-69.61	-128.0	-18.8	0.87	73.9
3	-87.2	52.7	54.8	0.91	44.4	65	14.1	-18.1	67.4	-47.20	-2.38	0.99	18.3
4	24.2	-7.3	-3.8	0.81	3.5	29.95	-14.5	-10.4	8.04	1.460	-3.63	0.91	3.8
5	34.3	-5.2	9.3	0.44	13.4	45.7	-13.4	28.7	-11.52	0.810	0.36	0.91	6.38
6	25.0	-6.7	1.7	0.37	4.9	81.38	-91.2	16.44	-10.91	30.100	0.08	0.98	1.9
7	25.5	2.9	7.3	0.23	25.1	-162.1	335.7	27	-76.01	-109.1	26.7	0.77	27.3
8	13.0	10.4	7.5	0.73	10.2	42.2	-33.5	-6.85	20.9	13.020	-6.37	0.89	7.86

d- on Gauge length and rate of loading

	Straight line relation					Quadratic relation							
	Coefficients of Regression					Coefficient of regression							
	a0	a1	a2	R2	MSE	a0	a1	a2	a12	a11	a22	R2	MSE
1	12.7	3.2	4.2	0.70	5.0	43.6	-6.7	-8.38	2.37	0.710	0.93	0.99	0.75
2	78.5	-16.1	52.4	0.71	76.6	-172.3	33.9	211.1	-15.7	-1.930	-16.7	0.84	80.5
3	-35.7	6.1	52.5	0.87	51.6	99.2	-19.6	-38.4	25.3	-1.600	0.34	0.99	23.3
4	21.6	-1.7	-4.1	0.72	4.2	33.1	-0.8	-7.7	0.85	0.710	0.38	0.99	0.55
5	33.6	-1.6	9.1	0.62	11.0	35.64	-2.1	20.7	-2.34	-0.002	1.45	0.81	9.2
6	20.1	-1.1	1.7	0.27	5.3	51.4	-14.9	17.2	-3.4	1.400	-1.22	0.98	1.72
7	24.1	1.2	7.1	0.24	24.9	167.7	-78.0	35.3	0.73	7.800	-6.25	0.96	11.3
8	13.0	3.0	7.4	0.71	10.5	31.2	-3.9	-4.9	5.8	0.430	-5.7	0.93	6.32

Table (7)

The coefficients of the conical equations, characterizing the dependence of the rove strength to Gauge length and rate of loading

No.	TYPE I						TYPE II					
	Coefficients of Conical Equation						Coefficients of Conical Equation					
	Z1	Z2	B 0	B11	B22	λ	Z1	Z2	B 0	B11	B22	λ
1	16.6	0.5	17.0	-0.9	0.38	1.51	1.5	4.3	30.0	-4.9	5.8	0.88
2	8.9	-5.0	51.2	-0.6	0.21	0.59	-2.3	-18	1057	-2.0	-262	5.56
3	5.2	7.7	69.1	-7.4	0.04	0.08	0.1	5.5	26.0	-32.8	8.1	0.33
4	5.5	2.4	7.0	1.7	-1.36	1.06	1.6	4.4	12.8	2.9	-4.5	0.93
5	4.9	1.4	41.3	4.0	-3.43	1.09	3.8	7.1	-1.3	1.9	-10.3	1.60
6	5.2	1.1	13.3	-3.6	4.52	1.42	1.5	3.8	12.8	26.1	-1.0	0.19
7	6.4	13.2	98.8	-0.8	5.26	0.46	1.5	1.8	61.9	15.7	-7.6	0.12
8	0.5	4.8	29.8	1.3	-0.69	0.42	-1.6	6.7	10.4	-12.2	2.4	0.97

No.	TYPE III						TYPE IV					
	Coefficients of Conical Equation						Coefficients of Conical Equation					
	Z1	Z2	B 0	B11	B22	λ	Z1	Z2	B 0	B11	B22	λ
1	1.5	0.03	32.0	9.0	-10.45	1.38	2.5	1.3	29.7	2.0	-0.4	1.10
2	-0.4	7.2	460.4	-138	-8.64	0.29	18.6	-2.4	-111	-20.1	1.5	2.31
3	0.3	0.2	65.4	15.7	-65.25	1.87	1.5	1.0	66.1	12.1	-13.3	1.08
4	2.2	1.0	8.8	3.7	-5.84	0.55	-0.9	11.3	-6.4	1.0	0.1	0.68
5	2.4	-0.8	17.8	-5.2	6.35	1.04	7.7	-9.0	18.3	-0.7	2.1	0.56
6	1.5	-0.05	12.3	-0.9	31.07	5.68	5.1	-0.1	13.0	-2.1	2.3	2.05
7	1.1	1.1	45.4	-119	36.59	0.26	4.9	3.1	33.6	7.8	-6.3	0.03
8	0.7	0.7	27.5	17.6	-10.93	0.44	1.7	0.4	26.8	1.6	-6.9	0.40

Table (8)

Ranking of the coefficient of correlation for different regression types

TYPE	Rove No.								
	1	2	3	4	5	6	7	8	Total
I	4	4	3	2	4	3	3	2	25
II	2	2	4	3	3	2	4	3	23
III	3	1	1	1	1	1	1	4	13
IV	1	3	2	4	2	4	2	1	19

Coefficient of Concordance w = 0.2625

Testing the hypothesis of the coefficient of concordance w indicate a significance at 90%, while eliminating the Rove no. 1 and 8, the coefficient of concordance increase to 0.611 with a significant level of which exceed 99%. From that the type III is the most staple and representative of all the four regression types. The coefficient of concordance of the other three types and w values was 0.11 and 0.0277 for 8 and 6 respectively. The type IV regression can be considered as the second representative of the results while the type I, II give no significance between one another.

1.3. Rove elongation.

The regression equation for different response surfaces are shown in table (9) for both Quadratic and conical form. From these results the Quadratic relation give a significant approximation to the obtained result, also the elongation is greatly affected by the length than the rate of loading.

1.4. Effect of experimental designs.

Analysing the significant level of different experimental designs, based on the ranking of these levels it can be concluded that there are no significant difference between the first and third set of experimental designs, while a difference can be attained between them and the second set of experimentations. While the shape of the obtained regressions are always the same.

Table (9)

The regression equations for different response surfaces characterizing the dependence of % Rove elongation on both length and rate of loading

	Quadratic relation — Regression coefficients								Coefficient of conical equation					
	a0	a1	a2	a12	a11	a22	R^2	SE	Z1	Z2	B0	B11	B22	λ
1	45.3	-17.3	1.13	2.74	2.1	0.007	0.99	3.7	0.4	-5.7	45.3	-0.670	2.8	2.0
2	-51	25.4	-0.02	0.03	-2.3	0.003	0.99	0.3	5.4	-23.3	18.0	0.003	-2.3	138.7
3	19.7	-2.7	0.83	-0.06	0.1	-0.006	0.96	5.2	12.7	8.3	6.0	-0.012	0.1	4.8
4	181	-45.7	-9.50	-0.13	4.6	0.185	0.99	8.3	5.5	27.9	-77	0.184	4.6	57.5
5	17.9	-0.3	0.45	0.002	-0.2	-0.0036	0.87	6.9	-0.6	62.0	31.8	-0.004	-0.2	206.4
6	35.8	-13.2	0.75	-0.22	1.9	0.006	0.99	0.5	2.6	-16.4	127	-0.001	1.9	16.8
7	-15	22.4	0.09	0.10	-3.0	-0.0003	0.93	25	-2.8	-374	-76	0.001	-3.0	57.3
8	9.2	-1.7	0.75	0.12	0.3	-0.0019	0.96	2.8	6.0	18.1	10.9	-0.012	0.3	5.7

CONCLUSIONS

The following can be concluded from the obtained results:

1- The Quadratic regression can significantly describe the effect of Gauge length and rate of loading on different tested tensile properties.

2- The effect of Gauge length on the breaking time is greater than that of the rate of loading.

3- The transformation of factors to logarithmatic scale for both Gauge length and time of break give a better representations of the obtained data.

4- The percentage elongation is greatly affected by Gauge length than the rate of loading.

5- The experimental design can affect the significant level but not the shape of regression.

6- The Rove characteristic has a great effect on the obtained results

REFERENCES

[1] **Meredith,** R. "The effect of rate of extension on the strength and extension of cotton yarns." J. Text. Inst. 41, T199 (1950).

[2] **Meredith,** R. "The effect of rate of extension on the behaviour of viscose and Acetate Rayon, Silk and nylon." J. Text. Inst. 45, T90 (1954).

[3] **Mereness** H. A. "A comparison of the tensile strengthes of yarns using different Gauge lengthes and rate of loading." Textile Res. J. 28, 351 (1958).

[4] **Midgley** E., **and Pierce** F. T. "Tensile tests for cotton yarns" Part 3 "The rate of loading".J. Text. Inst. 17, T330 (1926).

[5] **Salhotra** K. R. **and Balansubramanian** P. "Effect of strain rate on yarn tenacity".Textile Res. J. 55, 74, 1985.

[6] **Pierce** F. T. "Tensile Tests for Cotton yarns" Part 5 "The weakest link".J. Textile Inst. 17, T335 (1926).

[7] Neclakantan P. and **Aggarwal** S. K. "Using load-elongation curve measurements to characterize polyester fibers for yarn irregularity.Textile Res. J. 55, 136, 1985.