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The Prediction of Tear Strength of plain weave fabric Using Linear Regression Models

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***Abstract*—*The aim of the study is to predict the tear strength of plain weave fabric by knowing the yarn count, yarn tensile strength and the fabric linear density. A total of nine fabric samples (produced of three different yarn counts which were 36.88, 29.50 and 9.83 tex) were produced in deferent densities at weft direction which were 4.33, 7.08 and 8.26 threads per cm, while the density was fixed at the warp direction in 9.84 ends per cm . Tensile strength was tested for these fabrics at warp and weft direction. The results were analyzed and incorporated in the Min-Tab program and the development of regression coefficients and correlation between variables to obtain equations to predict the tear strength at warp and weft direction.*

Keywords*— *Tear strength, yarn count, fabric linear density, warp, weft, regression coefficient.

I. INTRODUCTION

Strength of the fabric is an important property that decides and influences all other performance properties of the fabrics (Teli et al, 2008). The tear strength of a woven fabric is very important, since it is more closely related to serviceability of the fabric. Tearing can be described as the sequential breakage of yarns or groups of yarns along a line through a fabric. Tearing can be described as the sequential breakage of yarns or groups of yarns along a line through a fabric. It is one of the most common types of failure in textile materials and in many cases, serves to terminate their useful life. The tearing strength is often used to give a reasonably direct assessment of serviceability than the tensile strength and a fabric with low tearing strength is generally an inferior product. The studies on tearing strength began with *Krook* and *Fox* they named the triangular distortion at the active region of tearing as 'del'. They stated that fabric structure is more important, which determines the del shape in the region of tear and strongly affects the tear strength of the fabric.(Eryuruk, Kalaoğlu, 2015). The main factors that affect tear strength are yarn properties and fabric structure. The mechanism of fabric tearing is different from linear tensile failure and relates to the ability of individual yarns to slide, pack together or 'jam' into a bundle, increasing the tearing force. Thus an open fabric structure contributes to more yarn sliding and jamming, and higher tear strength. An increase in yarn density in a woven fabric will decrease the tear strength of a fabric as yarns are broken individually as they have more restriction; preventing yarn slide (HU, 2008). Tear strength is the tensile force required to start, strength test is often required for woven fabrics used for applications including army clothing, tenting, sails, umbrellas and hammocks. It may also be used for coated fabrics to evaluate brittleness and serviceability (HU, 2008).The mechanical properties which most often decide their application into a given fabric include unidirectional stretching, tear and elastic properties (Witkowska, Frydrych, 2004). Taylor in his study of tensile and tearing strengths of cotton fabrics, states that this usefulness of the test for fabric strength is one of assessment of quality and not one of assessment of serviceability. Nevertheless, when a demand for a minimum strength is added to the cloth specification, the manufacturer is restricted to a minimum quality fiber and yarn and to a range of twist factors. Therefore, a fall in strength may yield a valuable warning of a change in the quality of raw material or yarn or of deterioration in the control of finishing processes. (Devsrakondn, Pope, 1970). The main aim of this study is to predict the tear strength of the fabric by knowing the yarn count and yarn tenacity and fabric liner density. Prediction of the mechanical properties of fabrics has been studied by numerous authors. Theoretical and mathematical models have been proposed in these studies. However, one of the most common statistical approaches is the multiple regression method. (Fattahi, Ravandi, 2013). The decision made in this study based on the p-value compared to the significant level.

II. MATERIALS AND METHODS

In this study, nine different fabric samples were produced on **PANTE** Textile machine, model **E5X** in **SHENDI Weaving mill**. The study used three different yarn counts with different tenacities. These yarns were from 100% cotton. The yarns used were 36.88, 29.50 and 9.83 tex.

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All the fabrics were woven in a plain weave structure, the weft densities were 4.33, 7.08 and 8.26 threads per cm, while the warp density were fixed in all the samples at 9.84 ends per cm. Tear strength properties were carried out in warp and weft direction in **Sur Military and Civil Clothing Factory** laboratory at standard weather conditions by **Elmtear2 (Digital Tear Tester 855.** From the test results which were two sets of data of yarns and fabrics in tear strength are used for warp and weft directions. One contains 30 results and the other 90. These two data from the laboratory (Table 1and 2) have been analyzed by using Mini-tab statistical analysis software to calculate the regression and relationship between the variables.

III. RESULTS AND DISCUSSION

The measurement of yarn tensile strength was illustrated in Table (1),

Table.1: Yarns Tensile strength

sample no.	Yarns Tensile strength (gf/tex)		
	36.88 tex	29.50 tex	9.83 tex
1	10.04	14.74	23.60
2	6.67	14.73	18.72
3	9.11	15.45	19.94
4	9.21	15.49	18.31
5	8.17	16.08	20.75
6	7.71	13.57	22.08
7	9.72	16.03	17.90
8	10.04	15.41	21.77
9	8.75	18.18	19.94
10	9.39	16.53	18.41
mean	**8.88**	**15.62**	**20.14**

While yarn counts and fabric densities and measurement of fabrics tear strength were illustrated in Table (2).

Table.2: Fabrics tear strength in warp and weft directions (kg)

Densities	Fabric tear strength produced of yarn 36.88 tex		Fabric tear strength produced of yarn 29.50 tex		Fabric tear strength produced of yarn 9.83 tex	
	warp direction	weft direction	warp direction	weft direction	warp direction	weft direction
11/25	0.41	1.01	1.40	1.05	3.67	2.69
	1.06	1.16	1.02	1.14	3.54	2.66
	1.14	0.95	2.28	1.18	3.52	2.77
	1.28	0.93	1.91	1.00	3.65	2.60
	1.45	1.04	1.62	1.13	4.05	3.11
mean	**1.07**	**1.02**	**1.65**	**1.10**	**3.69**	**2.77**
18/25	1.41	0.97	1.85	0.84	1.86	2.83
	1.61	1.03	1.62	0.82	1.95	2.73
	1.54	0.90	1.68	0.86	1.80	2.62
	1.62	0.94	1.69	0.84	1.92	2.66
	1.74	1.08	1.69	0.79	2.21	3.59
mean	**1.56**	**0.98**	**1.71**	**0.83**	**1.95**	**2.89**
21/25	1.13	1.13	1.40	0.82	1.83	3.03
	1.41	1.01	1.37	0.88	2.44	3.05
	1.37	0.88	1.33	0.87	1.33	2.71
	1.53	0.91	1.38	0.86	2.17	2.64
	1.41	0.98	1.45	0.87	2.55	2.65
mean	**1.37**	**0.98**	**1.39**	**0.86**	**2.06**	**2.82**

Table (3) illustrates the goodness of fit statistics of models for the fabric tear strength at the warp and weft direction.

Table.3: Goodness of fit statistics of models

statistical Parameter	R	R^2	Adj.R	SEE*
Fabric tear strength at warp direction	0.815	0.663	0.591	0.467
Fabric tear strength at weft direction	0.995	0.989	0.987	0.105

From table 3 the goodness of fit statistic of model, the (R) was 0.815 which means strong positive correlation between independent variables in the study and the dependent variable fabric tear strength at the warp direction. The simple coefficient of determination (R^2) was 0.663 which indicates a positive correlation between variables. The standard error of estimated was a low value which was 0.467. In the weft direction the correlation coefficient R was 0.995 which means strong positive correlation between independent variables in the study (yarn tenacity, yarn count (tex)) and the dependent variable tear strength. The simple coefficient of determination (R^2) was 0.989 which indicates a positive correlation between variables. The standard error of estimated was a low value which was 0.105.

IV. MODEL EQUITATION OF THE FABRIC TEAR STRENGTH AT THE WARP DIRECTION

Table.4: Analysis of variance (ANOVA) results

Source	DF	SS	MS	F	P
Regression	3	6.0213	2.0071	9.20	0.001
Residual Error	14	3.0540	0.2181		
Total	17	9.0752			

In table (4) the calculated F is 9.20 and the p-value equal 0.01 less than 0.05 which indicates high significant value.

Table.5: Regression coefficients, T-values and significance level of T-values of our linear regression model for fabric tenacity at the warp direction

Predictor	Coefficient	SD	T	P
Constant	1.81100	1.54400	1.17	0.260
Yarn Tensile strength	0.07603	0.07603	1.18	0.260
Fabric linear density	-0.04743	0.02632	-1.80	0.093
Yarn count	-0.01403	0.02106	-0.67	0.516

In Regression coefficients table (5) shows the degree of contribution of the different variables, where we find there is no effect for all variables (yarn tensile strength, fabric linear density, yarn count) where the p-value is 0.260 for the yarn tensile strength and 0.093 for the fabric linear density and 0.516 for the yarn count which bigger than 0.05. Therefore the model equation for the fabric tear strength at the warp direction is:

$$\mathbf{FTS_{wp} = 1.81 + 0.0760\ Y_t - 0.0474\ F_{ld} - 0.0140\ Y_c} \quad ... (1)$$

Where:

FTS_{wp} fabrics tear strength at the warp direction, Y_{ts} Yarn tensile strength, F_{ld} fabric linear density and Yc Yarn count.

V. MODEL EQUITATION OF THE FABRIC TEAR STRENGTH AT WEFT DIRECTION

Table (3) illustrates the goodness of fit statistics of models of the fabric tear strength at the weft direction. From the table the correlation coefficient R equal 0.995 which means strong positive correlation between independent variables in the study (yarn tenacity, yarn count (tex)) and the dependent variable tear strength at the weft direction. The simple coefficient of determination R^2 equal 0.989 which indicates a positive correlation between variables. In table (6) the F calculated is 422.86 and the p-value equal 0.00 less than 0.05 which indicates high significant value.

Table.6: Analysis of variance (ANOVA) results

Source	DF	SS	MS	F	P
Regression	3	13.9198	4.6399	422.86	0.000
Residual Error	14	0.1536	0.0110		
Total	17	14.073			

Table (7) shows the degree of contribution of the different variables.

Table.7: Regression coefficients, t-values and significance level of T-values of our linear regression model for fabric tenacity at the weft direction

Predictor	Coefficient	SD	T	P
Constant	5.87110	0.346400	16.95	0.000
Yarn tensile strength	-0.12092	0.014510	-8.33	0.000
Fabric linear density	-0.011236	0.005903	-1.90	0.078
Yarn count	-0.096895	0.004724	-20.51	0.000

where we find the effect of the yarn tensile strength is -0.12092 and the p-value is 0.000 which means this variable have an effect on the tear strength at the weft direction, as in yarn count the effect is significant p-value is 0.00 and the degree of impact is 0.096895, while the fabric linear density is not significantly in the tear strength at the weft direction because p-value is 0.078 which is bigger than 0.05. Therefore the model equation of the fabric tear strength at the weft direction is:

$$\mathbf{FTS_{wf} = 5.87 - 0.121\ Y_{ts} - 0.0112\ F_d - 0.0969\ Y_c} \quad ..... (2)$$

Where:

$\mathbf{FTS_{wf}}$ fabric Tear strength at the weft direction, Y_{ts} Yarn tensile strength, F_{ld} fabric linear density and Y_c Yarn count.

VI. CONCLUSION

Multiple linear regression equations were developed to predict the fabric tear strength in warp and weft direction as one of the most important fabric characteristics. For this aim nine samples of fabrics were produce by different linear densities and yarns 36.88, 29.50 and 9.83 tex were used in this study. Yarn tensile strength was tested by **Titan2 Universal Strength** instrument and the fabric samples were tested by **Elmtear** (**Digital Tear tester 855**. The study tested the type of relationship between fabric tear strength and independent variables (i.e. yarn tensile strength, yarn count and fabric linear density) one by one. Tests indicated that there was a relationship between the variables and fabric tear strength. The study showed that the fabric tear strength was affected by the yarn tensile strength and yarns count at the weft direction while it was affected by the fabric linear density and yarn count at the weft direction. The study devised equations to predict the tensile strength in the warp and weft direction as illustrated in equation (1) and equation (2).

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