Estimation of Tensile and Tear Strength of Woven Fabric of Different Weave Knowing One of the Bivariate Data

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Abstract
With the increasing of population demand for fabric goes in hike as one of the basic needs of human civilization. Advancement of technology peoples are leaned towards fashion trends which is fast moving. To balance with pace of fashion demand manufacturers are also trying to supply those within a short notice. But all garment manufacturers are neither in position to meet all types of testing facilities with their own nor to spent sufficient amount of hard waste before making the final product. Our aim is to support garment manufactures to predict fabric mechanical properties before start up new product design. In this paper we formularize a mathematical tool for estimating fabric mechanical properties based on statistical correlation regression method. Study is undergone on two count, 40s & 60s flax yarn to make plain and twill weave design grey linen fabric on automatic rapier loom. Mechanical properties to test under consideration are tensile and tear strength of fabric resistance. This paper tries to associate data in between six variants, two counts, two weave structures and two mechanical properties but having same aerial density and same fabric.

Keywords
Bivariate data, Correlation, Estimate, Plain & twill weave, Regression, Tensile strength, Tear strength

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1. Introduction

Fashion industry is moving fast with varieties of design using different types of fibrous and non-fibrous material. To balance this pace of moving fashion, apparel manufacturers are continuously updating them with the production of different varieties of designed fabrics. But in our day to day life such moving fashion garments are not preferable due to the difficulties in care and renovation. Basically, the fashion garments are made up of short term used concept but country like India and all third world countries common people are using their formal dresses with the fabric having better durability and easy to wash. So, the fabric manufactures keep in mind during fabric making that the fabric should be good resistant to wear and tear. But in India we have various sizes of industry, of which only a few having well equipped testing lab. Keeping in mind about the infrastructure of small-scale industries, who are not in position to check the mechanical properties of fabric all time, but having intension to cater the premium market segment with their efficient product structure, we have tried to formulize an equation connecting tear and tensile strength of fabric of different weave.

Our study starts with the objective that to support such small size industry having fewer testing facilities to judge the fabric performance but to supply proper quality of fabric in domestic as well as in international market. We have tried to establish a relationship between bivariate data through statistical correlation and regression method, where testing one variate other can be predicted without using testing machines before production in a cost-effective way. Our study involves in formulation of correlation, regression equation are of two prime testing parameter of fabric viz. tensile and tear strength.

The project work was aimed to analyze the tensile and tearing strength of fabric made up of the same fibre (flax) within the same condition but different weave design. In this study, the mechanical properties of two types of fabrics 1/1 plain & 2/1 twill weave were analyzed.

In our present study we are trying to create bivariate data like, tensile and tear strength of plain and twill fabric of different count of yarn and different GSM of fabric. We have done our experiment in the actual mill conduction in a state of art technology mill. The project was done by making of grey fabric of two different weave (plain and twill) from two different counts (40^s and 60^s) into different automatic Rapier loom under ambient atmospheric condition.

The produced samples are tested in Quality Control lab after proper conditioning before the testing. Data were collected in ambient testing condition and recorded.

The Textile Industry is always equipped with a good statistical Quality Control lab with R&D facility. Testing of sample in a long run produced huge amount of hard waste which can't be reconverted into a usable fibre state. In the statistical science formulation of proper tools can help to reduce evaluation of unnecessary hard waste as well as eliminate time bound study including engagement of Costly manpower. If we can establish a systematic mathematical equation involving different variables it will help to assess one of the variables of a bivariate data. During study of two variables simultaneously like tensile strength & tearing strength of fabric two problems may arise

i. whether the data may reveal some association between those variables or not and
ii. whether we are interested to measure numerically the strength of that association between the variables or not

In general, when we Study some characteristics of one variable only it is easy to establish statistical conclusion about that variable but when situation arise in which we may have to study two variables simultaneously like x and y, e.g., Tensile strength& Tearing strength, a measure will determine how will a linear or other equation explains the relation between the variables. This is the problem of correlation and regression.

In short correlation is concerned with the measurement of the degree of the association between variables while regression is concerned with the prediction of the most likely value of one variable when the value of the other variable is known [1].

2. Material and Method

The purpose of the present work deals with the formulation of regression equation of mechanical properties of twill weave on that of plain weave on same count & same GSM.

2.1 Specific Strength

During the testing of mechanical properties of fabric, we did the test both warp wise & weft wise. For the simplicity of the data, we derive a new mechanical property incorporating both warp and weft wise result in a single property called specific strength [2, 3].
a) Specific Tensile Strength =
(Tensile Strength of warp wise+ Tensile Strength Weft wise) / Fabric mass per unit area
b) Specific Tear Strength =
(Tear Strength of warp wise+ Tear Strength Weft wise) / Fabric mass per unit area

2.2 Fabric making procedure

In this study 4 different fabric sample are produced on PICANOL Rapier; Model: OPTIMAX-4-R; Type-102779.The Linen fabrics made for our study was restricted at grey level. We used two different yarn count as 40s (L-111) and 60s (L-121) made from 100% flax fibre. For 40s grey linen fabric of epi 45 and ppi 47 both in plain and twill weave. For 60s grey linen fabric of epi 51 and ppi 53 both plain and twill weave. The finished fabric width is 58" produced form 65" reed space for 40^s and that of 60" produced from 67" reed space for 60^s. For 40s linen total no of ends in the final fabric is 2944 and for 60^s total no of ends in the final fabric is 3440 including selvedge ends [4].
For 40s reed count was 44/2 and 60s and count were 50/2 both having 2 ends /dent.
For 40s loom no. of heald frame used= 4.
For 60s loom no. of heald frame used in the m/c= 6
For 40s 1/1 plains & 2/2 twill design

For 60s 1/1 plains 2/1 twill design
Both the fabrics were of different weaves in same count having same gsm and same yarn density.

2.3 Testing of samples

Tensile strength & Elongation test is done on m/c- SDL ATLAS, Type- GRAB Test, Standard – ASTM D5034;2008, no. of sample=16(in each direction).

Tear strength test is done on, machine James Heal, Model- 885 Elmatear Type- Pendulum Elmendorf, Standard – ASTM D 1424, Calibration wt.= E (13555gm), no. of sample =16(in each direction)
GSM Test is done on, machine Paramount, diameter =112 [5, 6].

Tables: 1 - Summary of average specific values and average GSM

Count	Weave	Specific Tensile	Specific Tear	GSM
40s	Plain	1.75	63.4	155.75
40s	Twill	1.875	109.225	151.57
60s	Plain	1.798	122.7	115.25
60s	Twill	1.64	151.15	115.75

Table 2 - Summary of Table for statistical data for mechanical properties of fabric

Count	weave	Mech. Prop.	$\bar{x}$	$\bar{y}$	σ_X	σ_y
40s	Plain	Tensile	1.75	-	0.0707	-
40s	Twill		-	1.88	-	0.174
40s	Plain	Tear	63.41	-	7.5	-
40s	Twill		-	109.22	-	9.64
60s	Plain	Tensile	1.8	-	0.0846	-
60s	Twill		-	1.63	-	0.1272
60s	Plain	Tear	122.71	-	8.75	-
60s	Twill		-	151.12	-	11.5

X= plain & Y= Twill
b_{xy}= Cov(x,y) / σ^2_y = r. σ_y/σ_X
$b_{yx=}$cov(x,y) / σ^2_X = r. σ_X / σ_y

Table 3 - Table for $b_{xy \text{ and }} b_{yx}$

Count	Mech. Prop	Cov (x, y)	σ_X	σ_y	r	b_{yx}
40s	Tensile	0.0117	0.0707	0.174	+0.950	0.386
40s	Tear	45.28	7.5	9.64	+0.996	0.775
60s	Tensile	0.0105	0.0846	0.1272	+0.977	0.6498
60s	Tear	98.26	8.75	11.5	+0.970	0.7380

2.4 Formulation of Regression equations

Regression equation of y on x is
$y - \bar{y} = b_{yx} (x - \bar{x})$
1. Regression equation of specific tensile strength for 40s plain & twill weave
y = 0.386x + 1.1995,
Where x= specific tensile strength for plain & y = specific tensile strength for twill
2. Regression equation of specific tear strength for 40s plain & twill weave
y = 0.775x + 60.09
Where x= specific tear strength for plain & y = specific tear strength for twill
3. Regression equation of specific tensile strength for 60s plain & twill weave
y = 0.6498x + 0.4717,
Where x= specific tensile strength for plain & y = specific tensile strength for twill

4. Regression equation of specific tear strength for 60s plain & twill weave
$Y = 0.7380x + 60.5974$,
Where x= specific tear strength for plain & y = specific tear strength for twill

2.5 Estimation of one of the bivariate-data knowing other

Let,
Estimate of y $\rightarrow y'$
then linear regression equation for estimate of y is
$y' - \bar{y} = b_{yx} (x - \bar{x})$

3. Conclusion

1. Table 1 reveals that tensile strength is higher in plain structure than that of twill due to more interlacement in the former. Better yarn to yarn cohesion effects high degree of strength.
2. It is also shown tear strength in twill is higher than that of plain due to Del effect, i.e. mobility of bunch of yarn is better in twill due to comparative loose packing. [7, 8]
3. It has been observed that 40s tensile strength is higher in twill, which may be justified as higher standard deviation in twill than plain, i.e. higher range of maximum and minimum value contributes irregular reading. More test on fabric property and corresponding yarn characteristics to be checked.
4. From Table 2, we see standard deviation of plain in both tensile and tear is lesser than that of twill. This can be explained due to weaker dimensional stability in twill. Plain fabric structure can contribute even resistance in every reading of test.
5. Table 3 show higher positive value of correlation coefficient nearer to +1 signifies degree of association of data for both tensile and tear strength in plain and twill structured fabric for each count are high and they are directly related, showing positive gradient of correlation straight line graph. i.e. a little change in any type of strength of plain structure gives sharp change in twill structure and vice versa.
6. From the table it has been shown positive regression coefficient of all strength data for both two count showing proper computation of data.
7. The all four regression equations formulated for both count and both strength between plain and twill structure will help in prediction of newer value for unknown structure having same for a known structure.

4. Summary

1. In short if we test tensile strength of plain weaved fabric, then we can predict the tensile strength of twill weaved fabric before making the fabric practically. Similarly, if we test tear strength of plain weaved fabric, then we can predict the tear strength of twill weaved fabric before making the fabric practically. The process can be extended for any kind of fabric and any type of fabric property.
2. Our study can be extended to take new data for plain weave of 40s and 60s count on tensile and tear and put it in the respective mathematical model of regression equation, the estimated value corresponding to twill weave is highly predicted.

5. Suggestion for further work

1. The study is restricted in two particular count 40s and 60s. Count variation of data to be collected.
2. Data of different popular gsm fabric to be computed.
3. Changing yarn CV, how they influence on fabric strength in this prediction to be justified.
4. This is a short span mathematical model. To make to full proof model extensive study and research to be performed with different changing parameters.

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