



## **Study on the Bursting Strength of Jute Fabric**

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**Abstract:** In bursting strength testing, fabrics are subjected to multidirectional pressure. Filled in jute bags in stacked condition are subjected to such type of pressure. In this paper bursting strength of six different types of jute fabrics are measured. The measured bursting strength values are then compared with calculated bursting strength values obtained from two mathematical models, one is based on the strengths of constituent yarns and the other on the uniaxial fabric strengths and a good conformity have been obtained between the experimental and the calculated values. So the uniaxial fabric strength testing, the age old practice in jute industry is adequate to predict the bursting strength.

**Keywords:** Bursting strength, membrane theory, multidirectional pressure, uniaxial strength

### **Introduction**

In industrial applications, textile fabrics are generally subjected to loads directed along the threads of the fabric, either uniaxial or biaxial or to pressures directed at right angle to fabric structure. Typical examples of the first case are the kinds of loads carried by drive belts or safety belts. The second kind of load occurs in fabrics for sacks, tents, water bag, filter cloth, parachute fabrics. Assuming that, during bursting, the samples were distended into spherical bowls, i.e., section of a sphere, Sommer [3] has suggested that the linear tension per unit length of the specimen along the arc of the great circle is

$$N = p \frac{a}{2} = p \left( \frac{c_b^2 + h^2}{4h} \right) \quad (1)$$

where  $p$  = pressure on the specimen,  $a$  = radius of the sphere of which sample bowl is a part,  $c_b$  = radius of the bowl base and  $h$  = height of the bowl. This equation is based on membrane theory of shell.

Zurek et al [2] have given the formula for calculating the bursting pressure based on the strength of the constituent yarns and fabric structure, assuming that the distended fabric sample is a part of spherical bowl:

$$p = \frac{1}{a} \left[ \left( \frac{F_1}{E_1 p_1} \right) + \left( \frac{F_2}{E_2 p_2} \right) \right] \quad (2)$$

$F_1$  and  $F_2$  are the breaking strengths of warp and weft yarns,  $p_1$  and  $p_2$  are the warp and weft thread spacing in deformed state,  $E_1$  and  $E_2$  are the relative increase in spacing of warp and weft thread,  $E_1 = \frac{p_1}{p_{01}}$  and

$E_2 = \frac{p_2}{p_{02}}$ ,  $p_{01}$  and  $p_{02}$  are warp and weft thread spacing in the un-deformed state respectively.

$E = \frac{e}{100} + 1$ ,  $e$  is the extension (%) of yarn; 'a' is the radius of the spherical bowl that can be calculated from the geometry of the distended specimen.

Ertugrul [3] predicted bursting strength of cotton knitted fabrics using intelligent techniques of neural network and neuro-fuzzy approaches with yarn strength, extension and fabric weight as the input parameters.

## II. Materials and Methods

Six types of jute fabrics, which are used commonly for making bags, were selected for experimental studies. The dimensional parameters of the fabrics are given in Table 1.

**Table 1. Particulars of the Fabric Samples**

| Sample code number | Thread density (threads/dm) |                        | Yarn linear density (tex) |                        | Yarn crimp (%)         |                        | Areal density (g/m <sup>2</sup> ) | Thickness (mm) |
|--------------------|-----------------------------|------------------------|---------------------------|------------------------|------------------------|------------------------|-----------------------------------|----------------|
|                    | Warp (n <sub>1</sub> )      | Weft (n <sub>2</sub> ) | Warp (T <sub>1</sub> )    | Weft (T <sub>2</sub> ) | Warp (c <sub>1</sub> ) | Weft (c <sub>2</sub> ) |                                   |                |
| 1                  | 45                          | 46                     | 298                       | 263                    | 3.9                    | 3.1                    | 271                               | 0.90           |
| 2                  | 47                          | 54                     | 279                       | 379                    | 4.3                    | 4.4                    | 354                               | 1.06           |
| 3                  | 99                          | 34                     | 292                       | 970                    | 6.6                    | 3.9                    | 635                               | 1.66           |
| 4                  | 75                          | 27                     | 256                       | 899                    | 4.3                    | 3.9                    | 498                               | 1.45           |
| 5                  | 69                          | 31                     | 268                       | 737                    | 4.8                    | 3.0                    | 417                               | 1.02           |
| 6                  | 136                         | 72                     | 225                       | 318                    | 10.3                   | 5.4                    | 629                               | 1.09           |

### Tensile Strength of Yarns

Strength of warp and weft yarns for each fabric sample are measured on Zwick Roell Z010 Tensile tester, with a gauge length of 200 mm and 300 mm/min testing speed (IS:1670 – 1970; method 3). Fifty specimens were tested and the average was calculated. The results are given in Table 2.

**Table 2. Tensile Test Results for Yarns**

| Sample code | Warp yarn          |                   |                        | Weft yarn          |                   |                        |
|-------------|--------------------|-------------------|------------------------|--------------------|-------------------|------------------------|
|             | Breaking Force (N) | Tenacity (cN/tex) | Extension at break (%) | Breaking force (N) | Tenacity (cN/tex) | Extension at break (%) |
| 1           | 33.71<br>(20.48)*  | 11.31             | 2.33<br>(21.67)        | 32.93<br>(15.53)   | 12.52             | 2.17<br>(11.76)        |
| 2           | 29.89<br>(20.74)   | 10.71             | 1.98<br>(21.16)        | 34.04<br>(21.67)   | 12.70             | 1.76<br>(20.92)        |
| 3           | 31.07<br>(15.26)   | 10.64             | 2.14<br>(12.24)        | 112.7<br>(10.48)   | 11.62             | 2.78<br>(16.65)        |
| 4           | 38.22<br>(15.21)   | 14.92             | 1.90<br>(10.92)        | 117.57<br>(10.26)  | 13.10             | 3.36<br>(20.50)        |
| 5           | 31.56<br>(19.83)   | 11.77             | 2.27<br>(10.16)        | 74.68<br>(22.50)   | 10.13             | 3.31<br>(14.88)        |
| 6           | 27.83<br>(17.80)   | 12.37             | 2.91<br>(16.39)        | 33.12<br>(19.80)   | 10.41             | 2.20<br>(13.28)        |

[\*Figures in the parentheses show the coefficient of variation (%)]

### Tensile Strength of Fabrics

Tensile strengths of fabrics are measured on Zwick Roell Z010 tensile tester following ‘ravelled strip method’ (IS:1969 – 1968) with sample size of 350mmX120mm. The specified width, 100 mm, of the specimen was obtained by removing yarns at the edges. The gauge length was 200 mm and the test speed was 460 mm/min. Results are shown in Table 3. Ten specimens were tested for each sample.

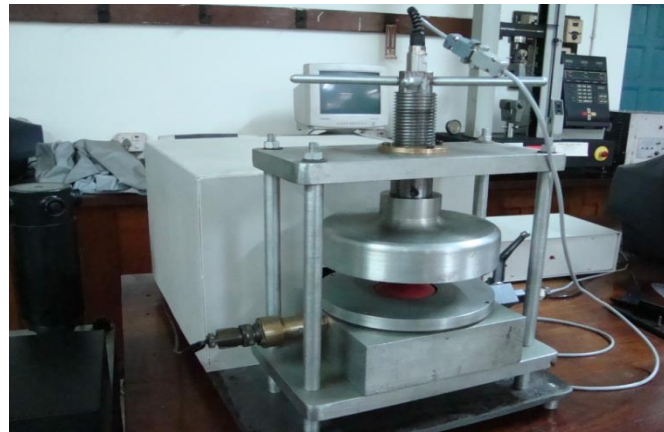
**Table 3. Tensile Strength Results of Fabric**

| Sample code | Warp way           |                  |                        | Weft way           |                  |                        |
|-------------|--------------------|------------------|------------------------|--------------------|------------------|------------------------|
|             | Breaking force (N) | Strength (kg/cm) | Extension at break (%) | Breaking force (N) | Strength (kg/cm) | Extension at break (%) |
| 1           | 1267.4<br>(3.73)*  | 12.92            | 5.77<br>(3.75)         | 1190.7<br>(9.56)   | 12.15            | 4.69<br>(4.79)         |
| 2           | 1392.6<br>(5.69)   | 14.21            | 5.83<br>(7.03)         | 1820.8<br>(7.02)   | 18.58            | 5.36<br>(4.91)         |
| 3           | 2933.1<br>(7.44)   | 29.93            | 8.45<br>(7.92)         | 2360.8<br>(15.96)  | 24.09            | 5.80<br>(10.13)        |
| 4           | 2227.5<br>(13.26)  | 22.73            | 5.42<br>(9.04)         | 1644.4<br>(14.29)  | 16.78            | 6.19<br>(14.19)        |
| 5           | 1844.4<br>(4.86)   | 18.82            | 6.13<br>(7.29)         | 1925.7<br>(16.38)  | 19.65            | 5.03<br>(4.66)         |
| 6           | 3033.1<br>(5.64)   | 30.95            | 13.87<br>(5.68)        | 2597.0<br>(8.56)   | 26.5             | 7.07<br>(6.90)         |

[\*Figures in the parentheses show the coefficient of variation (%)]

The bursting strength of the samples was tested in a bursting strength tester developed by CTRONIX, India which is shown in Figure 1(a). The schematic diagram of the instrument is shown in Figure 1(b). The diameter of the circular aperture is 76.2 mm, which is larger than the 25.4 mm diameter in commonly available instruments. The

larger aperture helps to burst the jute fabric properly; in case smaller aperture, bursting of heavy jute fabrics is not satisfactory. The chamber is filled with oil and pressure is raised by means of a pump. The pressure in the chamber is converted into an electrical signal by means of a pressure transducer. As the pressure builds up, the fabric along with the rubber diaphragm bulges out and the deflection of the central point of the distended fabric is recorded by means of a LVDT. The displacement recorded by the LVDT is the height of the central point of the distended fabric. The electrical signals from the pressure transducer and the LVDT are fed to computer software and a plot of pressure and height of the bulge in terms of displacement is obtained. A typical pressure – displacement curve obtained in case of first specimen of sample 1 is shown in Figure 2. When the fabric bursts the instrument stops automatically, the pressure reduces to zero and the probe of the LVDT recedes to its original position. The instrument records the bursting pressure and the height of the bulge at the time of burst. The results are given in Table 4. Ten specimens were tested for each sample.



(a)

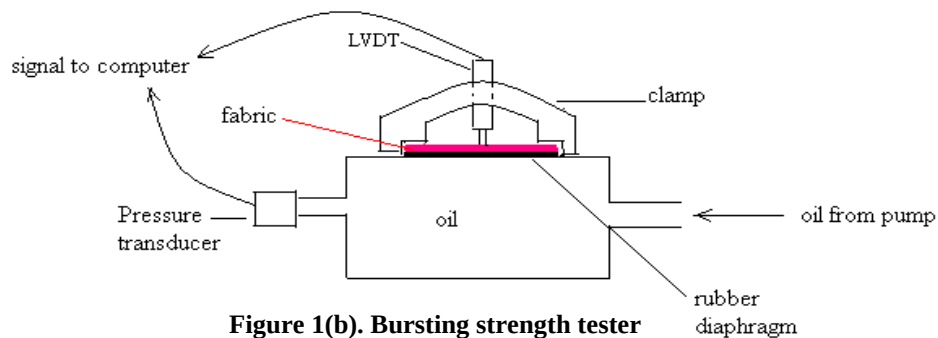


Figure 1(b). Bursting strength tester

**Table 4. Results Bursting Strength of Fabric**

| Sample code | Bursting strength              |                   |
|-------------|--------------------------------|-------------------|
|             | Pressure (kg/cm <sup>2</sup> ) | Displacement (mm) |
| 1           | 6.30<br>(8.86*)                | 19.80<br>(13.92*) |
| 2           | 5.70<br>(10.52)                | 13.80<br>(12.43)  |
| 3           | 12.30<br>(11.2)                | 16.30<br>(8.06)   |
| 4           | 10.90<br>(13.6)                | 14.00<br>(16.53)  |
| 5           | 7.68<br>(6.25)                 | 11.80<br>(16.12)  |
| 6           | 9.60<br>(5.95)                 | 15.80<br>(18.03)  |

[ \*Figures in the parentheses show the coefficient of variation (%) ]

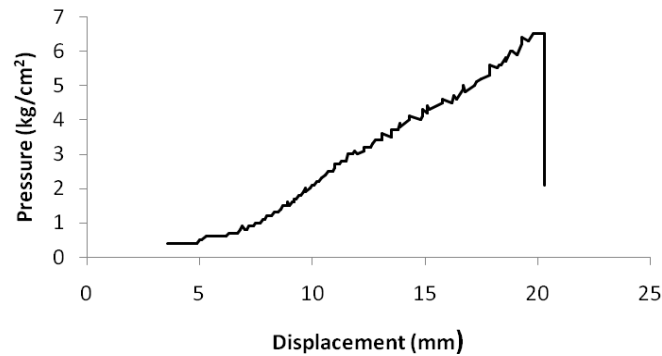


**Figure 2. Pressure – displacement curve of bursting strength test**

In the above Figure 2 the displacement values in the horizontal axis represent the height of central point of the distended fabric.

### III. Results and Discussion

During bursting testing, the distended fabric specimen can be considered as a spherical bowl [1] as shown in Figure 3.

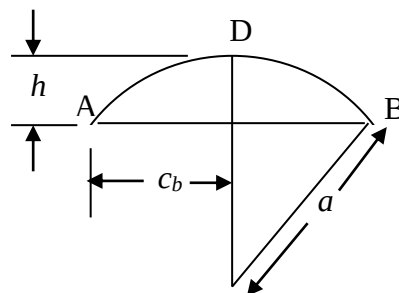


**Figure 3. Geometry of the distended specimen**

The radius of the sphere  $OB = OD = a$ . The normal section of the fabric is the arc  $ADB$ .  $AC = c_b$  is the radius of the circular aperture. In the present case  $c_b = 3.81$  cm (1.5 inch).  $CD = h$  = height of distension. From the right angled triangle  $OBC$

$$a^2 = c_b^2 + (a - h)^2$$

$$a = \frac{c_b^2 + h^2}{2h} \quad (3)$$

The values of  $h$  is obtained from the instrument are given in Table 4 and hence  $a$  can be calculated from equation (3).

The bursting pressures are calculated, using equation (2), for the fabric samples from the corresponding yarn test data, given in Table 2, and compared with the experimentally determined bursting pressures given in Table 4. These results are shown in Table 5.

**Table 5. Calculated and Measured Values of Bursting Pressure**

| Sample code number | Calculated bursting pressure<br>(kg/cm <sup>2</sup> ) | Measured bursting pressure<br>(kg/cm <sup>2</sup> ) |
|--------------------|-------------------------------------------------------|-----------------------------------------------------|
| 1                  | 6.50                                                  | 6.30                                                |
| 2                  | 5.46                                                  | 5.70                                                |
| 3                  | 13.12                                                 | 12.30                                               |
| 4                  | 10.20                                                 | 10.90                                               |
| 5                  | 6.62                                                  | 7.68                                                |
| 6                  | 11.40                                                 | 9.60                                                |

There is a reasonable agreement between the actual and the calculated values. The breaking strength and breaking extension values of the constituent yarns are required for calculating the bursting pressure.

Bursting pressure can also be calculated by considering the fabric as membrane, Clive [4] and the distended specimen is a part of a sphere then the pressure,  $p$ , inside the spherical shell is given by the following equation [4]

$$p = \frac{2N}{a}$$

$N$  is the fabric strength in kg/cm. Substituting the value of  $a$  from equation (3)

$$p = \frac{4hN}{c_b^2 + h^2} \quad (4)$$

Sommer [1] also reported the similar type of Equation (1). It is to be mentioned here that membranes are homogeneous and isotropic, but fabrics are non-homogeneous and orthotropic and the warp way and weft way strengths are different. The strength  $N$  in Equation (4) can be either warp way or weft way strengths. Bursting pressures are calculated for warp way, weft way and also the average value of the warp way and weft way strengths. The results of bursting pressure ( $p$ ), displacement ( $h$ ) in Table 4 and the fabric strength results in Table 3 are used to calculate the bursting pressures from Equation (4). The calculated bursting pressures are compared with the actual values of bursting pressure. These results are shown in Table 6 and shown in Figure 4.

**Table 6. Calculated and Measured Values of Bursting Pressure**

| Sample code number | Calculated bursting pressure (kg/cm <sup>2</sup> ) |                                        |                                          | Measured bursting pressure (kg/cm <sup>2</sup> ) |
|--------------------|----------------------------------------------------|----------------------------------------|------------------------------------------|--------------------------------------------------|
|                    | Higher value of fabric strength (kg/cm)            | Lower value of fabric strength (kg/cm) | Average value of fabric strength (kg/cm) |                                                  |
| 1                  | 5.6                                                | 5.2                                    | 5.4                                      | 6.30                                             |
| 2                  | 6.2                                                | 4.8                                    | 5.5                                      | 5.70                                             |
| 3                  | 11.4                                               | 9.1                                    | 10.25                                    | 12.30                                            |
| 4                  | 7.8                                                | 5.7                                    | 6.71                                     | 10.90                                            |
| 5                  | 5.83                                               | 5.6                                    | 5.7                                      | 7.68                                             |
| 6                  | 11.5                                               | 9.84                                   | 10.66                                    | 9.60                                             |

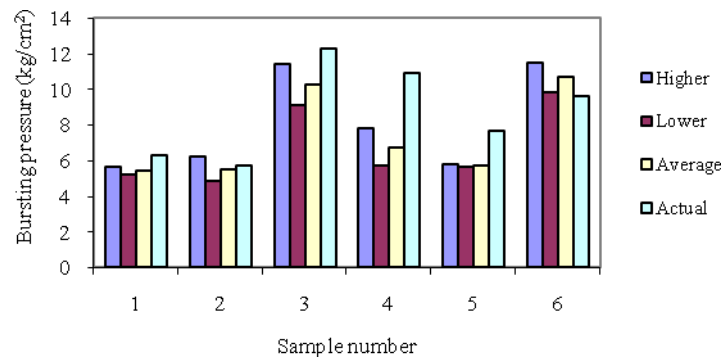


**Figure 4. Calculated and actual bursting pressures**

Table 6 and Figure 4.20 show that the calculated bursting pressures derived from the higher value of uniaxial fabric strength between warp and weft directions are, in general, closer to the actual bursting pressures obtained experimentally. These results show that the bursting pressure depends on the uniaxial fabric strength in the stronger direction.

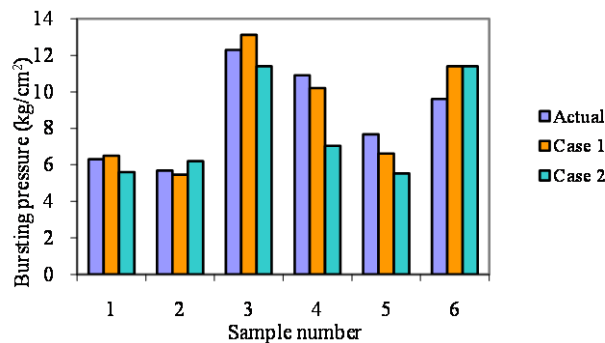


**Figure 5. Actual and predicted values of bursting pressure**

Figure 5 shows that both the equations (2) and (4) give reasonable prediction of the bursting pressures. Equation (4) predicts on the basis of the breaking strength of the fabric and hence more convenient. Moreover, since equation (4.7) is derived from membrane shell theory so it can be said that membrane shell theory is applicable in explaining deformation of fabric when the fabric forms shell like structure.

#### IV. Conclusions

Bursting strength depends on the higher value of the uniaxial fabric strength. Separate bursting strength tester is not required for jute fabric. Bursting strength can be predicted both from the strength of the constituent yarns as well as the uniaxial fabric strength, but the second method is simpler. Membrane shell theory is applicable in analysing fabric deformation.

#### V. References

- [1] H. Sommer, (1941), The Principles of Analysis of Fabric Bursting Strength, *Melliand Textilber.* **22**, 414.
- [2] W. Zurek and W. Bendkowska, (1983), Phenomenon Occurring in Bursting Strength of Circular Fabric Samples, Part I: Geometry of the distended Samples, *Textile Res. J.*, **53**, 19.
- [3] S. Ertugrul, N. Ucar, (2000), Predicting Bursting Strength of Cotton Plain Knitted Fabrics using Intelligent Techniques, *Text Res J.*, **70**, 845.
- [4] Clive L Dym. (1990), Introduction to the Theory of Shells, Hemisphere Publishing Corporation, Chapter IV