AJHS
Asian Journal of Home Science
Volume 14 | Issue 1 | June, 2019 | 22-27

DOI: 10.15740/HAS/AJHS/14.1/22-27
ISSN : 0973-4732 ■ Visit us: *www.researchjournal.co.in*

Research Paper

Impact of tensile strength and elongation on bursting strength of mulberry silk/viscose blended knitted fabrics

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Received: 31.07.2018; **Revised:** 04.04.2019; **Accepted:** 13.04.2019

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ABSTRACT : The bursting behaviour of mulberry silk / viscose blended knitted fabrics has been tested and its relationship with tensile strength and elongation has been analyzed. Bursting strength is an important characteristic for any knitted fabric. Stress is applied from all the directions to test the fabric. For the present study, mulberry silk /viscose blended knitted fabrics were developed in two unlike counts, by using weft knitting process and were subjected to bursting strength test. An investigation has been made of two alleged variables of bursting strength *viz.*, tensile strength and elongation of fabric and their relationship with bursting strength was analyzed using regression analysis. Statistical computations were carried out using SPSS 20 package. It was confirmed by calculation and comparison that tensile strength was a firm contributor to bursting strength with regression co-efficient of 0.038 in wale wise direction and 0.027 in course wise direction, however, a feeble but negative relationship was seen in case of elongation percentage and bursting strength with regression co-efficient of -0.106 in wale wise direction and -0.038 in course wise direction.

KEY WORDS: Bursting, Elongation, Fabric, Strength, Tensile

HOW TO CITE THIS PAPER : Bajaj, Shikha and Bains, Sandeep (2019). Impact of tensile strength and elongation on bursting strength of mulberry silk/viscose blended knitted fabrics. *Asian J. Home Sci.,* **14** (1) : 22-27, **DOI: 10.15740/HAS/AJHS/14.1/22-27.**

When linear stress is applied to knitted fabrics, they elongate very fast, ultimately change shape, free edges of the fabric get curled towards the centre, giving the appearance of soft rope like form. Knitted fabric finally breaks when its edge leaves the jaw at the testing machine and sudden change in configuration occurs. A knitted fabric is supposed to have some properties according to the fabric application area, therefore, in order to avoid this rapid modification of fabric configuration, the ideal test would be the one involving area, *i.e.* bursting strength test. In addition to the application fields, mechanical characteristics of knitted fabrics are very essential in downstream processes. It will be a problem for a knitted fabric which has deficient mechanical properties to be processed in finishing treatments. Among the mechanical characteristics of knitted fabrics, bursting strength is of great importance (Unal *et al.,* 2010). Under this test, the fabric is held on all edges during test and tension applied is in all the directions (Davis and Edwards, 2008).

Mechanical stressing leads to some molecular slippage, hindered by the crystalline fraction and its nature. This burden may be called the frictional set that does not allow full relaxation and thus molecular chains can rearrange only to certain permitted levels. This is what is labeled as the final stress level (Babu, 2013). When fabrics are subjected to rubbing over a large area, it may lead to thinning and a loss of strength, which leads to bursting or tearing (Vasumathi *et al.*, 2002).

Strength of fabrics depends on fabric forming materials such as fibre and yarn properties (Hossain *et al.*, 2016). Amongst all the compositions, silk fibre is as strong as steel filament of similar size (Awake watchtower library, 2006). Silk fabric, apart from having luxurious texture and beauty, masks extreme toughness. Researchers are still trying to unravel the reason behind what makes the luxurious fabric so strong (Sherwood, 2010). In a study by Thirugnanasambantham and Senthilkumar (2010), silk/modal fabric was found to have lower bursting strength than 100 per cent cotton and 100 per cent modal fabric, whereas, viscose fabrics were found to have lowest bursting strength in comparison to 100 per cent bamboo, 100 per cent cotton and 100 per cent mercerized cotton (Hossain, 2016). Therefore, a fabric developed by blending the two fibres must be an intelligent outcome carrying forward the favourable properties. In this world of competitive business, design constitution for apparel and goods must be endeavored in such a way that it gratifies the customer requirements in relation to trends and wishes. The performance of the apparel merchandise should also not loose post-production properties and its fibre properties (Akaydin and Can, 2012). Therefore, scientist intends to study the relationship of bursting strength with its alleged influencers *i.e.* tensile strength and elongation.

■ RESEARCH METHODS

Materials and equipment used:

Yarns were blended in proportion of 50 per cent mulberry silk: 50 per cent viscose by applying constant twist and were knitted by using yarns of two dissimilar counts *viz.*, 15 and 20 Nm. Blended knitted fabrics were utilized for carrying out the present course of experimentation. Details of testing methods and equipments have furnished in Table A.

Fabric thickness:

A thickness tester was used for checking thickness of fabric samples. The thickness tester carried a graduated dial gauge of 10 mm capacity with a least count of 0.01 mm. The pressure foot is 5 cm^2 in area and a pressure from 20 – 100 g/ cm^2 *i.e.* a load of 100 g to 500 g could be applied. The instrument carried a firm base and a heavy frame stable enough to be stationary. The fabric samples were kept in between plates of thickness tester and a pointer in the dial showed thickness of fabric. The test was conducted at five different portions of test sample and final calculations were made by taking mean of five measurements.

Diaphragm busrting :

Bursting strength is strength of the fabric against a multidirectional flow of pressure. The bursting test measures a composite strength of yarns in both the directions simultaneously and calculates the extent to which a fabric can bear a bursting type of force with a pressure being applied perpendicular to the surface of the fabric (Angappan and Gopalkrishnan, 1997). This method, for the determination of diaphragm bursting strength of knitted, nonwoven and woven fabrics is being used by the textile industry for the evaluation of a wide variety of end uses (ASTM International, 2018).

Hydraulic bursting strength tester shown in Fig A was used for measurement of bursting strength of test samples. Testing specimens were cut in circular shape with a diameter of 1.7 inches, which was ½ inch more than the diameter of the clamp over the machine. The liquid pressure at this instant is taken as a measure at the fabric strength. After fixation of test sample over the clamp, the machine was started. The fluid was

Table A : Equipments used in the study

Name of the equipment	Purpose	Test method
Bursting strength	Bursting strength tester	ASTM D3786 / D3786M
Tensile strength tester	Tensile strength and elongation	ASTM D 5034-95-Reapproved 2001
Thickness tester	Fabric thickness	B.S. 2544:954
Twist tester	Twist per inch	IS 832 “1985”

displaced at a constant rate of 95 ml/min. Due to increase in pressure, the diaphragm bulged, taking with it the specimen. At a moment, the fabric sample busted and pressure at the point was displayed over the screen. The reading was recorded. The test was repeated five times for each of the test specimen and final calculation was made by taking mean of the three readings.

Maximum breaking strength and elongation:

Maximum breaking strength is a measure of resistance of the fabric to a tensile load or stress in either lengthwise or widthwise direction (Angappan and Gopalkrishnan, 1997). Test method ASTM D 5034-95-Reapproved 2001, includes the grab and modified grab test procedures for calculating the breaking strength and elongation values of most of the textile fabrics. Tensile strength test-grab tester works on CRE (Constant rate of elongation) principle. The samples to be tested were conditioned moisture equilibrium. The machine was prepared and clamps were set 3 inches apart. The force range and loading rate were selected on it. The specimen was then set over the machine between the clamps. Care was taken to keep it as straight as possible so that same set of yarns should be clamped. The machine was started and it automatically stops when fabric specimen breaks. The readings of breaking strength, elongation percentage were recorded from the monitor of the computer attached with the machine. Also the stress strain graph was produced over the monitor, which was saved for each of the readings. The test was repeated five times for each of the fabric specimen and final calculation was made by taking the mean of five readings.

Fig. A : Bursting strength test

■ RESEARCH FINDINGS AND DISCUSSION

To comment on the mathematical calculations, these were analyzed by using SPSS 20 package programme.

Twist per inch :

Twist per inch was kept constant for both the fabrics (Table 1). Since, twist per inch is a parameter that influences output behaviour of yarns, it was viewed as being held constant. Variables are viewed as changing while parameters typically either don't change or change more slowly (Nykamp, 2018), therefore, all the yarns were incorporated with same amount of twist (10 twists per inch).

Fabric thickness :

Thickness of fabric knitted by using 15 Nm yarn was computed as 0.763 mm, whereas, that of fabric knitted by using 20 Nm yarn was 0.663 mm (Table 1).

Bursting strength :

Results for bursting strength have been furnished

Table 1 : Structural characteristics of blended knitted fabrics

Fabric composition	Yarn count (Nm)	Twist per inch	Fabric thickness (mm)
50% mulberry silk: 50% viscose	15	10	0.763
50% mulberry silk: 50% viscose	20	10	0.663

Table 2 : Analysis of bursting strength of blended knitted fabrics in composition of 50% silk: 50% viscose

Fabric composition	Yarn count (Nm)	Bursting strength (kg/cm^2)
50% silk: 50% viscose	15	6.757
50% silk: 50% viscose	20	4.730

in Table 2. It was observed that blended fabric, knitted by using 15 Nm yarn showed a higher value of bursting strength (6.757 kg/cm^2) than 4.730 kg/cm^2 of blended fabric knitted by using 20 Nm yarn. Being a thicker fabric, blended fabric knitted in 15 Nm yarn is apt to show high bursting strength. Sitotaw (2017) reported in his study that the structures having higher thickness have higher bursting strength properties.

Maximum breaking load :

If values for maximum breaking load were considered, it has been observed that blended knitted fabric with 15 Nm yarn has less breaking load (185.726 N) than fabric with 20 Nm yarn (196.132 N) in wale wise direction, however, the difference was not significant (t value 0.633). Maximum breaking load for blended knitted fabric with 15 Nm in course wise direction was found as 158.118 N, whereas, that of fabric with 20 Nm yarn was calculated as 138.882 N. A significant ($p \leq .05$) difference has been found in two values with a t value of 2.356. It has been observed that knitted fabric with 15 Nm yarn exhibited more amount of maximum breaking load than knitted fabric with 20 Nm yarn This was due to the fact that as the thickness of the fabric increases, it utilizes more load (Fig. 1).

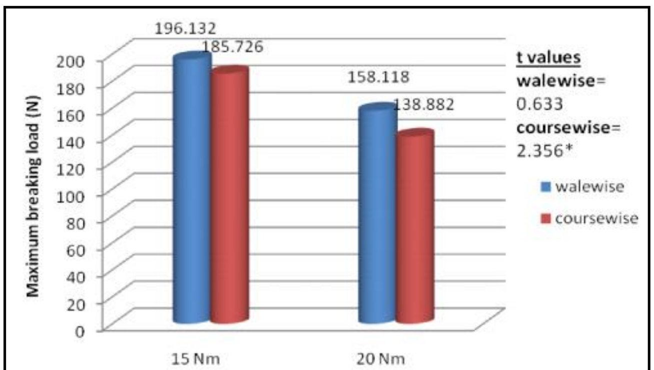

Fig. 1 : Analysis of maximum breaking load of blended knitted fabrics in composition of 50% silk: 50% viscose (*significant at 5 per cent level of significance)

Elongation percentage:

Findings for the elongation percentage (Fig. 2) depicted that blended knitted fabric using 15 Nm yarn has an elongation value of 46.284 per cent, while, fabric with 20 Nm yarn elongated upto 56.912 per cent in the direction of wales. Results clearly reveal that knitted fabric with 20 Nm yarn had significantly ($p \leq .05$) more wale wise elongation properties as in comparison to blended fabric knitted by using 15 Nm yarn with a t value of 3.814. In course wise direction elongation percentage for blended knitted fabric with 15 Nm yarn was 103.572 per cent, while that of fabric in 20 Nm was 114.852 per cent. However, the difference between the two fabrics was not found to be significant in this case with t value of 1.340. Gordon and Hsieh (2006) opined that when load is applied to the fabric, the yarn within the structure moves until it jams and then the yarn elongates, until it breaks. Under the applied load, plain knitted fabric has lower elongation in the wale wise direction than in course wise direction because wale wise jamming occurs earlier than course wise jamming.

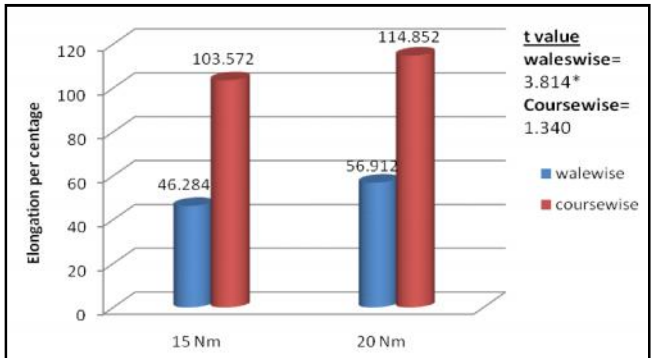

Fig. 2 : Analysis of elongation percentage of blended knitted fabrics in composition of 50% silk: 50% viscose (*significant at 5 per cent level of significance)

Regression analysis:

Table 3 elucidates the findings of regression analysis of bursting strength in relation to two independent variables *viz.* maximum breaking load and elongation percentage in wale wise direction. Regression co-efficient shows positive impact (0.038) of maximum breaking load on bursting strength, which clearly means that bursting strength also rises with rise in the value of tensile strength, however, effect was not found to be significant. As regards to elongation percentage, a negative co-efficient (-0.106) reveal a non-significant negative relationship. R^2 value of bursting strength showed that both breaking load and elongation percentage had 93 per cent variability in wale wise direction. Normal probability curve for wale wise direction shows meager deviation of values from the straight line (Fig. 3).

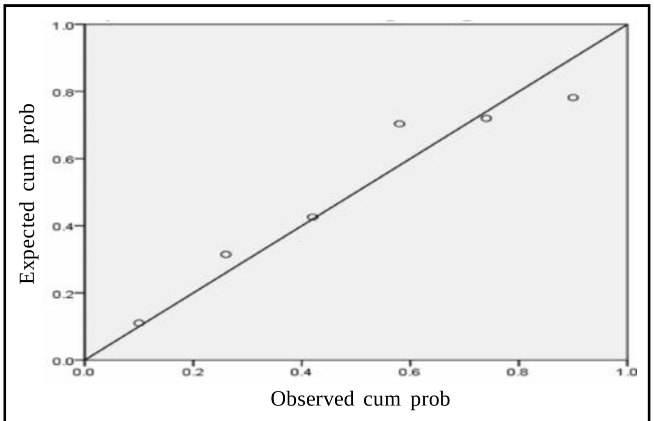

Fig. 3 : Normal probability plot of regression standardized residual (wale wise) dependent variable: bursting strength

Data pertaining to regression analysis of bursting strength in relation to two independent variables *viz.*, maximum breaking load and elongation percentage in course wise direction has been depicted in Table 4. Regression co-efficient (0.027) shows positive impact of maximum breaking load on bursting strength, a linear relationship was identified, which clearly means that bursting strength also rises with rise in the value of tensile strength, however, effect was not found to be significant. As regards to elongation percentage, a negative co-efficient (-0.038) reveal a non-significant negative relationship between elongation percentage and bursting strength. This may be explained by understanding the fact that stronger yarns in the fabric geometry are elastic, and reach the elastic limit earlier than weaker yarns, therefore; break earlier than the later. Less of elongation occurs in stronger yarns and they break early with application of bursting pressure. Degirmenci and Celik (2016), in their study, reported that there was no determined relationship between elongation percentage and bursting strength. R^2 value of bursting strength showed that both breaking load and elongation percentage had 51.8 per cent variability in course wise direction. Normal probability curve for wale wise direction shows minimal deviation of values from the straight line (Fig. 4).

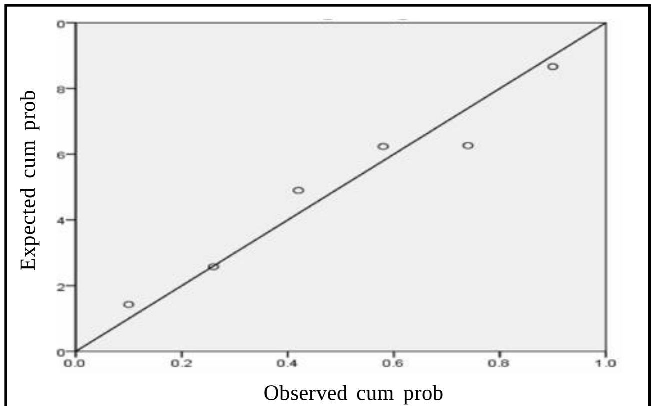

Fig. 4 : Normal probability plot of regression standardized residual (course wise) dependent variable: bursting strength

Table 3 : Effect of wale wise maximum breaking load and elongation percentage on bursting strength of blended knitted fabrics

Bursting strength	Independent parameters	Wales wise			
		Co-efficient	Standard error	t-value	p value
	Constant	3.416	2.758	1.239	0.304
	X_1	0.038	0.008	4.617*	0.019
	X_2	-0.106	0.036	-2.977	0.059
	R^2 (%)	93			

t-value= t statistic value, p= Probability value, * indicate significance of value at P=0.05
X_1= Maximum breaking load X_2=Elongation percentage

Table 4 : Effect of course wise tensile strength and elongation percentage on bursting strength of blended knitted fabrics

Bursting strength	Independent parameters	Course wise			
		Co-efficient	Standard error	t-value	p value
	Constant	6.068	6.180	0.982	0.399
	X_1	0.027	0.028	0.975	0.402
	X_2	-0.038	0.032	-1.183	0.322
	R^2 (%)	51.8			

t-value= t statistic value, p = Probability value, * indicate significance of value at P=0.05
X_1= Maximum breaking load X_2 =Elongation percentage

Conclusion:

The amount of maximum breaking load surely influences bursting performance of blended knitted fabrics. Rise in value of maximum breaking load increases bursting strength as well. In a study by (Ikeuchi *et al.*, 1999), highly significant correlations were noted in between tensile strength and bursting strength. Inventions such as dilatation balloon (Downey, 1994) are clear outcomes of positive relation between tensile strength and bursting strength of materials.

Elongation percentage was found to have negative relationship with bursting strength. Bursting strength decreases with rise in elongation percentage. Chowdhary *et al*. (2018) mentioned that extension is negatively associated with strength. Values of both the parameters were seen to have inverse behaviour in present experiment as well.

Acknowledgement:

We owe sincere thanks to staff members of M.S. Randhawa library, Punjab Agricultural University, Ludhiana, for their co-operation and timely help in successful completion of the work. Financial help from UGC is duly acknowledged.

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