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Article

The Study of Mechanical Properties of Knitted Fabrics: Tear and Bursting Strength

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ABSTRACT

Determination of tear and bursting strength of knitted fabric is important in order to understand resistance and elongation of the fabrics during use. This research aims at examining tear and bursting strength of single jersey polyester knitted fabric both in wale and course wise direction of the fabric based on with or without defects. Fabrics were tested for their tear strength using tensile testing machine and bursting strength using a ball type testing machine which was a recording constant-rate-of-extension-type (CRE). The results showed that the force required to tear the fabric with no defect in wale direction was 180.65N while in the course direction was 159.43N and the elongation till to break was high relative to the fabric which had a defect caused by the initial tear. The knitted fabric with initial tear had good strength and medium elongation. The bursting strength of the fabric was also tested and the results show that the fabric had a relatively high bursting strength because of its structure.

Keywords: Knitted Fabric, Tear Strength, Bursting Strength

Introduction

Strength of a fabric is an significant possessions that decides and effects other fabric presentation properties (Srinivasan et al. 2007). Consideration of fabric strength is essential factor considered when selecting suitable fabric for an intended use. Though the importance of the fabric strength in daily wear is understood, a systematic approach is required to correlate various strength properties with that of the yarn and fabric construction parameters (Teli, Khare, and Chakrabarti 2008). In selection of the appropriate fabrics for the garments or apparels manufacturing, strength is the first property which is considered (Ramakrishna, Cuong, and Hamada 1997). According to literature, the strength of a fabric does not only depend on the yarn strength alone, but also on other yarn properties including fiber type or blend use, yarn twist, yarn count, yarn spinning systems used, yarn bending behavior and frictional properties (Teli, Khare, and Chakrabarti 2008). It is also shown that the fabric geometry, loop density, weave design also has great influence on fabric strength. Some of experiments show that the fabric strength also change during wet processing on the basis of the processing condition (Khedher et al. 2009). In this regard it becomes necessary to find out the best approaches to determine the parameters affecting fabric strength before its manufacturing to ensure the minimum loss of materials, time, energy, labor and resources (Hossain, Datta, and Rahman 2016).

The tear behavior of materials is a major component of their mechanical performance (Semnani 2013). In particular, in the case of protective textiles, the tear resistance is generally among the requirements, for example with protective gloves and firefighter protective suits. A number of researchers have put enormous efforts in understanding the tearing behavior of textile materials. In the case of textiles, most of the work has been done with the tongue tear (trouser) configuration. Some authors have also studied trapezoid and wing tear geometries. The evaluation of the tearing resistance has been performed through maximum force or work determination. When a static load is applied to a pre-tear sample, a tearing area called the Del-zone is formed (Krook and Fox 1945) and arises from the stretching and slippage of longitudinal yarns (yarns parallel to the tear) along the transverse yarns as well as the widening and alignment/jamming of these transverse yarns. Due to contact friction between longitudinal and transverse yarns at the edge of the Del-zone, the load is transferred to the transverse yarns. Rupture occurs when they reach their maximum tensile strength.

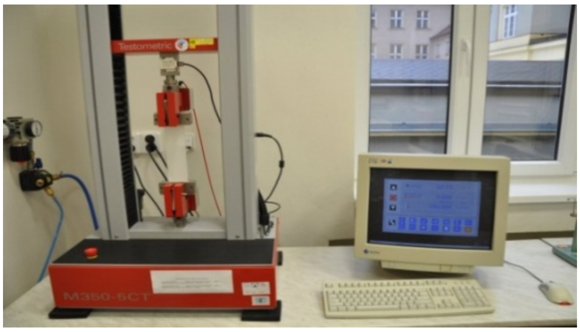
A knitted fabric is tailored to have properties suited for its intended use. For instance, a knitted fabric made for underwear must have high comfort properties(Spencer 2001). In addition to the application fields, mechanical characteristics of knitted fabrics are very essential in downstream processes (Wang, Felder, and Cai 2011). Among the mechanical characteristics of knitted fabrics, bursting strength is of great importance (Freytes et al. 2005). Fabrics are not only exposed to forces in the vertical and perpendicular directions but also they are exposed to multi axial forces during usage. Therefore, tensile and tear strength analysis are not enough for the determination of strength properties of the fabrics against the multi axial forces (Hu and Xu 2008). As a consequence, bursting strength is extremely important especially for knitted fabrics, parachutes, filtration fabrics and sacks (Özbayrak and Kavuşturan 2009). For this reason, evaluation of bursting strength of knitted fabrics is paramount (Ciobanu et al. 2016).

Bursting strength deals with the strength of the fabric when a multi-directional force is applied on it (Ertugrul and Ucar 2000). Especially for compression fabrics that stresses both in wale and course direction at the same time, this method is a good measurement for strength test. Compression extension, fabric thickness (Keller et al. 2007) and weight are important characteristics for engineering different compression garments (Wang, Felder, and Cai 2011). The aim of this study is to analyze the impact of introducing defect on the tear strength properties of knitted fabric based on different angles (0^0 and 90^0) and evaluate the ball bursting strength of single jersey polyester knitted fabric.

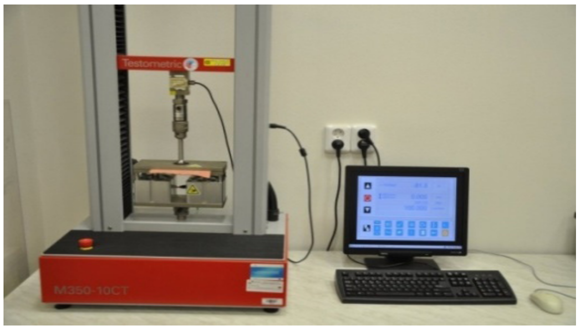
Materials and methods

Materials

The specifications of the fabrics used for this study are shown in Table 1. Table 2 shows the machine specifications used in testing the tear and bursting strength respectively while figure 1 shows the testing machines.



a) Testometric



b) ball bursting

Figure 1.a) Tear testing machine and b) Ball burst testing machine

Structure of Single Jersey Knitted Fabric

Comparable a basic weave for a woven fabric, solitary jersey is the modest form of knitted fabric. It is a direct construction by means of only knit stitches on the face of the fabric. The crown of the loop will be in the direction of the back of the fabric, and only the two legs will be noticeable in the form of a 'V' as show in Figure 2

Characteristics of Jersey Fabric

Single jersey typically has approximately twice the stretch in the width direction compared to the length direction.

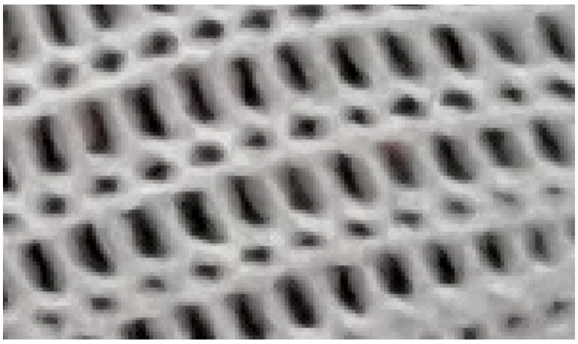
Table 1.Fabric Specification

Material type and Construction	Wales/cm (WPC)	Course/cm (CPC)	Linear density (Dtex)	GSM	Thickness (mm)
Polyester weft knitted Single jersey	18	36	75	163	0.53

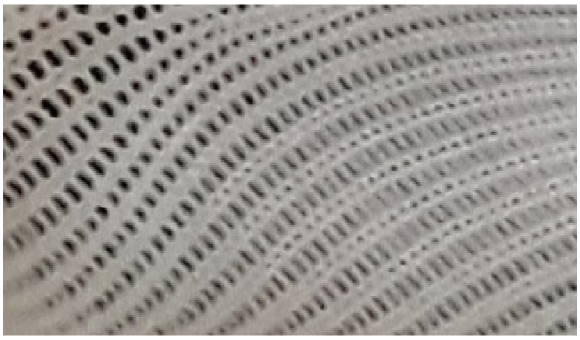
Table 2.Testing Equipment

Machine name	Testing speed	Load cell	Specimen dimension	Testing condition
Testometric	100mm/min	5000 N	(60 × 20) mm	Temprature:22±2 ºC and RH: 65 ±2 %
Ball bursting	100mm/min	5000N	(15×15) cm	

Cut fabrics will unravel from both ends very easily, and fabric thickness is approximately two-yarn diameters and jersey fabrics will curl at the edges. The sides will curl to the back, while the top and bottom edges will curl to the face. If a yarn is broken in a plain jersey fabric; a run will form vertically as the broken loop drops the loops below and above it. The plain jersey knit produces a relatively light-weight fabric and has a very high rate of production.



(a)



(b)

Figure 2.(a & b) Structure of single jersey knitted fabric

Testing Methods

Testing was done based on the fabric properties by introducing a defect as a tear and then tear strength of the fabric in the wale and course direction was evaluated. Fabrics with and without defect based on different angle of formation were tested for their tearing strength using tensile testing machine according to ASTM D2261 testing standard and ball bursting strength according to ASTM D6797 testing standard using constant-rate-of-extension-type recording (CRE) machine.

Data Analysis

The fabric properties were analyzed based on breaking force(N), elongation(mm), stress-strain curve and ball bursting strength on the maximum breaking force. All the data were analyzed using Excel.

Results and Discussion

Tear Strength

Table 3 shows the mean tear strength of ten samples in course direction without defect. Figure 3 illustrates the force-elongations curves of the samples and it shows they behave in the same way.

Figure 3, shows that as the tearing force were applied to the fabric, it increased exponentially until fabric tear. This is because as the force increase, the yarns tend to jam up together requiring high force to elongate and break them. At a higher force, the curve begins to oscillate because of the fabric starts to tear one yarn at a time until at a higher force all jam up yarns ruptures at once.

Table 4 shows the mean tear strength of ten samples in the wale direction with defect.

Figure 4, indicates the force vs. elongation of the fabric tested after a defect was introduced inform of initial tear. From the curve, it can be seen that force increases exponential because as the tearing force is applied to the fabric, the yarns gangs up together at the point of tear requiring higher force to break. Also at a higher force, the curve oscillates, this is because single yarns starts to break until all the yarns at the point of tear fails at once. At this moment, the fabrics tears continuously.

Table 5 shows the comparison between maximum force and maximum elongation of the fabric with defect and without defect.

Figure 5, shows that, the graph of tear strength at different angle and it indicates the force (N) needed to break the knitted fabric at 0 degree (without defect) and at 90 degree (with defect) in the wale and course direction of the fabric respectively.

- Maximum force need to break the fabric
- Maximum elongation till to break the fabric

Figure 5 Maximum force Vs elongation of the tear strength of the fabric

The material which has no defect obligatory high amount of breaking force compared to the fabric that had defect as illustrated in figure 5(a). If the fabric was exposed to initial tearing before applying the required amount of force, the tear propagates based on the slit and the force need to break is reduced because of the maximum resistance of the materials has dispersed during initial tearing. Determination of the resistance of a the materials which has defects or not by applying further tearing is important, especially for medical application areas and measuring the amount of forces needed to break it or its resistance. The elongation (mm) of fabric at 90 degree (with defect) and 0 degree(without defect) in the wale and course direction of the fabric as illustrated in and Figure 5(b), the measurement has slightly elongate with a little force apply because of there is the slippage of individual yarns in the tear area. When the force is apply on it, the

Table 3.Fabric Mean Tear Strength

	Breaking force (N)	Elongation at break (mm)	Elongation (%)	Energy to peak (Nm)	Time to break(Sec)
Min	100.910	75.834	37.917	2.197	45.556
Mean	121.639	99.487	49.744	3.410	60.045
Max	159.430	119.690	59.845	5.520	71.914

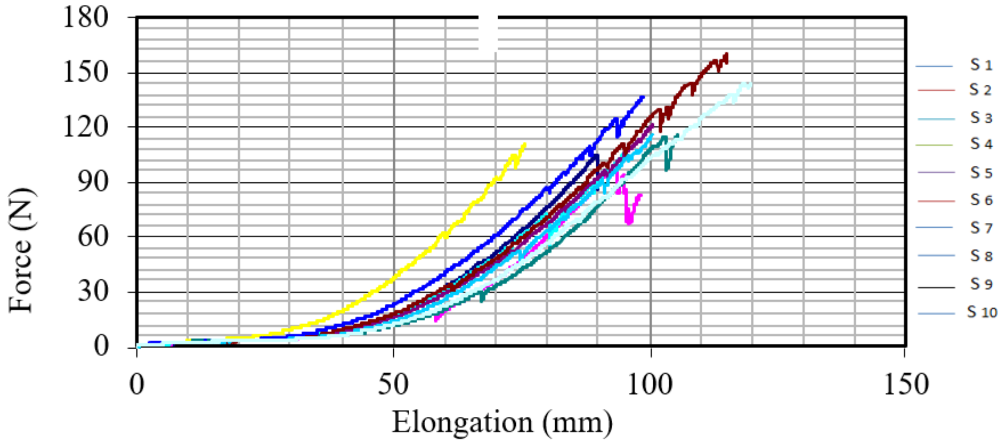


Figure 3.The force vs. elongation in the course direction in the fabric without defect

Table 4.Tear strength of fabric with defects

Number of samples	Elongation at break (mm)	Breaking force (N)	Time to break (Sec)	Energy to peak (Nm)
Min	44.694	52.000	26.865	0.951
mean	54.070	73.076	32.505	1.243
Max	70.456	97.610	42.343	1.484

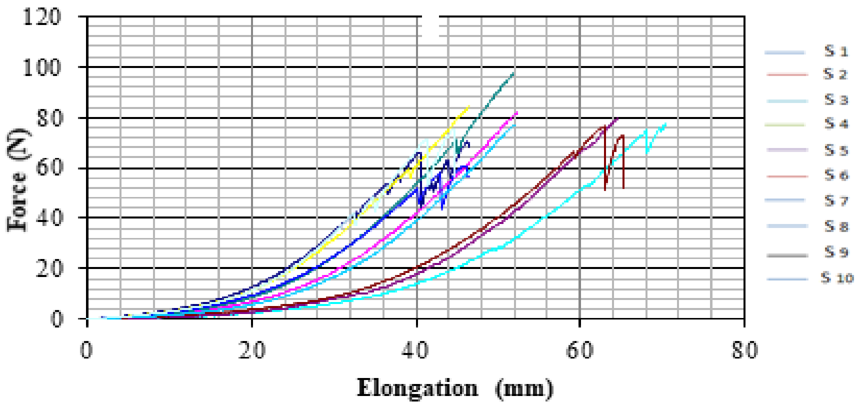
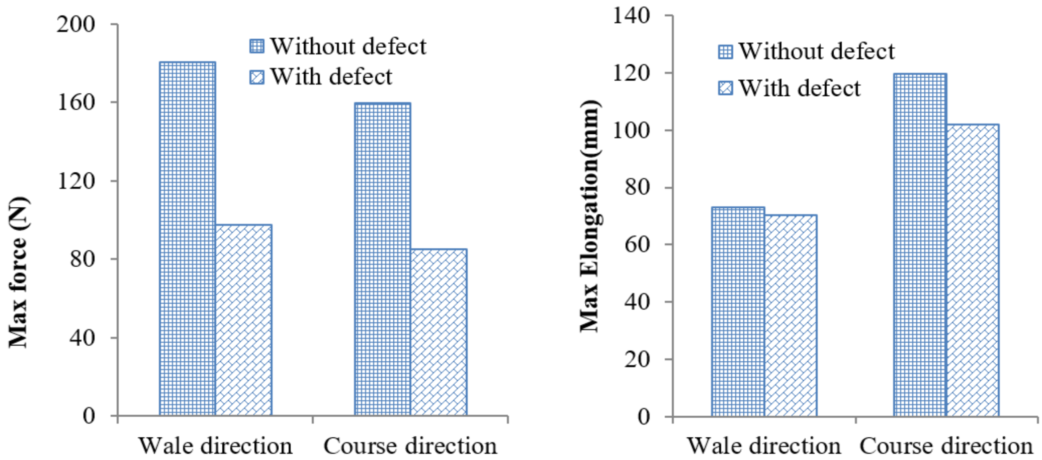


Figure 4.The force vs elongation in the wale direction in fabric with defect

Table 5.Shows the average maximum force and elongation of the fabric

	Samples without defect(0^0)				Samples with defect(90^0)			
	Wale direction		Course direction		Wale direction		Course direction	
No of samples	MF (N)	MEl. (mm)	MF (N)	MEl. (mm)	MF (N)	MEl. (mm)	MF (N)	MEl. (mm)
Average	180.65	73.027	159.43	119.69	97.61	70.456	84.99	101.8

where MF is Maximum force and MEl. is maximum elongation



a) Maximum force need to break the fabric **b) Maximum elongation till to break the fabric**

Figure 5.Maximum force Vs elongation of the tear strength of the fabric

yarn moves with some extent elongation without break and, but the force required to break is less because of the initial tearing. It is known that the elongation of knitted fabric in the course direction is greater than in the wale direction because of loop length. The loop in the wale or needle way has tied at the head and at the leg of the loop and it does not elongate much when the force is applied.

Stress – strain curve

Fabric stress property depends on the force required to break a given cross section area and when the force is applied on the specimen it will elongate and its length change until it breaks is the fabric strain. Stress-strain curve as illustrated in figure 6 indicates the deformation of the knitted fabric in the widthwise direction and the curve is elongated in the axis of strain and shows that the fabric has high amount of elongation in the course direction.

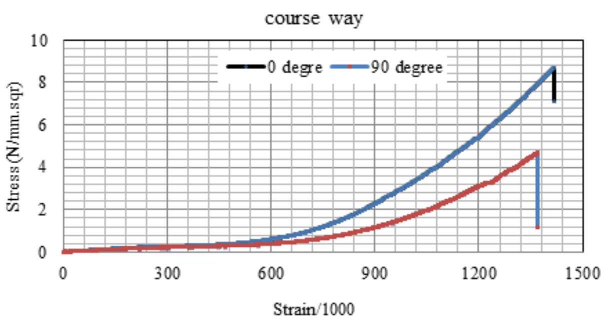


Figure 6.Shows the stress vs strain curve of the fabric in the widthwise

Ball Bursting Strength

The force needed to rupture the fabric (when a ball force is applied perpendicularly) is called bursting strength (Ciobanu et al. 2016). Extension refers to alteration in length due to stretching. Therefore, testing it for various types of knits will be appreciated contribution to the field. The apparatus used included ball burst attachment to a CRE (Constant Rate of Extension) machine. Sample size for these tests is (15 × 15) cm and it requires testing of ten specimens. The machine was operated at 100mm/min and the average results are shown in Table 6 and fabric before and after bursting testing are shown in figure 7.

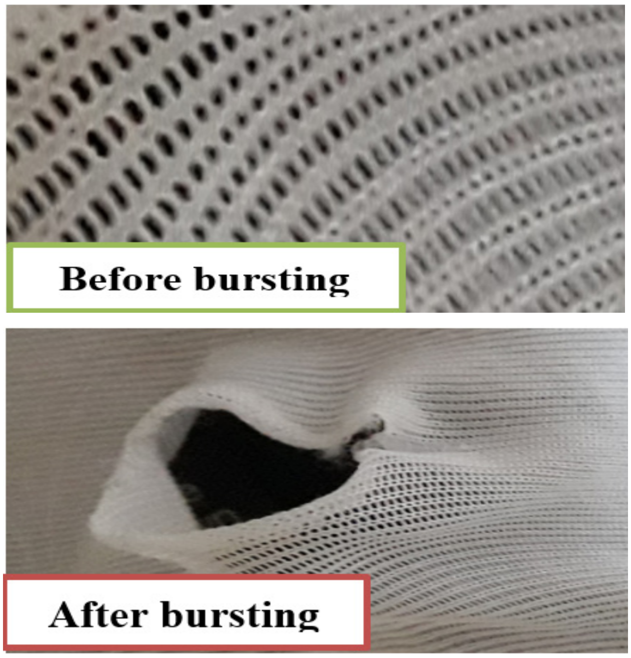


Figure 7.Fabric sample before and after bursting tests

Table 6.The Results of Bursting Strength and Elongation

Test No	Force @ Break (N)	Dist. @ Break (mm)	Energy to Break (N.m)
Min	682.000	22.369	3.883
Mean	786.680	24.181	5.193
Max	867.900	25.897	6.379
S.D.	65.974	1.388	0.901

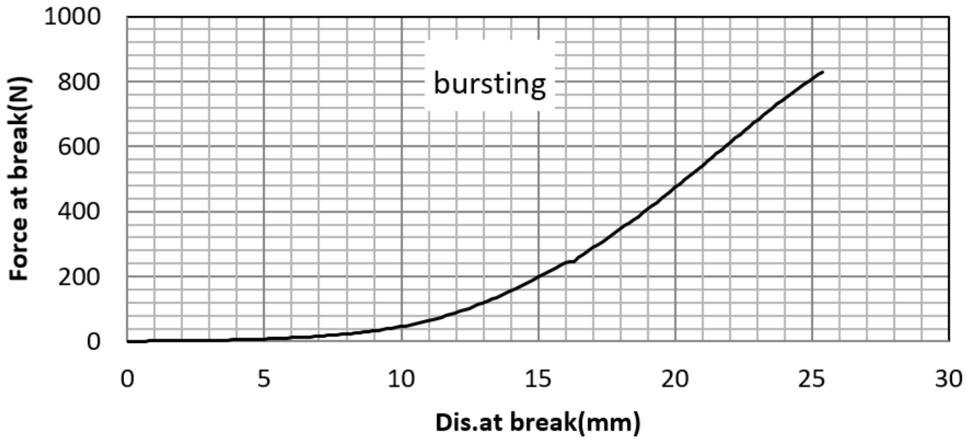


Figure 8. Force Vs elongation curve of ball burst (it is only one graph, where is the comparison)

The figure 8 indicates the graph of bursting strength and its elongation at break and the force is applied perpendicularly downward acts as axial forces which evenly distribute throughout the specimen circularly and it stretches up to burst for a single test of force Vs elongation. As indicated from the graph, the force increases exponential as the elongation increased until final rupture of the fabric.

Conclusion

Knits offer comfort to consumer because of built-in stretch, and are preferred by consumers worldwide. All knits have elasticity that lessens several fitting difficulties additional so than the woven fabrics. The study has described tear strength for knitted fabrics by means of the fabric which has imperfection and one deprived of defect. The tear resistance of the fabric without defect was higher than the fabric with defects because of the impact of initial tearing. Second, the study examined were the bursting strength of the knitted fabric by using the ball burst tester. However, in both cases the stretch ability of fabric is not much but the strength is preferable.

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