Failure Behavior of Polyester/ Lycra Single Jersey Knitted Fabric

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Abstract: The bursting strength property is one of the most important mechanical properties of knitted fabrics and varies according to different parameters. This study investigated the failure behavior of four different samples with different percentage of polyester/ lycra single jersey knitted fabric. Tensile and bursting strength were measured for the samples. The most important conclusion is that adding Lycra loaded the loop with un-balance forces and uneven distribution of stresses in the wale and course directions. Tensile, bursting strength and Young's modulus gave high coefficient of correlation with lycra percentage.
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1. Introduction

Many researchers investigated bursting strength of knitted fabrics taking into consideration the different parameters of knitted fabrics. The bursting strength varies according to different parameters such as spinning technology, fabric structure, raw material, blended materials with Lycra, and machine settings. Spinning technology changes the yarn structure and has a significant effect on the bursting strength. It was found that bursting strength values of compact yarn fabrics are higher than combed ring fabrics. It is due to higher breaking strength and elongation of compact yarn than that of combed yarn [1, 2]. Yarn counts have a significant effect on knitted bursting strength where as yarn count increased, the bursting strength of the knitted fabrics decreased [3, 4]. The ring rotor and air vortex yarn were used to investigate the bursting strength of knitted fabrics. The yarn made from ring rotor spinning system has the highest bursting strength due to high tenacity and uniformity, the air vortex yarn fabric follow the strength value of its respective yarn tenacity. The ring yarn fabric has good bursting strength (181.6 lbs/inch^2) [5]. Microdenier fabrics gave higher bursting strength compared with normal denier because in case of microdenier yarns the fact that more number of fibers can be accommodated in the yarn cross section for the same yarn diameter [6]. Strength affects on dimensional stability of knitted fabrics. It was used tuck loops in corporate with knit loops in wales and courses direction to derivatives of single Jersey knit. Higher presence of tuck in wales and course direction affected the bursting strength. It was observed that bursting strength decreases with the increasing of tuck loops in same wales or courses than plain single Jersey [7].There is inversely proportional between loop length and bursting strength where as the loop length increases the bursting strength decreases. The significant effect of the loop length on the bursting strength can be attributed to the less loop length associated with increasing the fabric weight which leads to higher bursting strength [3, 8]. A comparison of blended cotton with flax showed a significant effect on bursting strength of knitted fabrics. Fabrics made from cotton blended with cottonised flax yarns generally had lower bursting strength than those made from 100% cotton yarn. In addition to that there were significant differences among the 100% cotton fabrics and its blends with flax [4].Spandex yarn increases the bursting strength in knitted fabrics. The breaking load in the case of the full plating fabric where it was added the spandex yarn in every course is higher than for both the pure cotton fabric and the half plating fabric. It was concluded that the fabric produced from both cotton and spandex yarns is the most comfortable fabric [9]. Bursting strength of cotton/elastane single Jersey fabric is higher than the 100% cotton single jersy because it needs more pressure and more time to burst the knitted fabric. The amount of Lycra is significant effect on the bursting strength, as amount of Lycra increase, the bursting strength increase, because the Lycra made the fabric tighter [10]. The relationship between knitting machine gauge and bursting strength made from different structures was studied. It was concluded that as the machine gauge increases the bursting strength of the knitted fabrics increases [11]. It was investigated the behavior under biaxial tension of two glass knitted fabrics, a rib and Milano weft knit. The ultimate deformation in both wale and course directions was determined at different displacement ratios. It was predicting a geometrical model for ultimate deformation which agreement with the experimental results [12]. Yarns with elastomeric components increase tightness factors, giving better dimensional stability to single jersey fabrics [13]. In this work, the analysis of the effect of using different Lycra percentage on failure behavior of Polyester/Lycra single Jersey knitted fabric under tensile and bursting loading were investigated.

2. Material and Methods

2.1 Material

The specifications of four single Jersey knitted fabrics with different Lycra percentage are given in table (1).

Table (1) single Jersey knitted fabrics specifications

Sample no	1	2	3	4
Material	100% Polyester	12% Lycra, Polyester/Lycra	14% Lycra, Polyester/Lycra	16% Lycra, Polyester/Lycra
Wales/cm	18	17	16	16
Courses/cm	20	19	18	20
Yarn count (Nm)	50	50	50	50
Loop length (mm)	0.28	0.29	0.3	0.32
Fabric thickness (mm)	0.52	0.51	0.51	0.5
Fabric weight (gm/m^2)	180	145	148	150

2.2 Apparatus

The knitted samples were tested for tensile strength and bursting strength .The bursting strength was tested according to ASTM D 6797–02. The tensile strength tester (Tenso Lab), shown in (Fig. 1), was used with load cell capacity 1000 N and loading rate was 350 mm/minute.

Fig.1. The tensile strength tester

3. Results and Discussions

3.1. Knitted fabric deformation

The analysis of knitted fabric structure indicates that deformation under the load in one direction will change the loop forms in the perpendicular direction, and the deformation of the loops under the force will play an important role in determining the mechanical behavior of the knitted fabric and its end use. The feed of Lycra yarn during the knitting process, which posses high extensibility, will lead to the change of the knitted fabric extensibility in both the wale and course directions.

In the cases of applying uniaxial or biaxial loading on the knitted fabric, the interchanging of the loop dimension under load, as well as the change of the direction of the loop relative to the load, will affect both fabric breaking load and extensibility. During tensile and bursting loading tests, the shape of single Jersey loop changes as illustrated in (fig. 2). In the case of fabric in relaxation condition, the single Jersey loop appears as shown in (fig. 2-a). During tensile strength test in wale direction (fig. 2-b), the loop legs were extended and locked until they reach the jamming condition. That will depend on the yarn properties and its maximum extension till failure. Low stress of the yarns and high deformation of the knitted fabric usually expected for knitted fabrics.

3.2. Tensile strength

Figure (3) and Figure (4) illustrate the relations between load-extension curves in both wale and course directions. The values of breaking load and breaking extension in wale direction are higher than the breaking load values in course direction. Figure 3 illustrates that until the Polyester/Lycra fabric reaches the extension 60 mm, the fabrics have the same behavior of the Polyester knitted fabric. On approaching, the jamming condition, the Young's modulus increases.

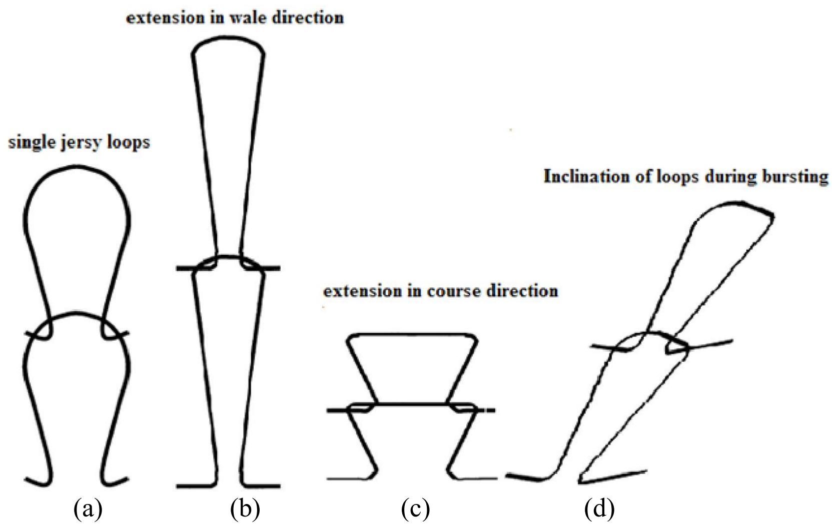

Fig.2. Change of loop shape during tensile and bursting tests.

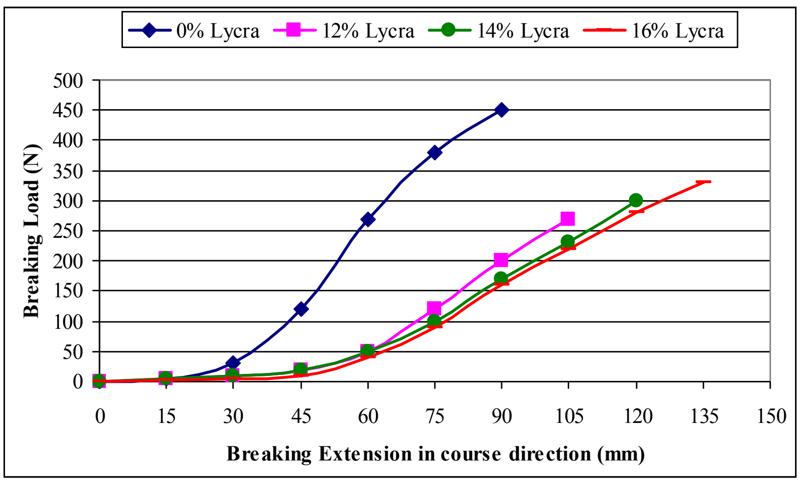

Fig.3. Effect of Lycra % on fabric tensile strength in wale direction.

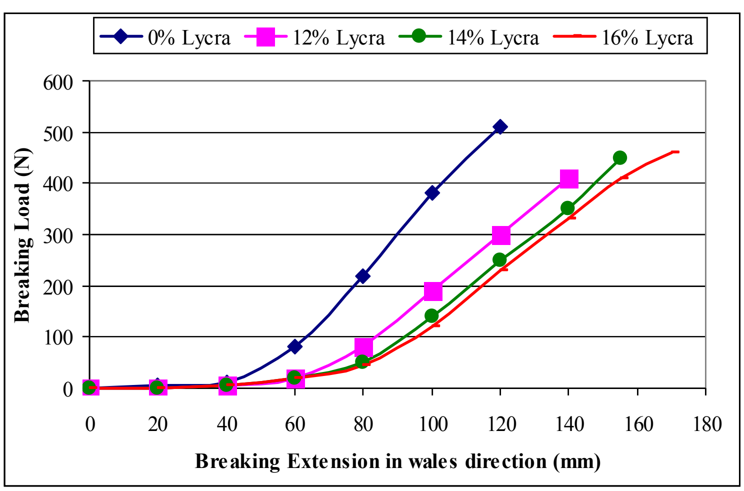

Fig.4. Effect of Lycra % on fabric tensile strength in course direction

The fabric with 100% Polyester gives the highest breaking load, Young's modulus and lowest breaking extension compared with Polyester/Lycra knitted fabric. This may be due to the Lycra increasing the unbalanced force between the face and back single Jersey knitted fabric so the snarling of the fabric edge increases as shown in (fig.5), leading to the failure of the fabric at less load compared to 100% Polyester knitted fabric. On the other side, in the three fabric samples with different Lycra percentage, the increase of Lycra percentage gives higher breaking extension and breaking load. As the Lycra percentage increases, the Young's modulus decreases. The values of Young's modulus for the different single Jersey knitted fabrics are illustrated in (fig. 6) in wale and course directions. It is clear that the 100% Polyester knitted fabric gave the highest values of the Young's modulus in both directions than fabrics with Polyester/Lycra knitted fabrics.

In the other hand, as percentage of Lycra increases, the Young's modulus decreases because of unbalanced force on the loop. The contraction of the knitted fabric under uniaxial loading leads to the inclination of the loop to the direction of the applied load.

Fig.5. Snarling of single Jersey edge during tensile test.

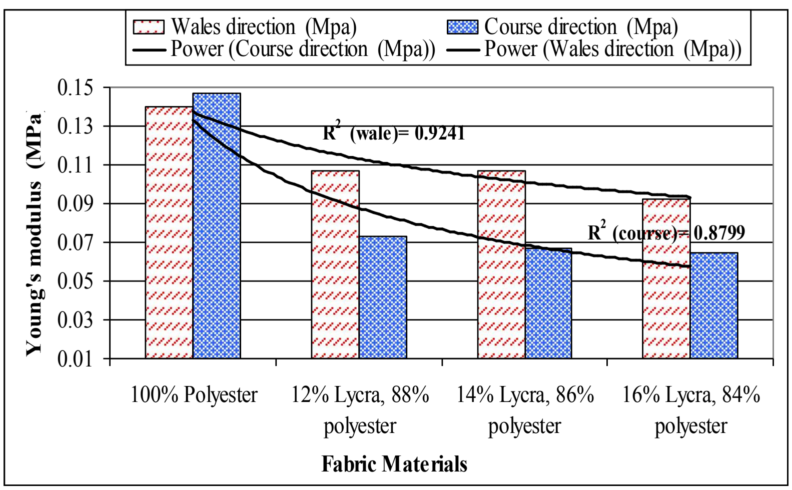

Fig.6. Effect of Lycra percentage on young's modulus in wale and course directions (MPa)

The use of Lycra filament having higher recovery properties will affect the tightness of the knitted fabric. This will affect the value of the fabric extension under the load till it reaches the jamming condition under uniaxial load. The percentage of Lycra expectedly changes the load elongation curve either in the wale or courses directions.

3.3. Bursting strength

In bursting strength test, the loops round to take the curvature of the bursting ball as it moves to burst the fixed fabric. Bursting test applies a concentrated force on the center of a fabric. In the case of equal wale and course densities, the bursting test acts as biaxial tensile test. It is because the force will be equal in the all directions. On the other side, if there are different stitch densities in wale and courses, it will not give the same effects on the yarn stress. The distribution of the extension on the fabric during the bursting test might be not equal in the wale and course directions. This will add a stress concentration on the wale and course line at the top of the ball.

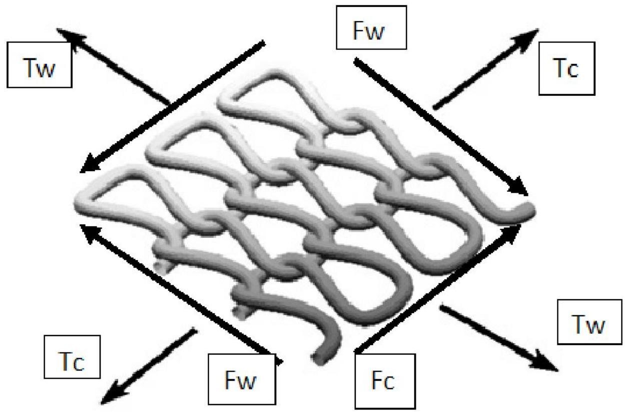

Fig .7. knitting structure under biaxial loads [14].

Stage (1) Stage (2) Stage (3)

Fig.8. Stages of deformation of single Jersey on bursting tester.

In the above case (fig. 7), values of Tw and Tc are not equal and the value of the shear forces Fw and Fc on the fabric element will not be equal too. This will skew loops as shown in figure (2-c and d). The skewed loops lead to applying higher stress in the yarn under a certain value of load. It was found that the degree of skewed loop will depend on the percentage of Lycra. Figure 8 shows three stages of deformation of single Jersey on bursting tester. It is obvious that as the force increases in unbalanced knitted fabric loop, the loops in wale straight and the loop legs close and lock in the sides of the bursting ball. Stage 3 shows that the loops open due to the highest force in the center. Both wales and courses will be stressed according to the radial position on the surface of the bursting ball. With the maximum stress acting on the wales and courses, that will be at the top point of the ball. The effect of the Lycra percentage on the bursting strength of single Jersey knitted samples is given in (fig.9). The bursting strength of the Polyester knitted fabric is higher than Polyester/Lycra knitted fabric, as the Lycra percentage increases, the bursting strength increases too.

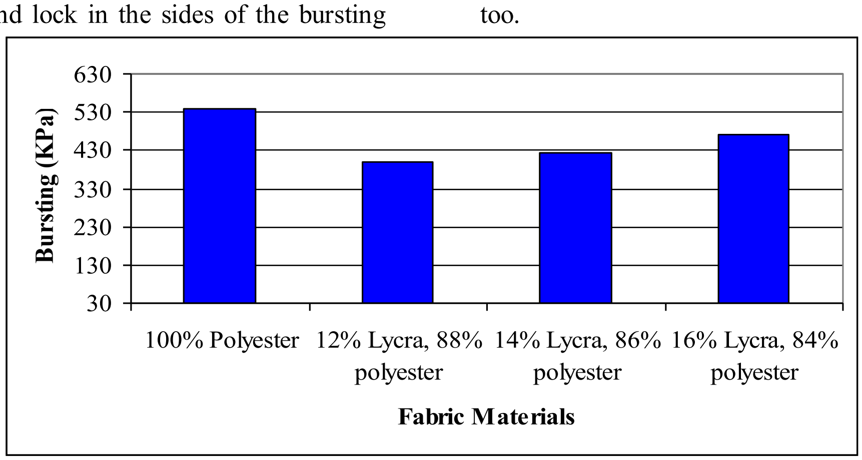

Fig.9. Effect of Lycra percentage on fabric bursting strength (kPa)

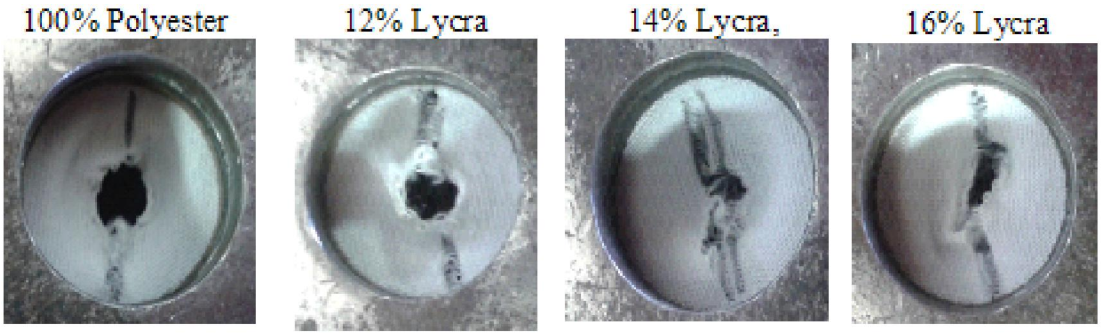

Fig.10. Shapes of fabric deformation on bursting tester.

In the case of knitted fabric with equal values of jamming extension for wales and courses, both will be subjected to the equal values of forces and failure in both directions is expected. The failure of the sample in bursting test will be a circular hole. This is in the case of 100% Polyester knitted fabric. If the jamming of a knitted fabric in the directions of the wale and course is not occurred at the same extension, biaxial force in this case causes expected different deformation of the fabric in the wales and courses directions. The jamming takes place under the same values of fabric extension in one direction earlier than in the other. Fabric failure will take place in the wale or course direction that has reached earlier jamming condition. In our cases, the wales reaches the jamming state earlier and yarns break as illustrated in figure (10). The ravels are happened in wale direction not in course. For single Jersey Polyester/Lycra knitted fabrics, the correlation between Lycra percentage and bursting, tensile strength in wale and course direction is found to be high (coefficient of correlation are 0.98, 0.94, respectively), while the Young's modulus is also highly correlated with the percentage of Lycra (coefficient of correlation are -0.86, -0.96, respectively).

4. Conclusion

It can be concluded that Lycra percentage changes the failure behavior of single Jersey knitted fabrics. Adding Lycra to the fabric leads to the unbalanced forces on the loop skewing loops. Lycra presence in a knitted Jersey fabric resulted in the reduction of tensile and bursting strength and reduction of Young's modulus and increasing the breaking elongation compared with 100% polyester. The increase of Lycra percentage results in the uneven distribution of stresses in the wale and course directions. In order to get balanced fabric under bursting load, the loops in the direction of lower jamming extension should be strengthen by the increasing the number of loops per centimeter in this direction.

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