The Effect of Sample Diameter and Test Speed on Bagging Behaviour of Worsted Fabrics

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Abstract

In this research, the effect of test speed and sample diameter on bagging behavior of worsted fabrics was investigated. Circular clamps in 56, 61, 66, and 71 mm diameter were constructed and then mounted on an Instron Tensile Tester machine. Different worsted fabrics with 45-55, and 20-80 wool-polyester fiber blend ratios were prepared and then the bagging behavior of these fabrics at different test speed (5.0, 6.0, and 7.5 mm/min) and under five cycles were investigated. The different bagging parameters including maximum bagging force at the first and last cycle, bagging resistance, fatigue and residual bagging height were calculated.

The result shows that the test sample diameter significantly affects on bagging behavior of worsted fabrics. With increasing test sample diameter, different bagging parameters significantly decrease. It is shown that bagging fatigue and residual bagging height of worsted fabrics tested at 7.5 mm/min speed significantly are higher than at 5 and 6 mm/min speeds. However, the result of experiment shows that the effect of test speed on bagging force and bagging resistance is in-significant. The results of this research revealed that worsted fabric samples with higher wool fiber content exhibited lower bagging force, bagging fatigue, bagging resistance and residual bagging height.

Keywords: Bagging; Worsted fabrics; Sample diameter; Test speed; Bagging parameters; wool-polyester fibres

1. Introduction

Fabric bagging is a three dimensional deformation of a fabric sheet subjected to a normal force. This deformation is a permanent deformation that occurs in knee, elbow and backside. The subject of bagging has been studied by many researchers both theoretically and experimentally [1-14]. A comprehensive literature survey of this subject is given in recent publications [7,9-11].

There are some factors influencing bagging deformation of fabrics. They include fibre- yarn mechanical properties, fabric design and structural properties [3], dimensions of sphere and fabric [1,2,6,8-12] and test speed [1,9,12]. These two latter factors are decisive in fabric bagging testing and also in clothing wear. Sengoz [1,9] examined the effect of frame shape and dimension, sphere dimension and pressing speed (test speed) on bagging behavior of woven cotton fabrics. She found that the square frame with 6 cm dimension, the sphere with 2 cm dimension at 7.5 mm displacement, and the test speed of 60 mm/min at one hour relaxation time gave the highest residual bagging height value. Kisliak [2] investigated the spherical deformation of fabric and calculated the membrane strain of fabric in terms of geometrical parameters of deformation and in particular the dimensions of sphere and fabric. Zhang *et al.*[6], theoretically investigated the stress distribution in the spherical corona and in the conical section based on the membrane shell theory and included the dimensions of fabric and sphere in their theoretical analysis. Abghari *et al.* [8] simulated the fabric bagging behavior using Finite Element Analysis Method and included the dimensions of fabric and sphere as the geometrical parameters. In a recent theoretical investigation, Amirbayat [10] predicted the fabric strain and bagging force in terms of fabric elastic tensile properties, bagging angle and sphere and frame (fabric) dimensions. The theoretical results shows that increasing the Poisson's ratio and the relative size of the ball, that is the ratio of ball to fabric radius, requires higher forces to deform the fabric to a given bagging displacement

It may be considered that there is not enough information to indicate to some extent the fabric and ball dimensions and also test speed influence the bagging behavior of worsted fabrics. Therefore, the aims of this work are to investigate the effects of test speed and fabric sample and ball dimensions on worsted fabric bagging behavior.

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2. Experimental

2.1 Material

In this work, 6 wool/polyester woven worsted fabrics were used. The fabric specifications are shown in Table 1. In addition, the fabric physical properties including thickness, bending rigidity in warp and weft directions, tensile strength, elongation and tensile initial modulus in warp and weft directions were measured [12]. Table 2 shows the results of fabric physical properties.

Table 1 Fabric specifications

Fabric ID	Construction	Fibre Composition	Yarn Count (Nm) Warp	Yarn Count (Nm) Weft	Weight (g/m^2)	Yarn density Ends/cm	Yarn density Picks/cm
1	Twill (2/1)	W20 P80	40	40	178	19	31
2	Twill (2/1)	W20 P80	40	35	209.7	18	29
3	Twill (2/1)	W20 P80	40	35	203.7	17	29
4	Twill (2/1)	W55 P45	40	30	211.9	20	29
5	Twill (2/1)	W55 P45	40	30	215.5	20	30
6	Twill (2/1)	W55 P45	40	35	218.5	22	32

- W = Wool, P=Polyester

Table 2. Fabric physical properties

Fabric	Bending rigidity (μNm) Warp	Bending rigidity (μNm) Weft	Thickness (mm)	Tensile Strength (N) Warp	Tensile Strength (N) Weft	Elongation (%) Warp	Elongation (%) Weft	Tensile Initial Modulus (N) Warp	Tensile Initial Modulus (N) Weft
1	25.67	16.756	0.45	952.67	584.45	23.9	23.7	1353.84	306.96
2	34.513	23.746	0.602	983.19	1298.38	32.09	40.67	781.38	1628.8
3	12.347	10.482	0.519	1033.48	854.01	35.38	33.1	855.59	321.67
4	35.492	25.292	0.608	938.21	629.67	34.08	27.07	467.69	551.99
5	33.28	22.51	0.596	873.26	544.93	29.57	24.32	379.13	306.27
6	32.301	25.073	0.562	753.81	442.68	35.89	27.33	455.83	247.08

2.2.Fabric Bagging Testing

To investigate bagging behavior of woven fabrics, an Instron tensile tester (Model 5566) was used (Figure 1). An aluminum stand with respectively inner and outer diameters of 10.5 and 11.8 cm was constructed and then mounted on the bottom jaw of tensile tester. A steel ball (sphere) with a diameter of 48 mm is attached to the upper jaw of tensile tester. 4 circular rings with inner diameter of 56, 61, 66, and 71 mm were constructed to hold fabric sample for bagging testing (Figure 2). In this way, 4 relative ball diameter (0.676, 0.73, 0.786 and 0.86), that is the ratio of ball diameter to sample diameter were used. The ring holders consist of upper and lower rings. The bottom ring has a special grooved surface in order to provide enough surface friction for fabric. The fabric samples with diameter of 61, 68, 71, and 78 mm is placed in a corresponding circular ring. Before clamping of fabric samples by screw, a special plastic circular stand was used to maintain fabric sample horizontally without any folding or buckling. After clamping fabric sample, the plastic stand is removed to make bagging testing. The crosshead speed was regulated at 5, 6, and 7.5 mm/min. The bagging height was set at a predetermined value of 12 mm and all tests were initiated under a preload of 1.3 N pressure force. For each fabric sample, the cyclic loading was performed 5 times and 5 tests were investigated. All experiments were carried out under conditions of 45% ±5% r.h., 25° ±3°C.

Fig. 1. A photograph of the fabric bagging tester

Fig. 2. A typical photo of a circular ring holder

2.3. Parameters Investigated:

A typical force-traverse for 5 cyclic bagging test is shown in Figure 3. The maximum load and corresponding work of loads and hysteresis percentage at first and last cycles are calculated and then bagging resistance, bagging fatigue and residual bagging height are calculated according to Zhang *et al.*[13,14]test method. The results of experiments were statistically analyzed using ANOVA test method [12].

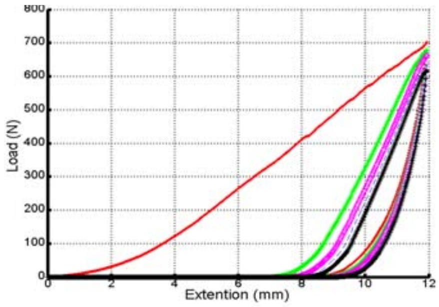

Fig. 3. A typical picture of force-traverse curve for 5 cyclic bagging test

3. Results and Discussion

3.1. Effect of test speed and sample diameter on maximum bagging force

As shown in Figures 4 to 7, the maximum bagging forces in the first and last cycle significantly decrease with sample diameter. This is because as sample diameter is increased, the ratio of ball diameter to sample diameter is decreased resulted a lower strain and hence a lower bagging force in the fabric. This result is in agreement with Amirbayat [10]. In his theoretical work, he indicated that as the ratio of ball diameter to sample diameter decreases, a lower bagging force is obtained. Statistical analysis performed on the maximum bagging force data reveals that the difference between the bagging force results for fabrics tested at two sample diameter of 66 and 71 mm is not statistically significant at the 5% level. Test speed has also no significant influence on maximum bagging force. It is also shown (Figures 3.25 and 3.30) that fabric with a lower wool fibre content has a higher maximum bagging force in the first and last cycle of loading. This is because worsted fabrics with lower wool content exhibited higher elastic tensile modulus compared with fabrics with higher wool content.

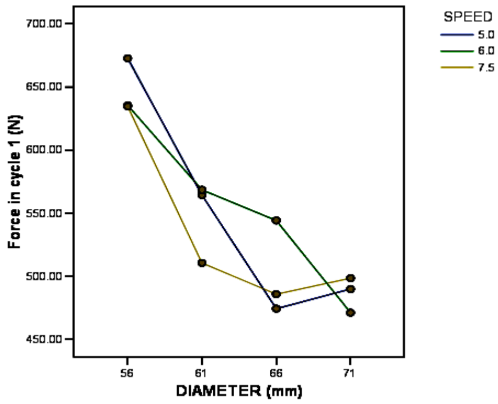

Fig. 4. Effect of sample diameter and test speed on maximum bagging force in the first cycle

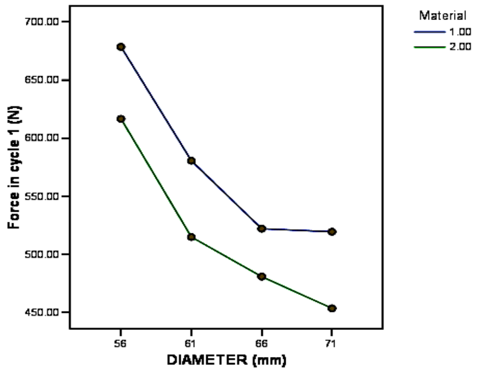

Fig. 5. Effect of sample dimeter on maximum bagging force in the first cycle for two groups of worsted fabrics (1; 20/80 wool/polyester, 2; 45/55 wool/polyester)

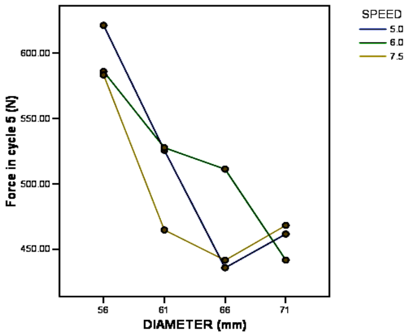

Fig. 6. Effect of sample diameter and test speed on maximum bagging force in the last cycle

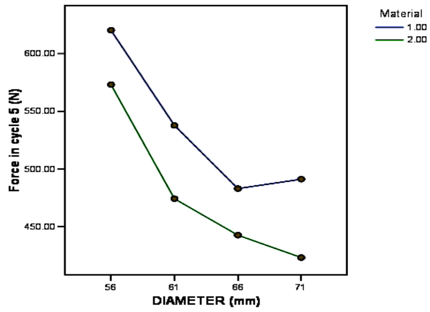

Fig. 7. Effect of sample diameter on maximum bagging force in the last cycle for two groups of worsted fabrics (1; 20/80 wool/polyester, 2; 45/55 wool/polyester)

3.2.Effect of test speed and sample diameter on fabric bagging resistance

As shown in Figures 8 to 9, with increasing sample diameter, the bagging resistance is non-linearly decreased. The statistical analysis results indicated that the effect of sample diameter on fabric bagging resistance is significant. However, test speed has no significant influence on fabric bagging resistance. As also shown in Figure 9, fabric with higher wool fibre content exhibits a lower bagging resistance value. The lower bagging resistance of fabrics with higher wool content can be attributed to the viscoelastic properties of wool fibre [3] as well as to the lower elastic tensile modulus of wool fibre.

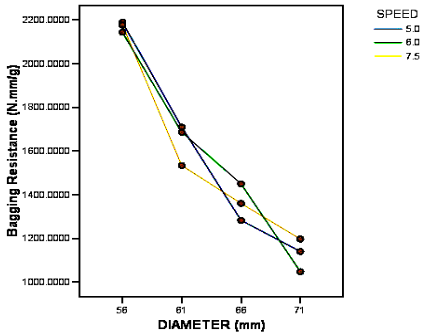

Fig. 8. Effect of sample diameter and test speed on bagging resistance

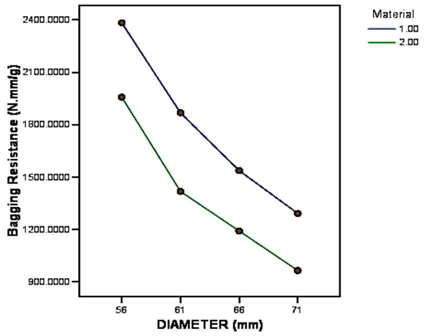

Fig. 9. Effect of sample diameter on bagging resistance for two groups of worsted fabrics (1; 20/80 wool/polyester, 2; 45/55 wool/polyester)

3.3.Effect of test speed and sample diameter on fabric bagging fatigue

The relationships between fabric bagging fatigue, sample diameter and test speed are shown in Figures 10 to 11. The statistical analysis results revealed that both sample diameter and test speed significantly influenced fabric bagging fatigue. It is shown that at test speeds of 5 and 6 mm/min, the difference between the results is in-significant. However, at higher test speed (7 mm/min), particularly at 66 mm sample diameter, fabric bagging fatigue results is significantly higher than other test speed values. Similar to bagging resistance results, increasing sample diameter significantly decreased fabric bagging fatigue. This result is attributed to the lower bagging force and hence lower elastic stored energy at higher sample diameter level. As also shown in Figure 11, fabric with lower wool fibre content has a higher bagging fatigue.

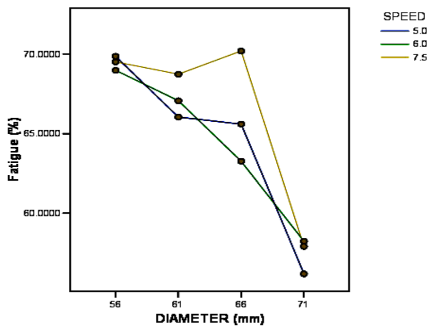

Fig. 10. Effect of sample diameter and test speed on bagging fatigue

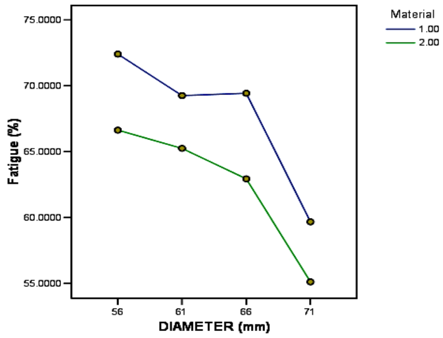

Fig. 11. Effect of sample diameter on bagging fatigue for two groups of worsted fabrics (1; 20/80 wool/polyester, 2; 45/55 wool/polyester)

3.4.Effect of test speed and sample diameter on fabric residual bagging height

The statistical analysis results revealed that both sample diameter and test speed significantly influenced fabric residual bagging height. As shown in Figure 12, with increasing fabric sample diameter, the residual bagging height is significantly decreased. It is shown that at sample diameter of 56 and 71mm values, the difference between the experimental results is significant. However, for fabric tested at 61 and 66 mm sample diameter values, the results is statistically in-significant. Sengoz [1,9] also indicated that increasing the circular and square frames dimension resulted to a lower residual bagging height value. Similar to the fabric bagging fatigue results, at test speeds of 5 and 6 mm/min the difference between the results is in-significant. However, at higher test speed (7 mm/min), worsted fabric exhibits higher residual bagging height value. As also shown in Figures 13 to 14, fabric with lower wool fibre content has a higher residual bagging height. Zhang *et al.*[5] also obtained a higher residual bagging height for polyester fabric.

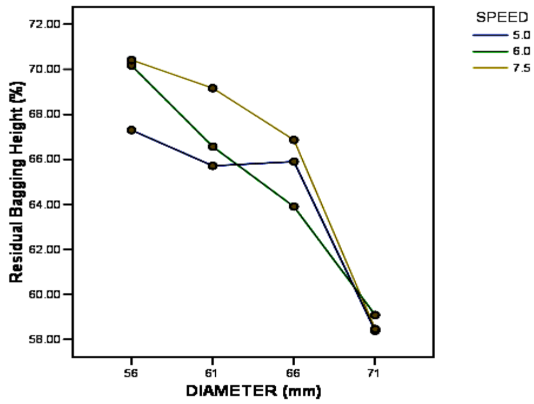

Fig. 12. Effect of sample diameter and test speed on residual bagging height

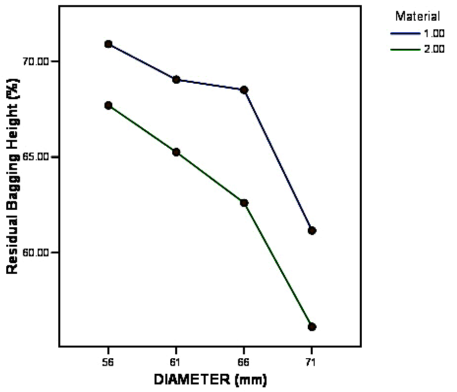

Fig. 13. Effect of sample diameter on residual bagging height for two groups of worsted fabrics (1; 20/80 wool/polyester, 2; 45/55 wool/polyester)

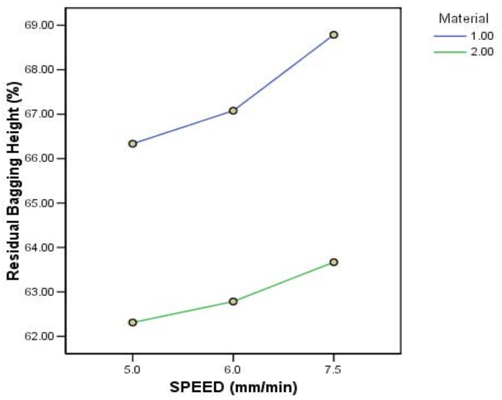

Fig. 14. Effect of test speed on residual bagging height for two groups of worsted fabrics (1; 20/80 wool/polyester, 2; 45/55 wool/polyester)

4 Conclusion

The aim of this work was to investigate the effects of test speed and sample diameter on bagging behavior of worsted fabrics. Circular clamps in 56, 61, 66, and 71 mm diameter were constructed and then mounted on an Instron Tensile Tester machine. Two groups worsted fabrics with 45-55, and 20-80 wool-polyester fiber blend ratios were prepared and then the bagging behavior of these fabrics at different test speed (5.0, 6.0, and 7.5 mm/min) and under five cycles were investigated. Different bagging parameters including maximum bagging force at the first and last cycle, bagging resistance, fatigue and residual bagging height were analyzed.

The results show that with decreasing ball to sample diameter ratio (increasing test sample diameter), different bagging parameters significantly decrease. The results of experiment shows that worsted fabrics tested at 7.5 mm/min test speed exhibited higher residual bagging height and bagging fatigue values than at 5 and 6 mm/min test speeds. However, test speed has no significant influence on bagging force and resistance. The experimental results also revealed that worsted fabric samples with higher wool fiber content exhibited lower bagging force, fatigue, bagging resistance and residual bagging height.

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