Effects of Wool Fiber Diameter and Bulk on Fabric Bursting Strength

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Abstract: In the present study the Egyptian Barki wool fibers were graded into five groups: coarse fibers with high bulk (G1), coarse fibers with low bulk (G2), fine fibers with high bulk (G3), fine fibers with low bulk (G4) and (G5) non-graded fibers (control). Results in the present paper indicate that G3 had the highest bursting strength among all groups, while G2was the lowest one. Previous result could be explained by the ability of fine fibers to stretch rather than being break because of crimps in addition to the springy behavior which makes these fibers more able to stretch under tension rather than cut. For that, bursting strength had a highly significant and positive correlation with bulk (r = 0.53), resilience (r = 0.67), crimp (r = 0.69) and staple strength (r = 0.77). Bursting strength had a negative with highly significant correlation with fiber diameter (r = - 0.69) and medullated fiber percentage (r = - 0.69). Also bursting strength had a negative and highly significant correlation with all irregularity measurements (r = - 0.68 with thin places, r = - 0.95 with thick places and r = - 0.60 with neps). Bursting strength also increased with increasing whiteness (r = 0.43), while decreased with increasing yellowness (r = -0.62). A highly significant positive correlation found between bursting and Tog (r = 0.83).

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1. Introduction

Tensile strength tests are usually used for woven fabrics, where there are definite warp and weft directions in which the strength can be measured in both directions, while bursting strength is an alternative method of measuring strength in which the material is stressed in all directions. Fabric strength is an important property that decides and influences most other performance of the fabric. Individual factors like twist, count and cover affected on the strength behavior of the fabric (Peyton *et al.,* 1993 and Bernard *et al.,* 1983). The present study discuss the correlation of fabric bursting strength coming from raw Barki wool with high and low bulk in both fine and coarse fibers with wool, yarn and other fabric characteristics.

2. Material and methods

The experimental work was designed to study the extreme variability in fineness and bulk of Barki wool fibers and its impact on bursting strength properties of wool fabrics. The Egyptian Barki wool fibers were graded into five groups: coarse fibers with high bulk (G1), coarse fibers with low bulk (G2), fine fibers with high bulk (G3), fine fibers with low bulk (G4) and G5(non-graded fibers as control group).

Raw Wool Measurements

Loose wool bulk (BUL) and resilience (RES) was measured using WRONZ loose wool Bulkometer (Dunlop *et al.,* 1974).Fiber diameter (FD) was measured using Image analyzer (LEICA Q 500 MC) with lens 4/0.12. A section of 0.2 mm in length was cut by a hand-microtom at a level of 2cm from the base of the staples of each sample. These cuttings were put on a microscope slide with 2-3 drops of paraffin oil and covered with a slide cover. About five hundred fibers chosen at random were measured from each sample. The mean fiber diameters (FD) together with the standard deviation of fiber diameter (SDFD) were calculated for each sample. While measuring fiber diameter, medullated fibers percentage (fiber contains medulla) as well as prickle factor (the percentage of fibers had greater than 30 µm in diameter) were calculated and recorded for each sample. Crimpness (Cr/cm) was obtained for fine and coarse fibers (one crimp =the distance between one bottom or top to the next one). Staple strength (SS) was measured by Agritest staple breaker (Agritest Pty. Ltd) after trimmed the bundles by cutting its tip. The (SS) was calculated and recorded in terms of Newton / Kilotex (Heuer, 1979 and Caffin, 1980). Point of break by length (POBl) was also calculated as percentage of tip length portion from the length of both tip and bottom.

Yarns Measurements

Yarn regularity was measured by the following abbreviations: Thin places (-50%): number of mass reduction of 50% or more in a yarn with respect to the mean value. Thick places (+50%): number of mass increase of 50% or more in a yarn with respect to the mean value. Neps (+200%): number of mass increase of 200% or more in a yarn with respect to the mean value.

Fabrics Measurements

All samples are woven as blankets with specifications of 20/2 metric cotton yarns with 11 threads/cm density were used as warp yarns while wool yarns used as wefts with 2 metric count and 12 weft/cm density. Weight Test, This test was carried out according to ASTM, Standard Test Method for Weight of Textile Materials, D 3776-96. A digital balance with 4 digits was used. Five samples (5X5) cm^2 sized were cut from different parts of each sample. The average of all reading was calculated. Thickness test was carried out according to ASTM, Standard Test Method for Thickness of Textile Materials, D 1777-96. Brightness (L) was measured using Macbeth double beam spectrophotometer (SDL-UK) attached with integrating sphere. The spectrophotometer was calibrated for photometric and wave length scales. The samples were pre-conditioned before testing at standard environment conditions of temperature (20±2 ^oC) and relative humidity (65 ± 5%) using standard conditioning room. Bursting test was carried out according to ASTM, Standard Test Method Bursting strength of textiles- Ball bursting, (D 3787, 2001). Thermal insulation Test was measured according to ASTM, D 1518-85. The thermal transmittance of a fabric or batting is of considerable importance in determining its suitability for use in fabricating cold weather protective gear and clothing. TOG is a measure of thermal resistance of a unit area. Air permeability defined as the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. This test was carried out according to ASTM, Standard Test Method for Air permeability of Textile Materials, D 737-96. Data were statistically analyzed according to SAS (2001) using general linear model (GLM) followed by Duncan's multiple range tests to examine the significance classification between means.

3. Results and Discussion

Raw wool Characteristics

Coarse groups had higher fiber diameter (7.5 μ), medullation fibers percentage (11.4%) and prickle factor(14.15%) than fine fibers groups. Bulk and resilience increased significantly as shown in table (1) in both G1 and G3 groups compared with the other groups. Previous results were in agreement with the results obtained by Helal, (2000) and Azzam, (1982). Crimp increased significantly in fine with high bulk group compared with course with high bulk group which indicates that crimp play a vital role in bulk characteristics in fine fibers. Shah and Whiteley (1971) and Raichev, *et al.* (1985) stated that number of crimps /cm increased with finer diameter. Elongation increased in both fine fibers groups compared with coarse fibers groups (Table 5). The same result was found by Helal *et al.* (2008). Both coarse fibers groups G1 and G2 had lower strength than fine groups G3 and G4, that could be related to the existence of the long channel medulla which makes the fibers fragile and easy to break under high tensions. Al-Betar (2008) found that in Barki wool, yarn spun from fine fibers with both high and low loose bulk had higher strength and elongation than yarns spun from coarser fibers with high and low loose bulk.

Yarns Characteristics

Regularity of yarn expressed as thin and thick places as well as number of neps found to be higher in both coarse groups (G1 and G2) compared with the fine groups (G3 and G4).Thin places also increased significantly in coarse with low bulk group compared with coarse with bulky fibers group. Inverse trend found in fine groups (G3 and G4), wherein thin places was higher in fine with bulky fibers group compared with fine with low bulk group (Table 1). De Groot (1995) also reported that the frequency of thin and thick places increased with increasing fiber diameter. The lowest thick places found in fine with high bulk group, while the highest thick places found in coarse with low bulk group. Number of neps considered as the most indicator for irregularity in yarn and affecting on yarn quality and yarn price found to be higher in control group followed by coarse with low bulk group, then coarse with high bulk group. Both fine groups had the least number of neps among other groups. Fine with bulky group was lower than fine with low bulk group. Many authors also reported that fine and bulky fibers gives better yarn quality compared with coarse and harsh fibers (Helal, 2008). The previous results indicate that with increasing the homogeneity of fibers in long, diameter and crimp the regularity in yarn increase.

Fabrics Characteristics

Weight of fabric increased in fine groups with increase in high bulk one, while it decrease in coarse groups with increase in low bulk one and that means there are an inverse trend within group found between coarse and fine groups. The lightness of coarse group could be related to the presence of medulla, which is a hallow space running lengthwise through the fiber center. The highest thickness found in fine fibers group with high bulk, while the lowest value of thickness found in coarse fibers with high bulk. Brightness increased slightly in both coarse and fine groups compared with control one. Whiteness decreased and yellowness increased in coarse fibers groups compared with the fine ones. Bursting strength differ significantly among all groups. Fine group with high bulk is the highest one among the other groups, while coarse fibers group with low bulk is the lowest on in bursting strength. This could be as a result of finer wools ability to stretch rather than being break because finer wools have a large number of crimps per length unit in addition to the springy behavior which makes these fibers more able to stretch under tension rather than cut. While coarse fibers have kemp and medullated fibers with low strength which are able to be broken under tension stress. Tog increased in fine and bulky group compared with the other groups. While Air permeability increased with coarse groups compared with fine ones especially fine group with low bulk which had the lowest value among all groups. As shown in table (3) bursting strength had a highly significant and positive correlation with bulk (r = 0.53) and resilience (r = 0.67), crimp (r = 0.69) and staple strength (r = 0.77). Elongation had a positive correlation but significant only (P<0.05) with bursting strength (r = 0.47), while bursting strength had negative with highly significant correlation with fiber diameter (r = -0.69) and medullated fiber percentage (r = -0.69), while negative with significant correlation with prickle factor (r = -0.45). Also bursting strength as shown in table (4) had a negative and highly significant correlation with all irregularity measurements with thin places (r = - 0.68), with thick places (r = - 0.95) and with neps (r = - 0.60). Results from tables (2 and 3) showed that bursting strength increased with increasing whiteness (r = 0.43), while decreased with increasing yellowness (r = -0.62). A highly significant positive correlation found between bursting and Tog (r = 0.83). Saram and Pant, found that bursting strength increased with the increase of thermal resistance in blends of camel hair with Merino wool (2013 a) and in Camel Kid Hair blend with Chokla Wool (2013 b).Weight found to have highly significant and positive correlation with bursting strength(r = 0.59), also significant and positive correlation found between bursting strength and thickness of fabric (r = 0.48).

Table (1); Means and standard errors of wool fibers, yarns and fabric characteristics among the studied groups

	Traits	G1	G2	G3	G4	G5	SE
Wool fibers	Bulk	30.4 [a]	26.2 [c]	30.2 [a]	25.4 [c]	28.0 [b]	0.422
	Resilience	9.7 [a]	8.1 [b]	10.8 [c]	7.9 [b]	8.7 [d]	0.210
	Fiber diameter	35.1 [a]	36.2 [a]	28.3 [c]	28.1 [c]	31.2 [b]	0.906
	Medullation %	13.5 [a]	25.9 [b]	9.2 [c]	7.4 [d]	18.7 [e]	0.287
	Prickle factor%	49.4 [a]	45.8 [a]	31.1 [b]	35.8 [ab]	37.7 [ab]	4.470
	Crimp	0.5 [a]	0.4 [b]	0.7 [c]	0.7 [c]	0.5 [a]	0.019
	Staple Strength	26.5[a]	16.8[b]	31.3[c]	32.8[d]	25.2[e]	0.119
	POB	39.9[a]	53.7[b]	44.2[c]	44.0[d]	48.2[e]	0.022
	EL	27.6[a]	23.8[b]	31.2[c]	34.3[d]	24.5[e]	0.063
Wool yarn	Thin Places	60.5 [a]	76.5 [b]	34.8 [c]	17.9 [d]	12.7 [e]	0.283
	Thick Places	12.8 [a]	22.1 [b]	6.9 [c]	12.0 [d]	13.0 [a]	0.178
	Neps	10.3 [a]	16.2 [b]	6.3 [c]	8.9 [d]	16.6 [b]	0.156
Fabric	Weight	457.3 [a]	460.5 [b]	599.3 [c]	555.5 [d]	442.4 [e]	0.146
	Thickness	4.5 [a]	4.9 [b]	5.4 [c]	4.7 [b]	4.9 [b]	0.066
	Brightness	69.5 [a]	70.6 [b]	71.0 [b]	71.0 [b]	66.8 [c]	0.275
	Whiteness	-23.2 [a]	-15.9 [b]	-6.3 [c]	-10.6 [d]	-19.8 [e]	0.132
	Yellowness	26.5 [a]	25.0 [b]	21.4 [c]	23.1 [d]	24.5 [b]	0.202
	Bursting	909[a]	831[b]	999[c]	917[d]	947[e]	0.398
	TOG	4.5[a]	3.1[b]	11.7[c]	2.3[d]	7.6[e]	0.035
	Air Permeability	61.7 [a]	62.8 [a]	55.5 [b]	43.2 [c]	65.5 [a]	1.270

-(G1) coarse fibers with high bulk, (G2) coarse fibers with low bulk, (G3) fine fibers with high bulk, (G4) fine fibers with low bulk and (G5) non-graded fibers (control).

- Within a row, means not followed by the same letter are differed significantly (P< 0.05).

Table (2) Correlation coefficientsamong fabric characteristics

	Brightness	Whiteness	Yellowness	TOG	AIRP	weight	thick
Bursting	-0.13 ^{NS}	0.43*	-0.62**	0.83**	-0.18	0.59**	0.48*
Brightness		0.61**	-0.33 ^{NS}	-0.15 ^{NS}	-0.58**	0.63**	0.24 ^{NS}
Whiteness			-0.92**	0.39 ^{NS}	-0.61**	0.93**	0.66**
Yellowness				-0.56**	0.51**	-0.87**	-0.68**
TOG					0.22 ^{NS}	0.42*	0.71**
AIRP						-0.70**	-0.01 ^{NS}
weight							0.54**

TOG =Thermal resistance of a unit area AIRP=Air Permeability ** (*P*< 0.01)* (*P*< 0.05) NS= Not significant

Table (3) Correlation coefficients among fabric and raw wool characteristics

	Bulk	Resilience	FD	Med%	PF	Crimp	SS	POB	EL
Bursting	0.53**	0.67**	-0.69**	-0.69**	-0.45*	0.69**	0.77**	-0.55**	0.47*
Brightness	-0.15 ^{NS}	0.07 ^{NS}	-0.12 ^{NS}	-0.31 ^{NS}	-0.02 ^{NS}	0.30 ^{NS}	0.20 ^{NS}	-0.07 ^{NS}	0.55**
whiteness	-0.14 ^{NS}	0.21 ^{NS}	-0.65**	-0.48*	-0.49*	0.63**	0.49*	0.06 ^{NS}	0.65**
yellowness	0.01 ^{NS}	-0.28 ^{NS}	0.75**	0.50*	0.60**	-0.67**	-0.56*	-0.01 ^{NS}	-0.58**
TOG	0.64**	0.78**	-0.39*	-0.25 ^{NS}	-0.37 ^{NS}	0.29 ^{NS}	0.32 ^{NS}	-0.16 ^{NS}	0.04 ^{NS}
AIRP	0.38*	0.21 ^{NS}	0.56**	0.72**	0.24 ^{NS}	-0.72**	-0.68**	0.32 ^{NS}	-0.89**
weight	0.06 ^{NS}	0.38 ^{NS}	-0.70**	-0.74**	-0.46*	0.78**	0.73**	-0.31 ^{NS}	0.84**
thickness	0.08 ^{NS}	0.40*	-0.24 ^{NS}	-0.09 ^{NS}	-0.15 ^{NS}	0.28 ^{NS}	0.15 ^{NS}	0.23 ^{NS}	0.11 ^{NS}

FD = Fiber diameter, Med% = Medullation percentage, PF = Prickle Factor, RES = Resilience, SS = Staple strength, POB = Point of break, EL= Elongation, TOG = Thermal resistance of a unit area and AIR P. = Air permeability.
** (P< 0.01) * (P< 0.05) NS= Not significant

Table (4) Correlation coefficients among fabric and yarn characteristics

	Thin.P	Thick.P	Neps
Bursting	-0.68**	-0.95**	-0.60**
Brightness	0.35 ^{NS}	-0.02 ^{NS}	-0.59**
whiteness	-0.28 ^{NS}	-0.43*	-0.61**
yellowness	0.49*	0.56**	0.54**
TOG	-0.30 ^{NS}	-0.67**	-0.34 ^{NS}
AIRP	0.38 ^{NS}	0.36 ^{NS}	0.62**
weight	-0.33 ^{NS}	-0.66**	-0.85**
thickness	-0.16 ^{NS}	-0.34 ^{NS}	-0.25 ^{NS}

Thin P= Thin places, Thick P= Thick places, ** (P< 0.01)* (P< 0.05) NS= Not significant

Table (5) Correlation coefficients of raw wool and yarn characteristics

	FD	Med%	PF	RES	Crimp	Thin P	Thick P	Neps	SS	POB	EL
Bulk	-0.10	-0.22	-0.24	0.84**	0.05	0.11	-0.51**	-0.37	0.19	-0.53**	-0.05
FD		0.69**	0.84**	-0.19	-0.80**	0.74**	0.69**	0.54**	-0.76**	0.29	-0.69**
Med%			0.32	-0.37	-0.89**	0.56**	0.86**	0.88**	-0.97**	0.81**	-0.92**
PF				-0.16	-0.44*	0.45*	0.40*	0.29	-0.38*	0.03	-0.34
RES					0.26	0.02	-0.66**	-0.56**	0.35	-0.48*	0.14
Crimp						-0.69**	-0.79**	-0.75**	0.92**	-0.55**	0.88**
ThinP							0.63**	0.19	-0.70**	0.26	-0.45*
ThickP								0.77**	-0.90**	0.74**	-0.66**
Neps									-0.81**	0.73**	-0.86**
SS										-0.75**	0.89**
POB											-0.60**

FD = fiber diameter, Med% = Medullation percentage, PF = Prickle Factor, RES = Resilience, Thin P= Thin places, Thick P= Thick places, SS= Staple strength, POB= Point of break and EL= Elongation,
** (*P*< 0.01)* (*P*< 0.05) NS= Not significant

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