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RESEARCH PAPER

Influence of weave on tensile Strength of cotton/flax blended fabrics

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Abstract: A study was carried out to investigate the effects of plain and 3/1 twill weave designs on the tensile strength of cotton/flax blended fabrics. Five different yarns *i.e.,* 100 % cotton, 100 % flax and 60:40, 70:30 and 80:20 cotton/flax blended yarns were produced using ring frame method in Zincer 351 machine at DKTE, Ichalkaranji. Plain and twill weave fabrics were woven on handloom at Khadi Handloom Development Centre (KHDC), Gadag, Karnataka, using pure cotton (2 ply 20s count) as warp and blended cotton/ flax (80/20, 70/30 and 60/40) yarn as weft. The produced fabrics were tested for physical properties (Fabric count, weight, thickness) and mechanical properties (tensile strength, abrasion resistance, pilling test and cloth drapability). Tensile strength of fabric samples was determined as per standard test method. The results revealed that twill woven fabric samples have considerable high tensile strength when compared to plain woven fabric samples.

Key words: C/F Blended Fabrics, Fabric Count, Plain weave, Tensile strength, Twill weave

Introduction

Tensile strength has been accepted as one of the most important attributes of woven textiles (Uttam, 2006). It is the main characteristic of woven fabric that distinguishes it from non-woven and knitted fabric. It provides a comprehensive check on most of the specifications of cloth construction. Due to this reason, a demand for minimum strength is added to the usual structural particulars of a fabric in order to ensure the quality of fabric, yarn as well as fiber (Taylor, 1959). Tensile strength is defined as a maximum load that a test specimen will endure when subjected to uniaxial tensile loading (Realff, 1997). The strength of a fabric depends not only on the strength of constituent yarns, but also on the yarn and fabric structure and many other factors.

The woven fabrics are made up of warp and weft yarns, interlaced perpendicular to each other in a specific way. There are a particular number of yarns per unit length in each direction. Fibers are of different material such as cotton, linen, polyester, acrylic and viscose etc. Thus the factors, which have influence on the tensile strength of fabric other than yarn strength, are yarn material, yarn fineness, number of ends and picks per unit length and weave design. In this study, an attempt has been made to study the influence of weave design on tensile strength of cotton/ Flax blended woven fabrics.

Material and methods

This experiment was conducted during the year 2018-19. The different variety of flax plants were collected from AICRP on MULLaRP Sceheme, UAS Dharwad. The flax fibres were extracted through water, chemical and enzymetic retting methods. The extracted fibres were further subjected for pre treatment *i.e*., scouring and bleaching to remove impurities from raw fibre and make fibre soft and white which can be easily blended with cotton for further spinning process. The extracted fibres were tested for fibre length, fineness and for bundle strength

The term blending is used by the manufacturers to describe specifically the sequence of processes required for mixing of at least two components which differ by at least one parameter which characterises the component fibres. Fibre blending consists of orientations of different fibres in the yarn structure in such a way that the content of each component remains same at every point of the yarn throughout its length (Samanta, 2014).

The blending of cotton and flax fibres in different proportions were carried out by stack method of manual blending. Layers of cotton and flax fibres are stacked alternately and later sliced vertically for proper mixing. Flax fibres were blended together with cotton in three different proportion *viz*., 60:40::70:30and 80:20:cotton/flax and spun on ring frame spinning machine *i.e* Zincer 351, Model No. C3 with rotor speed of 10000 rpm at Department of Spinning section, DKTE's Textile and Engineering Institute, Ichalkaranji, Maharashtra. The yarn properties were measured under standard conditions. Yarn count, Yarn twist, Count Strength Product (CSP), yarn eveneness and hairiness percentage of the yarns were tested Yarn unevenness, hairiness and imperfections were evaluated using Uster evenness tester

Weaving is the method of fabric production wherein, two sets of yarns are interlaced at right angles to each other. Plain and twill weave fabrics were woven on handloom at Khadi Handloom Development Centre (KHDC), Gadag, Karnataka, using pure cotton (2ply 20s count) as warp and blended cotton/ flax (80/20, 70/30 and 60/40) yarn as weft.

The produced fabrics were assessed for fabric count, fabric weight and fabric thickness and tensile strength. Tensile strength is the ability of the material to resist or rupture induced by external force. The specimen will be tested as directed in ASTM test method: 12616-1989. The tensile strength (kgf) and elongation (%) of the materials were determined using the strip test method in Instron Tensile strength tester.

Results and discussion

Fibre properties

The extracted fibres were tested for fibre length, fineness and for bundle strength. The results revealed that the length of the flax fibre ranges from 25.6 to 27.4 cm with fibre yield of 60 to 90 g/kg stalk. The fibre fineness varies from 1.7 to 1.39 dtex where as bundle strength of flax fibre was 14.34 to 15.84 g/tex (Table1).

Yarn properties

Yarn count (Ne), yarn twist (tpi) and Count Strength Product (CSP) of pure Cotton, Flax and Cotton/Flax blended yarns were tested. It is observed from Table 2 that, the pure Flax yarn can be spun to 16.8 Ne count with 9.98 tpi and 2654.6 CSP. The Cotton yarn was spun to 20 Ne count with 17.04 tpi and 2659.39 CSP.

Among the Cotton/Flax blended yarn, the Cotton/Flax blended fibres of 70/30 proportion could be spun to 13.75 Ne yarn count, 60/40 Cotton/Flax to 12.47 Ne count and 80/20 Cotton/Flax to 11.99 Ne count. This revealed that, increase in flax content in blend, there was decrease in yarn count *i.e* decrease in fineness of the yarn because higher the count, finer the yarn.

Among the blended yarns the CSP was highest in 70/30 Cotton/Flax blended yarn (1699.98) followed by 80/20 Cotton/ Flax blended yarn (1635.59) and 60/40 Cotton/Flax blended yarn (1532.83). CSP of cotton and flax fibre was highest compared to cotton/flax blended yarns. This may be due to the homogeneity of cotton, which increased cohesiveness and provided better compactness of yarn. However, blending other fibre reduce cohesiveness and compactness. Variation in count of blended yarns and cotton may also be responsible for difference in CSP. Finer the yarn, higher the count and better will be the strength (Saville, 2004).

Yarn evenness and hairiness (%) of Cotton and Cotton/ Flax blended yarn are presented in Table 3. It is observed that, the unevenness(%), thin(-50%), and thick (+ 50 %) places, Neps (+200 %) and total imperfections was found to be highest in cent per cent Flax yarn (24.63%, 1909.4% and 1412%, 3006.6% and 6328.0 respectively) followed by in Cotton /Flax (60/40) blended yarn (21.81%, 552.4% , 1056.6%, 1615.0% and 3224 respectively), 70/30 blended yarn (20.10%, 288.2% , 681%, 675.4% and 1644.6, respectively) and Cotton /Flax (80/20) blended yarn (19.12%, 193.3% , 726.4%, 1114.4% and 2034, respectively). However, selected pure Cotton yarn showed better evenness properties. Among the blended yarn, 80/20 Cotton/Flax is found to be better compared to 60/40 and 70/30 Cotton/Flax yarns in terms of unevenness percentage. This indicated that increased in the flax content in the yarn, there is increase in yarn uneveneness (%), thin places, thick places, neps (%) and total imperfections**.** However, yarn evenness (CV%) and yarn elongation significantly affect the final yarn quality. On the other hand, the yarn evenness is mainly affected by spinning system (Bouchraiet *et al.,* 2016). It is clear from the study conducted by Rehan and Ghosh (2015) that with the increased percentage of flax in polyester and flax blend ratios, yarn irregularities are higher and Oner *et al.* (2018) stated that, unevenness and hairiness of the yarns increased with increase of neps, short fibre index and trash content in the blend.

Table 1. Flax Fibre properties

Parameters	Flax
Fibre yield (g/kg stalk)	60-90
Fibre length (cm)	25.6 to 27.4
Fibre fineness (dtex)	1.7-1.39
Fibre bundle strength (g/tex)	14.34 to15.84

Table 2. Physical properties of Cotton, Flax and Cotton/Flax blended yarns

Yarns	Yarn count (Ne)	Yarn twist (tpi)	Count strength product (CSP)
Cotton	20.00[a]	17.04d	2659.39*a
Flax	16.80[b]	9.98e	2654.60a
60:40 (C/F blend)	12.47[d]	23.45*a	1532.83bc
70:30 (C/F blend)	13.75c	20.57b	1699.98b
80:20 (C/F blend)	11.99d	18.62c	1635.59bc
Mean	15.50	17.93	2036
S.Em ±	0.290	0.310	48.884
C.D.@5%	0.873	0.929	146.555
CV %	4.18	3.86	5.37

Table 3.Yarn evenness properties of Cotton, Flax and Cotton/Flax blended yarns

Yarns	Yarn Evenenss (%)					Yarn hairiness %
	Unevenness %	Thin places/ km(-50 %)	Thick places/ km (+ 50 %)	Neps/km (+ 200 %)	Total Imperfection	
Cotton (100 %)	11.22*a	0.00*a	22.8a	17.0*a	39.8a	7.02b
Flax (100 %)	24.634e	1909.4e	1412d	3006.6e	6328.0d	2.42*a
60:40 (C/F blend)	21.812d	552.4d	1056.6c	1615.0d	3224.0c	7.50c
70:30 (C/F blend)	20.104c	288.2c	681b	675.4b	1644.6b	8.51d
80:20 (C/F blend)	19.122b	193.2b	726.4b	1114.4c	2034.0b	8.72d
Mean	19.378	588.64	779.76	1285.68	2564.08	6.83
S.Em.±	0.394	111.769	35.290	102.363	235.337	0.078
C.D. (5 %)	1.161	329.717	104.104	301.970	694.244	0.229
C.V. (%)	0.240	1.250	0.610	0.817	0.828	0.343

*-Significant at 5 % level of significance; CD-Critical difference; CV-Coefficient of variation

Cloth count of Cotton and Cotton/Flax blended fabrics

Cloth count of the woven fabric is the number of ends and picks per unit length as counted, while the fabric is under zero tension and free from folds and wrinkles. Cloth count may also be described as the density of yarn (Booth, 1996). Irrespective of blend proportion, the warp yarn density was relatively greater in both plain and twill weave fabrics compared to weft yarns. Plain and Twill keeping the warp density 58 for all the plain weave samples and 87 for all Twill weave samples. Whereas in weft direction for plain woven fabrics, the picks per inch varied and lowest was found in Cotton x Flax union fabric (41). The more picks/inch was observed in Cotton x Cotton/Flax (70/30) blended fabric (46.0) followed by Cotton x Cotton/Flax (80/20) (45) and Cotton x cotton/flax blended fabric (60/40) 44.0.

In case of twill woven fabrics, the weft count varied from 39 to 48. Among the blended fabrics, the highest count in weft direction was found in Cotton x Flax union fabric *i.e.*, 48 followed by Cotton x cotton/flax (60/40) (44), Cotton x Cotton (43) and similar thread density in both Cotton x Cotton/Flax (70/30) and Cotton x Cotton/Flax (80/20) fabrics (39 and 40 respectively).

Cloth thickness of Cotton and Cotton/Flax blended fabrics

Fabric thickness affects fabric properties such as cloth stiffness, crease recovery angle, drapability, abrasion resistance and cloth geometry that in turn is influenced by fibre content, yarn count, yarn type and weave density. Thus, thicker the fabric, longer it takes to tear. The thick fabrics many times are not suitable for dress materials because of its bulkiness and stiffness. It is observed that, the cloth thickness of cotton x cotton fabric was lower when compared to blended fabrics. In case of twill weave fabrics, Cotton x Cotton/Flax (80/20) fabric showed highest thickness (0.60 mm) followed by Cotton x Cotton/Flax (60/40) and Cotton x Cotton/Flax (70/30) (0.57 and 0.56 mm) fabric respectively. The thickness was slightly higher in Cotton x Flax union fabric (0.49 mm) when compared to Cotton x Cotton fabric (0.47 mm) in both the plain and twill weave fabrics respectively

Cloth weight (g/sq.mt) of Cotton and Cotton/Flax blended fabrics

The factors contributing to the fabric weight are fibre content, yarn type and twist, cloth count, method of fabric construction and finish applied. In woven cloth the percentage composition of warp way and weft way yarns many times are not equal (Booth, 1996). Among the plain woven fabrics, Cotton x Cotton/Flax (80/20) fabric showed higher cloth weight (162.4 gsm) followed by Cotton x Cotton/Flax (60/40) fabric (160.8 gsm), Cotton x Cotton/Flax (70/30) fabric (153.6 gsm). Cent per cent Cotton x Cotton showed lowest cloth weight (116.8 gsm) compared to Cotton x Flax union fabric (131.2 gsm).

Among twill woven fabrics, the higher cloth weight was found in Cotton x Cotton/Flax (70/30) fabric (192 gsm), followed by Cotton x Cotton/Flax (80/20) fabric (188 gsm), Cotton x Cotton/Flax (60/40) fabric (172.8 gsm), Cotton x Flax (162.4 gsm) and lowest in Cotton x Cotton (152.8 gsm). However, the per cent warp in plain woven fabrics ranged from 46.79 to 59.36,

Table 4. Cloth count, thickness and cloth weight of plain and twill woven cotton and cotton/flax blended fabrics

Weave	Blended Fabrics	Cloth Count(Ne)		Cloth thickness (mm)	Cloth weight (g/m^2)		
		Warp	Weft		Initial weight	Per cent Warp	Per cent Weft
Plain	Cotton x Cotton fabric	58.0	43.0	0.38	116.8	69.33 (59.36)	44.00 (37.67)
	Cotton x Flax (Union fabric)	58.0	41.0	0.40	131.2	76.00 (57.93)	53.33 (40.65)
	Cotton x Cotton/Flax (60:40) fabric	59.0	45.0	0.46	160.8	76.00 (47.26)	82.67 (51.42)
	Cotton x Cotton/Flax (70:30) fabric	57.0	46.0	0.51	153.6	76.00 (49.48)	75.33 (49.04)
	Cotton x Cotton/Flax (80:20) fabric	59.0	45.0	0.47	162.4	76.00 (46.79)	81.33 (50.08)
	S.Em.±	0.592		0.01		1.386	
	C.D. (5 %)	2.41		0.02*		5.64	
	C.V. (%)	2.01		3.68		3.38	
Twill	Cotton x Cotton fabric	87.0	43.0	0.47	152.8	101.3 (66.29)	49.3 (32.26)
	Cotton x Flax (Union fabric)	79.0	48.0	0.49	162.4	106.7 (65.70)	52.0 (32.02)
	Cotton x Cotton/Flax (60:40) fabric	88.0	44.0	0.57	172.8	109.3 (63.25)	58.7 (33.97)
	Cotton x Cotton/Flax (70:30) fabric	79.0	39.0	0.56	192	109.3 (56.93)	77.3 (40.26)
	Cotton x Cotton/Flax (80:20) fabric	86.0	40.0	0.60	188	110.7 (58.88)	77.3 (41.12)
	S.Em.±	0.600		0.004		1.687	
	C.D. (5 %)	2.44		0.01*		6.87	
	C.V. (%)	1.64		1.59		3.43	

where as in twill woven fabrics, the range varied from 56.93 to 66.29 per cent. The lower thickness in cotton x cotton may be because of fibre fineness & higher yarn count and also lower fabric weight when compared to blended yarn and fabrics respectively. Thus, proving that increase in the fabric thickness increased the fabric weight.

Cloth Tensile strength (kgf) and Elongation (%) of plain and twill weave on Cotton and Cotton/Flax blended fabrics

The tensile strength is the fundamental ability of the fabric to resist strain or rupture induced by tension. The tensile strength properties of the fabric depend upon the fibre content and its inherent properties *i.e.*, yarn type, yarn count, yarn twist, threads per unit area, cloth cover and weave density. However, the yarn strength ultimately cannot be greater than the sum maximum strength of its component fibres, which determines the strength of the fabric.

Among the plain and twill weave fabrics, twill weave fabrics showed higher tensile strength and lower elongation (%) both in warp and weft directions than plain weave fabrics. It is found that the warp way tensile strength was higher in twill weave Cotton x Cotton/Flax (70/30) blended fabric (124.6 kgf) followed by Cotton x Cotton (123.3 kgf). While, the weft way tensile strength was found to be higher in Cotton x Flax union fabric (106.4 kgf). However, with regards to yarn influence, the tensile strength was found to be higher in Cotton X flax union fabric and Cotton X Cotton/Flax (70/30) union fabric, indicating that increase in the content of flax in the yarn, there was increase in the tensile strength.

In plain woven fabrics (Table 5 and Fig. 1a) the higher tensile strength was observed in Cotton x Flax Union fabric in both warp way (91.5 kgf) and weft way (90.9 kgf) followed by Cotton x Cotton/Flax (60/40) fabric (warp-82.3 and weft-86.8 kgf). The lowest was observed in Cotton x Cotton/Flax (70/30) in warp way (70.5 kgf) and in weft way Cotton x Cotton fabric (48.5 kgf). This may be because of blending of cotton with flax which in turn influences the yarn count, yarn strength, yarn twist and cloth count and ultimately the cloth tensile strength

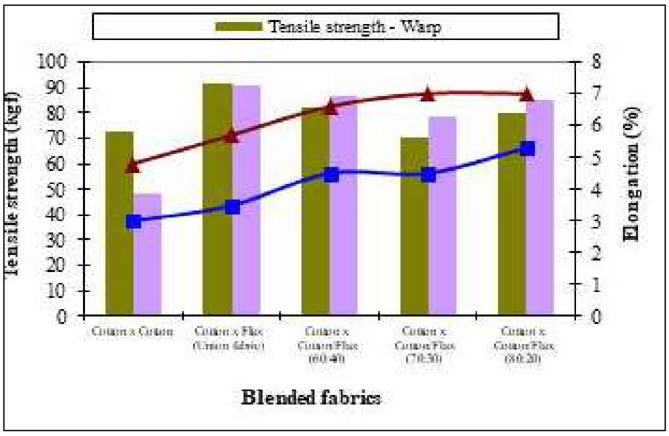

Fig. 1a. Cloth Tensile strength (kgf) and Elongation percentage of Plain woven Cotton and Cotton/ Flax blended fabrics

In plain woven fabric the highest warp way elongation percentage was observed in Cotton x Cotton/Flax (70/30) fabric and Cotton x Cotton/Flax (80/20) (7.0 %) fabric and lowest in Cotton x Cotton (4.8 %) fabric. However, the highest weft way elongation (%) is observed in Cotton x Cotton/Flax (80/20) (5.3 %) followed by in 60/40 and 70/30 (4.5 %) and lowest in Cotton x Cotton (3.0 %).

Among twill woven fabrics (Table 5 and Fig 1b) highest warp way elongation percentage was highest in Cotton x Cotton (5.7 %) and lowest in Cotton x Cotton/Flax (60/40) fabric (3.1 %). Whereas, the weft way elongation (%) was found to be highest in Cotton x Flax union fabric (14.2 %) and the lowest in Cotton x Cotton/Flax (60/40) (3.9 %) fabric.

Influence of Yarn count, Cloth count and weave on Tensile strength of Cotton and Cotton/Flax blended fabrics

Table 6 shows the influence of Yarn count and Cloth count on Tensile strength of Plain woven Cotton and Cotton/Flax blended fabrics. It is found that the influence of yarn count and cloth count on weft way tensile strength of plain woven cotton x cotton/flax (70/30) was significant and the influence was found to be 98.1 per cent. The influence of yarn count was positive

Table 5. Cloth Tensile strength (kgf) and Elongation (%) of Plain and Twill woven Cotton and Cotton/Flax blended fabrics

Weave	Blended Fabrics	Tensile strength (kgf)		Elongation (%)	
		Warp	Weft	Warp	Weft
Plain	Cotton x Cotton fabric	72.8	48.5	4.8	3.0
	Cotton x Flax (Union fabric)	91.5	90.9	5.7	3.5
	Cotton x Cotton/Flax (60:40)	82.3	86.8	6.6	4.5
	Cotton x Cotton/Flax (70:30)70.5	78.3	7.0	4.5	
	Cotton x Cotton/Flax (80:20)	80.2	85.1	7.0	5.3
	S.Em.±	1.593		0.124	
	C.D. (5 %)	6.48		0.51	
	C.V. (%)	3.51		4.16	
Twill	Cotton x Cotton	123.3	63.3	5.7	6.3
	Cotton x Flax (Union fabric)	119.1	106.4	5.0	14.2
	Cotton x Cotton/Flax (60:40)	117.0	62.3	3.1	3.9
	Cotton x Cotton/Flax (70:30)	124.6	71.6	4.6	4.8
	Cotton x Cotton/Flax (80:20)	118.5	73.7	4.4	4.8
	S.Em.±	2.405		0.123	
	C.D. (5 %)	9.79		0.50	
	C.V. (%)	4.25		3.73	

Table 6. Influence of Yarn count, Cloth Count and weave on tensile strength of Cotton and Cotton/ Flax Blended fabrics related to weave

Weave	Source	Warp				Weft			
		Co-efficient	Standard error	t-test	p-value	Co-efficient	Standard error	t-test	p-value
Plain weave fabrics	X1	0.49	1.16	0.43 NS	0.71	-5.04	2.44	-2.07 NS	0.17
	X2	-4.96	9.00	-0.55 NS	0.64	-12.42	6.37	-1.95 NS	0.19
	R^2		0.226				0.693		
Twill weave fabrics	X1	0.08	0.46	0.16 NS	0.88	3.14	3.99	0.79 NS	0.51
	X2	-0.29	0.42	-0.69 NS	0.56	-0.17	5.21	-0.03 NS	0.98
	R^2		0.236				0.389		

* t-value significant at 5 % level X1 – Yarn count X2-Cloth count R^2-Coefficient of determination

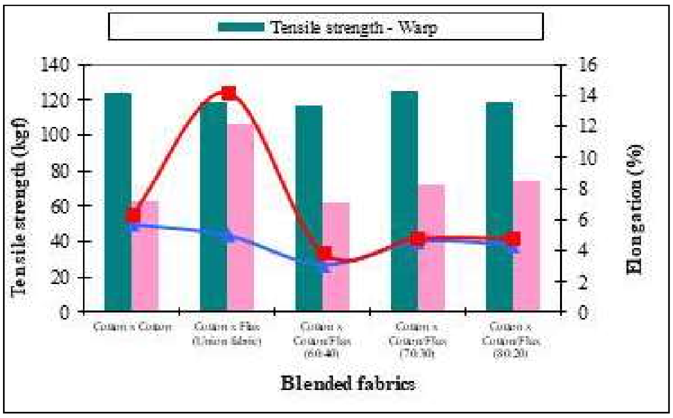

Fig. 1b: Cloth Tensile strength (kgf) and Elongation percentage of Twill woven Cotton and Cotton/ Flax blended fabrics

indicating that, increase in yarn count increased the weft tensile strength of the fabric. While the influence was negative in case of cloth count indicating that, increase in cloth count resulted into decrease in the weft tensile strength of the fabric. However, the influence was non-significant in warp way as well as in all the other fabrics.

It is also found that the influence of weave was significant in weft way tensile strength of plain weave fabric followed by twill weave fabrics *i.e*, the influence was found to be 69.3 per cent in plain weave and 38.9 per cent in twill weave fabrics. Thus, the plain weave had more influence on tensile strength of the fabric than twill weave may be because of lesser floats, more intersections and better density. The increase in tensile strength is noticed in weft direction may be because of use of Cotton/flax blended yarns in weft direction. Thus, it may be inferred that flax content in the yarn also influenced the tensile strength of the fabric (Table 6).

However, statistical analysis (t-test) showed significant difference in tensile strength in warp direction. where as in weft way direction there is no significant difference was found among the weave.

Conclusion

The results of this study showed that weave design played a significant role in the tensile strength of woven fabrics. In general the warp way tensile strength was higher in Cotton x Cotton/Flax (70/30) (124.6 kgf) twill woven fabrics and weft way in Cotton x Flax (106.4 kgf) union fabric compared to plain woven blended fabrics. However, it is observed that, the warp way tensile strength was higher than weft way tensile strength. In general, the tensile strength of twill woven fabric is higher than plain woven fabrics may be because of higher cloth count in twill than plain woven fabrics. Thus, weave design is an important parameter which has remarkable influence on the tensile strength of woven fabrics

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