Influence of Warp Yarn Tension on Cotton Greige and Dyed Woven Fabric Prosperities

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ABSTRACT

Fabric properties such as pilling and abrasion resistance and tensile strength vary when greige fabric is processed further. The quality of dyed fabric depends on the quality of greige fabric. Cotton Plain and Twill weave fabrics were woven at three different warp yarn tension and then dyed using monochlorotriazine, Drimerene Red Cl-5B dye gives difference in fabric properties. The ASTM, American International Standards were used to determine the greige and dyed fabric properties. It has been observed fabric woven at proper loom setting or warp yarn tension have high strength, less pilling and abrasion tendency as compared to fabric woven at variant warp yarn tension. Moreover, fabric tenacity is decreased after dyeing whereas, slight difference in pilling and abrasion values is observed after dyeing than that of greige fabric.

Key Words: **Pilling, Abrasion, Tensile Strength, Weave Structure.**

1. INTRODUCTION

Besides the aesthetic properties, mechanical and physical properties of fabric are considered as decisive quality parameters. Fabric structure plays a critical role for predicting the fabric properties. Among other fabric properties, fabric strength is one of the most important properties of woven fabric, especially for technical textiles application [1,2]. The warp yarn strength and ends per cm are two considerable factors, which affect on fabric strength in warp direction [3]. To determine the strength of fabric, it is necessary to have complete knowledge of fabric structure and the interaction between the warp and weft yarns during weaving process [4,5]. Tensile stresses are shared and transferred at the intersection points such as high number of interlacement has high resistant to tensile stresses.

During wet-treatment such as dyeing process, fabric is immersed in cold water, followed by hot water, steaming or a chemical treatment. In all treatments yarns are swelled and increased the yarn crimp. The greater yarn crimp increases the fabric extensibility property. Since, during weaving process warp yarns are under more tension, having more crimp and greater extensibility in the filling direction. Moreover, woven fabric exhibited much higher strength predicted from yarn strength at the same gauge length. Researchers investigated [6-9] that it was because of contact pressures at yarn crossovers, so there was a less chance for fabric failure as compared to yarn. Similarly, the strength behavior of fabric was also depended on the yarn manufacturing system (ring, rotor and friction) and

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fabric density. Yarn possessed the appropriate mean strength and strength distribution; permit the valid prediction of fabric strength [8].

Furthermore, Twill fabrics due to its floating structure are more flexible and easily bend, thus, improve the drapability. The fabric properties such as drapability, handle, wrinkle resistance and air permeability of greige woven fabric were similar to the dyed woven fabric. Fabric handle and density was constantly decreased with abrasion time while fabric thickness, air permeability, and softness were increased inconsistently [10]. During abrasion, cotton fibres [11] were lost that induced increase permeability of cotton fabric. If the fibres were accommodate between interstices of the yarns of fabric and established an equilibrium situation (loss of fibre = gain of fibres) then there were no change of permeability. The decrease in fabric density was minimized during short periods of assessment while the change in other physical properties such as compression, relaxation and air permeability was high [10]. Cotton fabric woven from compact yarn was reported to have less abrasion resistance than the ring spun yarn [12].

Much work has been reported on predicting the fabric properties using image processing such as fabric drape [13,14], handle [15,16], wrinkle resistance [16], fabric strength in warp direction [3]. Although image processing gives accurate results when fabric parameters such as ends and picks per inch, warp and weft linear density and etc were feed. Further, these parameters could measure after weaving. If the fabric weaves at improper loom setting such as variation in warp yarn tension, it has an effect on fabric properties due to high stresses on the yarns during fabrication. Therefore, in this paper fabric properties such as pilling and abrasion resistance and tensile strength after weaving and wet-treatment are determined and compared. The fabric samples, Plain and Twill weave were woven at three different warp yarns tension. The fabric properties are varied due to stress applied on yarns during weaving that weaken the fibre filaments of the yarns of the woven fabric.

2. MATERIALS

100% cotton greige and dyed fabrics, Plain and Twill weave each of 2m long were woven on Pieco Iwama Shuttle loom at three different warp yarn tension (when warp beam was stationary) [17]. The tension of weft yarn is kept constant, (47cN) during weaving process. The specifications of cotton greige fabrics of 64x36 tex is shown in Table 1.

3. METHODS

3.1 Dyeing

The fabric samples were dyed with Drimarene Red Cl-5B (3% owf) by an exhaust method on Rapid HT dyeing machine [17].

3.2 Pilling Test

The pilling test was performed before and after dyeing, in order to assess the resistance to the formation of pills and other related surface changes on textile fabrics under light

TABLE 1. FABRIC SPECIFICATIONS

Specimen Type	Ends and Picks per cm	Warp Tension (cN)	GSM
Pl-1	42x38	38-39	183
Pl-2	42x36	54-56	174
Pl-3	42x34	64	172
Tl-1	42x38	78	182
Tl-2	42x36	62	178
Tl-3	42x35	54	177

Pl-1, Plain fabric woven when back roller is in its respective position (considered as original position), T-2, Plain fabric woven when the back roller from its respective position, 2.5cm downward, Tl-3, Plain fabric woven when the back roller from its respective position, 2.5cm upward, Tl-1, Twill fabric woven when back roller is in its respective position (considered as original position), Tl-2, Twill fabric woven when the back roller from its respective position, 2.5cm downward, and Tl-3, Twill fabric woven when the back roller from its respective position, 2.5cm upward.

pressure. The test was performed using ASTM D4970 [18] American Standard on Martindale Abrasion and Pilling tester M235. Four pair of circular samples of 140 and 38mm was cut from each swatch. The test was performed using both 9 and 12K Pascal pressure for 2000 rubs according to the standard. The degree of pilling was visually assessed using pilling photograph 1-5, 1 means more pilling and 5 means no pilling.

3.3 Abrasion Resistance

Wearing a way of any part of a material by rubbing against another surface or abrasion resistance to textile material under light pressure determines the abrasion resistance. The test was performed according to the standard ASTM D4966-98 [19] on Martindale Abrasion and Pilling tester M235, before and after dyeing. Three samples each 38mm were taken and abraded against the woollen standard abraded fabric using 9 and 12K Pascal pressure. The end point of abrasion test was reached when two yarns were broken and then rubs resist by the fabric samples were recorded.

3.4 Tensile Strength

The tensile strength of 100% cotton woven fabric samples was assessed according to the ASTM D 4646-94 standard on USTER Tensorapid 4. It obeys the CRE (Constant Rate of Elongation) method and machines were operated as the instructions mention in UTR 4 manual [20].The test was carried out on both warp and weft direction each of the woven fabric (greige and after dyeing). Before strength testing, fabric samples were conditioned for 24 hours at standard atmospheric condition 22+-2^{o}C and 65% relative humidity. The samples of Plain and Twill weave each were fringed manually so that yarns were arranged in parallel fashion. USTER Tensorapid 4 was automatically applied the requisite force or load during testing and measured the tensile strength in cN/tex. The improper alignment and tension on the fabric samples during testing cause jaw break (fabric breakages 5mm above jaws). Five samples of warp and weft direction were taken of each Plain and Twill weave fabrics. The average of the tenacity (cN/tex) and elongation %age of five samples were determined.

4. RESULTS AND DISCUSSION

4.1 Pilling Resistance

The pilling tendency of woven fabric depends on the yarn evenness (thick, thin and neps), turns per meter and linear density. Fabric composes of uneven yarn and less turns per meter has more tendencies to pill formation. Similarly, fabric construction has also effect on pill formation, Twill weave fabric have more tendency to pills formation as compared to the Plain fabric (Table 2). The pills, small balls of fibre or fuzz that are formed on the fabric surface due to abrasion between the yarns, fabric to fabric, and fabric to skin contact. It has been observed from Tables 2-3, greige fabric has more resistance to pill formation as compared to dyed fabric after 2000 rubs. Plain fabric weave at requisite loom setting such as proper warp yarn tension (Pl-1) can be used for apparel and upholstery purpose. It is because Pl-1 fabric shows excellent to very good pilling rating in both 9 and 12K Pascal. Moreover, Pl-2 and Pl-3 fabric samples have slight to moderate pilling tendency (4-3 rating). The Pl-2 and Pl-3 fabrics were woven at varied or improper warp yarn tension that's not only change the fabric construction and GSM (Gram Per Square Meter) values but also have an adverse effect on fabric properties especially pilling formation. The pills on the fabric surface gives roughness and degrade the fabric quality.

Furthermore, Twill fabric has warp and weft yarn floats (2/2 up/down) causes the fibres in the yarns of the woven fabric to migrate when small force is applied. On the contrary, Plain fabric due to its construction (1/1 up/down) and compact weave, fibres in the yarns of the fabric are

difficult to migrate. Similar to Plain fabric, Twill weave fabric woven at improper warp yarn tension have moderate to poor pilling tendency. However, after dyeing Twill fabric shows slightly improvement in pilling rating it is due to the wet-treatment, cotton fabric shrink thus yarns are come close to each other and have more resistance to pills formation. Though, Twill fabric woven using 64x36 tex can only be used for apparel purpose and not suitable for heavy such as upholstery fabric. Hence, Plain and Twill weave fabric; woven at improper warp yarn tension (Tl-3 and Pl-3) gives rejected fabric quality as well as have an effect on pills formation as compared to Pl-1 and Tl-1 fabric.

4.2 Abrasion Resistance

Resistance to abrasion results of greige and dyed fabric samples each woven at different warp yarn tension is shown in Table 4. Similar to pilling test, Twill fabrics have less abrasion resistance than Plain fabrics. Among Plain weave fabrics, Pl-1 and Pl-2 abraded almost same number of rubs (2000) on greige and dyed fabric. The Plain fabric shows high resistance to pilling even at 12K Pascal. Whereas, Pl-3 fabric, a rejected sample in greige state also shows resistance to abrasion less than the other Plain fabrics (Pl-1 and Pl-2 fabric). On the contrary, Pl-3 has abrasion resistance more than that of the Twill weave fabrics.

TABLE 2. PILLING RATING OF GREIGE WOVEN FABRIC

Specimen Type	Pressure (K Pascal)	Large	Small
Pl-1	9	5	5-4
	12	5	5-4
Pl-2	9	5-4	4
	12	4	4-3
Pl-3	9	4	4-3
	12	4-3	3
Tl-1	9	5-4	4
	12	4	4-3
Tl-2	9	4-3	3
	12	3	3
Tl-3	9	3	2-1
	12	2-1	2

Twill fabric (2/2) has loose structure and more floating of yarns as compared to Plain weave fabric. In fabric with float yarns, fibres are free to move to absorb energy and less consistently exposed to abradant, therefore, Twill fabric shows superior abrasion. Further, both Plain and Twill fabric samples were woven using same linear density of warp and weft yarns but due to the difference of fabric structure, the tension of warp yarn on all Twill fabrics is much higher than the Plain fabrics. Hence, weaken the warp yarn due to more stresses on yarn

TABLE 3. PILLING RATING OF DYED WOVEN FABRIC

Specimen Type	Pressure (K Pascal)	Large	Small
Pl-1	9	5	5
	12	5-4	5
Pl-2	9	4	3
	12	4-3	3
Pl-3	9	4	3
	12	4-3	3
Tl-1	9	4	4-3
	12	4-3	3
Tl-2	9	3	3
	12	3	3
Tl-3	9	3	2
	12	3	2-1

TABLE 4. ABRASION RESISTANCE OF GREIGE AND DYED WOVEN FABRIC

Specimen Type	Pressure (K Pascal)	Greige, No. of Rubs	Dyed, No of Rubs
Pl-1	9	2000	2000
	12	2000	2000
Pl-2	9	2000	2000
	12	2000	1500
Pl-3	9	1500	1500
	12	1300	1250
Tl-1	9	1200	1400
	12	1100	1100
Tl-2	9	1100	1200
	12	1000	1000
Tl-3	9	900	1000
	12	850	900

during weaving. Tl-1, Tl-2 and Tl-3 fabric samples show less abrasion at 9K Pascal after dyeing as compared to before dyeing. As discussed in preceding Section, after dyeing fabric has been shrinking, yarns are much closer to each other hence, more resistance to abrasion and more thickly is fabric. However, no improvement has been observed at 12K Pascal, it might be because high pressure presses the yarns in the fabric which flattens the yarns, increases the gap between the yarns and makes fabric thinner thus abraded in the same manner as greige state. Similar to Pl-3 fabric, Tl-3 fabric samples have also less resistance to abrasion and yarns are broken after 850-900 rubs; that shows presence of weak yarn. The abrasion resistance indicates the durability of the fabric sample, higher the resistance means more durability and less resistance vise verse. The pressure 9 and 12K Pascal shows whether fabric is suitable for apparel or upholstery purpose.

4.3 Tensile Strength

Tensile strength results of greige and dyed fabric samples are shown in Figs. 1-2. It has been revealed that the tensile strength cN/tex, of the greige fabric is slightly higher than the dyed fabric. The strength of fabric depends on the strength of yarn, when compared the strength cN/tex of lea (1375 warp, 1184 weft) to the greige fabric such as Pl-1 fabric, the tenacity value cN/tex is 40.3% decreased in warp direction and 42.0% in weft direction and for Tl-1 fabric (2/2) tenacity value is 39.4% decreased in warp direction and 46.4% in weft direction. Hence, decreased in tenacity values are more in weft direction as compared to warp yarn direction of fabric.

Similarly, when compared the elongation % value of lea (6.98 warp and 4.77 weft) to the greige fabric, for Pl-1 fabric, it has been increased 167.2% in warp direction and 94.7%

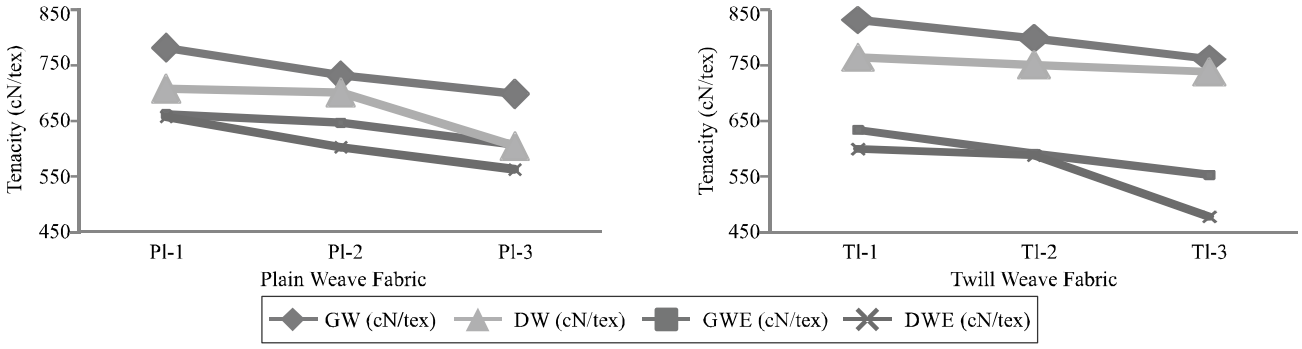

FIG. 1. TENACITY cN/TEX OF GREIGE AND DYED PLAIN AND TWILL WEAVE FABRIC.

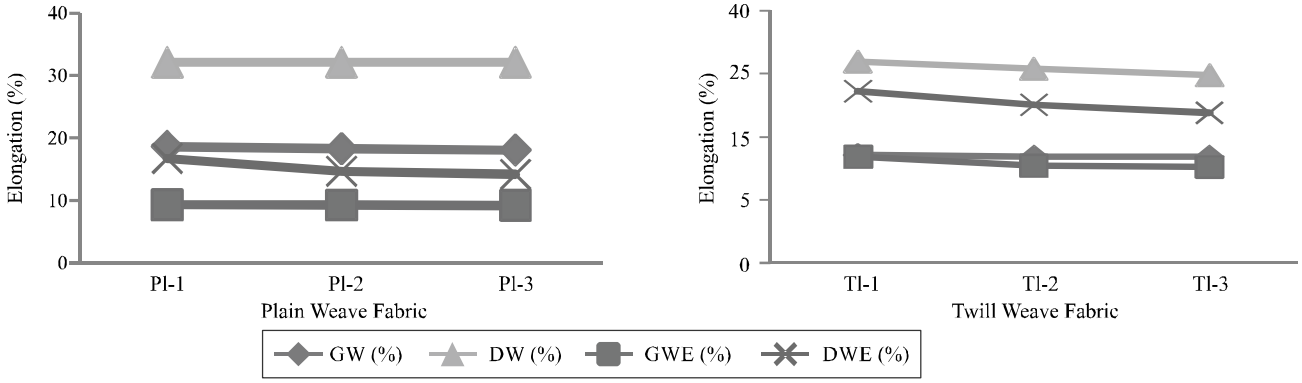

FIG. 2. ELONGATION, % OF GREIGE AND DYED PLAIN AND TWILL WEAVE FABRIC (WHERE, GW IS GREIGE WARP YARN, GWE IS GREIGE WEFT YARN, DW IS DYED WARP YARN, AND DWE IS DYED WEFT YARN)

in weft direction. In case of Tl-1 fabric, it has been increased 73.3% in warp yarn direction and 148.2% in weft yarn direction. It is because during fabric formation, yarns are interlaced at right angle and induce a crimp in the yarn. When a force is applied on the fabric either in warp or weft yarn direction, initially crimp is removed, yarns are straightened and then applied force causes to break the yarns thus fabric sample. Likewise, the elongation percentage value after dyeing is much higher than that of greige fabric in both Plain and Twill weave fabrics. It is due to the wet-treatment (Solomatic bleaching and dyeing process) yarns are swelled and after drying when yarns back to its position, they collapsed and come closer to each other, hence induce more crimp in the fabric sample. Due to the higher percentage of crimp the elongation % is increased.

However, the tenacity value after dyeing is decreased because the interaction of chemicals and heat treatment during pre-treatment and dyeing processes decreases the degree of polymerization of cotton fibre. Although, the strength of cotton fibre is higher when wet as compared to dry state. That is why, only 10 and 8.2% decrease in tenacity value for Pl-1 fabric and Tl-1 fabric in warp direction is observed. Whereas, in weft yarn direction the tenacity value is decreased 0.79% in case of Pl-1 fabric and 5.4% for Tl-1 fabric.

In addition, the tensile strength value of greige woven fabric samples Pl-1 is compared with Pl-2 and Pl-3 sample. Pl-1 sample has given high strength values such as 6.81 and 11.40% in warp direction and 2.52 and 9.12% in weft direction as compared to Pl-2 and Pl-3 fabric sample as shown in Table 5. After dyeing, Pl-1 fabric sample has given 1.2% high tenacity value in warp direction and 9% high tenacity value in weft direction when compared with Pl-2 fabric sample. Similarly, the tenacity value of Pl-3 sample is more than to 15% lower than the Pl-1 sample both in warp and weft direction as shown in Table 6. Hence, similar to other fabric properties such as pilling and abrasion, the tenacity and elongation % values are decreased Pl-1>Pl-2>Pl-3 fabric and for Twill fabric Tl-1>Tl-2>Tl-3. Thus, the improper tension of warp yarn has an adverse effect on the strength of dyed fabric.

TABLE 5. TENSILE STRENGTH OF GREIGE WOVEN FABRIC

Specimen Type	Sample Direction	Average		Coefficient of Variance	
		Tenacity (cN/tex)	Elongation (%)	Tenacity (cN/tex)	Elongation (%)
Pl-1	Warp Yarn	819.8	18.65	0.66	1.74
	Weft Yarn	686.2	9.29	0.35	0.67
Pl-2	Warp Yarn	763.9	18.28	0.88	1.79
	Weft Yarn	668.9	9.22	0.52	0.72
Pl-3	Warp Yarn	726.3	18.06	0.90	1.80
	Weft Yarn	623.6	9.17	0.64	0.72
Tl-1	Warp Yarn	832.1	12.10	0.65	1.25
	Weft Yarn	634	11.84	0.38	0.65
Tl-2	Warp Yarn	798.2	11.89	0.79	1.28
	Weft Yarn	590.7	10.42	0.52	0.72
Tl-3	Warp Yarn	761.2	11.87	0.79	1.28
	Weft Yarn	553.2	10.23	0.58	0.72

TABLE 6. TENSILE STRENGTH OF DYED WOVEN FABRIC

Specimen Type	Sample Direction	Average		Coefficient of Variance	
		Tenacity (cN/tex)	Elongation (%)	Tenacity (cN/tex)	Elongation (%)
Pl-1	Warp Yarn	737.5	32.06	0.70	1.80
	Weft Yarn	680.8	16.68	0.52	0.67
Pl-2	Warp Yarn	729.4	32.66	0.93	1.84
	Weft Yarn	619.5	14.65	0.69	0.72
Pl-3	Warp Yarn	621.4	32.06	0.95	1.85
	Weft Yarn	575	14.15	0.69	0.73
Tl-1	Warp Yarn	764.2	26.89	0.68	1.85
	Weft Yarn	600	22.22	0.40	0.74
Tl-2	Warp Yarn	749.9	25.76	0.84	1.88
	Weft Yarn	588	20.08	0.49	0.84
Tl-3	Warp Yarn	738.2	24.75	0.90	1.93
	Weft Yarn	478.5	18.83	0.68	0.83

5. CONCLUSION

Cotton Plain and Twill weave fabric samples were woven on shuttle loom at varied warp yarn tension. Fabric properties such as pilling and abrasion tendency and strength are important quality parameters and varied due to the further processing. The fabric woven at improper yarn tension not only having affects on fabric construction (thread density and GSM value) but also have an effect on fabric properties. Pl-1 and Tl-1 weave fabric has high strength value, less pilling and abrasion tendency as compared to Pl-2, Pl-3, Tl-2 and Tl-3 fabric. Moreover, fabric properties are deduced after dyeing process and due to the fabric shrinkage slight improvement in elongation percentage is observed.

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