Influence of Warp Yarn Tension on Cotton Woven Fabric Structures

UZMA SYED*, RAFIQUE AHMED JHATIAL, AND MAZHAR HUSSAIN PEERZADA***

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ABSTRACT

Control of the warp and weft yarn tension is an important factor. In this research, effect of warp yarn tension variations on the quality of greige and dyed woven fabrics was investigated. Six fabric samples (three Plain and three Twill weaves) were woven on shuttle loom at varied warp yarn tension. The fabric samples were then pre-treated and dyed (Drimarene Red Cl 5B, 3% owf) using laboratory singeing machine and HT dyeing machine. Greige fabric quality such as fabric inspection, fabric length, fabric width, GSM (Gram per Square Meter), EPI (Ends per Inch), PPI (Picks per Inch), and dyed fabric quality such as L*, a*, b*, C, h^o, $(K/S)_{\lambda max}$ and fastness properties were assessed according to the standard. It has been observed that fabric samples, both Plain and Twill weave; woven at improper warp yarns tension gives rejected greige fabric quality and 1-7% lower $(K/S)_{550nm}$ values as compared to the fabric weave at requisite warp yarn tension such as 38-39cN for Plain fabric and 78cN for Twill fabric for 42x38 and 64x36 tex construction. Hence, among other weave faults, warp yarn tension variation has influence on the greige fabric quality as well as caused improper and uneven dyeing behavior.

Key Words: **Tension Variations, Quality Control, Dyeing, Woven Fabric.**

1. INTRODUCTION

Warp and weft yarn tension; the force acting in the direction of the longitudinal axis of a yarn is considered as one of the most important parameter for fabric formation [1]. Various factors such as machine type, material properties and yarn stress affect on the yarn tension. It is of two types, static and dynamic. Dynamic tension variations are more frequently occurred in textile manufacturing process. It is because during weaving, yarns are moving from supply position to delivery position under the influence of force. The tension on the yarn can either increase or decrease; an increased yarn tension causes fabric deformation, fabric hole and over extension gives permanent change in internal structure of fibres. While decreased in yarn tension also affects on fabric quality such as loops in the pick. Therefore, for producing a high quality fabric at low cost, it is essential to pay an intensive attention on weaving preparation and weaving process [2,3]. Furthermore, the weave fabric or greige fabric quality exert influence on the quality of finished product especially defects per piece. The greige fabric can be used for apparel and home furnishing and the appearance of fabric is potential to improve by processing it through wet-treatment such as pre-treatment process [4,5]. Moreover, if there are faults in the greige fabric this leads to non-uniform dyeing as well as it affects on other fabric properties such as handle, appearance and etc.

*Assistant Professor, and ** Faculty Member,
Department of Textile Engineering, Mehran University of Engineering & Technology, Jamshoro.

During weaving process, the tension on the warp yarn is higher than the weft yarn and it has relatively slow tension variation due to the periodic changes of shedding and beat up processes [1]. During one cycle, the warp yarn moves back and forth through reed, heddle eyes and drop wires, therefore, studying the effect of warp tension variation is very important. However, certain cam of heddle frame can compensate the differences in warp yarn tension. Generally, the warp yarn tension varies from yarn to yarn, weaver beam to weaver beam and fabric structure to fabric structure such as plain and twill weave fabric. The warp yarn tension variation are due to the improper warping, sizing and working of tension sensor on let-off roller and occasionally visible in greige fabric. An uneven warp end tension over the fabric width had an effect on fabric quality and yarn crimp [6-12]. It was observed that the warp yarn had lower tension at the edge zone of warp beam as compared to the middle zone. It is due to the slippage of weft yarn inwards at the edge zones. However, these variations over the fabric width were minimized by increasing the weft yarn density [13] and varying the speed of warp beam [14]. In addition, an equation was designed for homogenized the warp yarn tension variation by controlling the warp let-off value on a warp knitting machine [15].

Similar to warp yarn, weft yarn tension had an influence on fabric properties such as fabric weight, width, strength and shrinkage and crimp level [16]. The difference in fabric properties due to the warp and weft yarn tension variations were depended on the type of loom, raw material and yarn properties such as count and twist level [17,18]. Though, tension on weft yarn could control by using intermediate yarn feeding device and tension measuring head [19,20].

However, much reserach has been done on the effect of warp and weft yarn tension variations on greige fabric only but no work has been carried out on the influences of warp yarn tension on greige and dyed weave fabric quality. In this research, Plain and Twill weave fabrics were woven at three different tension of warp yarn on shuttle loom and then pre-treated and dyed with reactive, monocholortriazinyl dye (3% owf); most abundantly used for dyeing the cotton fabric [21-27]. The effect of warp yarn tension variations on greige and dyed fabric quality was investigated at each stage of processing.

2. MATERIALS

100% cotton warp and weft yarns were purchased from SBCOS, Karachi, Pakistan, and their properties are shown in Table 1. Chemicals used for preparing the dyed samples were Sandopan DTC, Sirrix 2UD, Stabilizer Y2K and Lyogen WN kindly supplied by Clariant, Karachi, Pakistan. For dyeing the cotton woven fabric samples, Drimarene Red Cl 5B, a reactive dye was supplied by Clariant, Karachi, Pakistan.

3. METHODS

3.1 Fabric Formation

Two different types of fabric, Plain and Twill weave, were manufactured at three different position of back roller on Pieco Iwama shuttle loom. The loom was set at 100 rpm of main shaft and 720 rpm of motor, using dobby shedding mechanism.

The warp and weft yarn tension was measured using Electronic Yarn Tension meter Y226A in cN [28].

3.1.1 Plain Weave

For weaving a plain fabric (1/1, up/down) a single cylinder right hand mechanical dobby shedding was required with

TABLE 1. YARN PROPERTIES

Properties	Warp	Weft
Count, Tex	63.8	36
TPM (Twist Per Meter)	335.4	1016.4
Twist Direction	S	Z
Uniformity, U%	12.68	21.21
Thick +50% km	319	3202
Thin -50% km	10	2158
Neps +200% km	395	3634
Hairiness	8.76	7.86
Tenacity cN/tex (Single Yarn)	10.95	8.40
Elongation, % (Single Yarn)	6.35	4.46
Tenacity cN/tex (Lea)	1375	1184
Elongation, % (Lea)	6.98	4.77

four harness frames at draw- straight draft. As exemplify in Fig. 1, in the lattice, first row of holes in the leg represent the first pick and so on. The black circle shows peg was inserted in the wooden strip and lifted the harness frame. The plain weave was woven into three different warp yarn tension.

3.1.2 Twill Weave

The Twill weave was manufactured on the same shuttle loom using a right hand mechanical dobby. As shows in Fig. 2, the right hand twill lines run from the lower-left to upper-right side. A fabric with right hand twill on the surface has left hand twill on the back side. The sum of digits in the weave formula such as 2/2 twill requisite four harness frames. The twill angle was 45^o on the warp and weft density. The design and pegging plans shows 1-8 picks [29,30]. Similar to Plain weave fabric, Twill weave fabric was also woven at three different tension variations using the same number of ends and picks and linear density of warp and weft yarn.

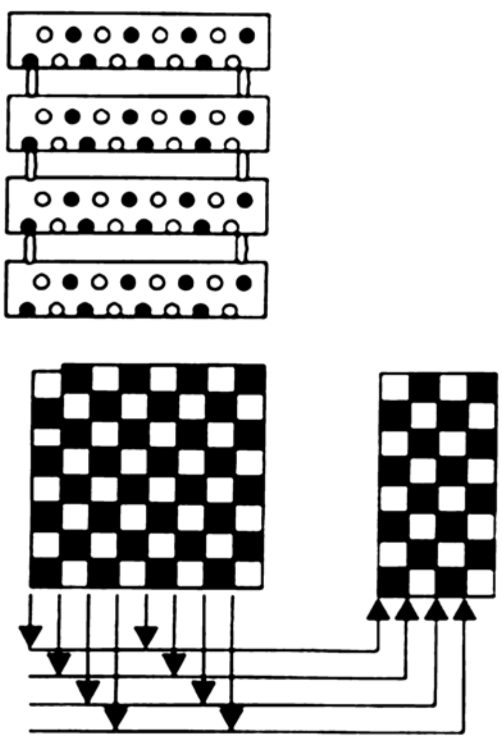

FIG. 1. PLAIN WEAVE

3.2 Greige Fabric Assessment

3.2.1 Fabric Grading

After weaving, the faults of fabric samples were detected and then removable faults were manually removed. The fabric samples were then graded based on the ISO 4.6 grading standard as shown in the Table 2.

3.2.2. Fabric Density

The fabric density was measured in GSM according to the BS EN 12127 ISO 3801 standard. A circular piece of woven fabric; having a diameter of 11.3cm was cut and then weighted. The weight (in gm) of fabric sample was then multiply by 100 as shown in Equation (1).

$$GSM = 100\ (Weight\ of\ Fabric\ in\ gm) \quad (1)$$

3.3 Dyeing Preparation

Greige fabric samples 80x16 inch were singed using laboratory singeing machine [31]. The singed fabric samples

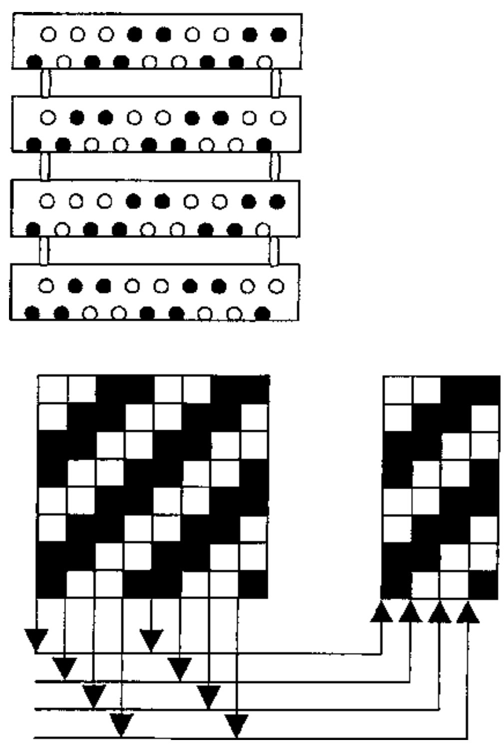

FIG. 2. TWILL WEAVE

were then Solomatic bleach by an exhaust method on Rapid HT dyeing machine. The Solomatic bleaching were carried out at a liquor to goods ratio of 15:1. The bath was set at 50°C, after 20 min detergent, Sandopan DTC ($4gl^{-1}$) and Sirrix 2UD, sequesting agent ($2gl^{-1}$) were added. Temperature was raised up to 90°C for 20 min, then 5% Caustic Soda (48°Be), 0.7% Stabilizer Y2K and 7% Hydrogen per oxide (35%) were added and further treated for 20 min at the same temperature. After bleaching, the fabric samples were rinsed with hot water for 10 min, then warm water for 10 min and before dried in an oven, rinsed with cold water for 5 min.

3.4 Dyeing

Cotton bleached fabric samples of 5gm were taken and dyed by an exhaust method on Rapid HT dyeing machine at a liquor-to-goods ratio of 15:1. The dyeing process was started at 40°C using Drimarene Red Cl 5B (3% owf) and water, after 10 min at the same temperature leveling agent, Lyogen WN ($2gl^{-1}$) were added, after 10 min Salt ($80gl^{-1}$) were added and then temperature was raised up to 60°C for 20 min and Soda Ash ($20gl^{-1}$) was added and then treated further for next 80 min (Fig. 3). The fabric samples were rinsed using Sandopan DTC ($1gl^{-1}$) at 100°C for 15 min and then warm and cold wash for 10 min each and at last dried in an oven.

3.5 Assessment of Bleached Fabric

The singed fabric samples were visually assessed using magnifying glass. The amount of size present in the fabric was determined using potassium iodide solution and then assessed using Tegwa scale giving rating 1-8, where 1 means no size (light green colour) and 8 means presence of sizing agents (dark purple colour).

The degree of whiteness, Berger whiteness of bleached fabric samples were measured on Data Color Spectrophotometer. The whiteness range 40-75 is acceptable for dyeing process.

For predicting, the dye uptake values, wicking test was performed. The bleached fabric samples were cut 10x1cm from the left, right and center from the width of fabric. The dye solution using turquoise reactive dye ($0.5gl^{-1}$) was prepared, and then fabric sample was marked at 1 cm apart and then dipped into the solution for a min. The absorbency rating (0-5) was then observed. Where, zero means no absorbency and five rating means excellent absorbency.

TABLE 2. FABRIC GRADING USING ISO 4.6 STANDARD

No.	Length of Fabric (m)	Points	Grade
1.	100	15	A
2.	100	22	A2
3.	100	30	B
4.	100	40	B2
5.	100	<40	Rejected
6.	100 having 5 Major Defects	4	Rejected

3.6 Dyeing Assessment

The spectral reflectance values (400-700nm), L*, a*, b*, c and h° were measured using a Data Color Spectrophotometer. For each sample, readings were taken four times, each at different position. The percentage reflectance values 'R' were converted to K/S values, using the formula shown in Equation (2).

$$K/S = \frac{(100 - R)^2}{200R} \tag{2}$$

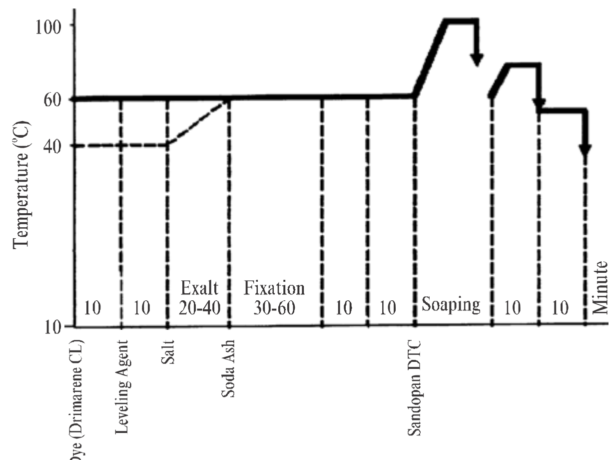

FIG. 3. DYEING PROCEDURE

3.6.1 Fastness

Rubbing fastness was performed according to the BS EN ISO 105-X12:2002 on crock meter. The fastness to washing was performed using BS ISO 105 CO3 standard on Wash Tec-P, Roaches International. Washing fastness samples were assessed using grey scale and staining scale.

4. RESULTS AND DISCUSSION

4.1 Fabric Grading

Table 3 shows with changing the position of back roller on let-off mechanism, the tension on the warp yarn is also varied. Weaving of Plain fabric at 2.5cm back roller downward position (Pl-2) has same grading as Pl-1 fabric but the difference in thread density is observed. It is due to the high tension on the warp yarn as compared to the fabric weave on its original position (Pl-1). During weaving, high warp yarn tension increases the stresses on the warp yarn. The warp yarn is coarser and when relax come closer to each other thus gives less number of picks. Similar results are observed in Pl-3 fabric sample, which has more warp yarn tension (when beam is on stationary condition) as compared to Pl-1 and Pl-2 fabric.

Furthermore, when comparing the warp yarn tension during weaving on upper and lower shed of Pl-1 to Pl-2 and Pl-3 fabric; at 2.5cm downward position of back roller, the tension on upper shed is high. Similarly, when back roller was 2.5cm upward, the tension on lower shed is high. The same variations in tension values on upper and lower shed are observed when comparing Tl-1 fabric to Tl-2 and Tl-3 (Table 4).

The behavior of warp yarn tension on Twill fabric samples is different to the Plain fabric samples. It is because in basic and most common weave [32], Plain, the harnesses are lifted alternatively (one up and one down) while in Twill weave two harnesses are simultaneously lifted up and remaining two moving downward, hence exert high stress on the warp yarn.

The warp yarn tension values are decreased with changing the position of back roller. In case of Pl-3 and Tl-3 fabric samples, fabric faults such as warp entanglement, warp float, warp breakage and selvedge roughness causes the fabric to be in R grading (rejected sample). In addition, yarn unevenness is also caused fabric faults, uneven yarn is weak, increase hairiness and neps thus have more chance to break during fabric manufacturing. However, rejected fabric sample can be used for pigment printing using flat, rotary and inkjet machine.

TABLE 3. PLAIN FABRIC ASSESSMENT

Fabric Assessment	Pl-1*	Pl-2*	Pl-3*
Warp Beam Tension when Stationary, cN	38-39	54-56	64
Warp Beam Tension during Running, cN	48	34	54
Warp Tension on Upper Shed during Running, cN	52	56	46
Warp Tension on Lower Shed during Running, cN	62	60	64
Weft Tension on Pirn, cN	47	47	47
Length of Fabric, m	2	2	2
Fabric Width, Inch	65	65	65
Ends x Picks per cm	42x38	42x36	42x34
Fabric Grade	B2	B2	Rejected

*Pl-1 when back roller was in its respective position (considered as original position), Pl-2 when the back roller was 2.5cm downward from its respective position, and Pl-3 when the back roller was 2.5cm upward from its respective position

TABLE 4. TWILL FABRIC ASSESSMENT

Fabric Assessment	Tl-1*	Tl-2*	Tl-3*
Warp Beam Tension when Stationary, cN	78	62	54
Warp Beam Tension during Running, cN	52	48	46
Warp Tension on Upper Shed during Running, cN	64	68	60
Warp Tension on Lower Shed during Running, cN	82	63	78
Weft Tension on Pirn, cN	47	47	47
Length of Fabric, m	2	2	2
Fabric Width, Inch	65	65	65
Ends, x Picks per cm	42x38	42x36	42x35
Fabric Grade	B	B	Rejected

*Tl-1, when back roller was in its respective position (considered as original position), Tl-2 when the back roller was 2.5cm downward from its respective position, and Tl-3 when the back roller was 2.5cm upward from its respective position

Hence, among other loom parameters, tension of the warp yarn on weaver beam and upper and lower shed should be check before and during weaving process. The yarn tension should be set according to the type of weave structure and fabric quality. If the tension on the warp yarn is not set properly it will affect the fabric quality and fabric faults. Sometime, the tension on warp yarn is varied within the beam that is also lead variations within the fabric sample from left side to right side. It is, therefore, recommended to weaver to check warp and weft yarn tension and set it according to the type of loom, weave, yarn thickness/density and fabric quality. Further, for controlling the warp yarn tension a sensor can be installed on let-off mechanism.

4.2 Fabric Density

It is revealed from Table 5 that the fabric density varies from weave to weave and within same weave due to the variations in warp yarn tension values. The average of five value of GSM is given in Table 5. It is observed from Tables 3-4 high number of ends and picks per cm gives high GSM values hence tighter fabric is. Moreover, inconsiderable difference in GSM values of Pl-1 and Tl-1 is observed, due to an approximately same thread density.

4.3 Degree of Whiteness and Absorbency

Table 6 is the average of four reading of degree of whiteness and average of three reading of absorbency. It has been observed that Twill bleached fabric samples have high degree of whiteness and absorbency values than that the Plain weave fabric samples especially Tl-1 fabric. It is due to the floating structure of Twill weave fabric. The degree of whiteness is necessary for level and uniform dyeing.

However, among Plain weave fabric, Pl-1 fabric gives the highest value of degree of whiteness as compared to Pl-2 and Pl-3 fabric sample. On the contrary, inconsiderable difference in absorbency values are observed in Pl-1 and Pl-2 fabric. The difference in degree of whiteness and absorbency values among fabric samples and within same weave are due to warp yarn tension variations during weaving which causes difference in fabric quality (ends and picks per cm and GSM) and hence lower chemical uptake values.

TABLE 5. GSM OF 100% COTTON WOVEN FABRICS

Fabric	Plain Fabric			Twill Fabric		
GSM	Pl-1	Pl-2	Pl-3	Tl-1	Tl-2	Tl-3
	183	174	172	182	178	177

4.4 Dye Uptake

Piece dyeing is the most productive method for dyeing the textile fabric. In this research, fabric samples were dyed by an exhaust method due to low absorbency values (Table 6). In exhaust dyeing method, fabric, dye, and dye auxiliaries have long interaction, thus time and temperature allows dye molecules to diffuse into the fabric. Hence, optimize the quality of the dyed fabric by enhancing its dye uptake values. L*a*b* values are given in Table 7 shows fabric samples are redder, bluer and towards medium in lightness. Similarly, inconsiderable difference in C* and h degree angle are observed among samples. However, $(K/S)_{550nm}$ value of Tl-1 fabric is highest, due to highest absorbency and degree of whiteness values. The $(K/S)_{550nm}$ values trend decrease Pl-1>Pl-2>Pl-3 fabric samples. Similar trends is observed in case of Twill (2/2) weave fabric (Tl-1 >Tl-2>Tl-3).

Furthermore, due to the tension variations on the warp yarn during weaving not only fabric construction is varied

TABLE 6. DEGREE OF WHITENESS AND ABSORBENCY VALUES OF COTTON WOVEN FABRICS

Specimen Type	Degree of Whiteness	Absorbency
Pl-1	43.34	3
Pl-2	42.31	3-2
Pl-3	39.43	2
Tl-1	53.31	4-3
Tl-2	44.73	3
Tl-3	44.46	3

TABLE 7. L*a*b* C, h^o AND $(K/S)_{550nm}$ VALUES OF COTTON WOVEN FABRICS

Specimen Type	L*	a*	b*	C	h_o	$(K/S)_{550nm}$
Pl-1	42.95	56.96	-1.93	56.99	358.06	12.01
Pl-2	43.30	56.79	-1.67	56.99	358.32	11.91
Pl-3	43.98	57.16	-2.31	57.21	357.69	11.19
Tl-1	39.25	55.14	-1.30	55.14	358.55	16.02
Tl-2	43.27	57.55	-1.41	57.56	358.60	12.07
Tl-3	45.00	56.37	-3.08	56.45	356.88	9.92

but also have considerable affect on dyeing behavior. Dyers have to add more dye, dye longer time and at high temperature in order to achieve the requisite shade matching. In the case when tension variations are occurred within the same sample, it gives unlevel and improper dyeing.

In addition, yarn unevenness and faults are prominent, if weaving is carried out at improper setting thus causes uneven dyeing and lower dye uptake values. Pl-3 and Tl-3 fabric samples are rejected due to warp breakage, warp miss and given the lowest $(K/S)_{550nm}$ values.

4.5 Fastness

The rubbing fastness results are given in Table 8 and washing fastness in Table 9 shows that the fabric samples Pl-2, Pl-3 and Tl-2 and Tl-3 have not only lower dye uptake values but also lower fastness values comparing to Pl-1 and Tl-1 fabric sample. However, fastness such as rubbing and washing are more depended on the dye class. Overall, reactive dye has very good rubbing and washing fastness properties.

TABLE 8. RUBBING FASTNESS OF COTTON DYED FABRICS

Specimen Type	Warp		Weft	
	Dry	Wet	Dry	Wet
Pl-1	5	5-4	5	5-4
Pl-2	5	5-4	5-4	4
Pl-3	4	4-3	4	4
Tl-1	5	5-4	5	5-4
Tl-2	5	5-4	5	5-4
Tl-3	4	4-3	4	4

TABLE 9. WASHING FASTNESS OF COTTON DYED FABRICS

Specimen Type	Multifibers						Dyed Fabric
	Acetate	Cotton	Acrylate	Polyester	Nylon	Wool	
Pl-1	5	5-4	5	5	5	5	5-4
Pl-2	5	4-3	5	5	5	5	5-4
Pl-3	5	4-3	5	5	5	5	5-4
Tl-1	5	5-4	5	5	5	5	5-4
Tl-2	5	4	5	5	5	5	5-4
Tl-3	5	4-3	5	5	5	5	5-4

5. CONCLUSION

From the technological and technical point of view this research is very helpful for efficiently manufacturing the textile fabric. It is concluded that the fabric samples (Plain and Twill weave) at different warp yarn tension have variations in fabric construction, GSM and quality. Furthermore, improper warp yarn tension gives lower absorbency, degree of whiteness and dye uptake values. The variations in dyeing properties are more observed in Pl-3 and Tl-3 fabric samples as compared to Pl-1 and Tl-1 fabric. It means Pl-1 and Tl-1 fabrics were woven at requisite warp yarn tension while Pl-2, Pl-3 and Tl-2 and Tl-3 were woven by changing the position of back roller thus at varied warp yarn tension. Therefore, for right first time dyeing among other parameters of dyeing, weaving at control condition is also recommended. Otherwise, weaving faults leads up to dyeing process and gives uneven and improper dyeing.

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