

A STATISTICAL APPROACH FOR OBTAINING THE CONTROLLED WOVEN FABRIC WIDTH

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Abstract:

A common problem faced in fabric manufacturing is the production of inconsistent fabric width on shuttleless looms in spite of the same fabric specifications. Weft-wise crimp controls the fabric width and it depends on a number of factors, including warp tension, temple type, fabric take-up pressing tension and loom working width. The aim of this study is to investigate the effect of these parameters on the fabric width produced. Taguchi's orthogonal design was used to optimise the weaving parameters for obtaining controlled fabric width. On the basis of signal to noise ratios, it could be concluded that controlled fabric width could be produced using medium temple type and intense take-up pressing tension at relatively lower warp tension and smaller loom working width. The analysis of variance revealed that temple needle size was the most significant factor affecting the fabric width, followed by loom working width and warp tension, whereas take-up pressing tension was least significant of all the factors investigated in the study.

Keywords:

Weaving parameters, Fabric width, Optimisation, Taguchi approach

1. INTRODUCTION

Weaving is the interlacement of two sets of yarns at right angles to each other[1]. One set of yarns runs in longitudinal direction (warp) and the other in crosswise direction (weft). Crimp is inserted during interlacement of the yarn sets. The extent of warp and weft crimp determines the fabric length and width vis-à-vis the length of yarns incorporated in that direction. Higher the stress on warp yarns during weaving, lower will be the crimp inserted in the warp and higher will be the crimp in the weft[2]. When woven on loom, fabric width is equal to the reed within the vicinity of the reed. However, as the fabric gets away from the reed or is taken off the loom, it narrows down in width. So, the on-loom width corresponds to the reeded width, while off-loom width is the width after weft contraction when it is taken off the loom.

Fabric width is the most important parameter of fabric, affecting its properties. Inequality in the fabric width results in variation of porosity and air permeability. Also, the mechanical and physical properties of fabric are dependent on its width. If the fabric width achieved is not the same as required, there will be variation in the ends/inch and ultimately the GSM (grams per square meter) of fabric. The problem becomes even more severe if there is variation in the width of different looms running with the same construction. A variation in the fabric strength will be observed due to varying width and number of ends/inch of the fabric. Keeping in view the problem, the fabric can be rejected by the customer, if he is more concerned with the width, as in pattern making and cutting, it is essential to have a controlled fabric width.

Weft crimp is generally of more importance compared to warp crimp since variations in weft crimp will result in variation in the off-loom fabric width. The higher the weft contraction, lower will be the off-loom width. Weft crimp may be affected by different factors, like the tension on the weft yarn during insertion[3]. The tension is mostly set according to the type of weave design and the fabric construction, which further affects the fabric areal density[4].

Some fibre and yarn variables like fibre fineness, staple length, and twist in the weft also have significant influence on the amount of weft-way fabric contraction. Previous research has indicated a direct relationship of weaving contraction with fibre staple length and yarn twist while inverse relationship with fibre micronaire[5]. Core-spun cotton yarns, with elastane in the core, have become quite popular in the textile industry. Fabric containing such yarns have more contraction in width due to higher retraction force[6].

The yarn crimp is also considerably affected by thread count and filling density – coarser the weft yarn, more is the warp crimp[7]. But with increase in filling density and coarser thread count, the weaving becomes difficult due to increase in cover factor. Many other factors like warp tension at beat up, weaving resistance, and warp and weft densities in loom state are affected by changes in closed shed warp tension and running weft tension[8]. According to Adomaitene *et al.*[9] the initial warp tension and heald crossing moment changes the fabric structure parameters, thus changing the behaviour of the fabric.

Loom working width is usually expressed in terms of reed space or useful reeding width. Looms with a variety of working widths are available in the market, ranging from 1500 to 3900 mm. The crimp in the weft causes the fabric to contract, and outer ends causing a sideways pressure on the reed dents. It can cause the reed to get damaged. The temples are installed on the loom to grip the cloth at the fell, keeping it stretched to the same width as that of the reed [10]. They also help to keep the weft contraction in the beat up zone to the lowest. Most common types of temples include the ring temples, roller temples and full-width temples.

Ring temples are the most widely used type of temples. These temples have pinned rings, which penetrate in the cloth [11]. The pins do not exert force on weft, but directly on the warp. The length of pins is governed by the type of cloth being woven and is about 1.5–2 times the fabric thickness. Brass rings can be used for all types of fabrics, while for delicate fabrics, plastic rings are preferred.

Taguchi method is one of the most commonly used statistical methods for process optimisation with minimum number of experimental runs. It focuses on improving the fundamental function of a product or process, aiding in flexible designs, reducing product costs, improving quality and simultaneously reducing development time. The purpose of parameter design is to investigate the overall noise variation when the levels of the control factors are allowed to vary widely [12].

No significant work has been reported in the literature on the effect of temple type, loom working width, take-up pressing tension and warp tension on the off-loom fabric width obtained in weaving. The aim of this study is to optimise the temple type, loom working width, take-up pressing tension and warp tension for obtaining controlled off-loom fabric width for specific fabric construction, using Taguchi approach.

2. Experimental

The material used in this study was 100% cotton yarns and the weaving of samples was performed on Tsudakoma Air jet loom (Zax Professional 9100) equipped with tappet shedding system. The properties of warp and weft yarns used for this study are shown in Table 1. Both the warp and weft were 100% cotton, having comparable values of tenacity and elongation. The twist in yarn and imperfections are also given in Table 1.

The densities of warp and weft were 50.5 and 23.5 threads/cm, respectively, in the samples produced, while all the samples were woven in 3/1 S Twill design.

The weaving parameters that were kept constant for all the fabrics are given in Table 2.

The variables and levels for each experimental variable are given in Table 3.

Taguchi Design of Experiment (TDOE) in Minitab (v 16.0) was employed for obtaining the orthogonal matrix given in Table 4.

Table 1: Properties of yarns used in present study

Property	Warp yarn	Weft yarn
Material	100% cotton	100% cotton
Count (tex)	30	37
Twist per meter (TPM)	720	630
Twist direction	Z	Z
Uniformity (U) %	12.70	11.03
Thick places, +50%/km	234	87
Thin places, -50%/km	21	0
Neps, +200%/km	148	131
Hairiness	7.66	8.03
Tenacity, g/tex	16.21	16.14
Elongation, %	4.2	4.02

Table 2: Loom parameters observed during weaving fabric samples

Parameters	Crank angle	Value
RPM	-	950
Beat up	360°	-
Picking	76°	-
Shed crossing	290°	-
Let-off	Continuous	4 times
Take-up	Continuous	-
Maximum shed opening	180°	76 mm
Back rest position	Easing: 290°	Horizontal = 5 mm Vertical = 45 mm

RPM: Revolutions per min

Table 3: Control factors and levels for experimental design

Factors	Level 1	Level 2
A: warp tension (N)	4200 N	5000 N
B: temple needle	Fine	Medium
C: take-up pressing tension	Medium	Intense
D: loom working width (mm)	1900	2100

Table 4: L8 OA for samples production

A	B	C	D
1	1	1	1
1	1	2	2
1	2	1	2
1	2	2	1
2	1	1	2
2	1	2	1
2	2	1	1
2	2	2	2

A: warp tension; B: temple needle; C: take-up pressing tension; D: loom working width (mm)

OA: Orthogonal array

After the production of fabric samples according to the TDOE, the off-loom width of the samples was tested according to ASTM (American Society of Testing & Materials) D-3774 test method, using option B[13]. The steel tape used for measurement had 1 mm graduations and length greater than the width of fabric to be measured. The relaxation time for the measurement of fabric width was 24 hours.

3. Results and Discussion

The average values of off-loom fabric width after each experiment are listed in Table 5, including signal to noise (S/N) values calculated according to Equation (1) (for higher the better), where n is the number of experiments in the orthogonal array and y is the i th measured value of fabric width.

Table 5: Experimental results of the samples produced

A	B	C	D	Fabric width (mm)		S/N ratio
				Average	Standard deviation	
4200	Fine	Medium	1900	1602.8	1.3038	64.0976
4200	Fine	Intense	2100	1602.8	0.8367	64.0976
4200	Medium	Medium	2100	1605.4	0.8367	64.1117
4200	Medium	Intense	1900	1613.4	0.8367	64.1548
5000	Fine	Medium	2100	1598.6	0.8367	64.0748
5000	Fine	Intense	1900	1603.0	0.5477	64.0987
5000	Medium	Medium	1900	1607.0	1.1402	64.1203
5000	Medium	Intense	2100	1604.8	1.1402	64.1084

A: warp tension; B: temple needle; C: take-up pressing tension; D: loom working width (mm)

$$S/N = -10 \log \left[\frac{1}{n} \sum_{i=1}^n \frac{1}{y_i^2} \right] \quad (1)$$

S/N value is the measure of performance variability of products/ processes in the presence of noise factors. It is a performance criterion, defined as the S/N ratio, in that, S stands for mean and is called signal and N stands for standard deviation and is called noise [14]. The higher the S/N value, better the quality of product.

For both levels 1 and 2, average S/N ratio is given in Table 6.

Table 6: Average S/N ratio at level 1 and level 2

Factor	Average S/N ratio (at level 1)	Average S/N ratio (at level 2)	Delta
A	64.12*	64.10	0.02
B	64.09	64.12*	0.03
C	64.10	64.11*	0.01
D	64.12*	64.10	0.02
*optimum factor level			

while the main effects plot for S/N ratio are shown in Figure 1.

The delta values were calculated by subtracting the higher S/N value from the lower value. The analysis of variance (ANOVA) for S/N ratios is shown in Table 7. P-values < 0.05 indicate that the effect of terms B and D is statistically significant with more than 95% confidence, while the p-values < 0.1 indicate that the terms A and C has significant effect on fabric width with 90% confidence. The R-sq value of the established linear model

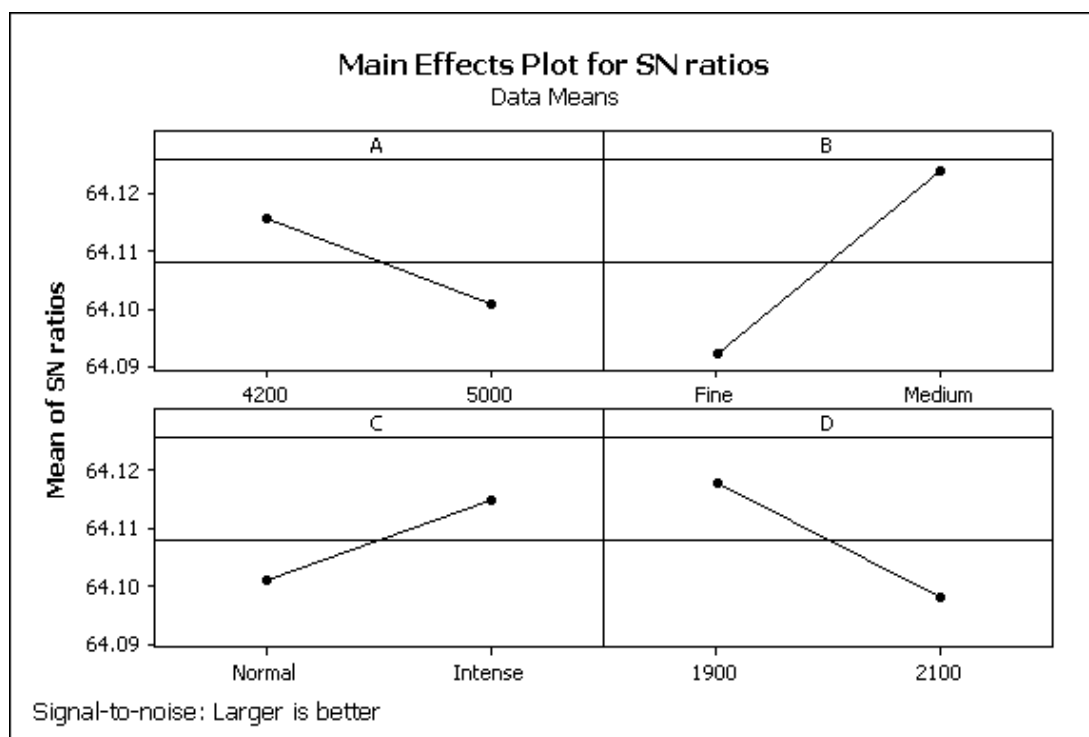


Figure 1: Main effects plot (data means) for S/N ratios

Table 7: ANOVA for S/N ratios

Source of variation	Degree of freedom	Sum of squares	Mean square	F-ratio	p-value
A	1	0.000442	0.000442	8.25	0.064
B	1	0.002004	0.002004	37.38	0.009
C	1	0.000380	0.000380	7.09	0.076
D	1	0.000779	0.000779	14.54	0.032
Residual error	3	0.000161	0.000054		
Total	7	0.003766			

ANOVA: Analysis of variance

was found to be 95.7%, indicating that 95.7% variation in fabric width could be explained by the terms included in the model.

It is obvious from Figure 1 and the delta values from Table 6 that the fabric width is affected the most with factor B (temple needle), followed by the factors D (loom working width), A (warp tension) and C (take-up pressing tension), respectively.

The fabric width increases with decrease in A (warp tension). At lower warp tension, the crimp in the warp will be higher but in the weft will be lower, a phenomenon known as crimp interchange[15].

The temple type has the most significant effect on the width of fabric. With fine needle type, the grip is not adequate enough to keep the fabric stretched compared to the medium needle type. Hence, medium temple needle results in higher fabric width compared to the finer temple needle.

With normal take-up pressing, the fabric contracts in the nip, causing a decrease in the fabric width. But in case of intense take-up pressing, more width is achieved.

In case of a wider width loom, the air pressure for weft insertion has the tendency to decrease at the receiving side, causing a little slackness in the weft yarn. So, more will be the crimp in weft, hence resulting in decrease in the fabric width[14].

The combination of factor levels for obtaining maximum fabric width was found to be $A_1B_2C_2D_1$, corresponding to a 4200 N warp tension, medium temple needle, intense take-up pressing tension and 1900 mm loom working width.

The fabric width values predicted from the Taguchi design for combinations of input variables not used in the original Taguchi design of experiment are given in Table 8.

Table 8: Comparison of experimental results with fabric width predicted from Taguchi design

A	B	C	D	Predicted fabric width (mm)	Actual fabric width (mm)		Difference between predicted and actual width (mm)
					Average	Standard deviation	
1	1	1	2	1600.1	1600.8	1.3038	-0.7
1	1	2	1	1606.3	1604.2	1.1402	2.1
1	2	1	1	1609.6	1607.8	1.2247	1.8
1	2	2	2	1608.5	1607.6	0.8367	0.9
2	1	1	1	1601.0	1599.8	1.2247	1.2
2	1	2	2	1599.9	1602.2	1.0954	-2.3
2	2	1	2	1603.2	1603.8	1.3038	-0.6
2	2	2	1	1609.4	1609.2	1.3038	0.2

Fabric samples were also manufactured on these combinations of input variables, followed by the measurement of their actual length. A comparison of the difference between the predicted and the actual width values in Table 8 shows good agreement between the predicted and actual values.

4. Conclusion

Weaving parameters could be optimised for obtained controlled off-loom fabric width using cost-effective Taguchi approach. It was concluded that the use of medium-sized temple needle and intense take-up pressing tension results in maximum fabric width at a relatively lower warp tension. Also, a smaller loom working width resulted in maximising the fabric width. The ANOVA test was used to determine the effect of independent variables on the dependent variable. Based on the ANOVA, it was further concluded that temple needle size was the most significant factor affecting the fabric width, followed by loom working width and warp tension, whereas take-up pressing tension was the least significant factor of all the factors investigated in the study.

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