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MATHEMATICAL MODEL FOR WARP TENSION WITH VARIOUS BACK REST SETTINGS AND RELATIONSHIP WITH TECHNOLOGICAL PARAMETERS

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ABSTRACT

In the textile industry, in order to better control loom warp tension and obtain better quality fabrics, it was very pivotal to analyze the influence of mechanical and technological parameters on warp sheet during weaving.

When warp ends are continuously subjected to tension variation numerous number of warp breakages may occur and as a result the quality of fabric produced as well as the loom production efficiency is impaired. In the fabric manufacturing process, warp breakages cost in weaving are far higher than in all other stages of production.

Uniform fabric density and cover factor in warp & weft way is vital for high quality fabrics such as technical textiles and smart textiles. So author attempt to model the tension in variation along the warp sheet from the weaver's beam up to the fabric formation zone under set of assumptions in this paper and derived a linear model which can be used to study the behavior of fabric fell.

In this study, the effect of the backrest roller type and position on the physical and mechanical properties of fabrics was investigated. Author has measured warp tension with computerized electronic tension device and shown with mathematical module and experimental data, the influence of backrest parameters on weavability.

KEYWORDS: Warp Tension, Weaver's Beam, Mathematical Model, Backrest

1. INTRODUCTION

Anyone who wants to produce top quality woven fabrics for technical textiles and smart textiles in large quantity must have correct selection and settings of devices of weaving machine and more or less uniform warp and weft tension. An additional criterion is thorough familiarity with the entire fabric formation process on the weaving machine, to ensure that fabric production is profitable.

Usually the basis for good warp running characteristics on the weaving machine is created in warp preparation. Faultlessly produced weaver's beams and precision work on the sizing machine, in combination with the correct selection of sizing materials and size application, are the conditions that have to be fulfilled. However excessive variation of warp tension due to wrong settings of certain devices of the weaving machine is led to high warp breakages over shadowing (fading) the good work done in the weaving preparation department. Weaving machine stoppage, whatever its cause, harbors the risk of a fabric defect.

Weaving machine stoppages adversely affect the weaving mill's productivity, reduce machine allocation per weaver and increase costs. If possible, such interruptions of production should be avoided. In order to eliminate stoppages, their cause and frequency must be known. Modern weaving machine terminals and mill management systems provide information on the number of stoppages but not about their exact causes.

Therefore the warp tension is the vital technological parameter of fabric formation process as the warp tension determines number of breakages on the loom and the quality of fabric produced. The tension variation of the weaver's beam also can cause to the irregular fabric density and it directly influences on fabric quality. In order to achieve a high quality fabric, it is desired to minimize the number of defects and consistency needs to be maintained in colour and appearance.

The backrest is one of the most important parts of a weaving machine, and lengthwise yarn of the fabric known as warp yarn passes over the backrest. One of the main functions of the backrest is to exert a basic tension on the warp yarns as they are unwound from the weaver's beam during the process of weaving. This tension must be held constant during the process and also during each weaving cycle of the loom. If this tension is kept at a constant then the fabrics will be woven with minimum number of warp breakages yielding a better loom efficiency and higher quality.

The correct selection of the backrest of a loom is vital in producing high quality woven fabric. Adjustments to the positioning of the backrest, its type are inevitable when the performance of the weaving machine can no longer be tolerated with standard settings for low weft density, high weft density, and extra heavy fabrics. Vary in fabric density is a crucial especially in technical textiles and smart textiles.

There are several researches done in order to define basic warp tension and warp deformation of the warp sheet on the weaving machine. However, it did not consider tension and deformation of warp yarn on the surface and layers in the weaver's beam up to certain extent. Further warp deformation on the backrest due to mechanical properties was not considered. To understand the movement of the fabric fell during beat up is a must to avoid reed marks, weft density variations and warp breakages due to bumping effect etc…

This has encouraged us to investigate the influence of the type and position of the backrest on properties of woven fabrics. During the process of weaving warp-sheet is subjected to lengthwise elongation, due which position of the fabric fell may vary in weaving. Fabric fell displacement creates various problems such as high warp breakages, variation in weft density, fabric defects such as reed marks, bumping effect etc…

In order to overcome above mentioned issues, it is vital to develop a mathematical model for the elastic warp gaiting system of the loom and investigate the relationship between fabric fell and the warp tension.

In this paper, author intends to introduce a mathematical module for the warp tension and warp deformation on the weaver's beam, on the backrest and other sections of the warp sheet to control the beat up zone and regulate the tension variation developed along the warp sheet from the weaver's beam up to the fabric formation zone. To develop a mathematical model for the elastic warp gaiting system of the loom and investigate the relationship between fabric fell and the warp tension.

Further author attempts to theoretically investigate the influence of the type and position of the backrest on properties of woven fabrics and to explain the relationship with the let off settings and the rationale behind at the stage of weaving. Rest of the paper organized in the following way. Experimental procedure to produce fabric samples with different positions of the backrest .Further type of fabric tests carried out for the woven fabric samples and results are briefly presented. Next Section dedicated for the discussion and the conclusions are briefed in final section.

2. THEORETICAL ANALYSIS

2.1 Backrest and Warp Tension

The weaver's beam with warp yarns is placed at the bottom part of the back of the loom. The warp yarns withdrawn from weaver's beam are taken around the backrest which has a cylindrical shape and it exerts the required tension to the warp sheet. Designing of backrests falls into 2 categories namely with stationary and movable axes. The backrest with a stationary axis can be further classified into fixed and rotational type.

If the backrest is of fixed type then due to friction between the backrest and warp yarns, they are subjected to additional tension. Therefore warp tension in the working zone (**K_2**) is greater than tension at the weavers beam (**K_1**), (refer Figure 1). Therefore a higher tension can be utilized in the fabric formation zone than the original tension at the weaver's beam.

If the backrest is of a rotational type then as warp yarns slide over the back rest, it rotates together with warp yarns and due to this rotation of the back rest, tension in the fabric formation zone (**K_2**) equals to the tension at the weavers beam (**K_1**). A movable or oscillating type backrest is used for equalizing the warp tension variation during shed formation.

In this paper, authors attempt to mathematically model the tension across the back rest and the influence of the number of fixed backrests on warp tension in fabric formation zone. Single backrest with warp yarns is shown in Figure 1 whereas the Figure 2 shows the double backrest with warp yarns.

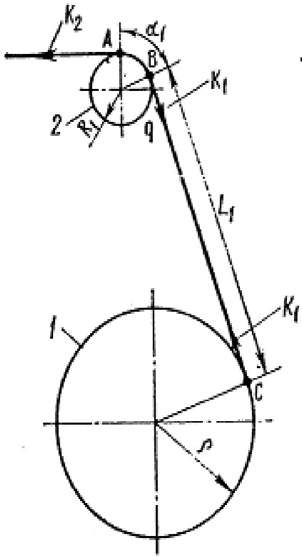

Figure 1

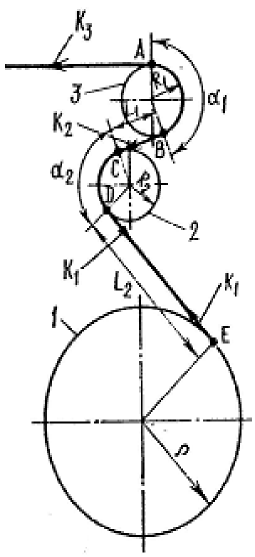

Figure 2

The warp tension in the working zone K_2 can be calculated by the equation.

$$K_2 = K_1 e^{f_1 \alpha_1}$$

Where; $\mathbf{f_1}$ is the friction factor between the warp yarns and the back rest, α_1, α_2, α_3 are the envelopment angle of the warp yarns with the 1st, 2nd and 3rd backrest respectively.

The warp tension in the working zone with double backrests can be written as

$K_3 = K_1 \mathbf{e}^{f_1(\alpha 1+\alpha 2)}$

In case of three backrests, warp tension can be expressed as

$\mathbf{K_4} = K_1 \mathbf{e}^{f_1(\alpha 1+\alpha 2+\alpha 3)}$

For instance if $\alpha_1 = \pi/2$, $\alpha_1+\alpha_2 = 1.4\pi$ and $\alpha_1+\alpha_2+\alpha_3 = 1.7\pi$ then

$\mathbf{K_2} = 1.265\, \mathbf{K_1}$, $\mathbf{K_3} = 1.6\, \mathbf{K_2}$, $\mathbf{K_4} = 2.014\, \mathbf{K_1}$,

Therefore with the increase of number of backrests, warp tension can be increased. Thus with multi backrest arrangements, warp tension can be significantly increased in the weaving zone by giving a lower initial (basic) tension at the weaver's beam. It prevents deformation possibilities of warp ends at the beam due to high warp tension.

In a multi backrest system the rapid dynamic tensions introduced on the warp sheet in the weaving zone due to the up and down motion of the healds and the beat-up forces of the slay are prevented from being transferred to the warp yarns from the backrest towards the weaver's beam.

2.2 Mathematical Analysis of Warp Deformation

Displacement of the fabric fell during weaving depends on various factors. However warp ends coming out from the waver's beam is elongated and it will significantly change the position of the fabric fell. Hence to understand actual value of the beat-up zone or fabric fell displacement, it is necessary to analyze warp deformation from the weaver's beam up to the fabric fell and flexural rigidity factor of the warp gaiting system of the loom.

In order to calculate the coefficient of rigidity of warp in loom gating system with single fixed backrest, it is necessary to study coefficient of rigidity of following elements of warp sheet. Section of warp AB wrapping around backrest 2, free length of warp BC between backrest and weaver's beam with a length of L_1 and section of warp on the surface of the weaver's beam.

As per in [3] the equivalent length of the section AB can be written as

$L_{R1equ} = R_1/f_1\ (1-1/e^{f1\alpha 1})$ (1)

Where R_1 is the radius of the backrest

Yarn tension over the backrest can be written as$K_2 = K_1\ e^{f1\alpha 1}$ (2)

If a warp of length of L_1 has a longitudinal elongation λ, it can be quantitatively expressed as

$\lambda = k_1 L_1/\ c_w$ (3)

Where, c_w is the flexural rigidity factor of warp ends.

Assuming that warp length is subjected to tension K_2imparts uniform and same elongation of λ, as warp yarns bending over the backrest and can be substitute with equivalent length of warp $L_{1equ}$and the following relationship can be derived

$\lambda = L_{1equ}\, K_2\, /c_w$ (4)

Elongation of the warp on the weaver's beam due to tension k_1 is

$$\lambda = k_1\rho / c_w f_2 \tag{5}$$

From equation (2), (3) and (4) equalent length for the section BC can be derived as

$$L_{1equ} = L_1 e^{f1\alpha1} \tag{6}$$

Equalent length of warp ends are subjected to elongation on the weaver's beam and it can be derived from equations (2), (4) and (5)

$$L\rho_{equ} = \rho / f_2\, e^{f1\alpha1} \tag{7}$$

The total equivalent length of this section under K_2 tension and can be defined approximately by the following equations.

$$L_{equ1} = R_1 (1- 1/e^{f1\alpha1})/f + (L_1/e^{f1\alpha1}) + \rho/(f_2 e^{\,f1\alpha1}) \tag{8}$$

Where, f_2 is the coefficient of friction of warp ends against the surface of the weaver's beam.

In case of double stationary backrests in Figure 2, it is necessary to consider section AB bending over first back rest, section BC between first and the second back rest, section CD bending over second back rest, section DE between second back rest and the weaver's beam and the equalent length of warp on the weavers beam.

Total equivalent length of above section is determined by the following equation

$$L_{equ2} = R_1(1- 1/e^{f1\alpha1})/f + (L_1/e^{f1\alpha1}) + R_2/ (fe^{\,f1\alpha1}) (1- 1/e^{f1\alpha2}) + L_2/e^{\,f1(\alpha1 + \alpha2)} + \rho/ (f_2 e^{\,f1(\alpha1+\alpha2)}) \tag{9}$$

The total equivalent length for three stationary backrests (L_{equ3}) can be derived from equation (1) to (5) in a similar way to equation L_{equ2}.

$$L_{equ3} = L_{equ2} + R_3/e^{f1(\alpha1+ \alpha2)} (1- 1/e^{f1\alpha 3}) + L_3/e^{\,f (\alpha1+\alpha2+\alpha3)} + \rho/f_2\, e^{f (\alpha1+\alpha2+\alpha3)} \tag{10}$$

3. EXPERIMENTAL PROCEDURE

3.1 Test Specification

An experimental design in this research includes air jet loom, Computerized tension measuring device, martindale abrasion tester, Instron strength testing machine, sample dyeing machine, Color matching computer and a personal computer.

In measuring the warp yarn tension, digital yarn tension measuring equipment was used.

The specifications of the tension measuring equipment can be stated as follows.

Make: ZIVY, Model: EL-TEN, Range: 0-400cN, Resolution: 0.1cN, Warp yarn count-24 tex

The experiment was carried out on the air jet loom with the following specifications.

Make: Tsudakoma, Model: ZA 203, Speed: 525 picks/min, Total warp ends 4470

Abrasion test was carried out on martindale abrasion tester.

Tests on Breakage load & Deformation of fabric samples were performed on Instron strength testing machine.

Fabric samples were dyed in sample dyeing machine

Colour matching computer was used to test colour variation

Following are the details of the fabric samples produced with different position of the back rest.

Weave	plain weave,	Yarn count	45s p/v warp & weft
Ends/inch	98	Picks/inch	84

Fabric samples were tested in the physical testing laboratory at R.H. 65% and Temp. 27^0 C

3.2 Test Procedure

An experiment was carried out to find the influence of the positioning of the backrest in relation to its height, on warp yarn breakages and the change on properties of woven fabric (Figure 3).

Experiment was conducted on the Tsudakoma Air Jet loom. The position of the backrest was changed in the vertical direction. Five positions were selected considering the front rest level of the weaving machine was adapted as the point of reference and the Initial warp tension was adjusted electronically and kept at constant for all fabric samples. All other settings of the weaving machine were not changed. Then fabric samples were woven for each position of the back rest.

According to the fabric testing standards, fabric sample sizes were made for Martindale abrasion tester and Instron strength testing machine, fabric samples were tested on Martindale abrasion tester and Instron strength testing machine

Dye ability of fabrics was tested with samples which were pretreated and dyed in one column in on a sample dyeing machine. Colours were matched by a colour matching computer.

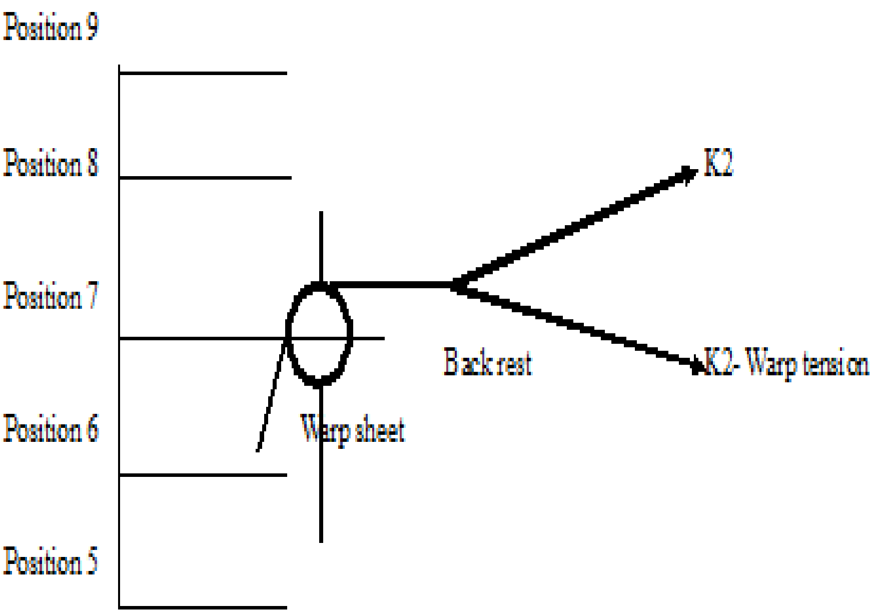

Figure 3: Back Rest Position at Different Heights

3.3 Test Results

Results of abrasion test of the face side and back side of fabric samples are given in the Table 1 and Graphs of percentage of weight loss of the same at different positions of the backrest are shown in Figure 4a and Figure 4b.

Table 1: Test Results of Abrasion Test for the Face Side and Back Side of the Fabric Samples for Different Position of the Back Rest

Percentage of Weight Loss after No Rubs	Back Side of the Fabric Sample				Face Side of the Fabric Sample	
	Position of the Back Rest				Position of the Back Rest	
	6	7	8	6	7	8
3000	1.2	0.8	0.5	1.8	0.3	0.4
5000	2.7	1.8	1.4	2.0	0.8	1.3
7000	3.5	3.4	3	6.6	1.7	2.2
9000	4.5	4.5	4.2	7.0	5.0	5.3
11000	5.7	6	5.4	7.7	6.5	7.4

Table 2: Test Results of Extension & Load in Warp Wise and Weft Wise Direction for Different Position of the Back Rest

Position of the Backrest	Average Load (N)		Average Extension (mm)	
	(Warp Wise)	Weft Wise	(Warp Wise)	Weft Wise
5	608.86	478	33.506	38.048
6	612.96	485.98	31.632	38.728
7	600.14	485.62	31.592	38.278
8	614.84	476.48	32.396	38.082
9	612.08	475.02	32.722	37.672
10	591.98	471.48	31.308	37.964

The strength testing was carried out with Instron 4301 Universal testing machine and the fabrics were tested in the warp and the weft directions. Average test results of breaking strengths and extensions at the break point for different positions of the backrest are given in Table 2 and Graphs of extension and load of warp & weft against the position of backrest are shown in Figure 5a and Figure 5b.

Dye ability of fabrics was tested with samples which were pretreated and dyed in one column. Colours were matched by a color matching computer. The fabric produced at position 5, was kept as the reference colour and it was compared with the fabrics produced at positions 6, 7, 8 and 9.

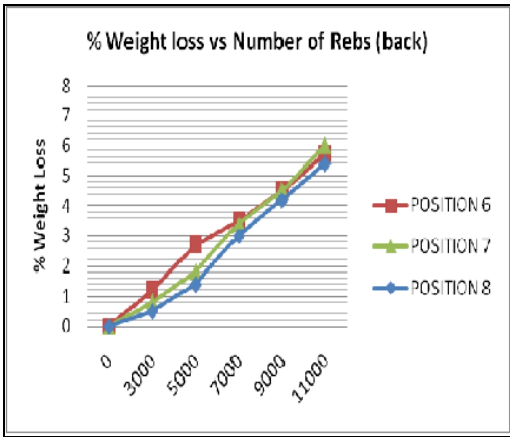

Figure 4a

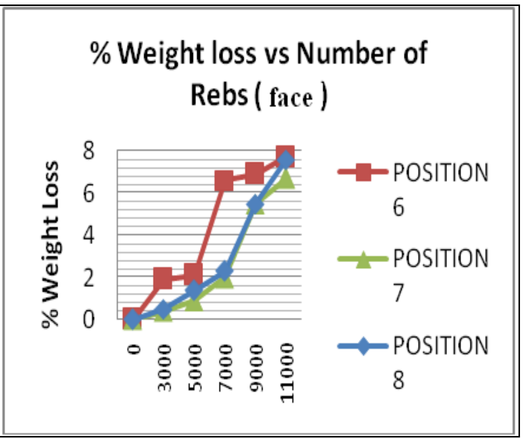

Figure 4b

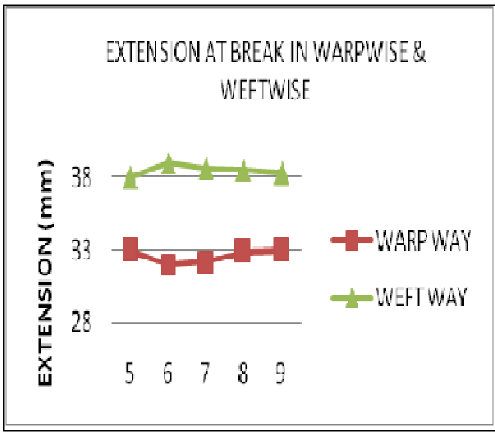

Figure 5a

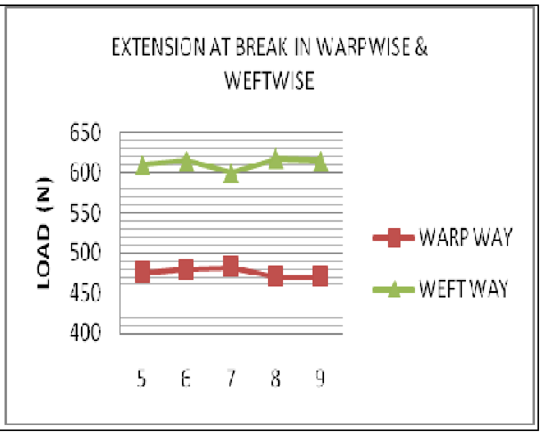

Figure 5b

DISCUSSIONS

The tension variations along the warp sheet and the weaver's beam makes uneven in the fabric formation zone and change of position of the fabric fell as the beam weaves down. Due to warp tension variation the woven fabric tends to have fabric defects, vary in fabric density, differential dye take –up at various places of the fabric. As warp ends are continuously subjected to tension variation, due to which numerous number of warp breakages occur and as a result the quality of fabric produced and the loom production efficiency is impaired. These scenarios would be evident in the test results. Vary in fabric density is a crucial aspect, especially in technical textiles and smart textiles. Samples produced were tested for fabric dye ability, strength and elongation in warp and weft directions. Apparently there was no difference in colour to the naked eye, but by analyzing the graphs obtained from the colour matching computer, a slight difference in colour reflection was observed.

To produce Medium and heavy weight fabrics high warp tension is required. By using increasing number of fixed type backrests with the same initial settings in the warp tension, the required higher tension in fabric formation zone could be achieved. Due to Initial low tension of warp ends between the backrest and the weaver's beam, elongation (deformation) of the warp sheet is reduced. Owing to which fabric fell displacement or beat-up zone is reduced. This will have a great impact on the warp breakages and the quality of fabric.

CONCLUSIONS AND RECOMMENDATIONS

This paper discussed theoretical influence of the position and the type of the backrest on warp tension during weaving and developed a mathematical model for the elastic warp gaiting system of the loom, in order to study the behavior of the fabric fell under set of assumptions. An experimental investigation on the performance of weaving machines was carried out using different heights of the backrest on a weaving machine. With the experiment carried out, authors have attempted to show the influence of position of the backrest on physical and mechanical properties of a woven fabric during the process of weaving. Further, samples produced at different backrest positions were tested for fabric dye ability, strength and elongation in warp and weft directions.

By increasing the number of back rests a higher warp tension in the working zone was achieved with low initial tension at the weavers beam. By having two backrests it is possible to have a higher warp tension in the working zone which is necessary to produce high density / heavy weight fabric at a low tension at the weavers beam. In addition, the rapid dynamic action imposed on yarn in the working zone which is transferred through a multi-backrest system is significantly weakened. Therefore it reduces the extension of warp yarns at the weaver's beam which in turn reduces the lengthwise deformation of warp yarn allowing the beat up zone to be reduced. Hence, the number of warp breakages is reduced and the quality of fabric produced is improved. Every stoppage prevented directly improves the fabric manufacture's profits.

When the backrest is set at a position other than position 7, top and bottom warp layers at beat up are subjected to different tensioning, owing to which the resistance of weft yarn to beating up is reduced. Beaten-up yarn slides more easily along the highly tensioned warp layers. As a result, the breakages were reduced and the shifting of warp yarns apart by weft gave a more regular spreading of warp ends and a fabric free from reed marks. This article provides a guideline to the fabric manufacturers about the importance of the selection and the placement of the backrest on a weaving machine according to the type of fabric to be produced in order to achieve uniform fabric properties. In the process of weaving, this mathematical module could be used to develop warp tension control system to control warp tension very effectively and obviously reduced the range of fluctuation of warp tension and beat up zone.

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