THEORETICAL ANALYSIS OF THE MECHANISM FORMING TEMPLE DEFECTS IN FABRICS

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ABSTRACT

Improper choice of temple specifications for certain fabric may lead to serious temple defects in the fabric. Incorrect setting of temple has also a bad effect on fabric quality. This work is a theoretical study of how, and to what extent the temple defect arise in the cloth. Equations are given, which can help in the selection of the proper temple specifications, and the correct temple setting relative to the selvedge end . The derived equations are compared with the actual observations. It is found that, the best utilization of the temple pin is achieved when the peripheral pitch between the pins is at least equal to twice the pick spacing and the axial pitch is at least equal to one warp end spacing. It is found also, that, the required number of temple pins to prevent temple defects depends mainly on the relative weft density, the ratio of the bending rigidity of warp to that of weft yarns, the coefficient of friction between warp and weft yarns, and the geometrical parameters such as the crimp in warp and weft directions.

NOTATIONS

b	The fabric width in the loom state
c	The crimp fraction
C.F.	The cover fraction = $t/28\sqrt{N_e}$
d	The yarn diameter = $1/28\sqrt{N_e}$
E	The fabric modulus
F	Tensile force in the yarn
$f_c(\theta)$	The function of the crimping angle θ
G	The size (width) of the temple defect
g	The increase of warp yarn spacing behind the temple pin due to weft slippage
h	The crimping wave height
j	The number of jammed warp threads at a temple pin excluding the first one
k	The fabric constant
k_s	The constant of a square fabric
l	Fabric length starting from the temple axis
m	The number of the temple pins to prevent fabric shrinkage
m_{cr}	The critical number of temple pins, which can prevent thread's slippage inside the fabric
m_{act}	The actually effective number of the temple pins.
M	The temple size (total number of pins on the temple rods)
N_e	The English yarn count
P_t	The pin spacing "pitch" on the temple rods
p	The yarn spacing "pitch" in the cloth.
r	The bending regidity ratio β_1/β_2
$2s_l$	Increase in the fabric width due to the temple reaction as a function of the fabric length l. It is equal to the decrement in the weft crimp fraction.
T	The total extending force in one side, the maximum of which is the required force to keep the fabric width in reed and is equal to the temple reaction.
t	The warp and weft densities = 1/p
v	The pressing force between the warp and weft at the point of intersection as a result of external force
Y	The total length of the temple rods
y	The used length of the temple rods
β	Bending moment for unit radius of curvature (bending rigidity of the yarn)
γ	The relative weft density = t_1/t_2
θ	The crimping angle
μ	The coefficient of friction between warp and weft threads
μ_{cr}	The critical coefficient of friction between warp and weft threads

Note: It is convenient to label c, C.F., d,F, h, θ, N_e, P, t and v by the subscript 1 when they are taken from a picture of a cross section along the warp and the subscript 2 for the weft cross section. Therefore , p_1, t_1, and p_{t1} are the spacing along the warp and not of the warp and accordingly t_1 represents the weft density.

INTRODUCTION

In practice, it is well established that, the quality of the woven fabrics affects the economy of the weaving sheds, as the sale price of the fabrics is decreased drastically with the increase of the frequency of fabric defects. In many cases, it was found that, the fabric is damaged within few centimeters from the selvedges of the fabric. Sometimes, the damage is severe and becomes in the form of holes and is known as temple defect or at least takes the form of intermittent stripes of varying intensity. Those stripes are known as temple marking. The function of the temples is to prevent the immediate fabric shrinkage in the weft direction due to the interlacing between warp and weft, so that the warp threads stay in their positions as in the reed dents and thus the contact friction between the reed wires and the warp threads is kept at a minimum value during the to and fro motion of the sley mechanism. The fabric shrinkage in the weft direction, which is known as a weft crimp, increases as the warp tension is increased in order to get stronger beat-up effect which is necessary for weaving fabrics with high weft densities.

The temple performs its function by means of needles or pins, which penetrate the cloth and move with it, as the fabric moves arround the temple rod. The pins disengage from the fabric, when it moves away from the circumference of the temple rod. In this way, the temple reactions are tangential forces in the weft direction towards the selvedges. These forces are concentrated on the points of contact between the temple pins and the fabric, causing an extension, and hence tension in the weft threads [1 - 6]. In some cases the temple pins prevent the widthwise movement of some warp threads, while other ends are free to move inward under the action of the crimping forces of weft threads causing gaps between the two sets of threads. This effect is irrecoverable deformation.

SCOPE OF WORK

The problem of the temple defects in the woven fabrics will be investigated in this work, in order to find a method of selection of the proper temple which is suitable for certain woven fabric specifications. At first, the mechanis causing such temple defects will be investigat theoretically as a function of both parameters geometrical fabric structure and temple specificatio The theoretical approach could be then compared with t experimental observations.

It is worth mentioning that the investigation is mai concerning one type only of temples, namely the pin ty which is the most common type.

MECHANISM OF DEFECT FORMATION

The weft thread is inserted in the shed during weavi and is then beaten up to the fell of the cloth forming weft line, having a length equal to the width in reed. Aft the interlacing between the two sets of threads has taken place, the threads of each group take a wavy shape in th formed woven fabric. This leads to a decrease in the fabri width relative to width in reed. However, it is ver important to keep the fabric width as it is in the region the cloth fell, by means of the temples to avoid excessiv friction in warp threads by reed dents.

In order to calculate the required force to be applie from each temple, it is assumed that the woven fabric width "b" was extended in a reversing way to the width i reed by means of the temple reaction as shown in Figur (1). The centre line of the cloth will stay withou distortion.

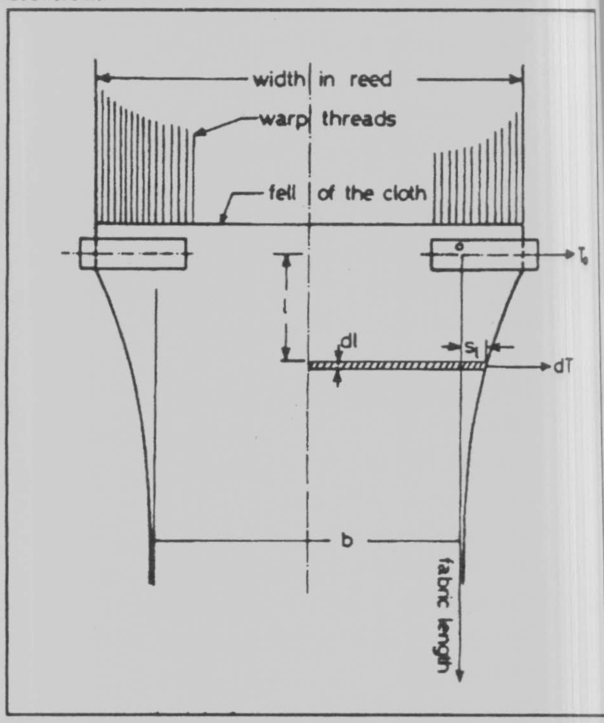

Figure 1. Calculation of the temple reaction.

Consider a fabric element of length dl, at a distance l along the fabric measured from temple axis, which has an elongation "s_l". The relation between the stress and strain could be written in the following form [7]

$$E_2 = \frac{dF_2}{p_1} / \frac{dp_2}{p_2}$$

$$= \frac{dT}{dl} \times \frac{b}{2s_l} \quad (1)$$

$$\text{i.e } dT = \frac{2E_2 s_l}{b} dl \quad (2)$$

The fabric elongation s_l decreases along the fabric and could be represented by the following equation taking the ultimate selvedge line as an abscissa of the fabric length with its origin on the axis of the temple, and in which the term $2s_l/b$ represents the decrement in the weft crimp with its max value c_2 at the temple:

$$s_l = c_2 \frac{b}{2} e^{-l} \quad (3)$$

and by substituting in equation (2), the equation becomes in the form

$$\int_0^{T_l} dT = -\int_{\infty}^{l} E_2 c_2 e^{-l} dl \quad (4)$$

which leads to

$$T_l = E_2 c_2 e^{-l} = \frac{2E_2 s_l}{b} \quad (5)$$

$$= E_2 (c_2)_l \quad (6)$$

Equation (6) shows that the extending force T_l at any point depends only on both the fabric modulus in the weft direction E_2 and the decrement in the weft crimp fraction $(c_2)_l$ at that point. Equation 6 reaches its max. value at the axis of the temple ($l = 0$) to give the temple reaction as a function in the fabric modulus and the completely removed weft crimp in the following form:

$$T_o = E_2 c_2 \quad (7)$$

The fabric modulus in the weft direction E_2 could be estimated by using the investigated model by Grosberg P. [7] which gives the value of the fabric modulus in the weft direction E_2 by the following equation:

$$E_2 = \frac{dF_2}{p_1} \times \frac{p_2}{dp_2}$$

$$E_2 = \frac{F_1}{2c_2 p_1} [(1+c_1)(p_2/p_1) + (c_1/c_2)^{1/2}(1+c_2)] \quad (8)$$

and therefore, the value of the temple reaction becomes

$$T_o = \frac{F_1}{2p_1} [(1+c_1)(p_2/p_1) + (c_1/c_2)^{1/2}(1+c_2)] \quad (9)$$

This reaction has to be transmitted from the temple to the cloth by means of many pins, which are arranged on rows along the temple axis. As the interlacing between the warp and the weft takes place, the weft threads have to be crimped, and accordingly the cloth becomes narrower. This is prevented by the temple. The result is higher tension in the weft direction and therefore, the weft threads are highly tensioned.

Figure (2) shows a sketch, which illustrates the mechanism of the defect formation. The temple reaction T_o is equally distributed on the number of temple pins "m".

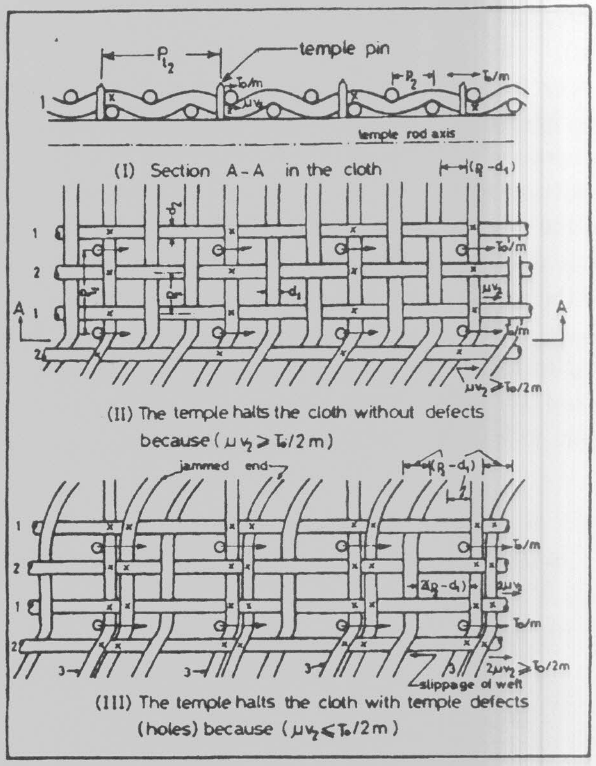

Figure 2. The mechanism of the temple defect formation.

The warp yarns that pass tangentially to the temple pins try to halt the fabric by means of the frictional forces between them and the weft threads number 1 and 2 at the points of intersection marked x. The friction forces in the other interlacing points keep the relative position between the warp and weft threads at the corresponding contact zones of each yarn. To avoid any distortion in the fabric, the value of friction forces between weft threads number 1, and 2, and warp thread touching the temple pin should exceed the reaction force exerted by one temple pin. Therefore

$$\mu v_2 \geq \frac{T_o}{2m}$$

$$\text{i.e } \mu v_2 \geq \frac{F_1}{4mp_1} [(1+c_1)(\frac{p_2}{p_1}) + (\frac{c_1}{c_2})^{1/2} (1 + c_2)] \quad (10)$$

in this case the temple can halt the fabric width as the width in reed without temple defects as in Figure (2-ii). On the other hand, if the friction force is ≤ 1/2 temple reaction per temple pin, the weft threads 1 and 2 will move under their tension taking the warp threads, leaving only the warp threads number 3 supported by the temple pins and thus causing temple holes as shown in Figure (2 - iii).

The frictional force between warp and weft threads in the interlacing point depends mainly on the reaction force v between the two perpendicular yarns. Two papers by Olofsson B. [8] and Kedia [9] have considered the effect of the external force F on the reaction between warp and weft threads v regarding the same geometric parameters of the woven fabric and taking into consideration that the shape of the yarn in the cloth is an elastica as shown in Figure (3). From the given analysis, the reaction force v could be driven using deformation energy interchange from weft to warp direction

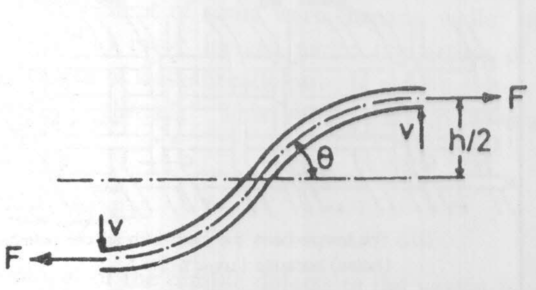

Figure 3. Forces acting on an elastica (after Kedia) [9].

$$F'_1 = - v_2 \frac{dh_2}{dp_1} = v_2 \frac{dh_1}{dp_1}$$

$$= - v_2 \frac{1-c_1}{1.5\sqrt{c_1}} \quad (11)$$

$$= - \frac{\beta_2}{\beta_1} \frac{p_1^3}{p_2^3} f_2(\theta). F_1 \quad (12)$$

where F'_1 is the force fraction in the warp direction causing the normal reaction v_2 between warp and weft yarns, and therefore

$$v_2 = \frac{\beta_2}{\beta_1} (\frac{p_1}{p_2})^3 f_2(\theta) F_1 \frac{1.5\sqrt{c_1}}{1-c_1} \quad (13)$$

Equations (10) and (13) together give the relations between the fabric parameters, the yarn properties and the specification of the suitable temple. The two equations could be rearranged as follows:

$m \geq m_{cr}$, where :

$$m_{cr} = \frac{[(1+c_1)(p_2/p_1) + (c_1/c_2)^{1/2}(1+c_2)](1-c_1)}{6 \mu p_1[\frac{\beta_2}{\beta_1} (p_1/p_2)^3 f_2(\theta)\sqrt{c_1}]}$$

$$= \frac{[(1-c_1^2)(p_2/p_1) + (c_1/c_2)^{1/2}(1+c_2)(1-c_1)]}{6 \mu p_1 \sqrt{c_1} \frac{\beta_2}{\beta_1} (p_1/p_2)^3 f_2(\theta)} \quad (14)$$

and $\mu \geq \mu_{cr}$, where

$$\mu_{cr} = \frac{[(1-c_1^2)(p_2/p_1) + (c_1/c_2)^{1/2}(1+c_2)(1-c_1)]}{6 m p_1 \sqrt{c_1} \frac{\beta_2}{\beta_1} (p_1/p_2)^3 f_2(\theta)} \quad (15)$$

The values of $f_2(\theta)$ [7] are given in the following table and taking the very closed approximation of $\simeq 106 \sqrt{c}$.

Table 1. Values of f_2 (θ).

θ in degrees	10	25	45
$f_2(\theta)$	1.19	1.11	0.92

By substituting the bending rigidity ratio $r = \beta_1/\beta_2$ and the relative weft density $\gamma = t_1/t_2 = \frac{\text{weft density}}{\text{warp density}}$, equations (14), and (15) will have the following forms

$m \geq m_{cr}$, where

$$m_{cr} = \frac{r\gamma^3 t_1[(1-c_1^2)\gamma + (c_1/c_2)^{1/2}(1+c_2)(1-c_1)]}{6\mu\sqrt{c_1}\, f_2(\theta)} \qquad (16)$$

and $\mu \geq \mu_{cr}$, where

$$\mu_{cr} = \frac{r\gamma^3 t_1[(1-c_1^2)\gamma + (c_1/c_2)^{1/2}(1+c_2)(1-c_1)]}{6m\sqrt{c_1}\, f_2(\theta)} \qquad (17)$$

Equations (16) and (17) show that the product $m.\mu$ is always equal to constant k where :

$$k = \frac{r\gamma^3 t_1[(1-c_1^2)\gamma + (c_1/c_2)^{1/2}(1+c_2)(1-c_1)]}{6\sqrt{c_1}\, f_2(\theta)} \qquad (18)$$

The constant k which is termed the fabric constant depends, as shown from equation (18) on:

1. The ratio r between the bending rigidity of warp and weft yarns. The higher bending rigidity of warps compared with the rigidity of weft yarns leads to more crimp in weft direction c_2 and therefore an increase in the total temple reaction (equation 7). However, the litrature 10,11, and 12 shows that the bending rigidity of a yarn depends mainly on the physical and mechanical properties of fibers, yarn count, twist factor and the technology of spinning and accordingly the geometrical structure of the yarn.
2. The relative weft density γ as well as the absolute weft density t_1. The increase of weft density t_1 and accordingly the relative weft density γ (in case of unchanged warp density t_2) leads to an increase in the fabric modulus in the weft direction E_2 (equation 7). Furthermore, the reaction force v_2 decreases (equation (13). The same effect would be found by decreasing the warp density t_2 relative to the weft density t_1, a matter which leads also to an increase in the relative weft density γ. In this case a longer temple with higher number of pins m is necessary.
3. The warp crimp fraction c_1. The decrease in the warp crimp c_1 would result, when weaving at higher warp tension level, a matter which causes higher crimp in the other direction (weft crimp c_2). This statement means, that the higher warp tension may cause temple defects, or in other words, the higher warp tension necessitates longer temples with more pins m. It is also worth mentioning, that the weft crimp c_2 plays its role in an opposite way in comparison with the warp crimp c_1.
4. The crimping angle θ. In order to illustrate the effect of the crimping angle θ on the fabric constant k, the values in table 1 are represented in Figure (4). The increase in the crimping angle means an increase in the weft crimp c_2 and a decrease in $f_2(\theta)$. This necessitates the use of a longer temple with higher number of pins m.

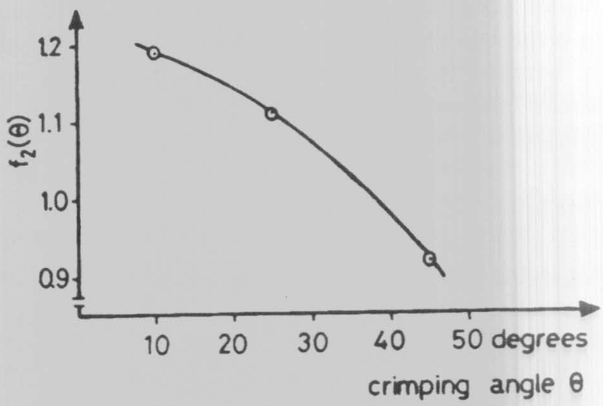

Figure 5. Values of $f_2(\theta)$against θ.

SPECIAL CASE

In case of weaving square plain fabric, a case in which the warp and weft directions are completely identical, i.e., r, γ, and c_1/c_2 are equal unity and θ_2 is about 30° ($f_2(\theta) \simeq 1.05$). Equation 18 could be then simplified to the following form:

$$k_s = \frac{t_1(1-c_1^2)}{3.15\sqrt{c_1}}$$

$$= \frac{1 - c_1^2}{3.15\, p_1\sqrt{c_1}} \qquad (19)$$

and by using the relations $h/p = (4/3)\sqrt{c}$ and (only for square plain weave $h = d = \frac{1}{28\sqrt{N_e}}$ inch and equation 19 becomes

$$k_s = 11.85\sqrt{N_e}\,(1 - c_1^2) \qquad (20)$$

$$= 11.85\sqrt{N_e}\,[1 - (0.75\ C.F.)^4] \qquad (21)$$

in which the cover fraction (for one direction) C.F. to the power 4 is negligible and accordingly.

$$k_s \approx 11.85\sqrt{N_e} \qquad (22)$$

The suitable number of temple pins for the square fabric can be then be easly selected according to the following equation

$$m \geq \frac{k_s}{\mu} \geq 11.85\frac{\sqrt{N_e}}{\mu} \qquad (23)$$

Equation 23 means that the required number of temple pins is the same for all square fabrics woven from certain yarn irrespective from all fabric parameters. The only decissive parameters are the yarn count (N_e) and the coefficient of friction μ.

TEMPLE SPECIFICATIONS

Regarding the scope of this work, the main specifications of the pin's temple are:

1. Design of the temple (rings or rods)
2. Pitch of pins in warp direction P_{t1}.
3. Pitch of pins in weft direction P_{t2}
4. Temple size M (total number of temple pins).

Practically there is no technical difference between the two types of pins temple. However, the ring type has the advantage of the setting possibility as shown in Figure (5) I,II, and III. The setting II by turning the ring cylinder towards the reed "forward setting" is suitable for fabrics

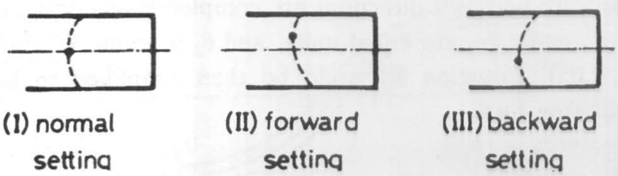

Figure 5. Different settings of the ring temple.

because each frictional force has to withstand two pin reaction, a case which might appear only with a very light fabrics having very little picks per inch. In fact, such a probability (having less than about 5 picks per inch) is practically negligible. In the other direction, the situation is different, where the reduction in the axial "parallel to the rod axis", pitch P_{t2} below the warp spacing p_2 means that two or more pins stand between two successive warp threads. Only the first pin is loaded while the other stands free. This means, that the required number of temple pins m must be increased as a number of pins are standing between two successive warp threads.

In practice, the fabric may run over a length y of the temple as shown in Figure 6, and about one third of the perimeter of the temple rod. The relation between the temple size M and the number of pins m required to prevent the cloth shrinkage could be easly written in the form:

$$M = 3\frac{mY}{y} \qquad (24)$$

where the ratio y/Y depends only on the setting of the temple relative to the selvedge of the cloth.

SIZE OF THE TEMPLE DEFECT

If the actual number of effective temple pins is less than the critical number m_{cr}, the slippage of the weft threads will take place as shown in Figure (2.iii). The warp threads, which are not standing at temple pins, will move with the weft theads without slippage at the points of intersection causing an increase in the warp spacing behind the temple pin. The movement of each warp thread is actually limited by its jamming position with the other warp threads at the next temple pin. Each jammed warp thread can then contribute in withstanding the temple reaction by adding two extra friction points with $2\mu v_2$. However the slippage of the weft threads will continue until the added frictional forces of the warp threads jammed together with that of the first one can withstand the temple reaction of the pin. Each jammed warp thread cause an increase in the warp spacing behind the temple pin equal to one warp space minus one yarn diameter. Table 2 shows the increase of the warp spacing against the actual number of temple pins.

In order to make use of the calculated results in the cases of temple defects in practice, the calculation could be now carried out in a reversed procedure to determine the safe number of temple pins using the following simple imperical equation:

safe number of temple pins = number of jammed ends multiplied by m_{act} (25)

which is always > m_{cr}

Equation 25 is only suitable for the quick reaction to prevent temple defects already noticed on the spot on the running looms and not for accurate calculations. It is worth mentioning, that the required increase in the number of temple pins according to equation (25) is completely different from the increase mentioned in the section "Temple specifications".

Table 2. Size of the temple defect.

m_{act}/m_{cr}	j^{*} warp ends	$\frac{g}{(p_2 - d_1)}$	$\frac{G}{(p_2 - d_1)}$
> 1	0	0	no defect
1/2 - 1	1	1	2
1/3 - 1/2	2	2	3
1/4 - 1/3	3	3	4
1/5 1/4	4	4	5
	and so on		

* The 1st yarn (no.3 in fig. 2) stands in its original position direct at the pin and is not included

woven without bumping (light fabrics with few picks per inch), while the backward setting in III by turning the ring cylinder towards the weaver is suitable for fabrics woven with bumping [13, 14]. In the latter case, the penetration of the temple pins in the fabric takes place later than the case of the normal setting in I. Thus, the pins prevent any probable slippage of the fabric during its return movement.

The distribution of the pins on the temple rings or rods is a very important parameter, because the given equations are based on the assumptions shown in Figure 2. In other words, the peripheral pitch P_{t1} in Figure (6) must be at least equal to twice the pick spacing in the cloth ($p_1 = 1/t_1$) and the axial pitch P_{t2} must be at least equal to the warp spacing ($p_2 = 1/t_2$).

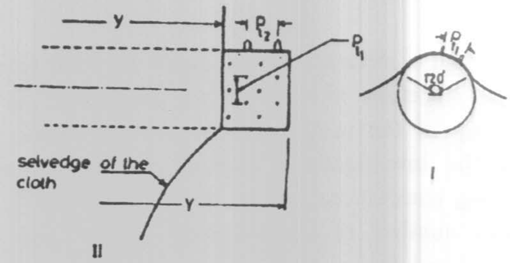

Figure 6. Distribution of pins on the temple rod.

If the peripheral pitch P_{t1} is in the range between one and two pick spacing p_1, the number of weft threads between two successive pins will be reduced to only one pick, the frictional force of which (μ v_2) has to withstand half of two needle reactions, i.e T_o/m. In this case, the required number of temple pins to be in action at a time must be duplicated as the calculated. Any further reduction in the peripheral pitch P_{t1} will lead to a further increase of the required number of temple pins m,

ACTUAL OBSERVATIONS

A fabric is woven from 20/1 N_e for warp and weft with 48 ends per inch, on a loom fitted with a temple in each side having two temple rods of 450 pins each (M = 900). By varying the weft density and the ratio y/Y, the following observations given in table 3 are found, which agree with the theoretical equations.

Table 3.Effect of the temple size on the observed number of the jammed ends*

t_1 P/in / P/cm	γ	μ^{**}	c_1 %	c_2 %	$f_2(\theta)$	m_{cr} pins	y/Y	$\frac{m_{act}}{m_{cr}}$	j ends
48 / 19	1	0.27	8	8	1.07	192	0.7	1.07	0
							0.6	0.918	1
							0.3	0.45	2
							0.15	0.225	4
43.2 / 17	0.7125		6.6	7	1.08	62	0.5	2.38	0
							0.3	1.43	0
							0.15	0.71	1
53.3 / 21	1.11		10	10.5	1.05	280	0.9	0.964	0
							0.5	0.55	1
							0.25	0.27	3

* In all cases P_{t1} = 157 mils > $2p_1$, P_{t2} = 236 mils > p_2, and r = 1

** μ is obtained from a previous work [15]

CONCLUSIONS

The temple defects can be easily avoided through the correct selection of the temple size and the suitable mounting of the temple relative to the fabric selvedge. From the investigations carried out in this work, the following conclusions can be drawn:

i. The number of the effective temple pins must be increased in case of using warp threads of higher bending rigidity compared with that of weft threads.
ii. The number of the effective temple pins must be increased drastically in the cases of producing woven fabrics with higher weft density or with lower warp density. The weft density ratio is a very important factor.
iii. The geometrical parameters such as the crimp fraction in each direction and angle of crimp have an influence on the required number of the effective temple pins. However, their effect is not so prominent as the relative weft density, and the relative bending rigidity of warp threads.
iv The number of the effective temple pins is in inverse proportion to the ceofficient of friction between the two series of threads (warp and weft).
v. In the case of weaving square fabrics, the number of the effective temple pins is dependent only on the yarn English count and its coefficient of friction. Accordingly the same temple size is suitable for all square fabrics woven from a certain yarn irrespective of the warp and weft densities or in other words from the fabric weight per squared yard.
vi. The pin distribution on the surface of the temple rod is a very important factor compared with the warp and weft spacing in the woven fabric. The peripheral pitch must be at least equal to two pick spacing while the axial pitch must be at least equal to only one warp end spacing, otherwise the required number of temple pins must be increased.
vii. A quick response suitable for the industrial applications is described and is also recommended to prevent the noticed temple defects on running looms. The proper temple size could be easily determined according to the number of the jammed ends and by the aid of a given imperical formula.

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