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CALCULATION OF PARAMETERS OF BATTENING PROCESS

S.D. NIKOLAEV, N.A. NIKOLAEVA, N.A. INOZEMTSEVA

(The Moscow State Textile University named after A.N. Kosygin)

Beating up of weft to the edge of fabric holds a special position. Correct course of this process ensures production of rational structure, high quality with minimal end, warp and weft breakage and with maximum possible productivity of labour and performance of equipment.

In the course of beating up of weft to the edge of fabric a new element of fabric is formed. Technological parameters of the battening process (primarily, warp and weft tension) should be such that they would ensure the assigned structure of the fabric element to be formed.

Formula for calculation of phase sequence of grey fabric's structureis:

$$F = \frac{9\varphi + 1}{\varphi + 1}, \qquad (1)$$

where φ – relation of wave heights of warp and weft bends.

Relationship of wave bend heights equals to:

$$\varphi = \frac{h_o}{h_y} = \frac{P_o^3 E_y I_y}{P_y^3 E_o I_o}, \qquad (2)$$

where h_o, h_y – wave heights of warp and weft bends correspondingly; P_o, P_y – warp and weft density of fabric correspondingly; E_o, E_y – elasticity moduli of warp and weft correspondingly; I_o, I_y – inertia moments of sections of warp and weft yarns correspondingly.

In the fabric, sections of yarns are represented as ellipses. Inertia moments of warp and weft sections of yarn can be determined by the following formulas:

$$I_o = 0.05 d_{ов}^3 d_{ог}, \qquad I_y = 0.05 d_{ов} d_{уг}, \qquad (3)$$

where $d_{ов} d_{ог}$ – vertical and horizontal warp diameters in fabric; $d_{ув}, d_{уг}$ – vertical and horizontal weft diameters in fabric.

Yarn diameters in fabric are determined from the following relations:

$$d_{ов} = d_o \eta_{ов}, \quad d_{ог} = d_o \eta_{го}, \qquad d_{ув} = d_o \eta_{ув} \quad d_{ог} = d_o \eta_{гв}, \qquad (4)$$

where d_o, d_y – round section diameters of warp and weft yarns prior to weaving, which are determined by the following formulas:

$$d_o = 0.1 c_o \sqrt{0.1 T_o}, \; d_y = 0.1 c_y \sqrt{0.1 T_y}, \qquad (5)$$

where c_o, c_y – coefficients which depend on the type of composition of yarn fiber; T_o, T_y – linear density of warp and weft yarns.

For all single-texture fabrics the following relation is true:

$$d_{ов} + d_{ув} = h_o + h_y, \qquad (6)$$

where h_o, h_y h_o and h_y – wave heights of warp and weft bend in the fabric element under formation.

Consequently,

$$h_o = \varphi h_y, \quad \varphi h_y + h_y = d_{ов} + d_{ог}, \tag{7}$$

$$h_y = \frac{d_{ов} + d_{ув}}{\varphi + 1}, \quad h_o = \frac{\varphi(d_{ов} + d_{ув})}{\varphi + 1}.$$

Since temples on a loom define the width of threading by beating up of weft to the edge of fabric, then absolute deformation of weft from battening equals to:

$$\lambda'' = \sqrt{h^2 + \left(\frac{100}{P_o}\right)^2} - \frac{100}{P_o}. \tag{8}$$

Relative deformation of weft from battening process equals to:

$$\varepsilon'' = \frac{\lambda'' P_o}{100}. \tag{9}$$

Tension of weft in the course of battening equals to:

$$\sigma_y = E_y \varepsilon_y, \tag{10}$$

where ε_y – total deformation of weft in the course of battening.

$$\varepsilon = \varepsilon'_y + \varepsilon''_y,$$

where ε'_y – deformation of weft before the start of battening process.

Tension of weft before the process of battening equals to

$$\sigma_y = \frac{F'_y}{S_y}, \tag{11}$$

where F'_y – weft tension before the battening process; S_y – cross-section area of weft yarn.

$$S_y = \frac{\pi d_{уг} d_{ув}}{4}. \tag{12}$$

Interrelation of tension and deformation of weft before the battening process can be represented by the following expression

$$\sigma' = E_y \varepsilon'', \quad \varepsilon' = \sigma' / E_y. \tag{13}$$

Interrelation of stress, tension and deformation of weft from the battening process can be represented by the following relations:

$$\sigma'' = E_y \varepsilon'', \quad F_y = \sigma'' S_y. \tag{14}$$

For the purpose of preserving useful properties of fabric it is advisable, in order sequence of fabric construction phase (relation of wave peaks of warp and weft bend) in fabric, removed from the loom and in the element of fabric under formation, could be equal.

Wave heights of warp and weft bend of yarn on the loom can be determined by the following formulas:

$$h_o = \frac{N}{2F_o}\left(\frac{100}{P_y} - \sqrt{\frac{E_o I_o}{F_o}}\right), \tag{15}$$

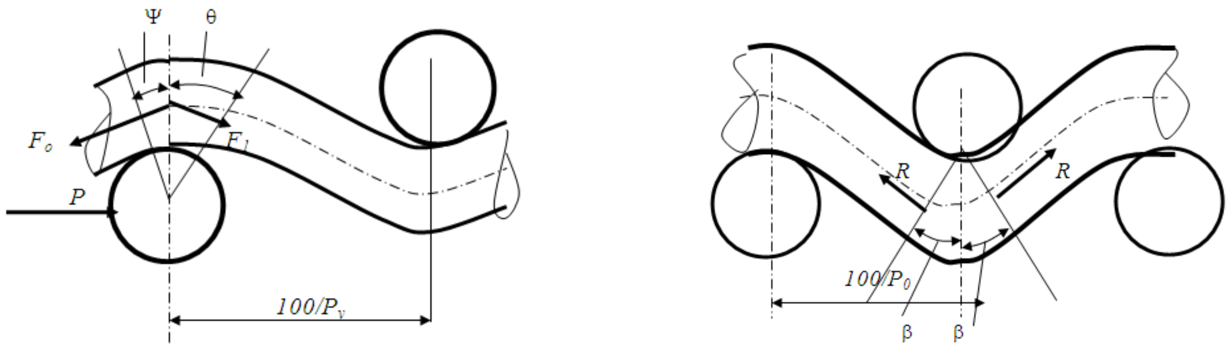
$$h_y = \frac{N}{2F_y}\left(\frac{100}{P_o} - \sqrt{\frac{E_y I_y}{F_y}}\right).$$

Yarn strain in the course of battoning σ_y will be formed from tension of weft before the battoning process σ'_y and tension of weft from the battoning process to the edge of fabric σ'':

$$\sigma_y = \sigma'_y + \sigma''. \tag{16}$$

We will cite methods of calculating forces, acting at the moment of battening, by means of equations, formally coinciding with equilibrium equation according to d'Alembert's principle. Battening process is considered as quasistatic.

Below are methods of calculating technological parameters of battening for production of plain weave fabrics. The following forces have been calculated: tension of warp at the fabric edge (F_o), tensions of warp inside of fabric element under formation (F_1), tension of weft yarn (R) inside of fabric element under formation (P), friction force ($F_{тр}$). Diagram of acting forces in the fabric element is given in Fig. 1.



a) b)

Fig. 1. Geometric models of construction of fabrics (a - along the warp, б - along the weft).

Calculation has been carried out with the aid of Microsoft Excel (Fig. 2).

Input data	
Linear warp density, To, tex	11,8
Linear weft density, To, tex	11,8
Warp density, Po, yars/10cm	421
Warp density, Po, yarns/10cm	472
Breaking force of warp yarn, Pp, cH	140,42
ange ψ, rad	0,0174
angle ψ, rad	1,566
Calculation of values	
d_o=d_y	0,135784756
φ	0,709610922
d_o+d_y	0,271569512
h_y	0,158848723
h_o	0,112720789
100/Po	0,237529691
100/Py	0,211864407
Angle θ	0,488951521
Angle β	0,589445684
Fthread	14,042
Ffor battoning	21,063
Ffor beating at the edge	37,9134
Ffor beating at the edge	25,2756
Output parameters	
B at the start of beating	
Tension of warp yarn inside the fabric, F1, cH	34,26191226
Beating force, P,cH	7,660360199
Tension of weft yarn, R,cH	15,067897
Friction force, Tтр,cH	3,65148774
At the end of beating	
Tension of warp yarn	
inside of fabric, F1, cH	27,62233298
Friction force, Tтр,cH	10,29106702
Beating force, P,cH	37,77517559
Tension of weft yarn, R,cH	25,43772095
Post-battening period	
Tension of warp yarn inside the fabric, F1, cH	27,9693651
Friction force, Tтр,cH	2,6937651
Tension of weft yarn, R,cH	12,48912859

Fig. 2. View of program on display

Angles β и θ, according to Fig. 1, are determined by the formulas:

$$tg\theta = h_o/(100/P_y),$$
$$tg\beta = h_y/(100/P_o). \qquad (17)$$

Calculation of tension of warp edge of fabric is carried out in the following order.

Tension of warp threading in the area of "backrest - drop-wires" or tension of warp before the start of battening process is taken to be equal to 10% of the breaking strain of yarn P_p:

$$F_з = 0.1P_p, \quad P_p = pT_o. \qquad (18)$$

where p – relative breaking strain of warp yarn; T_o – linear density of warp.

Warp tension with weft in the area of "backrest–drop–wires" is taken approximately 1.5 times higher than threading tension of warp:

$$F_{appr} = 1.5\ F_з. \qquad (19)$$

Warp tension with weft in the area of "backrest – drop – wires" is taken equal to:

$$F_{пр} = 1.8F_з. \qquad (20)$$

Warp tension with weft at the edge of fabric is equal to:

$$F_o = 1.8F_{пр}. \qquad (21)$$

Calculation of forces acting in the fabric at the initial moment of battening is the following.

Tension of warp yarn in fabric F_1:

$$F_1 = F_o e^{-f(\psi+\theta)}. \qquad (22)$$

Force of beating up P :

$$P = F_1(\cos\psi - e^{-f(\psi+\theta)}\cos\theta). \qquad (23)$$

Weft yarn tension R :

$$R = [(\sin\psi + e^{-f(\psi+\theta)})F_1 / 2\sin\beta. \qquad (24)$$

Friction force between the warp and weft T_{fr}:

$$T_{тр} = F_o - F_1 = F_o[1 - e^{-f(\psi+\theta)}]. \qquad (25)$$

Calculation of forces, which act in fabric, at the final moment of beating up is carried out by similar formulas, but in this case the angle is $\theta = 90°$.

Calculation of forces acting in the fabric in the post-beating up period is the following.

Tension of warp yarn in fabric F_1:

$$F_1 = F_o e^{f(\psi+\theta)}. \qquad (26)$$

Tension of weft yarn R:

$$R = F_1\sin(\psi+\theta)/2\sin\beta\sin\theta. \qquad (27)$$

Friction force, acting during sliding of weft on the warp T_{fr}:

$$T_{тр} = F_1 - F_0 = F_o[1 - e^{f(\psi+\theta)}]. \qquad (28)$$

This program appears on the computer's display in the following way (Fig. 2).

Analysis of obtained results allows to define conclusions as follows:

– tension of warp at the edge of fabric reaches its maximum value at the end of the beating up process;

– tension of warp inside the fabric element under formation decreases in the course of beating up; in the post-beating up period it changes insignificantly;

– tension of weft in the course of beating up increases sharply up to the values, which are commensurable with the tension of warp; in the post-battoning period it decreases by more than 2 times;

– beating up force increases sharply and reaches its maximum value at the end of the beating up process;

– friction force between the warp and weft yarns in the course of the beating up increases for the majority of fabrics by more than 3 times; in the post-beating up period it is slightly less than at the start of beating up process.

CONCLUSIONS

1. In the course of frontal beating up of weft yarn to the edge of fabric with consideration of tension in depth of threading, structure

parameters of the produced fabrics and properties of yarn used method for calculation of technological parameters has been proposed.

2. The proposed method of calculating parameters of tensioned-deformed state of yarns in the course of frontal beating up can be used as a basis for development of the automated system for designing technological process of weaving as one of blocks.

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