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Analytical dependence of the base thread tension increase on the weaving machine

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ABSTRACT: The theoretical dependence of the increments in tension of the main threads on the loom due to the break is obtained, which depends on the stiffness of the warp thread, increments in the length of the thread in the machine's filling areas, the length of the base, and a number of other factors, and can be used to find the optimal filling parameters of the loom**.**

KEYWORDS: thread tension, increase in tension, loom, warp threads, stiffness coefficient, optimal parameters**.**

1. INTRODUCTION

In the modern period of market relations, one of the important tasks facing workers in science and the silk industry is to increase the efficiency of manufacturing fabrics from natural silk on modern shuttle less looms.
Known, that all deformable solid materials, including textile threads and yarns, in certain intervals of deformation changes obey Hooke's law and exhibit elastic properties during deformation [1].
To solve many applied problems, mechanical models have been proposed that describe the deformation processes of elastic viscoelastic bodies [2], in [1], ways of solving the main problems of the strength of textile threads, taking into account the peculiarities of textile production, are determined.
To calculate the thread tension prof. V.A. Gordeev suggested using the stiffness coefficient instead of the elastic modulus, since the calculation of the latter is associated with a complex shape and a sharply changing cross-sectional area of the thread. The coefficient is the ratio of the thread tension to its absolute elongation [3, 4].
Professor ED Efremov [5 - 7] and others made a great contribution to the development of the theory of warp threads deformation from the impact of shedding and combat mechanisms. In [8], the viscoelastic properties of the base and fabric made of natural silk were determined under conditions of short-term loading. A method has been developed for determining the length of a deformed warp thread on a weaving spool, which makes it possible to practically determine the length of a warp on a weaving spool, which undergoes longitudinal deformation during machine operation, with taking into account the real operating conditions of the machine [9]. Some issues of research and improvement of the process of making fabrics from natural silk on looms are highlighted in the work [10].
In the work of N. Kucher, E. Danilchuk, the viscoelastic deformation of filaments is investigated, models of linear and nonlinear viscoelastic deformation of materials under finite deformations are considered [11]. In the work of I.G. Schwartz, S. Kovachevich, K. Dimitrovsky investigated the mechanical and deformation properties of a single thread, determined the areas of elastic, viscoelastic and plastic deformation of the thread [12].

II. METHODOLOGY

It is known that in the total cyclic deformation of the elastic threading system, the components of deformation arising in the formation of the throat and beating of the weft thread are of the greatest importance. Deformations resulting from the removal of the fabric and the dismiss of the warp with the beam are of comparatively less importance.
E.D. Efremov developed a method for calculating the deformation of the threads during shedding and breaking, which allows calculating the deformation and tension of any point of the thread in the repeat of the weave at any location of the front and rear points of the throat, at any position of the eye of the heddle heddle at the spade, the angle of inclination of the trajectory of the hedge, patterns the movement of the hedge for any kind of throat [5 - 7].
The work of deformation of stretching of the warp threads depends on the increment of the warp thread tension due to the break, the width of the break strip and refers in general to the entire elastic system of threading the base, which is

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all subject to deformation by the width of the break strip and receives an increment of tension during the break ΔK, determined through the break force.
We can obtain an analytical dependence of the increment of the warp thread tension on a loom with an additional rock, which will allow us to consider the total work of the warp thread deformation during break, taking into account various deformations and tension in each threading zone from beams to the edge of the fabric.

III. THEORETICAL PART

Based on [5], let us consider the problem of theoretically determining the increment in the tension of the warp threads when breaking on a loom with an additional rock in the zone of the rock-price bar.

Let us introduce the designations (Fig. 1): $K_1, K_{CC}, K_2, K_{ПП}, K_3, K_4$ - the tension of the warp thread, respectively, in the zones of the beam - additional rock, additional rock - rock, rock - price bar, between price bars, price bar - headers, headers - edge of fabric; $L_1,\ L_{CC},\ L_2,\ L_{ПП},\ L_3,\ L_4$ - thread length in zones; $C_1,\ C_{CC},\ C_2,\ C_{ПП},\ C_3,\ C_4$ - the stiffness coefficients of the warp thread when stretched in the zones; C_0 - coefficient of stiffness of a meter section of the warp thread; λ_H - additional deformation of the warp thread on the beam due to the break; $\lambda_{ДС}$ - additional deformation of the warp thread on the additional rock due to the break; λ_C - additional deformation of the warp thread on the rock due to the break; $\lambda_{П2}$ - additional deformation of the warp thread on the back (2nd) price bar from the edge of the fabric; $\lambda_{П1}$ - additional deformation of the warp thread on the front (1st) price bar from the edge of the fabric;

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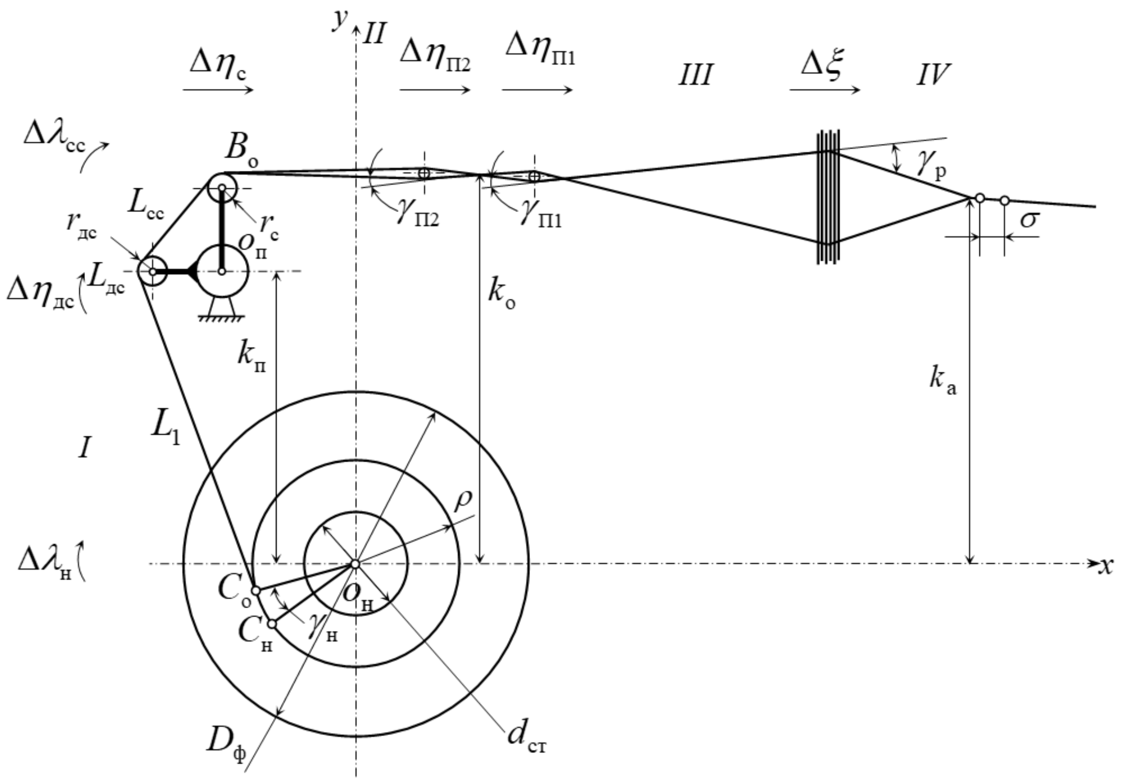

Fig 1 - Scheme of threading the warp thread on the weaving machine

τ - tension of the main thread in the winding on the bevel;

γ_H - the central angle corresponding to the sliding arc $C_H C_O$ of the thread on the beam winding;

$\gamma_{ДС}$ - angle of coverage of the additional rock by the thread;

γ_C - the angle of coverage of the rock by the thread;

$\gamma_{П2}$ - angle of coverage of the back (2nd) thread from the edge of the fabric of the price bar;

$\gamma_{П1}$ - the angle of coverage of the thread of the front (1st) from the edge of the fabric of the price bar;

γ_P - the angle of bending of the thread in the eyes of the heddles of the hedge;

$\sigma = AA_0$ - the size of the break strip;

$\eta_{ДС}$, η_C, $\eta_{П2}$, $\eta_{П1}$, ζ - the magnitude of the displacement of the thread due to the break through an additional rock, rock, the back (2nd) price bar from the edge of the fabric, the front (1st) from the edge of the fabric, the price bar and the peephole of the heddle heddle;

f_H, $f_{ДС}$, f_C, $f_{П2}$, $f_{П1}$, f_P - the coefficients of friction of the thread on the winding of the beam, along the additional rock, along the rock, respectively, in the rear (2nd) and front (1st) price bar from the edge of the fabric and in the eye of the heddle heddle;

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$\rho, r_{ДС}, r_C, r_{П2}, r_{П1}$ - radius of winding of the warp on the beam, radius of additional rock, radius of rock, radius of the rear (2nd) and radius of the front (1st) from the edge of the fabric of the price bar.
Let us compose the conditions relating the increments of deformation and tension of the thread in each zone of threading during breaking.

During the break in the beam zone, the additional rock changes to ΔL_1 the length of the warp thread L_1. The length of the thread $\Delta\lambda_H$ enters this zone from the beam and from this zone the length goes to an additional rock $\Delta\eta_{ДС}$. Therefore

$$\Delta K_1 = C_1\left(\Delta L_1 - \Delta\lambda_H + \Delta\eta_{ДС}\right). \tag{1}$$

In the zone an additional rock - the rock is changed to ΔL_{CC} by the length of the warp thread L_{CC} due to the rotation of the rock brackets. This zone receives the length of the thread $\Delta\eta_{ДС}$ due to slipping through the additional rock, and the length of the thread $\Delta\lambda_{ДС}$ due to the additional deformation of the thread on the additional rock. From this zone the length goes to the rock $\Delta\eta_C$. Therefore

$$\Delta K_{CC} = C_{CC}\left(\Delta L_{CC} - \Delta\eta_{ДС} - \Delta\lambda_{ДС} + \Delta\eta_C\right). \tag{2}$$

Equations for other zones were obtained similarly and the resulting equations were combined into the system

$$\begin{cases} \Delta K_1 = C_1\left(\Delta L_1 - \Delta\lambda_H + \Delta\eta_{ДС}\right) \\ \Delta K_{CC} = C_{CC}\left(\Delta L_{CC} - \Delta\eta_{ДС} - \Delta\lambda_{ДС} + \Delta\eta_C\right) \\ \Delta K_2 = C_2\left(\Delta L_2 - \Delta\eta_C - \Delta\lambda_C + \Delta\eta_{П2}\right) \\ \Delta K_{ПП} = C_{ПП}\left(\Delta L_{ПП} - \Delta\eta_{П2} - \Delta\lambda_{П2} + \Delta\eta_{П1}\right) \\ \Delta K_3 = C_3\left(\Delta L_3 - \Delta\eta_{П1} - \Delta\lambda_{П1} + \Delta\zeta\right) \\ \Delta K_4 = C_4\left(\Delta L_4 - \Delta\zeta\right) \end{cases} \tag{3}$$

From the equations of this system, the quantities $\Delta\eta_{ДС}$, $\Delta\eta_C$, $\Delta\eta_{П2}$, $\Delta\eta_1$ and $\Delta\zeta$ can be successively excluded.

We exclude the value $\Delta\eta_{ДС}$ from equations (1) and (2). For this, we multiply the first equation by the C_{CC} and the second by the C_1, and adding the resulting equations, we have

$$C_{CC}\Delta K_1 + C_1\Delta K_{CC} = C_1 C_{CC}\left(\Delta L_1 + \Delta L_{CC} - \Delta\lambda_H - \Delta\lambda_{ДС}\right) + C_1 C_{CC}\Delta\eta_C. \tag{4}$$

This equation is interesting in that it connects the increments of the thread tension in the zones of the beam - additional rock and additional rock - rock.
The equation shows that these increments in the aggregate depend on the corresponding stiffness coefficients, the increments in the length of the thread in these zones, on additional deformations of the thread on the beam and additional rock, as well as on the amount of movement of the thread through the rock.

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We multiply the obtained equation (4) to C_2 and the third equation of system (3) to C_1C_{CC}, and by adding the obtained equations, we get

$$C_{CC}C_2\Delta K_1 + C_1C_2\Delta K_{CC} + C_1C_{CC}\Delta K_2 = C_1C_{CC}C_2 \cdot$$
$$\cdot\left(\Delta L_1 + \Delta L_{CC} + \Delta L_2 - \Delta\lambda_H - \Delta\lambda_{ДC} - \Delta\lambda_C\right) + C_1C_{CC}C_2\Delta\eta_{П2}. \quad (5)$$

Thus, the totality of the tension increments ΔK_1, ΔK_2 and ΔK_3 depends, in addition to the previously mentioned, on the amount of movement of the thread through the back (2nd) price bar from the edge of the fabric.

Similarly, excluding the quantities $\Delta\eta_{П2}$, $\Delta\eta_{П1}$ $\Delta\zeta$ we get

$$C_{CC}C_2C_{ПП}C_3C_4\Delta K_1 + C_1C_2C_{ПП}C_3C_4\Delta K_{CC} + C_1C_{CC}C_{ПП}C_3C_4\Delta K_2 +$$
$$+ C_1C_{CC}C_2C_3C_4\Delta K_{ПП} + C_1C_{CC}C_2C_{ПП}C_4\Delta K_3 + C_1C_{CC}C_2C_{ПП}C_3\Delta K_4 =$$
$$= C_1C_{CC}C_2C_{ПП}C_3C_4\left(\Delta L_1 + \Delta L_{CC} + \Delta L_2 + \Delta L_{ПП} + \Delta L_3 + \Delta L_4 -\right.$$
$$\left. - \Delta\lambda_H - \Delta\lambda_{ДC} - \Delta\lambda_C - \Delta\lambda_{П2} - \Delta\lambda_{П1}\right). \quad (6)$$

The resulting equation determines the relationship between the increments of the thread tension in the threading zones due to the break with the increments of their lengths, as well as with additional deformations of the thread on the warp and the rock. The equation contains the stiffness factors in all zones.

Notice, that

$$C_1 = \frac{C_0}{L_1'}; \quad C_{CC} = \frac{C_0}{L_{CC}'}; \quad C_2 = \frac{C_0}{L_2'}; \quad C_{ПП} = \frac{C_0}{L_{ПП}'}; \quad C_3 = \frac{C_0}{L_3'} \quad C_4 = \frac{C_0}{L_4'}. \quad (7)$$

Since during the beating, the thread moves along all the guides towards the edge of the fabric, the tension of the thread in the zones can be expressed through the tension K_2 and their increments ΔK_2 in the zone of the rocks - the price bar as follows

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$$\left.\begin{aligned}
&K_1 = K_2 e^{-(f_C\gamma_C + f_{ДC}\gamma_{ДC})}\\
&K_{CC} = K_2 e^{-f_C\gamma_C}\\
&K_2 = K_2\\
&K_{ПП} = K_2 e^{f_{П2}\gamma_{П2}}\\
&K_3 = K_2 e^{f_{П2}\gamma_{П2} + f_{П1}\gamma_{П1}}\\
&K_4 = K_2 e^{f_{П2}\gamma_{П2} + f_{П1}\gamma_{П1} + f_p\gamma_p}\\
&\Delta K_1 = \Delta K_2 e^{-(f_C\gamma_C + f_{ДC}\gamma_{ДC})}\\
&\Delta K_{CC} = \Delta K_2 e^{-f_C\gamma_C}\\
&\Delta K_2 = \Delta K_2\\
&\Delta K_{ПП} = \Delta K_2 e^{f_{П2}\gamma_{П2}}\\
&\Delta K_3 = \Delta K_2 e^{f_{П2}\gamma_{П2} + f_{П1}\cdot\gamma_{П1}}\\
&\Delta K_4 = \Delta K_2 e^{f_{П2}\gamma_{П2} + f_{П1}\gamma_{П1} + f_p\gamma_p}
\end{aligned}\right\} \quad (8)$$

Dividing equation (6) by $C_1C_{CC}C_2C_{ПП}C_3C_4$, using expressions (7) and (8), we obtained

$$\begin{aligned}
&\Big[L_1' e^{-(f_C\gamma_C + f_{ДC}\gamma_{ДC})} + L_{CC}' e^{-f_C\gamma_C} + L_2' + L_{ПП}' e^{f_{П2}\gamma_{П2}} +\\
&+ L_3' e^{f_{П2}\gamma_{П2} + f_{П1}\gamma_{П1}} + L_4' e^{f_{П2}\gamma_{П2} + f_{П1}\gamma_{П1} + f_p\gamma_p}\Big]\Delta K_2 =\\
&= C_0(\Delta L_1 + \Delta L_{CC} + \Delta L_2 + \Delta L_{ПП} + \Delta L_3 + \Delta L_4 -\\
&- \Delta\lambda_H - \Delta\lambda_{ДC} - \Delta\lambda_C - \Delta\lambda_{П2} - \Delta\lambda_{П1}.
\end{aligned} \quad (9)$$

Let us replace in the formula (9) the increment of the warp thread deformation on the new, additional rock, rock, rear (2nd) and front (1st) price bar with the expressions:

$$\Delta\lambda_H = \frac{\rho'}{C_0 f_H}\left(1 - e^{-f_H\gamma_H}\right)e^{-(f_C\gamma_C + f_{ДC}\gamma_{ДC})}\Delta K_2; \quad (10)$$

$$\Delta\lambda_{ДC} = \frac{r_{ДC}'}{C_0 f_{ДC}}\left(1 - e^{-f_{ДC}\gamma_{ДC}}\right)e^{-f_C\gamma_C}\Delta K_2; \quad (11)$$

$$\Delta\lambda_C = \frac{r_C'}{C_0 f_C}\left(1 - e^{-f_C\gamma_C}\right)\Delta K_2; \quad (12)$$

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$$\Delta\lambda_{\text{П}2} = \frac{r'_{\text{П}2}}{C_0 f_{\text{П}2}}\left(1 - e^{-f_{\text{П}2}\gamma_{\text{П}2}}\right)e^{f_{\text{П}2}\gamma_{\text{П}2}}\Delta K_2\,; \tag{13}$$

$$\Delta\lambda_{\text{П}1} = \frac{r'_{\text{П}1}}{C_0 f_{\text{П}1}}\left(1 - e^{-f_{\text{П}1}\gamma_{\text{П}1}}\right)e^{f_{\text{П}2}\gamma_{\text{П}2}+f_{\text{П}1}\gamma_{\text{П}1}}\Delta K_2\,. \tag{14}$$

Then, after bringing similar terms, we get:

$$\begin{aligned}\Delta K_2\Big[\; & L'_1 e^{-(f_C\gamma_C + f_{\text{Д}C}\gamma_{\text{Д}C})} + L'_{CC}e^{-f_C\gamma_C} + L'_2 + L'_{\text{ПП}}e^{f_{\text{П}2}\gamma_{\text{П}2}} + \\ & + L'_3 e^{f_{\text{П}2}\gamma_{\text{П}2}+f_{\text{П}1}\gamma_{\text{П}1}} + L'_4 e^{f_{\text{П}2}\gamma_{\text{П}2}+f_{\text{П}1}\gamma_{\text{П}1}+f_\rho\gamma_\rho} + \\ & + \frac{\rho'}{f_H}\left(1-e^{-f_H\gamma_H}\right)e^{-(f_C\gamma_C+f_{\text{Д}C}\gamma_{\text{Д}C})} + \frac{r'_{\text{Д}C}}{f_{\text{Д}C}}\left(1-e^{-f_{\text{Д}C}\gamma_{\text{Д}C}}\right)e^{-f_C\gamma_C} + \\ & + \frac{r'_C}{f_C}\left(1-e^{-f_C\gamma_C}\right) + \frac{r'_{\text{П}2}}{f_{\text{П}2}}\left(1-e^{-f_{\text{П}2}\gamma_{\text{П}2}}\right)e^{f_{\text{П}2}\gamma_{\text{П}2}} + \\ & + \frac{r'_{\text{П}1}}{f_{\text{П}1}}\left(1-e^{-f_{\text{П}1}\gamma_{\text{П}1}}\right)e^{f_{\text{П}2}\gamma_{\text{П}2}+f_{\text{П}1}\gamma_{\text{П}1}}\Big] = \\ & = C_0\left(\Delta L_1 + \Delta L_{CC} + \Delta L_2 + \Delta L_{\text{ПП}} + \Delta L_3 + \Delta L_4\right).\end{aligned} \tag{15}$$

The expression enclosed in a square bracket will be denoted by B, then (15) can be written as:

$$\Delta K_2 = \frac{C_0}{B}\left(\Delta L_1 + \Delta L_{CC} + \Delta L_2 + \Delta L_{\text{ПП}} + \Delta L_3 + \Delta L_4\right). \tag{16}$$

The value B in formula (16) has the meaning of the reduced length of the base in the filling. The quantity B is dimensionless, but numerically equal to the length in meters.

Formula (16) will be useful in mathematical modeling of the weaving technological process in order to optimize it.

V. CONCLUSION

1. Research has been carried out on the theoretical determination of the increment in the tension of the warp threads on the loom as a result of breaks.
2. The theoretical dependence of the increment of the warp thread tension due to the breaking for the rock-price bar zone is obtained, taking into account variable factors.
3. The increase in the tension of the thread due to the breaking in the zone of the rock-price bar is directly proportional to the stiffness coefficient of its meter section and the sum of the length increments in the threading zones, inversely proportional to the reduced warp length in the threading.
4. The obtained theoretical dependence of the increment of the warp thread tension due to the breakingwill be useful in mathematical modelling of the weaving technological process in order to optimize it.

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