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DYNAMICS MODEL OF YARN TRANSPORTATION THROUGH THE SHED

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Abstract. *On the basis of previous reserch, original model of yarn transportation through the shed at weaving looms with projectile Sulzer and STB type is established. The model is based on theoretical and experimental research, since yarn tension force obtained on the basis of measurement results is taken as a resultant of external forces. Dynamic model of yarn movement during projectile braking in reception box is also established.*
Through the solution of the second model, expression for calculating the "loop" length, i.e. yarn surplus length drawn into the shed under the action of inertial forces is determined. Loop is used as a basic parameter for yarn compensator synthesis and for certain machanisms work synchronisation.

1. Introduction

The process of transporting the yarn through the shed is very complex, because within a very short interval of time (about 0.2 s) the work of great number of mechanisms is to be synchronized, and the work is performed with yarn which in sensitive to strike and impulse load. Because of that, it is necessary to perfom modeling of this process in order to estimate the influence of specific parameters on the process itself.

The yarn (2) unwinds from the spool (1), comes through the guide (3), then between the brake plates (4) and compensator ears (5), Fig.1. By the projectile (10), to wich the initial speed v_o is notified in the shock box, the yarn is transported through the shed (8). When the projectile is in the last third of the way, the yarn brake starts to act, with the task of slowing down the yarn movement. The projectile stops within a very short time interval in the reception box (9). Due to inertia forces, more yarn is drawn into the shed than the length of the loom itself l, Fig. 2. This surplus is called "the loop". The compensator (5) has the task to pull out the surplus yarn from the shed and provide the

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necessary strength of the yarn before beating up the weft.

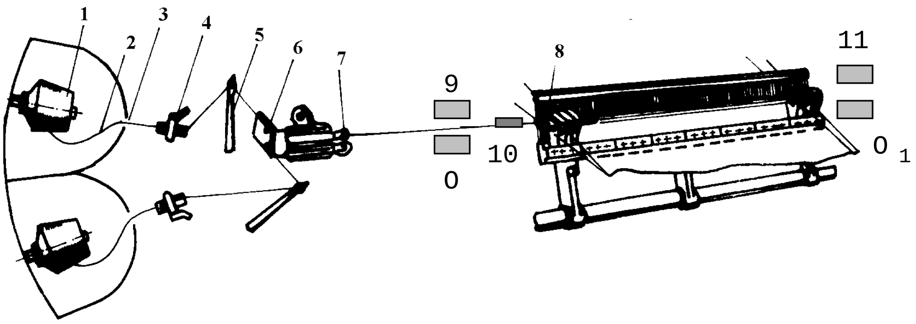

Fig. 1. Technological scheme of transporting yarn through the shed.

2. DYNAMICS OF YARN DURING TRANSPORTATION THROUGH THE SHED

Movement of the projectile-yarn systems through the shed is considered as the movement of a body with changeable mass, so the equation of this movement has the following form:

$$\frac{d}{dt}\left\{[m_p + (l_o + s)\cdot \mu]\frac{ds}{dt}\right\} = F_{(t)} \tag{1}$$

where: m_p = 0.040 kg - is the projectile mass,

l_o = 0.8m - is the yarn length from the spool to the shock box,

$F_{(t)}$ - is the resultant of all external forces affecting the yarn during its transporting through the shed, wich is obtained on the basis of experimental results and has the form:

$$F_{(t)} = \sum_{i=0}^{n} A_i \cdot t^i \,.$$

A_i - the coefficientes,

μ [kg/m] - line mass of the yarn.

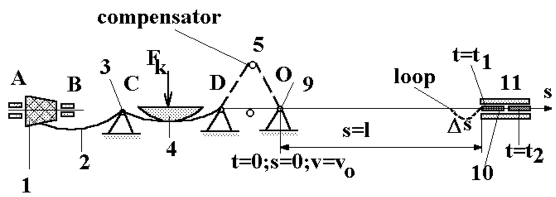

Fig. 2. Kinematics scheme

In previous papers [4, 5, 6], the force $F(t)$ has been determined on the basis of certain suppositions, however now, it has been determined by approximations based on experimental results.

By introduction of symbols $a = m_p + l_o\,\mu$ and $b = \mu$ the equation (1) is reducted to:

$$a \cdot \ddot{s} + b \cdot [s \cdot \ddot{s} + \dot{s}^2] = F_{(t).} \tag{2}$$

As $s \cdot \ddot{s} + \dot{s}^2 = (s \cdot \dot{s})'$, the equation (2) is reducted to:

$$a \cdot \ddot{s} + b \cdot (s \cdot \dot{s})' = F_{(t)} \,. \tag{3}$$

By making previous equation integral, the following is obtained:

$$a \cdot \dot{s} + b \cdot s \cdot \dot{s} = \int F_{(t)} dt + C_1 = \Re_{(t)} + C_1 \,, \tag{4}$$

where $\Re_{(t)} = \int F_{(t)} \cdot dt = \int \sum_{i=0}^{n} A_i \cdot t^i \cdot dt = \sum_{i=0}^{n} \frac{A_i}{n+1} \cdot t^{n+1}$

After determining the integration constant C_1 from the initial conditions $t = 0$, $s = 0$, $\dot{s} = v_o$, $\Re_{(t)} = 0$, where v_0 - the initial speed is determined in [1], the equation (4) has the form:

$$a \cdot \dot{s} + b \cdot s\dot{s} = \Re_{(t)} + a \cdot v_o \,. \tag{5}$$

From the previous equation the speed of the projectile-yarn system changes in accordance with the law:

$$\dot{s} = \frac{ds}{dt} = v = \frac{\Re_{(t)} + a \cdot v_o}{a + b \cdot s} \,. \tag{6}$$

The differential equation (6) separates the variables, so its positive solution has the form:

$$s = \frac{\sqrt{a^2 + 2 \cdot b \cdot \Im_{(t)}}}{b} - \frac{a}{b} \,, \tag{7}$$

where:

$$\Im_{(t)} = \int [\Re_{(t)} + a \cdot v_o] \cdot dt = \sum_{i=0}^{n} \frac{A_i}{(n+1) \cdot (n+2)} \cdot t^{n+2} + a \cdot v_o \cdot t + C_2 \,.$$

The integration constant which appears in the solution is equal to the zero, $C_2 = 0$ for initial conditions, $t = 0$; $s = 0$; $\Im_{(t)} = 0$.

3. Yarn dynamics at projectile braking

Having passed through the shed the projectile brakes in a reception box (O_1), fig.1 and fig. 2, in the time interval corresponding to the change of loom main shaft turing angle of 233^0 to 250^0, that is from $t = t_1 = 144$ ms to $t = t_2 = 178$ ms, when loom operates with rotation number of $n = 270$ resolution per minute (rpm).

During projectile braking yarn tension force is equal to the tension force at the moment $t = t_1$, that is $F = F(t = t_1)$.

Dynamic beheaviour of yarn in this period can be described by differential equation (1), and appropriate constans should be determined for new initial conditions. In this period projectile inertion force influence can also be disregarded, that is new coefficients are: $a_1 = l_o\,\mu$ and $b = \mu$

$$a_1 \cdot \dot{s} + b_1 \cdot s \cdot \dot{s} = \int F_{(t)} dt + C_3 = \Re_{(t)} + C_3 \,. \tag{8}$$

At the moment of the beginning of projectile braking, that is for, $t = t_1$; $s = l$; $v = v_1 = \dot{s}(t = t_1)$; $\Re(t) = \Re(t = t_1)$, the integration constant is $C_2 = v_1 \cdot (a_1 + b_1 \cdot l) - \Re(t_1)$, where $l = 2.12$ m - is loom width, Fig. 2.

Law of projectile speed change in the period of braking in the reception box can be written in the form:

$$\dot{s} = \frac{\Re(t) - \Re(t_1) + v_1 \cdot (a_1 + b_1 \cdot l)}{a_1 + b_1 \cdot s} \,. \tag{9}$$

Differential equation (8) separates variables, so it can be written in the following form:

$$b_1 \cdot s^2 + 2 \cdot a_1 \cdot s = 2 \cdot \Im_1(t) + C_4 \,, \tag{10}$$

where:

$$\Im_1(t) = \int [\Re(t) - \Re(t_1) + v_1 \cdot (a_1 + b_1 \cdot s)] \cdot dt =$$
$$= \sum_{i=0}^{n} \frac{A_i}{n+1} \cdot t \cdot \left(\frac{t^{n+1}}{n+2} - t_1^{n+1} \right) + a_1 \cdot b_1 \cdot l \,.$$

Integration constant C_4 is determined from the starting condition; for $t = t_1$, $s = l$,

$$C_4 = l \cdot (2 \cdot a_1 + b_1) - 2 \cdot \Im_1(t_1) \,.$$

Equation (10) now can be written in the form:

$$b_1 \cdot s^2 + 2 \cdot a_1 \cdot s - 2 \cdot [\Im_1(t) - \Im_1(t_1)] - l \cdot (2 \cdot a_1 + b_1) = 0 \,. \tag{11}$$

Low of natural coordinate change in the period of projectile braking represents positive solution to the equation (11):

$$s = \frac{\sqrt{a_1^2 + 2 \cdot b_1 \cdot a_1 \cdot l + b_1^2 \cdot l + 2 \cdot b_1 \cdot l \cdot [\Im_1(t) - \Im_1(t_1)]}}{b_1} - \frac{a_1}{b_1} \,. \tag{12}$$

Yarn length drawn into the shed at the end of projectile braking can be obtined if $t = t_2$ is inserted in the expression (12):

$$s = s(t = t_2) = \frac{\sqrt{a_1^2 + 2 \cdot b_1 \cdot a_1 \cdot l + b_1^2 \cdot l + 2 \cdot b_1 \cdot l \cdot [\Im_1(t_2) - \Im_1(t_1)]}}{b_1} - \frac{a_1}{b_1} \,. \tag{13}$$

Yarn drawn into the shed during projectile braking represents surplus yarn which is called "loop". Loop length (Δs) is regulated by yarn braking force intensity (F_k), yarn brake action duration and by right yarn brake action and yarn compensator action synchronization. Yarn compensator function is to pull out surplus yarn, loop, drawn into the shed. Theoretically, the compensator should act after the projectile has been stopped in the reception box, although in practice it acts somewhat earlier, that is, before the projectile is brought into the reception box (11). The compensator function is to ensure necessary yarn tension before it is attached to the warp by the action of a reed mechanism. When loop length Δs is greater than it is necessary, the compensator cannot pull all the surplus yarn out from the shed, therefore yarn is not tensed enough before it is attached to the warp, but slack, which affects directly the fabric quality. If loop length is smaller than necessary, then when pulling the loop out from the shed by means of compensator, it can come to yarn breaking, or to undesrable deformations. All these undesirable effects, except yarn breaking, can be obsered only after the final phase of fabric manufacture, that is only after dyeing and finishing. Because of that it is necessary to determine the loop length and to examine the possibilities of its regulation. On the basis of the pulling the loop out from the shed, synthesis of the yarn compensator mechanism and synchronisation of the yarn brake action and yarn compensator action are carried out.

Loop length can be calculated if yarn length brought into the shed at the beginning of projectile braking is subtracted from the total yarn length brought into shed at the end of projectile braking $s = s(t = t_2)$, that is we subtract $s = s(t = t_1) = l$.

$$\Delta s = \frac{\sqrt{a_1^2 + 2\cdot a_1 \cdot b_1 \cdot l + l \cdot b_1^2 + 2\cdot b_1 \cdot [\Im_1(t_2) - \Im_1(t_1)]}}{b_1} - \frac{a_1}{b_1} - l \,. \tag{14}$$

If aproximation of the experimental tension force values is carried out by polynome on the third power, that is:

$$F_{(t)} = \sum_{i=0}^{n=3} A_i \cdot t^i = A_3 \cdot t^3 + A_2 \cdot t^2 + A_1 \cdot t + A_0 \,,$$

where coefficients are:

$A_3 = 2174.24$; $A_2 = -2548.0491$; $A_1 = 219.05022$ and $A_0 = -11.979644$

Replacing appropriate values into the expression (14) for conditions in wich examinations are carried out, loop length value is obtained, which is $\Delta s = 19.3$ cm.

3. CONCLUSION

Dynamic model of yarn transportation the shed is given in this paper. Movement of the system projectile-yarn is observed as movement of variable mass body. As a resultant of external forces acting on yarn during its movemen, force values obtained by measuring yarn tension force in industrial conditions are taken. Results obtained experimentally are approximated by polynome on the nth power. Differential equations with adequate starting conditions represent expressions for the change of velocity and cover the distance of yarn transported through the shed.

Dynamic model of yarn movement during projectile braking is also given. We have also established an expression for yarn length, "loop", determination which is drawn into the shed during this period, becouse loop length is an important technological parameter, and has great importance in projection and regulation of yarn brake and yarn compensator mechanism.

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DINAMIČKI MODEL TRANSPORTOVANJA PREĐE KROZ ZEV

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Na osnovu dosadašnjih istraživanja u radu je postavljen originalni model transportovanja pređe kroz zev kod tkačkih razboja sa projektilima tipa Sulzer i STB. Model se zasniva na osnovu teorijskih i eksperimentalnih istraživanja, jer je kao rezultanta spoljašnjih sila, uzeta sila zatezanja pređe koja je dobijena na osnovu izmernih rezultata. Postavljen je i dinamički model kretanja pređe u toku kočenja projektila u prijemnoj kutiji. Rešenjem drugog modela određen je izraz za izračunavanje dužine "petlje", odnosno, dužine viška pređe koja se uvuče u zev usled dejstva inercijalnih sila. Petlja služi kao osnovni parametar za sintezu kompenzatora pređe i za sinhronizaciju rada pojedinih mehanizama.