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ВПЛИВ ТЕРТЯ РОБОЧИХ ОРГАНІВ В'ЯЗАЛЬНОЇ МАШИНИ НА ДИНАМІЧНІ НАВАНТАЖЕННЯ В ПАРІ ГОЛКА-КЛИН

У даній роботі представлені результати досліджень по оцінці впливу тертя робочих органів в'язальної машини (голки, клини, стібки) на величину динамічних навантажень, що виникають в зоні взаємодії голок і клинів. Представляємо вплив тертя на динамічні навантаження в в'язальному механізмі круглов'язальної машини з жорстким і пружним кріпленням клинів.

Ключові слова: в'язальна машина, голка, клин, стібок, тертя, динамічне навантаження.

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THE KNITTING MACHINE WORKING BODIES FRICTION EFFECT ON DYNAMIC LOADS IN THE NEEDLE-WEDGE PAIR

The efficiency of knitting machines largely depends on the mutual friction of the working bodies (needles, wedges, stitches) of the knitting mechanism. Frictional forces significantly affect the dynamic loads of the knitting mechanism, reducing the reliability and durability of its operation. The analysis shows that the reduction of dynamic loads can be achieved by reducing the friction of needle-wedge and needle-stitch pairs. Therefore, the task of these studies is to analyse the effect of friction of the working bodies of the knitting machine on dynamic loads in the most responsible pair of the needle-wedge knitting mechanism.

The object of research is the influence of friction on dynamic loads in the needle-wedge pair of a knitting machine. Modern methods of theoretical research based on the theory of machine dynamics and the theory of designing knitting machines were used to solve the problems.

Given the relevance of the question of increasing the efficiency of knitting machines by reducing the friction of the working bodies of the knitting mechanism, the article is devoted to the analysis of the effect of friction and the method of fastening the wedge on the amount of dynamic loads arising in the most responsible needle-wedge pair.

The analysis of operation of the knitting mechanisms of circular knitting machines showed that the main reason for needle failure is significant dynamic loads arising in the needle-wedge pair. It is also noted that one of the factors that significantly affects the amount of dynamic loads in the needle-wedge pair is the friction forces in the needle-wedge and needle-stitch pairs (guide needles). It is obvious that the reduction of friction of the working bodies of the knitting mechanism leads to a reduction of dynamic loads in the needle-wedge pair and, accordingly, to a reduction of needle failures.

The analysis of the obtained results shows that with an increase in the friction forces of the working bodies of the knitting machine, the impact force of the needle on the wedge with both rigid and elastic fastening significantly increases, which negatively affects the efficiency of the machine (the number of needle failures increases and the durability of the wedges decreases) and on the quality of the fabric (increase in the percentage of defective fabric)

Key words: knitting machine, needle, wedge, stitch, friction, dynamic load.

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Articulation of issue

The analysis shows that it is possible to reduce dynamic loads by reducing friction of needle-wedge and needle-stitch pairs. Therefore, the task of this research is to analyse the effect of friction of the working bodies of the knitting machine on the dynamic loads in the most responsible pair of the needle-wedge knitting mechanism.

Sources analysis

The efficacy of knitting machines largely depends on the mutual friction [1] of its working bodies (needles, wedges, stitches). As it is known [2, 3], frictional forces significantly affect the dynamic loads of the knitting mechanism, thereby reducing the reliability and durability of its operation.

The purpose of this paper is: to analyse the effect of friction and the method of fastening the wedge on the amount of dynamic loads that occur in the most responsible needle-wedge pair.

Presentation of basic material

Friction affects the operation of machine mechanisms [1], to include the knitting mechanism of knitting machines, significantly. The practice of operating knitting machines, in particular circular knitting machines, shows that with insufficient lubrication of the knitting mechanism friction pairs, the number of needle failures increases, and thus decreases the efficiency of the machines and the quality of the knitted fabric.

The results of the analysis of the operation of the knitting mechanisms of circular knitting machines [2-4] show that the main cause of needle failure is significant dynamic loads arising in the needle-wedge pair. It is also noted that one of the factors that significantly affects the amount of dynamic loads in the needle-wedge pair is friction forces in the needle-wedge and needle-stitch pairs (guiding needles). Therefore, it is clear that by reducing the friction of the knitting mechanism working bodies it is possible to reduce dynamic loads in the needle-wedge pair and, accordingly, bring the needle failures to the minimum.

Let us analyse the effect of friction on dynamic loads in the knitting mechanism of KO type circular knitting machine. As it is known [4], there are two ways of interaction between the knitting mechanism needles and wedges, namely: interaction of needles with wedges with rigid fastening (rigid wedges); interaction of needles with wedges with elastic fastening.

With rigid fastening of the wedges, the maximum value of dynamic loads of the needle-wedge pair (the impact force of the needle on the wedge) is found as follows:

$$F_{\max} = V\sqrt{\frac{mC}{K}}tg\alpha + \frac{F}{K}. \quad (1)$$

Where: $F_{\max}$ is the maximum impact force of the needle on the wedge;
V is a circular speed of the needle (needle cylinder);
m is the needle mass;
C is the stiffness of the needle-wedge pair in the impact zone;
F is a technological load on the needle;
K is the knitting system design parameter,

$$K = \text{ctg}(\alpha + \rho) - \frac{2a+b}{b}tg\rho_1; \quad (2)$$

ρ , ρ_1 are friction angles of needle-wedge and needle-stitch pairs, respectively (usually $\rho = \rho_1$);
a is an impact force arm;
b is the needle support arm (needle groove depth).

As can be seen from the foregoing, the reduction of frictional forces in the area of interaction of the knitting machine working bodies (needles, wedges, stitches) due to, e.g., improved lubrication system, has a positive effect on the knitting system design parameter and, accordingly, on the reduction of dynamic loads in the needle-wedge pair.

Let us analyse the effect of friction on dynamic loads in the knitting mechanism of KO-2 type circular knitting machine. Using machine parameters [5] and research results [6], the following is taken as initial data: $V = 1{,}1$m/s; $\alpha = 56^0$; $m = 0{,}477 \cdot 10^{-3}$kg; $C = 824{,}5 \cdot 10^3$N/m; $a = 1{,}5$mm; $b = 3{,}8$mm; $F = 0{,}17$N.

Assuming that as a result of lubricating the friction pairs [1], the friction angle of the needle-wedge-stitches ρ may vary from 3^0 to 12^0 (with $\rho > 12{,}45^0$ $K < 0$, resulting in needle jamming), the dynamic loads in the needle-wedge pair with a rigid fastening (friction angle variation interval $\Delta\rho = 0{,}5^0$) were calculated. The results are given in Table below.

To evaluate the effect of friction of the knitting machine working bodies when replacing rigid fastening of wedges with an elastic one on dynamic loads, let us consider the knitting mechanism of KO-2 circular knitting machine, where the wedge is fastened to the block of locks with the help of an elastic beam with following operational dimensions (selected for design reasons, given the peculiarities of the knitting mechanism): length 48 mm; section thickness 5 mm; cross-section width 10 mm. In this regard, initial data are the following: $V = 1{,}1$m/s; $\alpha = 56^0$; $m_1 = 0{,}477 \cdot 10^{-3}$kg (needle mass); $m_2 = 36{,}41 \cdot 10^{-3}$kg (total reduced mass of wedge and beam); $C_1 = 824{,}5 \cdot 10^3$N/m (reduced stiffness of the needle-wedge); $C_2 = 2486{,}6 \cdot 10^3$N/m (reduced stiffness of the wedge fastening unit); $a = 1{,}5$mm; $b = 3{,}8$mm; $F_1 = 0{,}17$N (technological load on the needle); $F_2 = 9{,}67$N (static pressure of needles on the wedge); $\rho = 3^0 \ldots 12^0$; $\Delta\rho = 0{,}5^0$.

To define the needle impact force on the wedge with an elastic fastening (F_{1max}) and dynamic load in the zone of its elastic fastening (F_{2max}), depending on the friction (friction angle ρ), it is reasonable to use the following algorithm [4]:

1. Determine the value of λ : $\lambda = \frac{2a+b}{b} tg\rho.$ (3)

2. Determine the value of ψ : $\psi = 1 - \lambda tg(\alpha + \rho).$ (4)

3. Determine the value of γ : $\gamma = C_1 \frac{m_1+\psi m_2}{m_1 m_2}.$ (5)

4. Determine the frequency of oscillation of β_1 , β_2 masses of the needle-wedge-elastic fastening of the wedge system:

$$\beta_{1,2}^2 = \frac{C_1(m_1+\psi m_2)+C_2 m_1 \pm \sqrt{[C_1(m_1+\psi m_2)+C_2 m_1]^2 - 4\psi C_1 C_2 m_1 m_2}}{2m_1 m_2}. \quad (6)$$

5. Determine the value of z : $z = \beta_1^2 - \beta_2^2.$ (7)

6. Determine the value of Δ_1, Δ_2: $\Delta_1 = \gamma - \beta_1^2$; $\Delta_2 = \gamma - \beta_2^2.$ (8)

7. Determine integration constants A, B :

$$A_{11} = \frac{\frac{C_1}{m_2} - \Delta_2}{z} \cdot \frac{F_1}{\psi};\ A_{12} = \frac{\Delta_1 - \frac{C_1}{m_2}}{z} \cdot \frac{F_1}{\psi};\ A_{21} = A_{11} \frac{m_2}{C_1} \Delta_1;\ A_{22} = A_{12} \frac{m_2}{C_1} \Delta_2;$$

$$B_{11} = \frac{C_1 V \Delta_2}{\beta_1 z};\quad B_{12} = -\frac{C_1 V \Delta_1}{\beta_2 z};\quad B_{21} = B_{11} \frac{m_2}{C_1} \Delta_1;\quad B_{22} = B_{12} \frac{m_2}{C_1} \Delta_2. \quad (9)$$

8. Determine the total of integration constants:

$$D_{11} = \sqrt{A_{11}^2 + B_{11}^2};\quad D_{12} = \sqrt{A_{12}^2 + B_{12}^2};\quad D_{21} = \sqrt{A_{21}^2 + B_{21}^2};\quad D_{22} = \sqrt{A_{22}^2 + B_{22}^2}. \quad (10)$$

9. Determine constant components of dynamic loads: $a_1 = \frac{F_1}{\psi}$; $a_2 = \frac{F_1}{\psi} + F_2.$ (11)

10. Now, determine dynamic loads in the knitting mechanism:

$$F(D_{11} + D_{12} + a_1)(\alpha + \rho)_{1max};\ F21_{22} a_2 \mathrm{tg}_{2max}. \quad (12)$$

The results obtained are now summarised in Table below.

Table

The results of calculating the effect of friction on dynamic loads in the knitting mechanism of KO-2 type circular knitting machine

Friction angle ρ, degrees.	Dynamic loads, N		
	$F_{\max}$ (in a needle-wedge pair with rigid fastening of the wedge)	F_{1max} (in a needle-wedge pair with elastic fastening of the wedge)	F_{2max} (in the zone of elastic fastening of the wedge)
3,0	45,753	39,651	24,241
3,5	47,055	41,178	24,647
4,0	48,469	42,834	25,105
4,5	50,013	44,637	25,626
5,0	51,708	46,612	26,222
5,5	53,581	48,788	26,912
6,0	55,666	51,202	27,719
6,5	58,008	53,903	28,673
7,0	60,663	56,953	29,820
7,5	63,711	60,437	31,222
8,0	67,260	64,470	32,973
8,5	71,464	69,218	35,216
9,0	76,556	74,928	38,189
9,5	82,901	81,983	42,303
10,0	91,115	91,030	48,340
10,5	102,346	103,261	57,975
11,0	119,045	121,203	75,464
11,5	147,822	151,589	114,761
12,0	217,434	223,260	235,935

Conclusions

The analysis of obtained results shows that:

- increased friction forces of the knitting machine working bodies results in significantly increased force of the needle impact on the wedge with both rigid and elastic fastening, which negatively affects the efficiency of the machine (the number of needle failures increases and the durability of wedges decreases) and the quality of the fabric (the percentage of defective fabric increases);

- with $\rho > 12{,}45^0$friction angle, KO-2 type circular knitting machine K design parameter acquires negative value, and, therefore, causes jamming and needle breakage (F_{max});

- as effective, it is advisable to recommend the mode of operation of the knitting machine, in which the needle-wedge pair friction ratio does not exceed 0,1 ($\rho \leq 5,7^0$);

- the method of fastening wedges (rigid or elastic) practically does not affect the amount of dynamic loads in the needle-wedge pair.

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