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ANALYSIS OF THE EFFECT OF FRICTION OF THE WORKING BODIES OF KNITTING MACHINES ON THE WEDGES LIFE CYCLE

In this paper, we present the results of research on the evaluation of the knitting machine working bodies (needles, wedges, stitches) friction effect on the wear of working surfaces of wedges and on their life cycle. The object of research was to analyse the effect of friction of needle-wedge and needle-stitch pairs (guide needles) on the intensity of wear of working surfaces of wedges, which determines their life cycle. Modern methods of theoretical research based on the theory of friction and wear and the theory of designing knitting machines were used to resolve the problems. Increased efficiency of knitting machines can be achieved by reducing the friction losses of the working bodies of the knitting mechanism (mainly needle-wedge and needle-stitch friction pairs). Therefore, the task of this research is to analyse the effect of friction of the working bodies of the knitting machine on the wear of the working surfaces of wedges and on their life cycle.

The analysis of obtained results shows that the friction of working bodies significantly affects the wear of wedges of knitting machines and, accordingly, their life cycle.

The rational mode of operation of the KO-type circular knitting machine is its mode when the ratio of friction of the needle-wedge and needle-stitch pairs is within 0.08...0.1 (which is achieved by choosing appropriate type of lubricant and lubrication modes of the knitting mechanism). At the same time, the life cycle of the stitch cam ranges from 208.79 · 103 to 76.97 · 103 hours (from 16,312 to 6,013 days at 2-shift operation of the machine).

With the existing mode of operation of the KO-2 circular knitting machine, as shown by research, the life cycle of the stitch cams does not exceed 9 · 103 hours (703 days)

Key words: knitting machine, needle, wedge, stitch, friction, wedge wear, wedge life cycle.

ПЛЕШКО СЕРГІЙ
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АНАЛІЗ ВПЛИВУ ТЕРТЯ РОБОЧИХ ОРГАНІВ В'ЯЗАЛЬНИХ МАШИН НА ЖИТТЄВИЙ ЦИКЛ КЛИНІВ

У цій роботі представлені результати дослідження з оцінки впливу тертя робочих органів в'язальних машин (голок, клинів, стібків) на знос робочих поверхонь клинів та на їх термін служби. Наведено приклад впливу тертя пар голка-клин та голка-стібок круглов'язальної машини КО-2 на термін служби кулачків стібків.

Аналіз отриманих результатів показує, що тертя робочих органів суттєво впливає на знос клинів в'язальних машин і, відповідно, на їх термін служби.

Раціональним режимом роботи круглов'язальної машини типу КО є її режим, коли співвідношення тертя пар голка-клин та голка-стібок знаходиться в межах 0,08...0,1 (що досягається шляхом вибору відповідного типу мастила та режимів змащування в'язального механізму). Водночас, термін служби кулачка стібка коливається від 208,79 · 10³ до 76,97 · 10³ годин (від 16 312 до 6 013 днів при 2-змінній роботі машини).

За існуючого режиму роботи круглов'язальної машини КО-2, як показали дослідження [2], термін служби кулачків стібка не перевищує 9 · 10³ годин (703 дні).

Ключові слова: в'язальна машина, голка, клин, стібок, тертя, знос клина, термін служби клина

Increased efficiency of knitting machines can be achieved by reducing the friction losses of the working bodies of the knitting mechanism (mainly needle-wedge and needle-stitch friction pairs). Therefore, the task of this research is to analyse the effect of friction of the working bodies of the knitting machine on the wear of the working surfaces of wedges and on their life cycle.

The results of research on the evaluation of the effect of friction of working bodies of the knitting machine (needles, wedges, stitches) on the wear of the working surfaces of wedges and on their life cycle, as well as an example of the effect of friction of needle-wedge and needle-stitch pairs of the KO-2 circular knitting machine on the life cycle of stitch cams are hereby presented.

The object of research was to analyse the effect of friction of needle-wedge and needle-stitch pairs (guide needles) on the intensity of wear of working surfaces of wedges, which determines their life cycle. Modern methods

of theoretical research based on the theory of friction and wear and the theory of designing knitting machines were used to resolve the problems.

Given the relevance of the issue on increasing the efficiency of knitting machines by increasing the life cycle of the knitting mechanism wedges, this paper is devoted to the analysis of the effect of friction of the knitting machine working bodies on the wear of working surfaces of wedges and their life cycle.

The effect of friction on the life cycle of the stitch cam of the KO-2 circular knitting machine was analysed. At the same time, the design features of the machine and the results of previous studies were also considered.

The analysis of obtained results shows that the friction of working bodies significantly affects the wear of the knitting machine wedges, and accordingly, their life cycle.

The rational mode of operation of the KO-type circular knitting machine is its mode when the ratio of friction of the needle-wedge and needle-stitch pairs is within 0.08...0.1 (which is achieved by choosing appropriate type of lubricant and lubrication modes of the knitting mechanism). At the same time, the life cycle of the stitch cam ranges from $208.79 \cdot 10^3$ to $76.97 \cdot 10^3$ hours (from 16,312 to 6,013 days at 2-shift operation of the machine).

With the existing mode of operation of the KO-2 circular knitting machine, as shown by research [2], the life cycle of the stitch cams does not exceed $9 \cdot 10^3$ hours (703 days).

Key words: knitting machine, needle, wedge, stitch, friction, wedge wear, wedge life cycle.

Articulation of issue

The object of research was to analyse the effect of friction of needle-wedge and needle-stitch pairs (guide needles) on the intensity of wear of working surfaces of wedges, which determines their life cycle. Modern methods of theoretical research based on the theory of friction and wear and the theory of designing knitting machines were used to resolve the problems.

Given the relevance of the issue on increasing the efficiency of knitting machines by increasing the life cycle of the knitting mechanism wedges, this paper is devoted to the analysis of the effect of friction of the knitting machine working bodies on the wear of working surfaces of wedges and their life cycle.

Sources analysis

Increased efficiency of knitting machines, as known from [1-3], can be achieved by reducing the friction losses of the working bodies of the knitting mechanism (mainly needle-wedge and needle-stitch friction pairs). Therefore, the task of this research is to analyse the effect of friction of the working bodies of the knitting machine on the wear of the working surfaces of wedges and on their life cycle.

Presentation of basic material

Using the results of research [4, 5], the life cycle of wedges is determined as follows:

$$T = \frac{H_{\max} r_{np}^{0,5\beta t}}{60nzKf^t q^{1+0,5\beta t}} = \frac{H\ {}_{np}^{a}{}_{max}}{NKf^t q^b}, \tag{1}$$

Where: T is wedges service life in hours (life cycle);

H_{max} is maximum allowable wedge wear measured normal to its working surface;

r_{np} is reduced radius of curvature of the pair of needle-wedge heel (hereinafter – the needle-wedge);

a is an exponent,

$$a = 0,5\beta t; \tag{2}$$

β is a needle-wedge pair surface characteristics considering ratio,

$$\beta = \frac{1}{1+2\nu}; \tag{3}$$

ν is support surface curve ratio;

t is a needle-wedge pair contact fatigue curve exponent;

N is the number of friction pair load cycles during one hour of operation,

$$N = 60nz = \frac{360Vz}{\pi d}; \tag{4}$$

n is the machine needle cylinder rotation frequency (for a circular knitting machine);

z is the number of needles in the needle cylinder;

V is the needle cylinder linear speed;

d is the needle cylinder diameter;

K is a parameter that characterizes the friction pair material features,

$$K = 2K_0 \left(\frac{4\eta}{\pi}\right)^{0,5} \cdot 0,418^c E^{0,5c} \frac{c}{c+0,5};\ K_0 = C_1 \left(\frac{1-\mu_1^2}{E}\right)^{c-t} \left(\frac{K_1}{C_2\sigma_0}\right)^t;\ \eta = \frac{1-\mu_1}{E_1} + \frac{1-\mu_2}{E_2} = \frac{2(1-\mu)}{E}; \tag{5}$$

μ_1, μ_2 are the needle and wedge materials Poisson's ratios, $\mu_1 = \mu_2 = \mu$;

E_1, E_2 are the needle and wedge materials elasticity modulus;

E is a given needle and wedge materials elasticity modulus, $E = E_1 = E_2$;

c is an exponent,

$$c = 1 + \beta t; \tag{6}$$

$$C_1 = \frac{1,2\nu^{0,5}}{K_2(1+\nu)}; \tag{7}$$

K_2 is the ratio chosen depending on the νparameter;

K_1 is a proportionality ratio between the specific force of friction and stress;

$$C_2 = \left(\frac{b_1}{2}\right)^\beta \left(\frac{2,35}{K_2}\right)^{1-\beta} \left(\frac{r}{h_{max}} ()^{0,5(1-\beta)}\right); \tag{8}$$

b_1 is support surface curve ratio;

r is an average radius of vertices and ridges of micro-uniformities of friction surfaces, $r = \sqrt{R_1 R_2}$;

R_1, R_2 are the radii of curvature of micro-uniformities of friction surfaces in the transverse and longitudinal directions of surface treatment;

$h_{\max}$ is the maximum height of micro-uniformities of the wedge surface;

σ_0 is the strength limit at single tension of a needle-wedge pair;

f is the needle-wedge pair friction ratio;

q is a specific normal pressure in the needle and wedge contact zone, $q = \frac{F_{max}}{l \sin \alpha}$;

F_{max} is the maximum impact force of the needle on the wedge (horizontal component);

l is the width of contact area between the needle and the wedge;

α is the angle of the needle with wedge meeting at the moment of impact;

b is an exponent, $b = 1 + 0{,}5\beta t$.

Given that the purpose of this research is to analyse the impact of the needle-wedge pair friction on the wedge life cycle, let's convert the formula (1) into the following, convenient for analysis form:

$$T = \frac{A}{f^t F_{max}^b}, \tag{9}$$

Where:

$$A = \frac{H_{\max} r_{np}^a (l \sin \alpha)^b}{NK}. \tag{10}$$

Let's analyse the effect of friction on the KO-2 circular knitting machine stitch cam life cycle.

Given the design features of the machine [6] and the results of research [1-3, 7], the following is taken as initial data: the diameter of the needle cylinder of the machine - $d = 450$mm; the needle cylinder linear speed - $V = 1{,}0$m/sec.; the number of needles in the cylinder - $z = 1224$; the needle material is У7А steel, HRC - 68…70; the stitch cam material is ШХ 15-type steel, HRC - 62…65; the width of contact area between the needle and the wedge - $l = 2{,}5 \cdot 10^{-3}$m; the angle of the needle with wedge meeting at the moment of impact - $\alpha = 56^0$; the needle and the stitch cam elasticity modulus and Poisson's ratios - $E_1 = E_2 = E = 1{,}96 \cdot 10^{11}$N/m^2; $\mu_1 = \mu_2 = \mu = 0{,}29$; the stitch cam maximum allowable wear - $H - 3_{max}$m; support surface curve ratio - $\nu = 3$, $b_1 = 5$; the radii of curvature of micro-uniformities of friction surfaces - $R_1 = 16$μm, $R_2 = 11300$ μm; the maximum height of micro-uniformities of the stitch cam surface - $h_{\max} = 3{,}2$μm; the strength limit at single tension of a needle-wedge pair -$\sigma_0 = 7 \cdot 10^8$ N/m^2; the ratios -$t = 3$, $K_1 = 2$, $K_2 = 0{,}69$.

Using the initial data and the foregoing dependencies, we find the following : a =0,2145; $b = 1{,}2145$; $c = 1{,}429$; $\beta = 0{,}143$; $N = 3{,}117 \cdot 10^6$cycles/hour; $\eta = 0{,}724 \cdot 10^{-11}$; $C_1 = 0{,}753$; $C_2 = 26{,}5$; $r = 425{,}2$μm; $K_0 = 595{,}4 \cdot 10^{-15}$; $K = 0{,}898 \cdot 10^{-10}$; $q = 4{,}395 \cdot 10^4$Н/м; $q^b = 43{,}544 \cdot 10^4$; $r_{\text{пр}}^a = 99{,}8 \cdot 10^5$; $A = 11781$.

Given the foregoing, formula (9) turns as follows:

$$T = \frac{11781}{F_{max}^{1{,}2145^3}} \text{ hours.} \tag{11}$$

Substituting the f values of the needle-wedge (stitch cam) pair friction ratio and the $F_{\max}$values of the maximum needle impact force on the wedge (stitch cam), which corresponds to the given value f [7], in formula (11), using the developed program, we thus find the required life cycle of the KO-2 circular knitting machine stitch cams (the results are presented in the Table below and in Fig. 1 - curve 1).

The effect of friction on the wear of wedges can be estimated by converting formula (1) into a form convenient for this purpose:

$$H = \frac{\text{TNKf}^t F_{max}^b}{r_{np}^a (l \sin \alpha)^b t^b{}_{max}}, \tag{12}$$

Where:

$$B = \frac{TNK}{r_{\text{пр}}^a (l \sin \alpha)^b}. \tag{13}$$

Accepting that $T = 10 \cdot 10^3$hours, we obtain $B = 0{,}51 \cdot 10^{-3}$. Therefore, formula (12) turns to be as follows:

$$H = 0{,}51 \cdot 10^{-3} F_{max}^{1{,}2145^3}, \text{м} = 510 F_{max}^{1{,}2145^3} \text{μm}. \tag{14}$$

Substituting the $F_{\max}$ and f values (see Table below) in formula (14), using the developed program, we thus find the required value of wear of the working surface of KO-2 circular knitting machine stitch cams at $T = 10 \cdot 10^3$hours. The results we obtained are presented in Table below and in the figure – curve 2.

Table 1

The results of calculating the effect of friction on the life cycle of the KO-2 circular knitting machine stitch cams and their wear (at $T = 10 \cdot 10^3$hours)

Needle-wedge (stitch cam) pair friction ratio, f	Needle-wedge (stitch cam) friction angle ρ , degrees	Maximum needle impact force on the wedge (stitch cam), F_{max} , Н	The wedge (stitch cam) life cycle T , 10^3 hours	The wedge (stitch cam) wear value, H , μm at $T = 10 \cdot 10^3$ hours
0.0524	3.0	45.753	788.15	7.62
0.0611	3.5	47.055	480.48	12.50
0.0699	4.0	48.469	309.56	19.41
0.0787	4.5	50.013	208.79	28.77

Table 1 continuation

Needle-wedge (stitch cam) pair friction ratio, f	Needle-wedge (stitch cam) friction angle ρ , degrees	Maximum needle impact force on the wedge (stitch cam), F_{max} , H	The wedge (stitch cam) life cycle T , 10^3 hours	The wedge (stitch cam) wear value, H , μm at $T = 10 \cdot 10^3$ hours
0.0875	5.0	51.708	145.89	41.18
0.0963	5.5	53.581	104.81	57.32
0.1051	6.0	55.666	76.97	78.05
0.1139	6.5	58.008	57.52	104.45
0.1228	7.0	60.663	43.47	138.20
0.1316	7.5	63.711	33.28	180.53
0.1405	8.0	67.260	25.60	234.64
0.1494	8.5	71.464	19.78	303.67
0.1584	9.0	76.556	15.27	393.48
0.1673	9.5	82.901	11.76	510.68
0.1763	10.0	91.115	8.96	670.27
0.1853	10.5	102.346	6.70	896.25
0.1944	11.0	119.045	4.83	1243.39
0.2034	11.5	147.822	3.24	1852.55
0.2125	12.0	217.434	1.78	3375.44

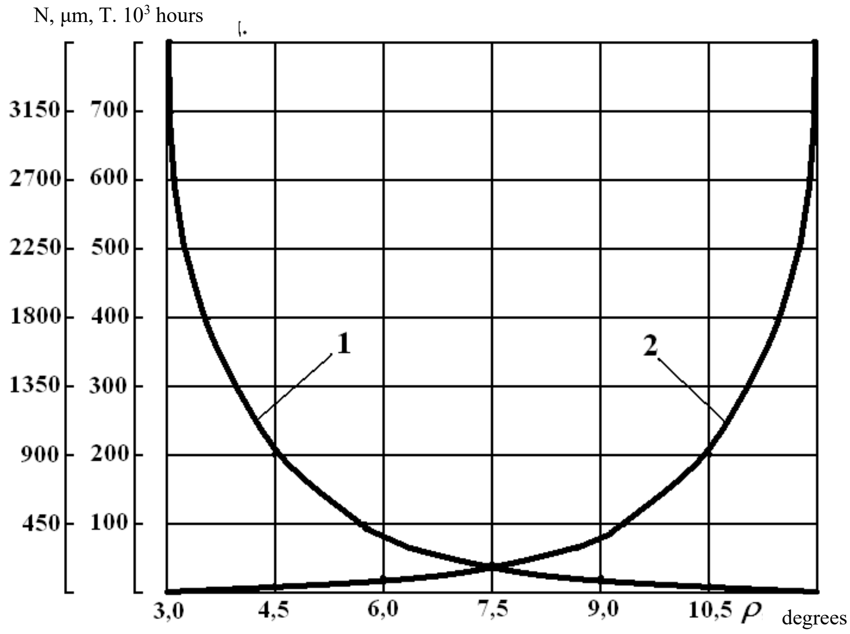

Fig.1 The effect of friction on the life cycle of the KO-2 circular knitting machine stitch cams (curve 1) and their working surface wear (curve 2) at $T = 10 \cdot 10^3$ hours

Conclusions

The analysis of obtained results shows that the friction of working bodies significantly affects the wear of wedges of knitting machines and, accordingly, their life cycle.

The rational mode of operation of the KO-type circular knitting machine is its mode when the ratio of friction of the needle-wedge and needle-stitch pairs is within 0.08...0.1 (which is achieved by choosing appropriate type of lubricant and lubrication modes of the knitting mechanism). At the same time, the life cycle of the stitch cam ranges from $208.79 \cdot 10^3$ to $76.97 \cdot 10^3$ hours (from 16,312 to 6,013 days at 2-shift operation of the machine).

With the existing mode of operation of the KO-2 circular knitting machine, as shown by research [2], the life cycle of the stitch cams does not exceed $9 \cdot 10^3$ hours (703 days).

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