MODERNIZATION OF A SCRAPER-CHAIN DEVICE OF BALLAST CLEANERS

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ABSTRACT

Increase in productivity of modern track machines leads to power growth of actuators' drives. The article offers a way towards modernization of a chain scraper working body of the new generation of ballast cleaners. The developed techniques and the comparative results of the calculations before and after modernization, leading to power gain, show the advantages of the proposed engineering solutions.

Keywords: track ballast cleaner, modernization, scraper-chain actuator, specific energy, resistance force.

Background. *Known designs and methods of modernization of cutting tools of ballast cleaning devices are generally reduced to increase in the power of the machine to increase its operating speed and the rotation speed of a driving star gear of a bar chain. However, this option in addition to the improvement of performance is characterized by excessive energy consumption and high wear of machine components.*

It should be noted that the total resistance to movement of the bar chain is defined as a sum of the following components: [1]

– Ballast resistance to cutting P_1;

– The resistance from ballast friction forces on ballast in the cutting zone P_2;

– Resistance of scraper friction forces on ballast in the cutting zone P_3;

– Ballast resistance to movement along the gutter P_4;

– Resistance from friction of a scraper chain on the surface of gutters P_5.

According to the method of calculation [1], an important role in determining the performance and specific energy consumption is played by a coefficient of filling between-scrapper space [2].

Objective. *The objective of the authors is to sugget and to substantiate engineering solutions regarding modernization of a scraper-chain device of ballast cleaners.*

Methods. *The authors use general scientific and engineering methods, mathematical calculation, modeling, comparative analysis, graph construction.*

Results. *In the course of modernization of a cutting tool any of the availbale methods suggest to replace sliding friction to rolling friction or completely eliminate it. The most suitable components for this purpose are:*

– Resistance from the scraper friction forces on ballast in the cutting zone P_3;

– Ballast resistance to movement along the gutter P_4;

– Resistance from friction of a scraper chain on the surface of gutters P_5.

To reduce the friction force of the scrapers on ballast, as shown by our study, it is possible to install roller bearings at the bottom of scrapers. In this case, the force P_3 *can be written as:*

$$P_3 = f_{1.1}(k_r, R) G_c \frac{B}{L_c}; \quad (1)$$

$$f_{1.1} = \frac{k_r}{R}, \quad (2)$$

where B – width of a bar chain, m;

k_r *– coefficient of rolling friction of steel on the ground (in the absence of experimental data for the rolling friction coefficient «ballast-steel» the pair «asphalt-steel» – 6 mm [3]), the closest on the properties, is selected, mm;*

R – the radius of a supporting roller (based on design considerations for scrapers of the machine SCHOM-1200 of upgraded cutting tool we take R = 24 mm), mm;

L_c *– total length of a chain, m;*

G_c *– gravity force of a chain, kN.*

Resistance force to ballast movement along the gutter can be significantly reduced through the installation of belt conveyors on the bottom and side wall of the working gutter, belt speed of which is synchronized with the speed of scraper-chain cutting tool. In this case, the force can be determined by the formula:

$$P_4 = \rho g S_{scr} K_{fil}(B, h, k_l, V_m, V_ц, S_{scr}) L_g \sin \alpha_g. \quad (3)$$

Here the coefficient of filling of between-scraper space is determined by the following dependence [3]:

$$K_{fil}\left(B, h, k_p, V_m, V_c, S_{scr}\right) = \frac{BhV_m k_l}{V_c S_{scr}}, \quad (4)$$

where ρ – loosened ballast density t / m^3;

g – acceleration due to gravity, m / s^2;

S_{scr} *– area of a scraper, m*^{2};

h – thickness of the cut layer of ballast, m;

k_l *– coefficient of loosening of the ballast;*

V_m *– operating speed of movement of the machine, m / s;*

V_c *– speed of a bar chain, m/s;*

L_g *– length a working gutter, m;*

α_g *– angle of slope of a gutter in the operational position, rad.*

The friction force of a chain on gutters' surface if they are equipped with conveyors becomes zero ($P_5 = 0$*).*

Let's compare the results.

For the sake of convenience of calculations common two-parameter (depending on the speed of rotation of a bar chain and feed rate – movement of the machine) formulas for calculating power and energy intensity of the process were derived – as is the case with upgraded cutting tool, and for commercially available ballast cleaners of new generation SCHOM-1200.

Power on the star gear of a scraper-chain working body before modernization:

$$N_{sg} = \frac{B}{\eta_{scr}}\left(k_1 k_\beta k_2 h V_m + 0{,}5\rho g f_2 B h V_m k_l + \frac{f_1 G_c V_c}{L_c} + \rho g L_g \left(\sin\alpha_g + f_1 \cos\alpha_g\right) h V_m k_l + \frac{2 f_1^1 G_c L_g \cos\alpha_g V_c}{L_c B}\right) + \frac{\rho f_1^1 G_c L_g \cos\alpha_g V_c}{\eta_{scr}}\left(H_g + V_c^2\right). \quad (6)$$

A similar power after modernization:

Table 1

The values of coefficients before modernization

Parameter name	Notation	Value	Dimension
Calculated ballast resistivity to cutting	k_1	700	kN/m²
Coefficient, taking into account the angle of cutting	k_β	0,83	–
Coefficient of loosening of ballast in sleeper boxes	k_2	0,7	–
Coefficient of loosening of contaminated ballast	k_l	1,3	–
Coefficient of steel friction on ballast	f_1	0,45	
Coefficient of ballast friction on ballast	f_2	0,85	–
Coefficient of steel friction on steel in case of a strong abrasive	$f_1^{\,1}$	0,2	–
Density of loosened ballast	ρ	1,6	t/m³
Acceleration due to gravity	g	9,8	m/s²
Efficiency of the scraper working body	η_{scr}	0,6	–
Lifting height of the cut ballast on the gutter	H_g	5,9	m
Length of a working gutter	L_g	11,8	m
Width of ballast cutting	B	3,9	m
Thickness of cut ballast	h	0,4	m
Gravity force of a chain	G_c	50	kN
Total length of a chain	L_c	30	m
Area of a scraper	S_{scr}	0,09	m²
Angle of slope of a gutter in the working mode	α_g	0,523	rad

Table 2

The values of coefficients after modernization

Parameter name	Notation	Value	Dimension
Calculated ballast resistivity to cutting	k_1	700	kN/m²
Coefficient, taking into account the angle of cutting	k_β	0,83	–
Coefficient of loosening of ballast in sleeper boxes	k_2	0,7	–
Coefficient of loosening of contaminated ballast	k_l	1,3	–
Ratio of a friction coefficient to a radius of a roller	$f_{1.1}$	0,25	–
Coefficient of rolling friction for the pair «asphalt-steel»	k_r	6	mm
Radius of a supporting roller	R	24	mm
Coefficient of ballast friction on ballast	f_2	0,85	–
Density of loosened ballast	ρ	1,6	t/m³
Acceleration due to gravity	g	9,8	m/s²
Efficiency of the scraper working body	η_{scr}	0,6	–
Lifting height of the cut ballast on the gutter	H_g	5,9	m
Length of a working gutter	L_g	11,8	m
Gravity force of a chain	G_c	50	kN
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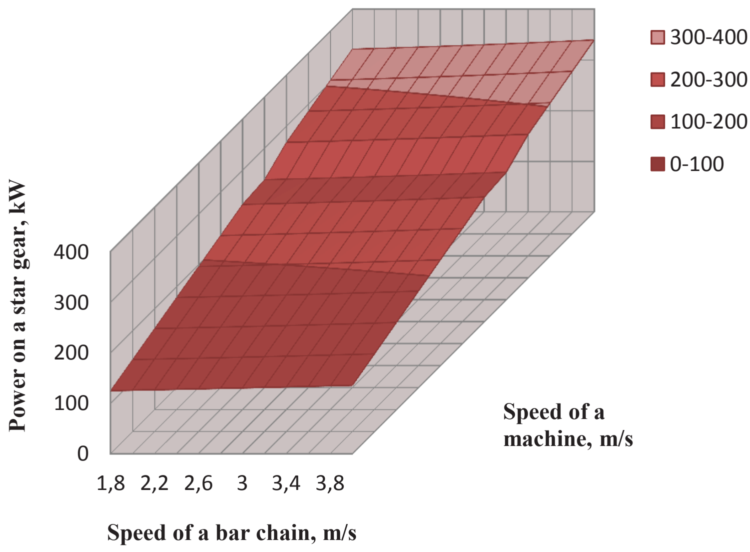
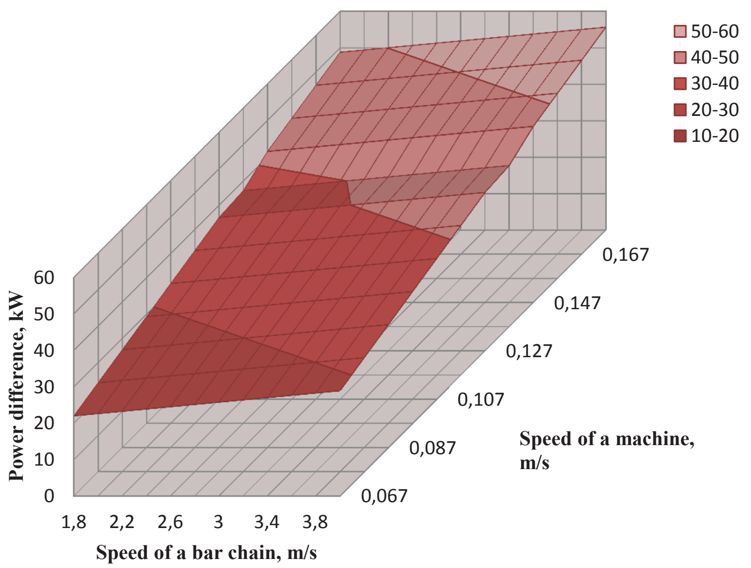
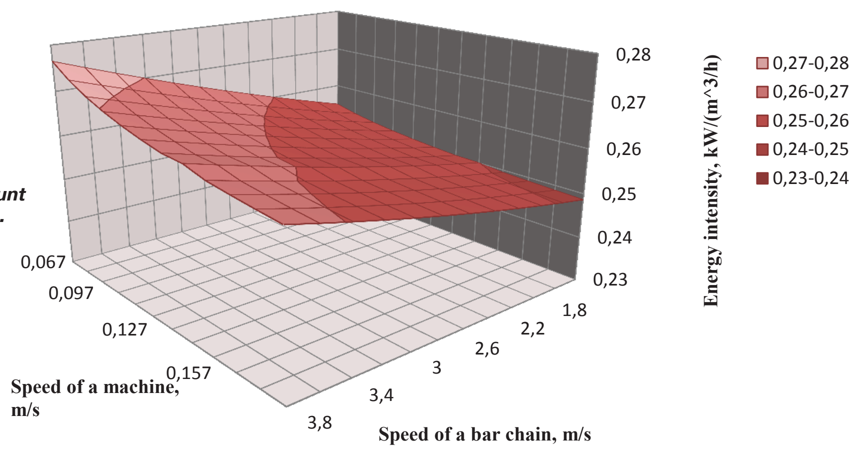


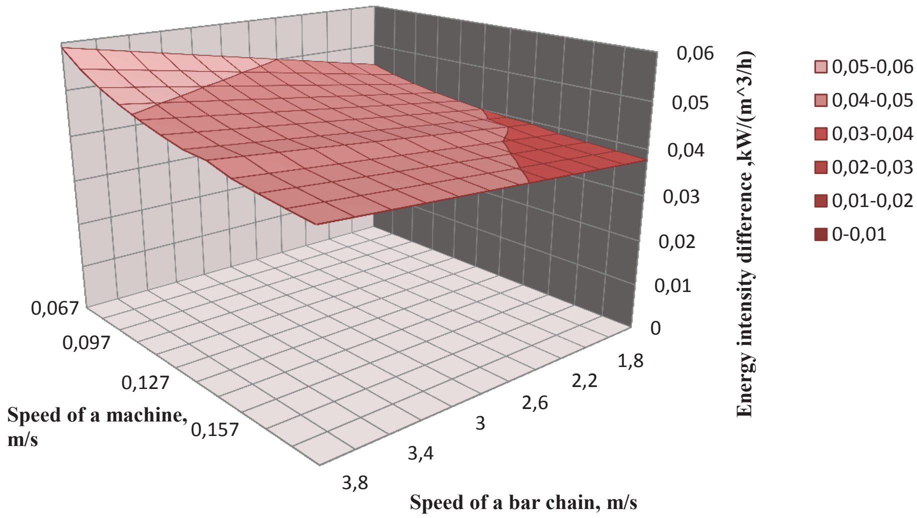
Pic. 1. Power on a star gear with account of modernization.



Pic. 2. Power difference before and after modernization.



Pic. 3. Energy intensity with account of modernization.



Pic. 4. Energy intensity difference before and after modernization.

$$N_{sg}=\frac{B}{\eta_{scr}}\left(k_1k_\beta k_2hV_m+0,5\rho gf_2BhV_mk_l+\right.$$
$$\left.+\frac{f_{1.1}G_cV_c}{L_c}+\rho gL_g\sin\alpha_ghV_mk_l\right)+$$
$$+\frac{\rho BhV_mk_l}{\eta_{scr}}\left(H_g+V_c^2\right). \qquad (7)$$

The formula of energy intensity in this case:

$$e=\frac{N_{sg}}{BhV_mk_l}.$$

Based on technical characteristics SCHOM-1200 in the calculation speed of the machine and a bar chain varied from 0,067 to 0,167 m / s and from 1,8 to 3,8 m / s, respectively. The calculation results are presented in Pic. 1–4.

Conclusion. *Analysis of the obtained dependencies shows that as a result of the proposed technical solutions it is possible to reduce the power of a motor of a rotation drive of a scraper-chain working body of a track ballast cleaner SCHOM-1200 by 50 kW, and energy intensity – by 21%.*

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