International Journal of Psychological Rehabilitation, Vol.24, Issue 07, 2020
`Issn: 1475-7192

Research of The Processes of Wearing the Working Bodies of Road Mills

Tulkun Ishanovich Askarkhodzhaev, Sharofiddin Asatullaevich Pirnaev, Batir Tokhta-Muradovich Mirnigmatov, Shohsanam Murodjon qizi Abdukarimova¯

Abstract: This article is written about the study of the processes of depreciation of the working bodies of road milling machines. The article analyzes the performance, conservation and extension of the working bodies of road milling machines and the calculations of prolonging their effective operation.

Keywords: depreciating/wear of working bodies, road milling cutters, resistance of incisors, preservation of operability, preservation of operability.

I. INTRODUCTION

Resistance of working cutters DF when cutting asphalt concrete, i.e. their ability to maintain performance, resisting breakdowns to wear, plays an important role. The insufficient durability of the incisors is currently the main obstacle to the effective use of DF.

In analogy, we can consider the process of blunting a tool during the operation of the executive body of a rock-boring machine of a mining enterprise (Fig. 1). When using a blunt cutter, the cutting force of the rocks increases 3-4 times, and the feed force - 4-5 times or more. The friction work of the site, which is formed as a result of blunting the trailing edge of the cutter against the rock, can achieve, depending on the size of this site and the chip thickness, 95–97% of the entire work of destruction [1].

Figure 1 - The working body of a roadheader (analogue of the working body road miller).

Meanwhile, road miller cutters lose their durability due to either breakage or wear. Depreciation is the result of wear, manifested in the form of a change in the size and geometry of the cutter along the friction surface and evaluated either directly by the change in size or by indirect signs.

Quantification of wear can be assessed through various indicators, which can be called wear criteria. Directly measured wear criteria can be expressed in units [2] characterizing linear wear along the rear or front face, or in units characterizing the change in the area of the front face of the tool, the profile area of the tool, the area resulting from wear

¯**Askarkhodzhaev T.I.** a Professor of the Tashkent Institute of Design, Construction and Maintenance of Automotive Roads.
Pirnaev Sh. A, a Researcher of the Tashkent Institute of Design, Construction and Maintenance of Automotive Roads. Email: Sharofiddinpirnaev928@gmail.com, Sharofiddin2306@mail.ru.
Mirnigmatov B.T., a Senior Teacher of the Tashkent Institute of Design, Construction and Maintenance of Automotive Roads.
Abdukarimova Sh.M., a Teacher of the Tashkent Institute of Design, Construction and Maintenance of Automotive Roads.

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

on the rear face, or in units characterizing weight or volume wear.

These criteria cannot be considered universal, because depending on the specific conditions, each of them may be most preferable. All of these criteria obtained by measurements are absolute quantitative characteristics of wear. Along with them, relative characteristics can be applied, which are the amount of wear per unit length of the path of the cutting tool in contact with asphalt concrete, unit volume of the destroyed asphalt concrete, unit time, etc. Such relative criteria may be called specific wear indicators. Sometimes inverse indicators are used, representing the private compartments, for example, the total length of the friction path or the total volume of the destroyed material by the total amount of wear.

II. LITERATURE REVIEW.

I. An imitation model of the wear process by developing Art. Researcher Askarkhodzhaev T.I. Criteria for wear of the incisors and their calculations, a graph of the dependence $\boldsymbol{\psi_{\Delta в}} / \boldsymbol{\psi_{\Delta д}} = \boldsymbol{\alpha}$, as well as a block diagram of the algorithm for determining the form of wear of the incisors were carried out by scientific researcher Sh.A. Pirnaev.

II. MATHERIALS AND METHODS

The purpose of the study was to study the effect of Thus, depending on the structure, the wear criteria for DF cutters can be divided into absolute and relative, and the latter, in turn, into direct and reverse.

The rational choice of the wear criterion is of great scientific and practical importance. The latter is primarily due to the fact that during the operation of the DF, as experience shows, it is necessary to systematically control the wear of the cutting tool in order to timely replace the cutters that have reached the maximum permissible degree of blunting. The permissible degree of blunting is determined by the installed engine power and the maximum feed force of the machine (since cutting forces increase with increasing blunting of the tool) [7]. Premature replacement of the incisors is clearly impractical.

To calculate the feed and cutting forces with a blunt tool, it is necessary to know the magnitude of the blunting site of the cutter. But under operating conditions, it is practically impossible to directly measure this indicator, since for this the machine must be stopped for a long time. At the same time, the DF driver can quite accurately determine the linear wear of the cutters.

Factors affecting the wear of the cutters can be divided into the following three groups:

1) the properties of destructible material;

2) parameters of the cutting mode;

3) characteristics of the cutting tool.

In cutting studies, the first group is formed by the following characteristics of asphalt concrete:

- contact strength, p_c;
- coefficient of strength by the method of crushing samples of irregular shape, f_{cr};
- crushing strength coefficient, f_τ
- Shore number, T_{Sh};
- abrasiveness indicator, a.

The value of the specific wear *ψΔ* of the cutter with abrasion indices α, is dependent and is expressed by the equation

$$\psi_\Delta = 0{,}28_\alpha^{1{,}4}\, mm/km. \quad (1)$$

There is also a dependence of the path length L_c of the cutter in contact with asphalt prior to the stabilization of the wear rate on the abrasion index α and the amount of wear Δ_c at the end of the path L_c, and can be expressed by the following equations:

$$L_{\mathrm{c}} = \frac{0{,}14}{a^{0{,}7}}\, km, \quad (2)$$

$$\Delta_c = 0{,}25\alpha^{0.5}\, mm. \ (3)$$

Substituting Values ψ_Δ, L_c and Δ_c from formulas (1), (2) and (3) in the equation, we get:

$$\Delta = 0{,}25\alpha^{0{,}5} + 0{,}28\alpha^{1{,}4}\left(L - \frac{0{,}14}{\alpha^{0{,}7}}\right), \ (4)$$

Expression (4) we agree to call the equation of the wear curve of the cutter.

The factors of the second group affecting the wear of the cutters include: chip thickness h; cutting pitch t; cutting speed v. Knowing the specific consumption of cutters Z, it is possible to establish the time spent on auxiliary operations during the operation of the road miller (RM), which is very important for evaluating their technical and economic indicators of road repair. According to the previous section, the specific consumption of cutters Z during RM operation can be determined by the formula:

$$Z = \frac{1}{L_{ti}th}, \ (5)$$

where Z – specific consumption of incisors, pcs / m ^{3};

t – cutting step, m;

h – average chip thickness, m;

L_{mp} – tool path in contact with the rock before its failure, km.

In the third group, the most significant factors are the point angle of the tip tool and the angle of attack. Point angle δ (fig. 2) called the angle between the front and rear edges of the cutter. Attack angle β (fig. 2) called the angle between the axis of the cutter at the considered point of the cutting edge and the cutting plane.

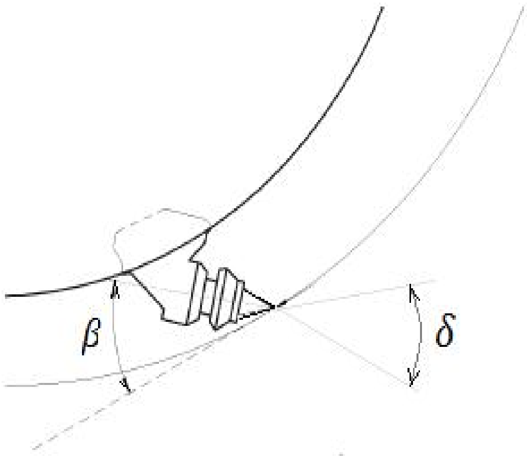

Figure 2 – Cutter geometry

The properties of the hard alloy from which the tip of the cutter is made significantly affects the wear resistance, experiments on the use of various machines for the destruction of road surfaces and rocks indicate the following [3- 4,7, 8,9, 10,11,12,]:

1. the wear resistance of a hard alloy cannot be evaluated only by its brand, since the tips of one can batch sharply differ in terms of hardness *HRA.*
2. the main criterion for the wear resistance of the RM cutter, it is advisable to take a hardness indicator *HRA*, as the linear wear along Δ and the size of the blunt pad *F* depend on the hardness of the alloy tip.
3. the wear rate of the cutter, estimated by the value of the specific linear wear on the rear face ψ_Δ, can be determined by the formula:

$$\psi_\Delta = \psi_{\Delta Э}\frac{100-HRA}{100-HRA_Э}, \ (6)$$

where $\psi_{\Delta Э}$ - specific linear wear along the edge of the cutter edge taken as a reference;

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

HRA - hardness alloy tip cutter;

HRA_r - hardness of the reference tip.

Concluding the consideration of the wear of the tool, we return to the wear equation (4). This equation can be taken as the basis for the engineering calculation of RM. The use of this formula in other cases requires the introduction of correction factors. Analysis of the influence of various factors on the wear rate of the RM cutters allowed us to conclude that three correction factors should be introduced into the wear equation:

- cutting speedK_v;
- on tool geometryK_g;
- on the properties of hard alloy $K_{h.a}$.

Therefore, taking into account correction factors for cutting speed K_c, tool geometry K_g and carbide properties $K_{h.a}$ the alignment of the linear wear of the RM cutter will take the following, final form:

$$\Delta = K_g K_v K_{h.a.} \left[0{,}25a^{0{,}5} + 0{,}28a^{1.4}\left(L - \frac{0{,}14}{a^{0{,}7}}\right)\right] mm. \quad (7)$$

When using this formula, the values of the correction coefficients can be taken: the correction coefficient for the cutting speed, the correction coefficient for the geometry of the cutter - according to the correction coefficient on the properties of the hard alloy - according to the formula (6).

Equation (7) also allows you to determine which path a cutter of a certain type will go in contact with the road surface before it reaches the maximum permissible degree of blunting.

III. EXPERIMENTAL RESULTS

Cutter wear equation

The effectiveness of the use of cutters is determined by a number of criteria, one of which is their reliability - the ability of the tool to maintain its performance for a long time until the limit state occurs under certain operating conditions. As an indicator of the wear of the RM cutter, the specific cutting path with one cutter (L, km / pc) passed to breakage was adopted. MTBF is determined by the results of testing prototypes in real operating conditions [3].

The value of *Lmp* can be calculated from the expression

$$L_{mp} = \frac{11{,}37\Delta_{pb}}{\psi_{\Delta b}}, \quad (8)$$

$$\psi_{\Delta b} = K_v K_o K_{t/h} K_d K_m a^{0{,}69} \sigma_{comp}^{0{,}12}, \quad (9)$$

where Δ_{mp} – maximum permissible tip exposure, after which it breaks, mm;

$\psi_{\Delta h}$ – wear rate of tool holder, mm / km;

K_v – coefficient taking into account the influence of cutting speed;

K_o – coefficient taking into account the influence of the supply of water or aqueous solutions to the zone of interaction of the cutter with RM;

$K_{t/h}$ – coefficient taking into account the influence of the ratio of the cutting step *t* and chip thickness *h*;

K_d – coefficient taking into account the influence of the diameter of the tip;

K_m – coefficient taking into account the effect of tool holder hardness;

a – asphalt abrasiveness, mg;

σ_{comp} – tensile strength of cutting material with uniaxial compression, MPa.

$$\Delta_{mp} = \left(0{,}0001 \cdot \sigma_{comp} - 0{,}0175\right) \cdot d^2 + \left(-\,0{,}0058 \cdot \sigma_{comp} + 1{,}19\right) \cdot d, \quad (10)$$

where *d* – tip diameter, mm.

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

For longitudinally axial cutting crowns [5]

$$K_v = 0{,}24 \cdot V + 0{,}754, \quad (11)$$

where V – cutting speed, m / s.

$$K_{t/h} = \frac{0{,}27t}{gtg\varphi h^{0{,}5}}, \quad (12)$$

where K_G – coefficient taking into account the influence of the geometry of the cutter;

$tg\varphi$ – indicator of the brittle-plastic properties of asphalt concrete.

$$K_m =- 0{,}0012 \cdot T^2 + 0{,}006 \cdot T + 0{,}55, \quad (13)$$

where T – hardness toolholder *HRC*.

$$K_G = K_d K_a K_r K_\gamma, \quad (14)$$

where K_α – coefficient taking into account the influence of the angle at the tip of the carbide tip;

K_r – coefficient taking into account the influence of the tip radius;

K_γ – coefficient taking into account the influence of the shape of the head of the holder.

$$K_d = 0{,}07d + 0{,}38, \quad (15)$$

$$K_a = 0{,}00036a^2 - 0{,}043a + 2, \quad (16)$$

where α – angle at the tip of the carbide tip, deg.

$$K_r = 0{,}115r + 0{,}98, \quad (17)$$

where r - radius of rounding of the tip of the carbide tip, mm.

$$K_\gamma = 0{,}0033\gamma + 0{,}8, \quad (18)$$

where γ – angle at the top of the head of the holder, degrees.

$$h = \frac{P_z - 4{,}9 K_G K_{bp} K_{fr} K_{dp} \sigma_{comp}^{0{,}94}}{0{,}353 K_G K_{bp} K_{fr} K_{dp} \sigma_{comp}^{0{,}94} t}, \quad (19)`$$

where P_z – cutting force, H;

K_{bp} – coefficient taking into account the influence of the brittle plastic properties of asphalt concrete;

K_{fr} – coefficient taking into account the effect of fracture of asphalt concrete;

K_{dp} – coefficient taking into account the impact of the destruction of the pavement.

For the case when the wear rates of the toolholder and carbide insert are comparable, by L_{mp} the change in the insert height during the wear process also begins to influence, which must be taken into account when calculating the path length of the cutter before its failure and the specific consumption of cutters *Z*. In [5, 6], the method for taking this influence into account was not described, but the dependence of the ratio of the wear intensities of the carbide tip $\psi_{\Delta b}$ and the holder $\psi_{\Delta d}$ on the abrasiveness of the material being destroyed is given (fig. 3).

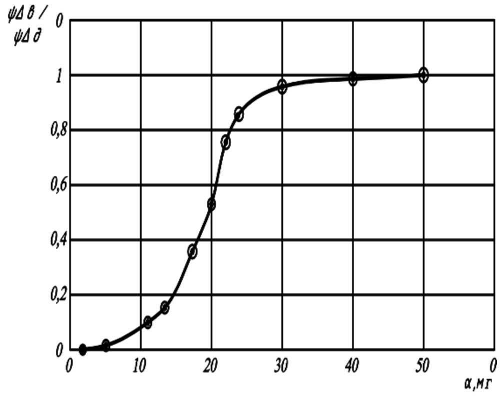

Figure 3 - Dependency Graph $\psi_{\Delta в}$ / $\psi_{\Delta д}$ = α

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

Using the considered methodology allows the calculation of the specific consumption of RM cutters under various operating conditions.

Simulation model of the wear process of the RM cutter

The formulas used in this method do not allow us to evaluate the shape of a worn cutter after its operation for a certain period of time, which is necessary to diagnose the current state of the cutter and determine its further life. To solve this problem, the following simulation model of the wear process of the RM cutter was developed.

Based on a visual inspection of the incisors that worked on asphalt up to the moment immediately preceding the breaking out of their carbide tip, it was concluded that the worn part of the incisor has almost the same appearance, shown in Figure 4.

Figure 4 - View of the cutter of a worn cutter [13]

The indicated conclusion was the basis of the simulation model developed for the destruction of the pavement cutter with different strength and abrasiveness.

Initial data:

- the object of analysis is the cutter that worked as part of the executive RM until the moment immediately preceding the breaking out of the carbide tip;
- coordinates of the location of the cutter on the drum: radius r = 0,25 m, central angle $\varphi_i = 80^o$, cutting pitch t = 14 mm, attack angle $\theta = 45^o$;
- cutting speed V_p taking into account the speed of rotation of the executive body – 1 m/s;
- average chip thickness h = 35 mm;
- destructible material – asphalt concrete (uniaxial compression strength σ_{comp} =10÷15 MPa, abrasiveness a = 10 ÷ 20 mg, in accordance with GOST 9128-2013);
- ultimate track cutter - 13.5 km.

Assumptions:

- destructible massif is monolithic (no fracture) and homogeneous;
- toolholder hardness 44*HRC*;
- the working conditions of the cutter are normal, i.e. without jamming of rotation around its axis, which provides a symmetrical form of wear.

Accepted Designations:

h_j – coordinate of the determined point in height, mm;

X_j – coordinate of the determined point along the cutter section, mm;

S_j – coordinate of a point located at a height h_j, determining the wear of the cutter at the time of breakdown of its tip, mm (determined from the form of rotary cutters);

b_j – coordinate of a point located at a height h_j, determining the position of the forming carbide insert, mm;

a_j – coordinate of a point located at a height h_j, determining the geometry of the cutter, mm;

e_j – the amount of wear of the cutter at a point located at a height h_j, mm;

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

Δ_{WV} – tip wear value, mm;

Δ_{MP} – maximum permissible tip exposure, determining its wear, mm;

Δl_{PP} – the difference in the length of the tip and its part protruding from the end of the head part of the tool holder, mm.

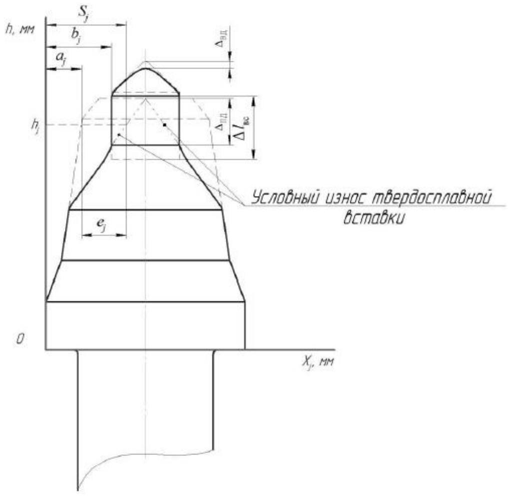

Figure 5 - The shape of the cutter before (dashed line) and after culling

To evaluate the geometric parameters of the worn part of the cutter after its operation, a certain period of time requires information on the amount of wear e_j and the wear rate i_j at every point j at the moment preceding the breakage of the cutter. Under wear rate i_j refers to the ratio of the thickness of the worn part of the holder (the amount of wear) in each section of the cutter to the distance traveled, i.e.:

$$i_j = \frac{e_j}{L_{UW}^{cif}}, \quad (20)$$

where e_j – amount of wear, mm;

L_{UW}^{cif} – ultimate wear path preceding carbide insert failure, km.

Within the framework of the developed model, it is proposed to calculate these parameters geometrically by comparing the shape of the head of the cutter before and after operation (fig. 5).

Since carbide tip interacts with asphalt, and the end part of the toolholder precisely this part undergoes the most intensive wear and has the most wear zones, the value of i_j for it should be maximum. But since its wear is limited by the tip and the actual value of e_j is small, to eliminate this contradiction, it was decided to extend the wear geometry for the main part of the holder to its end part (dash-dot line in Figure 6).

The wear rate of the toolholder was determined at points h_j at a point spacing of 0.5 mm.

$$e_j = S_j^A - \alpha_j, \quad (21)$$

where S_j^A – the coordinate of the point j in the worn part of the toolholder at the time of failure of the carbide insert at a height h_j, mm;

a_j – the coordinate of the point j of the tool holder before operation at a height hj, mm

Based on the shape of the carbide tip before and after operation, it is similarly proposed to calculate the values of e_j, i_j for this component of the cutter.

The simulation model of the wear of the cutter during cutting of asphalt concrete is a system of equations that determine the geometry of the cutter in each j_{th} section of the cutter f_{jL} on the calculated distance traveled L_{calc}:

$$f_j^L = \begin{cases} a_j \left[\begin{cases} \frac{e_j}{L_{UW}^{cif}} L_{calc} \; at \; V_{\text{p}} = 1\frac{m}{s} \\ \frac{e_j K_v}{L_{UW}^{cif}} L_{calc} \; at \; V_{\text{p}} \neq \frac{1m}{s} \end{cases} \right] at \; e_j^L > (b_j - a_j), \\ b_j \; at \; e_j^L > (b_j - a_j) \end{cases} \quad (22)$$

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

International Journal of Psychological Rehabilitation, Vol.24, Issue 07, 2020
`Issn: 1475-7192

Since the cutting speed of the cutters is determined by the radius of their fastening *r*, it was necessary to introduce the corresponding coefficient K_v.

The amount of wear at a point at a height h_j, mm at calculation design L_{calc}:

$$e_j^L = \frac{e_j}{L_{UW}^{cif}} L_{calc} = i_j^{cif} L_{calc}, \quad (23)$$

where L_{calc} – the path traveled by this point, km;

i_j^{cif} – wear rate, mm / km.

Calculation e_j, i_j allowed to build a nomogram (Fig. 6) changes in the wear rate of the holder and carbide tip of the cutter along its section.

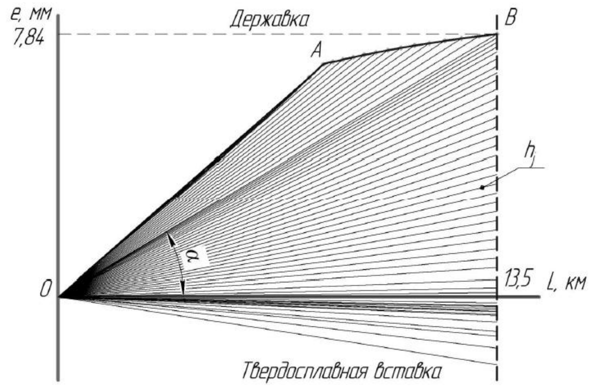

Figure 6 - Nomogram of the wear rate of the cutter during the destruction of asphalt concrete

Here, each section point h_j corresponds to its own line, the slope of which corresponds to the wear rate at this point. The *OAB* line is the line for limiting the amount of toolholder wear due to the presence of a carbide insert (excluding the dash-dot line in Figure 6).

Substituting into this nomogram any path in the range from *0* to the limiting value of 13.5 km, one can determine the wear value e_j for this path at any point of the cutter cross section and thus evaluate its shape.

The indicated solution was modeled in the *Microsoft Excel* software environment, the solution algorithm of which is shown in Figure 7.

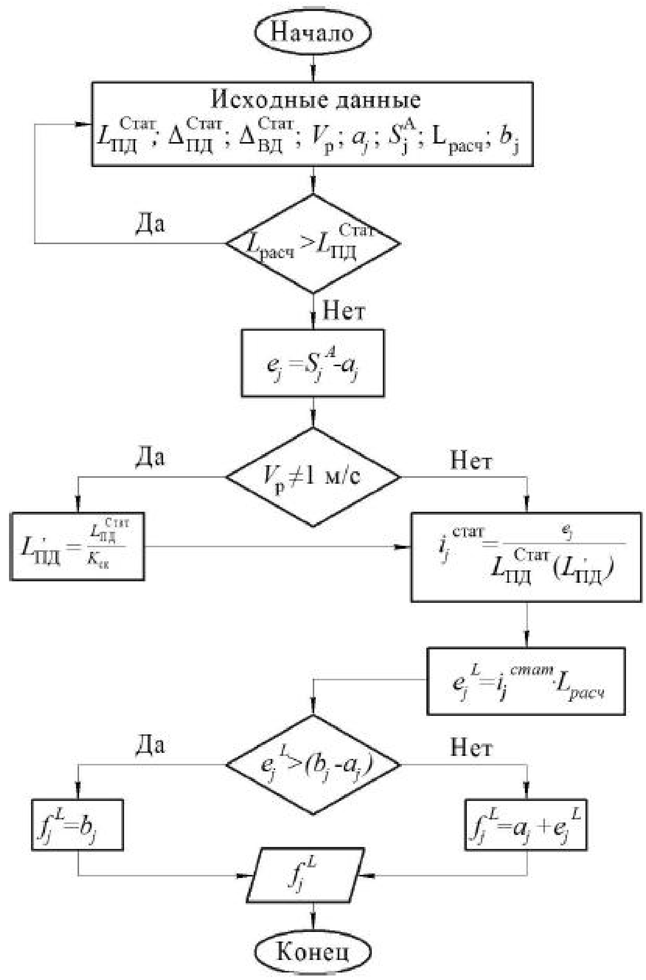

Figure 7 - Block diagram of the algorithm for determining the shape of the wear of the cutter DF in the destruction of asphalt depending on the distance traveled

The program allows you to calculate the wear form of the cutters installed at other points of the executive body, which is taken into account by introducing into the limiting cutting path L_{UW}^{cif} corresponding speed factor:

$$L_{mp} = \frac{L_{UW}^{cif}}{K_{ck}}, (24)$$

where L_{mp} – пlane to failure, passed by the turning *n*-th cutter, km;

Moreover, the amount of wear at a point at a height h_j, mm is calculated from the equality

$$e_j^L = i_j^{cif} L_{calc}, (25)$$

where L_{calc} – the path traveled by this point, km.

i_j^{cif} – wear rate determined by the algorithm (Fig. 7), mm / km.

Final coordinatef_j^L the worn-out part at the *j*th point at a height h_j is calculated from the conditions specified in the algorithm.

The calculated change in the shape of the head of the cutter during the cutting process is illustrated in Figure 8 and 9.

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

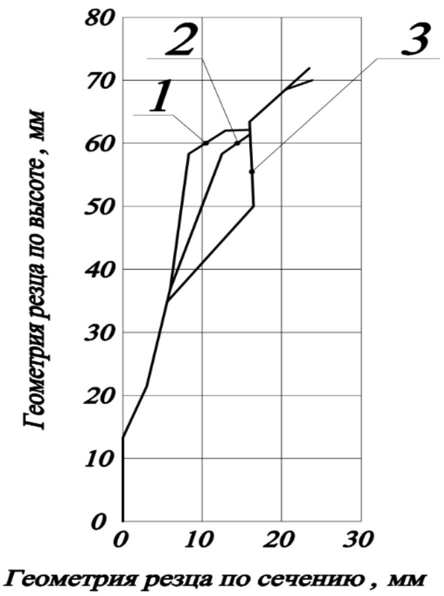

Figure 2.8 - Diagram of the wear of the cutter in height during the destruction of asphalt on the traveled path L_{calc} = 0 km (*1*), L_{calc} = 5 km (*2*), L_{calc} = 13 km (*3*)

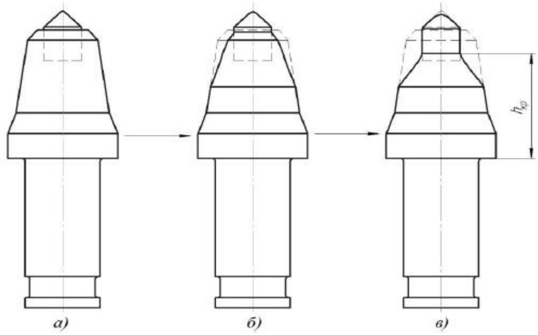

Figure 9 - Forms of wear of the cutter on the distance traveled during the destruction of asphalt concrete with a strength of 10 MPa and an abrasiveness of 20 mg: L_{calc} = 0 km (*a*), L_{calc} = 5 km (*б*), L_{mp} = 13 km (*б*) – at the time of breaking out of the tip

The developed simulation model allows you to determine the geometry of the cutter after the path covered, taking into account the milling parameters and the properties of the road surface, which makes it possible to determine its residual life.

IV. . CONCLUSION

The most significant factors affecting the wear of RM cutters include the properties of the material being destroyed, the parameters of the cutting mode and the characteristics of the cutting tool. To calculate the wear of the cutter, it is important to consider the abrasiveness of the asphalt concrete, the speed and cutting forces, as well as the hardness of the tip and its geometry. Therefore, the equation of wear of the RM cutter includes a correction factor for the cutting speed K_s, tool geometry K_g and the properties of the hard alloy $K_{(ts)}$

The wear equation of the carbide tip allows you to determine which path a cutter of a certain type will go in contact with asphalt before reaching the maximum permissible degree of blunting. Knowing the numerical value of this path, it is possible to calculate the specific consumption of the cutting tool during RM operation, which is very important for evaluating their technical and economic indicators of road repair.

The developed algorithm allows you to calculate the shape of the wear of the cutter during the destruction of road surfaces with different strength and abrasiveness. The simulation model allows you to determine the geometry of the tool along the path with various cutting parameters and the physico-mechanical properties of the road surface, which in turn allows you to determine the residual life of the tool used.

V. REFERENCES

[1] Baron L.I., Glatman L.B. Ob udel'nom vese raboty trenija pri rezanii gornyh porod. - «Nauch. soobshh. IGD im. A.A. Sochinskogo», vyp. XX, 1963.

[2] Baron L.I., Glatman L.B., Gubenkov E.K. Kriterii i metody izmerenija iznosa rezhushhego instrumenta dlja gornyh porod. M., IGD im. A.A. Sochinskogo, 1961.

[3] Razrushenie gornyh porod prohodcheskimi kombajnami. Tom I. Nauchno-metodicheskie osnovy. Razrushenie rezcovym instrumentom. Baron L.I., Glatman L.B., Gubenkov E.K. Izd-vo «Nauka», 1968. – p.1-216.

[4] Talerov, M.P. Povyshenie jeffektivnosti primenenija povorotnyh rezcov prohodcheskih kombajnov vyborom racional'nyh geometricheskih parametrov instrumentov: dis. … kand. tehn. nauk: 05.05.06/ Talerov Mihail Pavlovich. – SPb., 2012. – p.147.

[5] Levankovskij, I.A. Nauchnye osnovy sozdanija vysokojeffektivnyh instrumentov dlja razrushenija gornyh porod i porodosoderzhashhih kompozitov: dis.…dokt. tehn. nauk: 05.05.06, Levankovskij Igor' Anatol'evich. – M., 1999. – p.335.

[6] Levankovskij, I.A. Raschet iznosostojkosti povorotnyh rezcov pri rabote prohodcheskih kombajnov. Razrushenie gornyh porod i kompozicionnyh materialov povorotnymi rezcami: Sb. nauchnyh trudov. M.: AGN. 1998. – Vyp.1. – pp.110-128.

[7] Fomin K.V. Modelirovanie i raschet verojatnostnyh harakteristik momenta soprotivlenija na rabochem organe dorozhnoj frezy. Nauchno-tehnicheskij vestnik Brjanskogo gosudarstvennogo universiteta, 2019, #3. pp. 407-417.

[8] Krasnoludkij A.V. Opredelenie racional'nyh parametrov jekscentrichnoj dorozhnoj frezy: Dis. … kand. tehn. nauk. – Saratov, SGU,2004. – p.177.

[9] Balovnev, V.I. Dorozhno-stroitel'nye mashiny i kompleksy / V. I. Balovnev, A.B. Ermilov, A.N. Novikov i dr.; pod obshh. red. V.I. Balovneva. – M.: Mashinostroenie, 1988. – p.384.

[10] Beljakov Ju. I. i dr. Zemljanye raboty. M.: Strojizdat, 1983. – pp. 82-109.

[11] Bandakov B.F. Dorozhnye frezy. «Mashinostroenie»,1971. - p.136.

[12] Shmakin I.G., Sedenkov N.B. Matematicheskaja model' processa razrushenija porody rezcom. Na poroge tret'ego tysjacheletija: Sb. nauchn. tr. Tula: TulGU, 1999. – p.98-101.

[13] Popov S.N., Antonjuk D.A. Analiz haraktera iznosa i opredelenie kriteriev rabotosposobnosti rabochih organov dorozhnyh frez. Problemi tribologiï.–2007.-#1.–pp. 3-12.

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019