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ASSESSMENT OF INFLUENCE OF CUTTING TOOL BREAKAGE ON DRIVE LIFE TIME OF CUTTING UNIT OF HEADING MACHINE

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Abstract:
In this work a necessity to develop means of technical diagnostics of cutter's performance without stopping heading machine was grounded. There was theoretically demonstrated the possibility of essential decrease in life time of transmission elements of cutting unit during prolonged work of heading machine with broken cutting tool. It was defined that influence of cutting tool breakage on life time of transmission elements depends on cutting tool position on cutting head according to the assembly drawing.

Key words: *heading machine, cutting unit, cutting tool, life time, transmission, diagnostics*

THE PROBLEM AND ITS CONNECTION WITH SCIENTIFIC OR PRACTICAL TASKS

The most important condition of mining works' well stimulation is raising the pace of developments. It is possible only while using heading machines with high rates of reliability and life length. One of the most loaded heading machine subsystems is transmission of cutting unit drive. Its loading is created as a result of "external" disturbance, i.e. cutting force of rock on tool of cutting head. Clearly, the state of cutting instrument and, first of all, breakage of separate cutting tools both influence on loads in transmission. However, breakage of cutting tool does not lead to heading machine's failure and very often cannot be found out before its full stop and after visual examination of a cutting unit. As a result such work of the heading machine with broken cutting tool inevitably leads to deterioration in life time of transmission elements.

ANALYSIS OF RESEARCH AND PUBLICATIONS

There are known developments in the sphere of assessment and raising life time of element construction in mining machines based both on theoretical and experimental research methods. Thus, in this work [1, 7] there were proposed methods of assessment of individual remaining life according to factor of high-cycle fatigue and runout on the basis of "information storage module" [2]. The work [3] demonstrates essential influence of heading machine's life time on the pace of developments. However, there are no research works on cutting tool breakage influence on life time of transmission elements of cutting units equipped with cross-axial cutting heads.

SETTING OF THE TASK

The aim of this work is to assess the change in life time of transmission element of cutting unit during heading machine's work with broken cutting tool. Experimental realization of this research would have consumed a lot of time and money, that is why the change in life time was calculated theoretically on the basis of data on loads in drive obtained by simulation modelling.

PRESENTATION OF THE MATERIAL AND RESULTS

The object of research is heading machine KPD equipped with two cross-axial cutting heads 1000 mm in diameter. To carry out the experiment the authors of this work developed mathematical model of working process of heading machine taking into account the possibility of cutting tool breakage.

The main factors influencing the characteristics of working process of heading machine are:

- characteristics of decomposed working end such as profile, structure, hardness of rock seams;
- parameters of technical state of heading machine;
- treatment scheme of working end – sequence of decomposing mode of working end (horizontal cut, vertical cut, etc.) and their parameters (cutting head intake velocity and speed of cutting head rotation, depth of cut and cutting step).

During the experiment it is necessary to assess statistic characteristics of the torque in transmission, including probability distribution necessary for calculating transmission's elements' life time through well-known methods. As only duration of some decomposing modes of working end is important, not their sequence, the latter should be excluded from the number of factors of the experiment.

For simulating tests there were created representative conditions of heading machine exploitation, such as: working end consisting of 3 seams with the same parts by volume: top rock with weighted contact resisting power p_C = 400mPas, coal seam with cuttability of 250 N/mm, layer of floor p_C = 800mPas. There were adopted 3 variants of working end profile in mining in accordance with technical characteristics of heading machine – 11; 16 and 25 m^2.

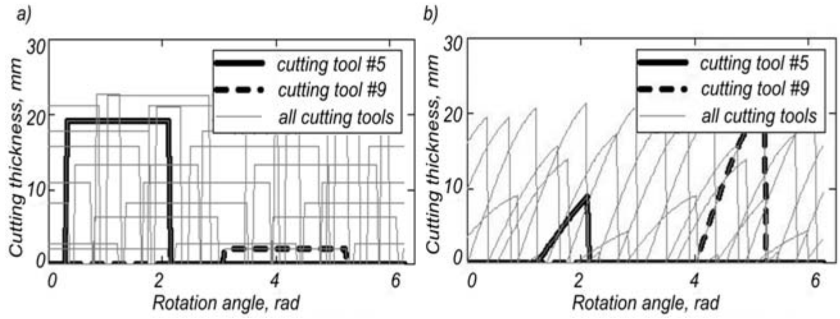

Fig. 1 Depth of cut on cutting tools of the cutting head at horizontal cut (a) and vertical cut (b)

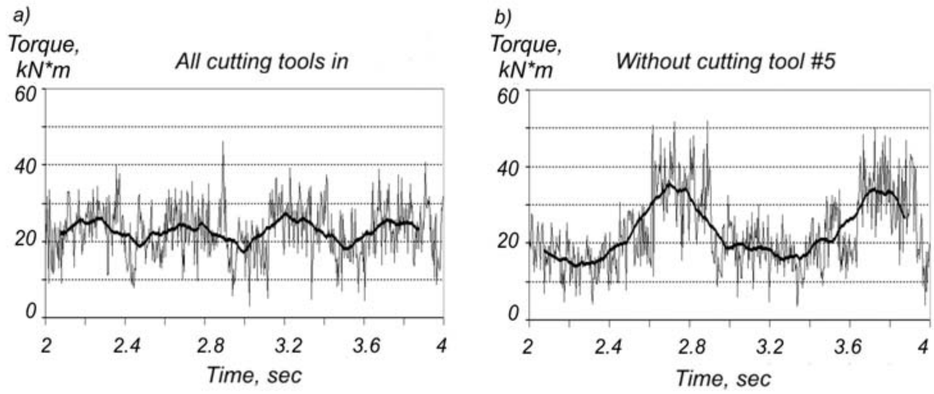

Fig. 2 Change in transmission torque приведенного к cutting unit at horizontal cut with complete set of cutting tools (a) and without 5th cutting tool (b)

Those variants of assemble drawings of cutting tools on the cutting head where cutting tools in different cutting lines are missing, were considered to be the parameters of technical state of heading machine. It is known that at different decomposing modes of working end the essentially different parameters of cut are formed on cutting tools of cross-axial cutting head. Thus, Fig. 1 shows a change in thickness of cut on some cutting tools per one turn of cutting head in the mode of horizontal cut (a) and vertical cut (b), dynamics of cutting unit movement is not taken into account.

Clearly, the cutting tool №5 breakage will influence greatly formation of external disturbance vector in the mode of horizontal cut, while cutting tool №9 breakage will do the same in the mode of vertical cut. That is why the both possible variants should be provided for by the plan of simulation experiment.

Thus, the following assembly drawings are to be considered as parameters of technical state of heading:

- with complete set of cutting tools;
- without cutting tool #5 (more substantially loaded at horizontal cut);
- without cutting tool #7 (equally loaded at horizontal and vertical cuts);
- without cutting tool #9 (more substantially loaded at vertical cut).

Besides, the parameters of real cutting head construction differ from the predetermined by assembly drawing ones because of manufacturing technological errors. These deviations were taken into account in simulation experiment as an additional random factor by introducing into simulation model random variables simulating deviation of cutting tools coordinates.

Parameters of working end decomposing by cutting heads are as follows: depth of cut *B*, cutting step Δ*H*, intake velocity V_l and rotation velocity *ω* considerably influence on loading of cutting unit. That is why, while planning simulation experiment, there were taken different values of *B* and Δ*H* (taking into account construction of cutting unit), whereas values of velocity were selected taking into account physiomechanical characteristics of mining rock to provide maximum performance capacity according to recommendations of this work [4].

The simulation experiment was carried out according to the developed plan. The results of the simulation demonstrated that cutting tool breakage leads to considerable increase in dynamic loads (as an example, realization of torque for horizontal cut is shown on Fig. 2) mainly because of increasing irregularity in low-frequency component of lead (rotating frequency of cutting head).

Analysis of histogramic probability distribution of torque in transmission (Fig. 3) shows that cutting tool breakage leads to increasing possibility of maximum and minimum values of the torque while probability of average values shows some decrease. This brings the change in cumulative damaging of transmission elements and correspondingly influences their life time.

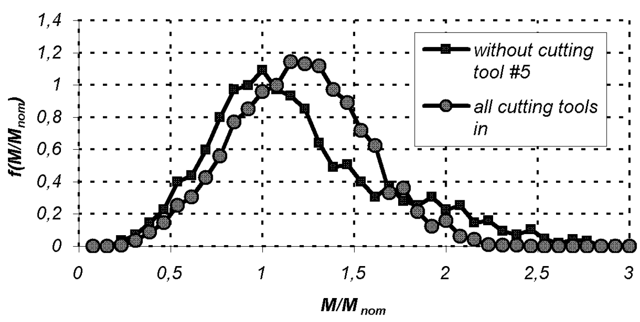

Fig. 3 Histogram of probability distribution of specified torque in transmission at horizontal cut by cutting head with complete set of cutting tools and with damaged cutting tool №5

Distinctive peculiarity of heading machine with cutting unit equipped with cross-axial cutting heads is the big number of modes of decomposing working end. As it is shown on the work [5] there can be more than 5-6 such modes in detailed calculation. However, in view of transmission load only the most intensive modes are of importance. At the same time, for example, undercut is carried out in the weakest part of working end (coal seam) and could be excluded from calculations. Alongside with this, as the work shows [6], if parts by volume of decomposing working end with contact resisting power p_{C1}, p_{C2}, u p_{C3} make up to d_1, d_2, u d_3 in the working end, then duration of decomposing i –seam make up to (see Fig. 4):

In horizontal cut mode

$$t_{HCi} = \frac{60(S - 2L_H H)d_i}{\Delta H_i V_{I.HCi}} \qquad i = 1..3, \tag{1}$$

in vertical cut mode

$$t_{VCi} = \frac{60 H d_i}{V_{I.VCi}} \qquad i = 1..3, \tag{2}$$

where:

S, H – working section area and headroom in working end;

L_H – length of cutting head;

$V_{I.HCi}$, $V_{I.VCi}$ – intake velocity of cutting head at horizontal and vertical cut on i–seam;

ΔH_i – cutting step of i–seam.

Cumulative damaging per 1m of working end roadheding

$$CD_L = \frac{\omega}{2\pi B}\sum_{i=1}^{3}\left[t_{HCi}\int_0^{M_{\max}} M^m f_{HCi}(M)dM + t_{VCi}\int_0^{M_{\max}} M^m f_{VCi}(M)dM\right] \tag{3}$$

where:

ω, M – rotation speed and transmitted torque of the given element of transmission;

M_{max} – volume of torque corresponding to yield point of the given element of transmission;

m – exponent of power of fatigue curve of the given element;

$f_{Hci}(M)$, $f_{VCi}(M)$ – probability density functions of torque in horizontal cut mode and vertical cut mode on i-seam.

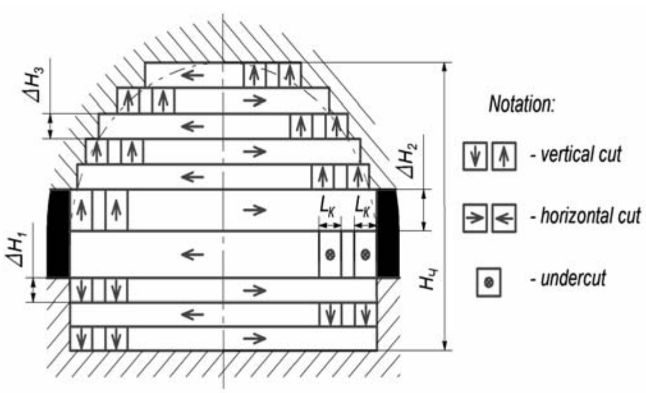

Fig. 4 Working end processing drawing

Decreasing life time of transmission elements at continuous work with damaged cutting tool in comparison with work with complete set of cutting tools was assessed in percentage:

$$\delta T = 100\frac{CD_L^{-1} - CD_L'^{-1}}{CD_L^{-1}}, \tag{4}$$

where:

CD_L, CD'_L is accumulated damage per 1m of working end roadheding with complete set of cutting tools and with broken cutting tool correspondingly.

Table 1 demonstrates results of calculation of decrease in life time of transmission elements of KPD heading machine. The results depend on the number of broken cutting tool, exponent of power of fatigue curve and working section area of working end. Analysis of the obtained data allowed us to come to the following conclusions:

a) work with broken cutting tools may lead to significant decrease in life time of transmission elements of heading machine's cutting unit, in particular up to 60-70% for shafts and gear components, up to 22-25% for bearing parts;

b) influence of cutting tool breakage on life time of transmission elements depends on cutting tool position on cutting head according to the assembly drawing. Thus, breakage of cutting tools #5 and #7 affects life time significantly, whereas breakage of cutting tool #9 decreases life time not more than by 10-12%;

c) section area of working end does not have any significant influence on relative life time decreasing.

Table 1
Relative life time decreasing (%) of transmission elements of KPD heading machine at the time of different cutting tools breakage

Broken cutting tool number	**Working section area, m²**		
	11	16	25
m = 3			
5	25	26	27
7	22	23	23
9	2.7	2.5	2.3
m = 6			
5	73	74	74
7	66	67	68
9	10	9,9	9,5
m = 9			
5	92	92	92
7	91	91	91
9	12	12	11

CONCLUSIONS AND THE FURTHER LINE OF RESEARCH

At present time there is no possibility to find out breakage of cutting tool of heading machine before it is stopped. Prolonged work of heading machine with broken cutting tool may lead to considerable decrease in life time of transmission elements of heading machine's cutting unit, in particular up to 60-70%. It is important that influence of cutting tool breakage on life time of transmission elements depends on cutting tool position on cutting head according to the assembly drawing. That is why it is necessary to develop technical diagnostic tools of technical state of cutting tool without stopping the heading machine. It is also necessary to ground effective strategy of life-expired tool replacement, especially while periodic working with hard rock cutting.

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