

## DIAGNOSTICS OF BREAKDOWN OF CUTTING TOOLS OF AXIAL CUTTING HEAD OF THE П110-04 TYPE HEADING MACHINE

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**Abstract:**

The operation of a heading machine with an out-of-work cutting tool can cause essential reduction of the machine element resource. The diagnostics of the cutting tool breakdown on the longitudinal axial cutting head in the real – time mode can be implemented on the basis of the spectral decomposition of the current of the cutting engine of the cutting unit. The ratio of the coefficients of the spectral decomposition corresponding to the cutting head rotation frequency and its threefold value can be the parameter under the diagnosis.

**Key words:** heading machine, cutting unit, cutting-tool, abrasive wear, diagnostics

**INTRODUCTION**

The analysis of usage of high performance winning complex showed the necessity of essential raise of mine working heading rate which could be reached only due to efficient usage of the potential of heading machines including the cutting unit parameters that provide efficient rock cutting. Cutting tool wearing and breakdowns depend on many factors and cannot be forecast accurately before the heading machine operation under the specific conditions. The strategy of replacement of the worn-out cutting tools based on visual examination of the heading machine used by the heading machine operators is ineffective as it results in operation of the machine with excessively worn out or broken cutting tools. The company “Gorny Instrument” [4] has carried out the cutting tool industrial tests at faces of the Kuzbass Region mines and obtained the data on the reasons of the cutting tool failures (Table 1).

**Table 1**  
**Cutting tool failure type specific weight**

№	Cutting tool failure type	Failure percentage, %
1	Body one-side wear with the cutting insert breaking	45
2	Body even wear	27
3	Cutting tool losses	25
4	Cutting tool body breaking	3
<b>TOTAL</b>		<b>100</b>

According to the test data only 27% of the cutting tools reach the end of their service life. Almost 50% of the cutting tools fail prematurely and 25% are lost. As a result late replacement of the worn-out cutting tools can cause

departure of the heading machine technical level indices from the standard values specified by its technical characteristic.

**LITERARY SOURCE ANALYSIS**

Paper [1, 2, 3, 7] states that continuous operation of the heading machine with the transverse head and the worn-out cutting tool causes 60-70% reduction of the cutting unit transmission element resource. The current methods of the technical diagnostics of the operating tool are based on visual examination of the cutting unit as to the presence of the cutting tools on the head which requires the heading machine stopping. The replacement strategy is ineffective as it results in operation of the machine with the broken or lost cutting tools.

The methodology of detection of the cutting tool breaking for the heading machine КПД with axial heads has been developed [5]. However, the mode of face working made by the cutting units equipped with the longitudinal heads (П110-4 and other heading machines) differs greatly from the axial head operation modes and this requires additional research.

Goal is to state the parameters of the diagnostics of the state of the cutting unit of the heading machine П110-04 equipped with the transverse head and their limiting values that provide the machine resource improvement.

**THE BASIC CONTENTS**

The carried out model research was based on the mathematical model of the external disturbance vector that influences the transverse head [6]. The main factors that influence the characteristics of the heading machine operation are as follows: the face cutting characteristics- its section, structure, rock layer hardness; the heading machine technical state parameters; the face processing scheme – the breaking mode sequence and parameters (the head rotation and feed speed, cutting depth and cutting step).

It is to be mentioned that there are three modes of the face processing for the heading machine of the selective action: cutting, side cutting, vertical cutting (up/down). As a rule the cutting is made at the weakest point of the face (a coal seam) and it makes for the maximal loads on the cutting unit to be considerably lower than in other modes and this does not influence the accumulated damageability forming. That is why the cutting mode was not taken into account when the model experiment was planned.

The sequence of the face processing modes when the accumulated damageability in the transmission elements of the cutting unit drive is specified is not taken into account either as according to [8] the loading diagram is the initial data to calculate the transmission elements.

The parameters of the head real construction differ from those given by the set scheme because of the making technology faults. The departures were taken into account during the computing experiment as the additional random factor by input of the random values that model the cutting tool coordinate departures into the mathematical model.

The parameters of the face cutting made by heads with the cutting depth  $\Delta L$ , cutting step  $\Delta H$ , feed rate  $V_n$  and rotation  $\omega$  influence greatly the cutting unit loading. That is why different values  $\Delta L$  and  $\Delta H$  (with taking into account the cutting unit construction) were specified during the computing experiment planning and the speed values were speci-

fied with taking into account physical and mechanical characteristics of the rock to provide the maximal productivity.

The experiment was full-factor and different combinations were tested. The registered parameters were the torque in the transmission and the drive actuator current. Fig. 1 shows the fragments of changing of the rotational torque for the head 1 turn.

According to the modeling results the cutting tool failing causes considerable growth of the loading dynamism first of all at the expense of growth of irregularity of the loading low-frequency component (the head rotation frequency). The loading diagram shown in Fig. 2 was built for the case of the cutting tool complete set and absence of the 6<sup>th</sup> cutting tool in the set scheme.

Analysis of Fig. 2 showed that the cutting tool fail causes the raise of probability of maximal and minimal values of the moment under some reduction of the probability of its average values. This proves that if there is no cutting tool the accumulated damageability in the transmission elements is changed and it influences the resource.

The accumulated damageability was assumed as the quantitative characteristic of the heading machine resource estimation. The accumulated damageability was calculated according to the following dependence:

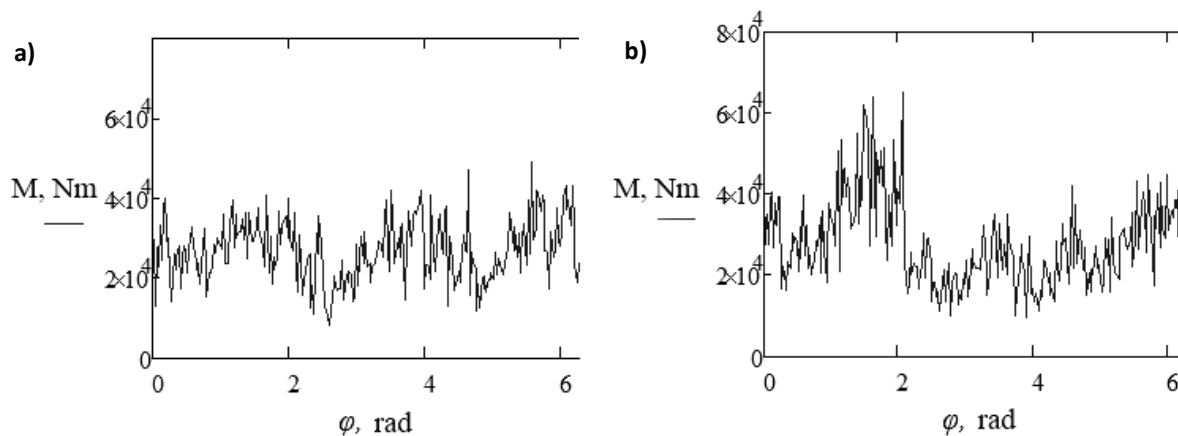


Fig. 1 Changing of the rotational torque which is formed on the head under one turn of the cutting unit in the side cutting mode: if there are all the cutting tools (a) and if there is no 6<sup>th</sup> cutting tool (b)

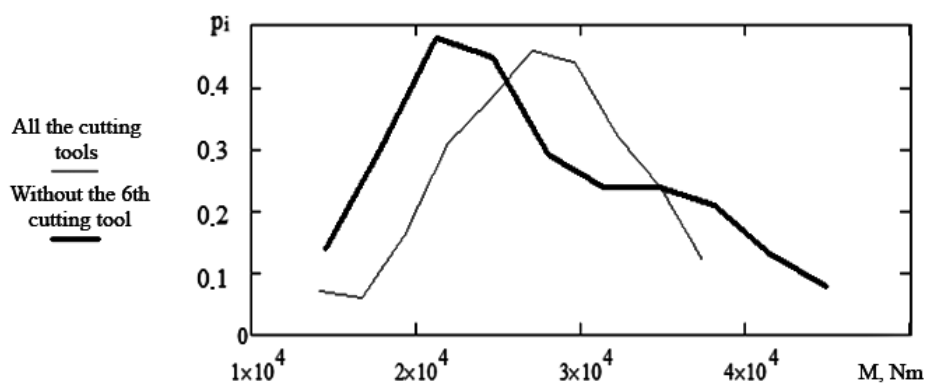


Fig. 2 Distribution of the probability of resisting moment on the heading machine cutting unit in the side cutting mode

$$HII_V = \frac{30\omega}{\pi S V_n} \int_0^{M_{max}} M^m f(M) dM \quad (1)$$

where:

M – angular velocity and transmitted torque of the transmission element under examination,

S – face cut surface projection in the direction of the head feed,

V<sub>n</sub> – the head feed speed to the face,

M<sub>max</sub> – the value of the rotational torque corresponding to the yield point for the transmission element under examination,

m – the index of the degree of S-N curve for the element under examination,

f(M) – the rotational torque probability density.

Changing of the transmission element resource under the constant operation with the broken cutting tool in comparison with the operation with the cutting tool complete set was estimated in percentage:

$$\delta T = 100 \frac{HII_L^{-1} - HII'_L^{-1}}{HII_L^{-1}} \quad (2)$$

where:

HΠ<sub>L</sub>, HΠ'<sub>L</sub> – damageability accumulated within one meter of mine working sinking under the operation with the cutting tool complete set and with the broken cutting tool correspondingly.

The computing experiment result analysis shows considerable (1, 2-4 times as much) reduction of the cutting unit element resource under the lack of the 4<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> cutting tools. It is to be mentioned that the resource change dynamics increases greatly if the head section is decreased and, as a result, the number of the cutting tools contacting with the rock mass is reduced which is the characteristic of the cutting of the rock of high hardness. Thus, one of the ways to improve the heading machine drive transmission element resource can be diagnostics of the cutting tool state under the hard rock cutting done without the machine stoppage.

Modern heading machines are equipped with the devices that control the machine element working parameters which, as a rule, control the cutting unit drive engine current value. So, we assume the engine current to be the fixed parameter for the diagnostics of the head technical state. The current spectral decomposition coefficients obtained with the help of Fourier method are assumed to be the engine current change characteristics:

$$k_j = \frac{1}{\sqrt{n}} \sqrt{\left( \sum_{k=1}^n x_k \cos\left(\frac{2\pi jk}{n}\right) \right)^2 + \left( \sum_{k=1}^n x_k \sin\left(\frac{2\pi jk}{n}\right) \right)^2} \quad (3)$$

$j = 1..n/2$

We choose the spectral decomposition amplitude coefficients corresponding to the cutting unit rotation frequency – k<sub>1</sub> and the spiral rotation frequency – k<sub>3</sub> (the cutting unit has 3 spirals).

Some results of the model experiment data processing in specifying of the value k<sub>13</sub> that corresponds to the ratio of the coefficients k<sub>1</sub> to k<sub>3</sub> are given in Table 2.

**Table 2**  
**Changing of the coefficient k<sub>13</sub> if there is no i-cutting tool under down-cutting**

ΔL	ΔH	All the cutting tools are in good order, k <sub>13max</sub>	There is no cutting tool №, k <sub>13min</sub>	
			1	4
	450	0.691	0.465	1.249
300	300	0.481	0.293	0.943
	160	0.418	0.269	0.792

The table analysis shows that if there are no cutting tools that influence considerably the transmission element resource, the minimal value of coefficient k<sub>13</sub> with the probability of 0.9 is not less than 0.79, and with the cutting tool complete set the value of the coefficient does not exceed the value of 0.7.

Thus, the condition (k<sub>13max</sub>)<sub>max</sub> > k<sub>13j</sub> can be assumed as the cutting tool absence diagnosis criterion. Here (k<sub>13max</sub>)<sub>max</sub> > k<sub>13j</sub> is the maximal value of the coefficient k<sub>13</sub> obtained under the processing of the face with different parameters if there is the cutting tool complete set at the beginning of the machine operation (the heading machine self-instruction); k<sub>13j</sub> – is the current value k<sub>13</sub> obtained during one turn of the head during the heading machine operation.

### CONCLUSIONS

1. The continuous operation of the heading machine with the out-of-work cutting tool can reduce the cutting unit transmission element resource up to 400% depending on the cutting scheme, rock hardness and the position of the cutting tool according to the set scheme. That is why the development of the facilities of technical diagnostics of the cutting tool technical state without the heading machine stopping is required.
2. It was stated that the diagnostics of the cutting tool breakdown on the longitudinal axial cutting head in the real – time mode could be implemented on the basis of the spectral decomposition of the fragments of the cutting unit drive engine current with the durability that corresponds to 1-3 head turns. The diagnosis parameter that meets the requirements of repeatability, sensitivity and single value is the ratio of the coefficients of spectral decomposition corresponding to the head rotation frequency and its threefold value.

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