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# AN ELECTROPHYSICAL TECHNOLOGY FOR IMPROVEMENT OF THE DURABILITY (UNDER WEAR) OF THE CUTTERS OF THE CUTTER-LOADERS

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ABSTRACT

The high durability (under wear) of the cutting tools (cutters) determines both continuous and stable operation of the cutter loaders. The continuous contact of the teeth (cutters) to the material mass being destructed is to be characterized by significant impact loading, variable characteristics of the forces, and a highly expressed abrasion. In this comparative study, which was carried out under the field conditions of the pit "Babino" (the Bulgarian "Bobov dol" mines), a possibility for improvement of the durability (under wear) of the cutters by means of its preliminary treatment in the "MUS-1" device is to be commented, said device being replicated the action of a combined electrophysical method. The outcome of an investigation for long shows: decrease of the abrasion from two to two and a half folds for the teeth being preliminary treated in the "MUS-1" device; significant decrease of the number of the teeth being subject to wear following from fatigue (breakage and break off of the crowns).

## INTRODUCTION

In the underground exploitation and mining of the deposits are used high-performance machines, by means of which both significant increase of the productivity and decrease of the production costs is achieved.

The advantages possessed by the cutter-loaders, particularly in the case of the complex technological lines for mining of the (ores and) minerals, are determining the actuality of their enhancement and effective use. Of significant importance for the effective use of the cutter loaders is the resistance to wear (i.e. the durability) of the cutting tools- the cutters mounted to the cutting drum of the working head thereof.

The operation of the cutter-loaders is characterized by a continuous contact of the teeth (cutters) to the material mass being destructed. Each of the cutters draws a complex curve in the space during the cutting with a small cut (chip). The chips being cut from the separate cutters have different cross-sections, hence the loading of both individual cutters and the working head is uneven. The same effect results from the material mass when being none homogenous. Consequently, the total loading of the working head at a significant extent is defined from both cutting properties of its individual cutters and their durability (under wear).

The latter defines the purpose of this study, i.e. to increase the cutters' durability (under wear), and thus to enhance both cutting process stability and labor productivity by the application of a combined magnetic-ultrasound treatment.

## RESEARCH PROCEDURE

The cutter-loaders used in the underground pits separate (ores and) minerals from the mass and load it into a transport. The use of heading machines in the mine practice represents the most progressive means for working.

The present comparative study was accomplished under real production conditions in the pit "Babino" of the mines "Bobov dol" (Bulgaria) in the case of a type "ГПК-1С" heading machine featuring selective action of its working head [*Инструкция за монтаж и експлоатация ...*]. Usually, under service conditions the working head of the combined cutter-loader cuts in the destroyed layer and after that successively process the surface of the face, thus performing a rotary motion around its proper axis at a rotational speed n = 54 $min^{-1}$, and a tilting motion in both horizontal and vertical plane thereof. To the working head in a suitable manner are mounted 39 pieces of tangential cutting teeth of the type "РКС-1И". The body (i.e.the gripping part of the cutting teeth) is made of the GOST grade "30Г5" manganese steel, and in the front conical part of the tooth (its head) is embedded the hard- alloy crown made of a monocarbide hard alloy of the type К40 (ВК8).

The data for the section of the pass part of the work-mass are corresponding to hardness (abrasion) of 10 $m^2$ , categorized as being of the IV$^{th}$ degree, according to Protodiakonov.

The teeth wear was given by the " weighing method" via measuring by means of a technical scales with an accuracy of 0,01 g. For this purpose, both initial mass, **m** in, of the every tooth and its mass after 15-shift (120 hr.) service, **m** out, were measured, thus the resulting difference giving their abrasive wear.

## EXPERIMENTAL INVESTIGATIONS AND ANALYSIS OF THE OUTCOME OF THE TEST

The investigations for determining the wear resistance of both **"standard"** (i.e. untreated) and **"treated**" teeth (i.e. preliminary treated in the "MUS-1" device, see Fig. 1) by means of a combined electrophysical method [*Македонски, А.; Makedonski A. et al.*] were performed under strict observation of the requirements for the tools comparison during their service stage [*Кругa*, 1983; *Башков и др.*, 1985].

With this purpose in view, the treated group of teeth were prepared for treatment in the "MUS-1" type apparatus (Fig. 1), said apparatus reproducing said combined electrophysical method.

The essence of said method consisting of a placement of the tooth in a constant magnetic field under preliminary given both magnitude of the current (i.e. field strength) and treatment time. At the same time, the tooth is submitted to the influence of a mechanical vibration energy with a frequency in the ultrasound range in direction parallel to that of the applied magnetic field. The method is carried out under room temperature and its impact is of short duration (from some seconds to few minutes). The mechanism of the exercised influence features complexity in its nature proper. The energy input in the materials treated by the method leads to their strengthening, the latter resulting from induced movements of defects and dislocations, which are bringing sometimes to both transformation of the crystal lattice and forming of new structure configurations.

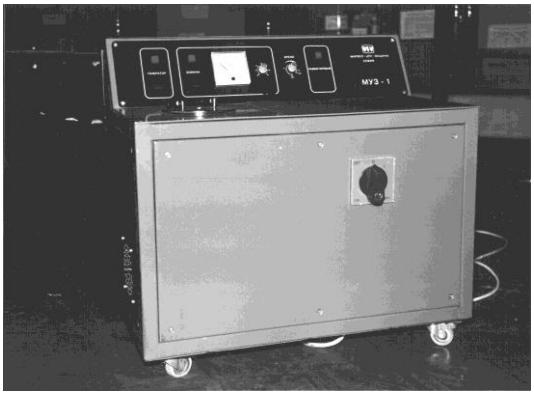

*Figure 1. The MUS-1 device*

During the drawing up of the matrix of the full factor experiment of the kind $N = 2^2$ (Table № 1) and determination of the levels for the factors' variation- the amperage **I,** in [ A ] and the treatment time **τ,** in [ s ]- the *a priori* information received in previous similar studies was considered [*Makedonski A.*, 2001].

After treatment with subsequent demagnetizing in the MUS-1 apparatus, the teeth were mounted in the working head of the combined cutter-loader in the following succession: standard tooth – treated tooth – standard tooth, etc. Thus, the accidental factors, e.g. various composition of the (ores and) minerals, stability of the working head or that of the heading machine (i.e. the coal getter-loader) , etc., or all of the quantities entering in the generalized notion of the "working conditions" have been considered, in order to eliminate the coarse errors in the final outcome from the research. On the other hand, again in order to minimize the experimental errors in every point of the factor's space, four or three teeth have been investigated, i.e. the condition for a recurring has been observed.

The duration of the teeth service was 15 shifts or 120 hr. work in the pit, after which the teeth were disassembled, brought to the ground surface and for every tooth was carried out a control in two directions:

- Measurement of the final weight (mass) thereof by means of a technical scales;
- Recording of the external changes occurred- deformation and cracking- deformation and cracking of the body, and breakage (tears off) in the hard-alloy working head (Fig.2).

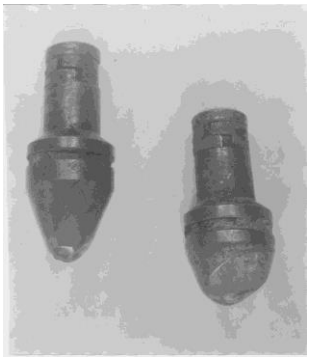

*Figure 2.*

Both outcome of the measurements and calculated values are given in the Table 1.

From the statistical treatment of the experimental data, the following statistical model for the wear of the treated teeth, W, was obtained both in code and natural expression:

$$\hat{Y} = 2.468 - 0.075X1 - 0.075X2 - 0.016X1X2 \quad (1)$$

$$\bar{U} = e^{2.793} \cdot I^{-0.02} \cdot \tau^{-0.041} \cdot (I.\tau)^{-0.032} \quad (2)$$

The statistical analysis approves the reproducibility of the tests, the importance of the coefficients and the model adequacy.

Table 1

| Tooth Code № | The code designation | | The PMF + US Natural values | | Outcome of the measurement | | $\bar{U}$ | $Y = \ln \bar{U}$ | $\hat{Y}$ |
|---|---|---|---|---|---|---|---|---|---|
| | X1 | X2 | I [A] | τ [s] | M in [g] | M out [g] | g | | |
| 1<br>1'<br>1''<br>1''' | 1 | 1 | 6 | 60 | 460 | 450<br>450<br>450<br>449 | 10 | 2.302 | 2.302 |
| 2<br>2'<br>2''<br>2''' | -1 | 1 | 2 | 60 | 460 | 449<br>448<br>448<br>448 | 12 | 2.485 | 2.484 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3<br>3´<br>3´´<br>3´´´ | 1 | -1 | 6 | 10 | 460 | 449<br>448<br>447<br>447 | 12 | 2.485 | 2.484 |
| 4<br>4´<br>4´´<br>4´´´ | -1 | -1 | 2 | 10 | 460 | 447<br>447<br>446<br>446 | 12,5 | 2.602 | 2.602 |
| 5<br>5´<br>5´´<br>5´´´ | 0 | 0 | 4 | 35 | 460 | 448<br>448<br>447<br>447 | 12 | 2.485 | 2.468 |
| Untreated teeth | | | | | 460 | 430<br>410 | 30<br>50 | | |

## TECHNICAL AND ECONOMICAL ANALYZIS

The technical-economical effect represents a generalized indicator for evaluation the outcome of this research. Bearing in mind the fact that this effect is a multilateral notion, its can be evaluated regarding different criteria, e.g.:

**Providing for a high productivity**

One of the factors providing a high productivity during machining is the enhanced tool life, or the durability (under wear) of the cutting tools, respectively.

From the results obtained after treatment of the teeth by the combined electrophysical method it is evident that its significantly reduces the wear thereof, also, break off (breakage) in the hard-alloy crowns which, on the one hand, improves the productivity- as a result of the created possibility for bigger number of teeth to take part to a greater extent in the cutting process-, and on the other hand, following the many times decreased auxiliary time for the tools change. All of this positively reflects on both stabilization of the work of the mining machine and cutting process as a whole.

**Lowering of the (manufacturing) cost**

Considering the essence of the process, i.e. cutting of a rocky mass without the requirement for accuracy and quality of the cut surface, to cut the cost is to be considered determining in the decision making process. The increase of the cutting tools life leads to a decrease of the number of the tools needed for a given process accomplishment This, in turns, contributes for lowering the cost of produced items.

From the research made in the "Bobov dol" mines and bearing in mind the production conditions in the pit "Babino", in particulars: number of combined cutter-loaders- four pieces, unit price per tooth-10 BGN, and assuming an yearly consumption of 8,112 teeth, it turn out (to be) that the application of the process of magneto-ultrasound treatment of the teeth will bring to costs lowering thereof of the order of some 45,240 BGN.

Arriving at a conclusion, from the accomplished comparative study one may draw the following generalized deductions:

1. The wear resistance of the treated teeth is from two to two and half times higher than that of the standard (untreated) ones.
2. The typical breakage and break off of the hard-alloy crowns for the standard teeth are not observed in the case of treated ones (Fig. 2).
3. The technical- economical analysis of the results shows that under existing conditions, bearing in mind only the purchasing price of the cutters, the implementation of one apparatus of the type MUS-1 will have a return on investment period (ROI) from four to five months.
4. With a high degree of authenticity one may forecast the yearly need for teeth for every pit (mine), the latter being directly related to the effective management of the tool flows thereof.

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