ANALELE UNIVERSITĂŢII
"EFTIMIE MURGU" REŞIŢA
ANUL XII, NR. 1, 2005, ISSN 1453-7394

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Delivery of a Methodology of Choose of Drilling Jumbos for ore Mines

In the paper the main factors influencing the chose of drilling jumbos and the determination of efficiency of drilling process is presented. The general principles and methodology of establishing the main parameters of drilling in different ores is discussed. The main criteria of choosing the drilling jumbos are presented.

1. Introduction

The blast hole drilling in underground ore mining is a labor intensive operation. In order to reduce labor consumption, drilling jumbos are widely used, both in ramps, drifts and stopes heading and in face extraction works. The selection of the most rational type of drilling jumbo suitable for the given mining conditions is a problem with dramatic cost implications.

The paper deals with the delivery of a method to assess the technical-economical metrics of a given drilling jumbo, for given mining conditions, in order to select the most appropriate type of jumbo.

2. Drilling jumbo metrics assessment

The main metrics to assess the performances of the drilling jumbo are:

-the productivity of the jumbo;

-the number of jumbos necessary to realize a requested annual output;

-the number of drilling shifts per year and the utilization factor of the drilling jumbo;

-the cost of drilling operation in case of maximal number of faces;

-capital intensity of the endowment with drilling jumbos.

In order to reach this requirement the following steps must be carried out:

- Selection of the appropriate drilling method for the given conditions;
- Selection of the drillhammer type ;

- Establishing the necessary data for the assessment of technical economical metrics;
- Assessment of the number of working cycles per shift;
- Assessment of the number of drilling jumbos necessary to realize the required output;
- Assessment of the economic efficiency and selection f the most rationale type of drilling jumbo;
- Establishing the drilling regime parameters for the selected drilling jumbo.

In the paper a comparative example of the calculation of the main drilling parameters for two drilling jumbos, the Russian one UBS – 315 and the Finnish Minimatic Universal (Tamrock).

The Protodiakonoff hardness index of the rocks is considered f = 8 , the hole length 3 meters and holes diameter 52 mm.

The UBS – 315 drilling jumbo is equipped with two GBG – 180 – 250 rotating-percussive hydraulic drillhammers with the following technical features:

- Mechanical drilling rate (initial) 1.2 meters/minute
- Percussion frequency 2067 perc./minute
- Drill rod rpm. 532 min^{-1}
- Torque 300 Nm

The productivity per shift of drilling jumbos is calculated using the formula:

$$P = \frac{(T_S - T_O) \cdot K_p \cdot n_p}{t_p + T_1 + T_2 + T_3 + T_4} \qquad (1)$$

where:

T_S - shift duration , min;

T_0 - break downs duration , min;

K_p - factor of readiness of the jumbo;

n_p - number of drillhammers on the jumbo;

K_S - factor of simultaneity of the working of drillhammers;

t_p - specific drilling time until the depth of hole L, min/m;

$t_p = \frac{1}{V_p}$ in which V_p - average drilling rate until the depth L, m/min;

L – depth of drillhole required by the working technology;

T1,T2,T3,T4 – specific duration of auxiliary operations respectively retraction of rod from the hole; change of drill bit; positioning of drill rod and start of drilling; displacement of the jumbo in other location, min/m;

The cost of drilling is determined with the relation:

$$C = \frac{C_1}{P} + C_2 \quad , \quad \text{\$/shift} , \tag{2}$$

in which :

C_1 = cost related to the jumbo operation, \$/shift;

C_2 = cost related to the rod and bit , \$/shift;

The following expenses are taken into account when calculating operation costs: salary, capital return, electric energy, compressed air, auxiliary materials, water, and maintenance. Rod and bit expenses are taken into account base don the bit's wear and rod replacement.

Using appropriate values for the costing elements above, for drillholes with depth between L = 0.25 ÷ 5m the corresponding values for the productivity, drilling cost and drilling operation duration were obtained.

The results are summarized in the graph shown in figure 1.

As an example, for holes with L= 3 m, in given conditions the values are:

- Drilling cost : 0.8 \$/m;
- Productivity per shift : 190m/shift;
- Duration of drilling: 225min/shift

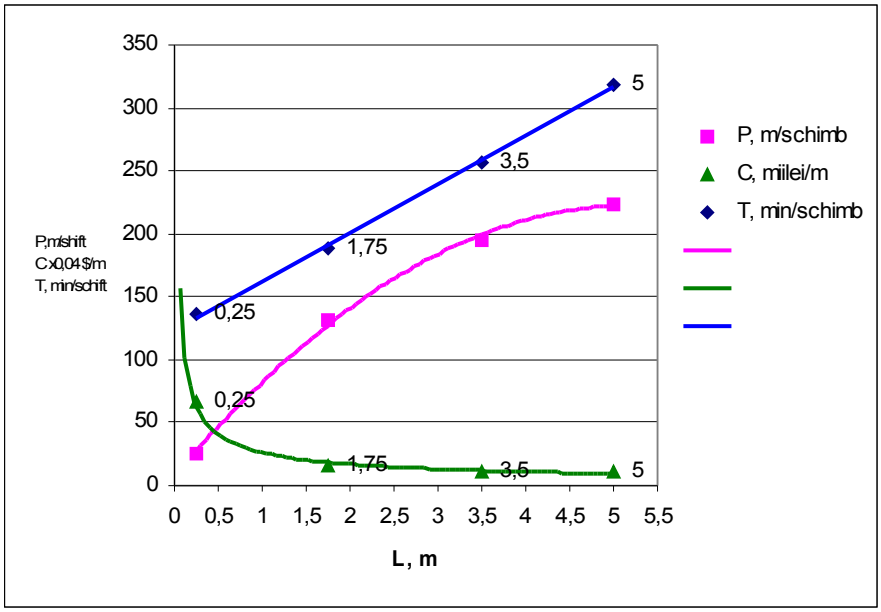
The drilling jumbo „Minimatic Universal" s equipped with two percussive-rotating drilling hammers type E 400T actuated with compressed air with following working parameters:

- Mechanical drilling rate 0.9m/min.;
- Rod rpm. 167 $min.^{-1}$.

The same parameters were calculated for this jumbo too. The results are summarized in figure 2.

For the depth of hole 3 m the values below results:

- Cost of drilling : 0.48\$/m;
- Productivity of drilling: 181 m/shift.;
- Duration of drilling: 237 min/shift.


350
300
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P,m/shift
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P, m/schimb
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Figure 1. Calculated metrics for the jumbo UBS-315

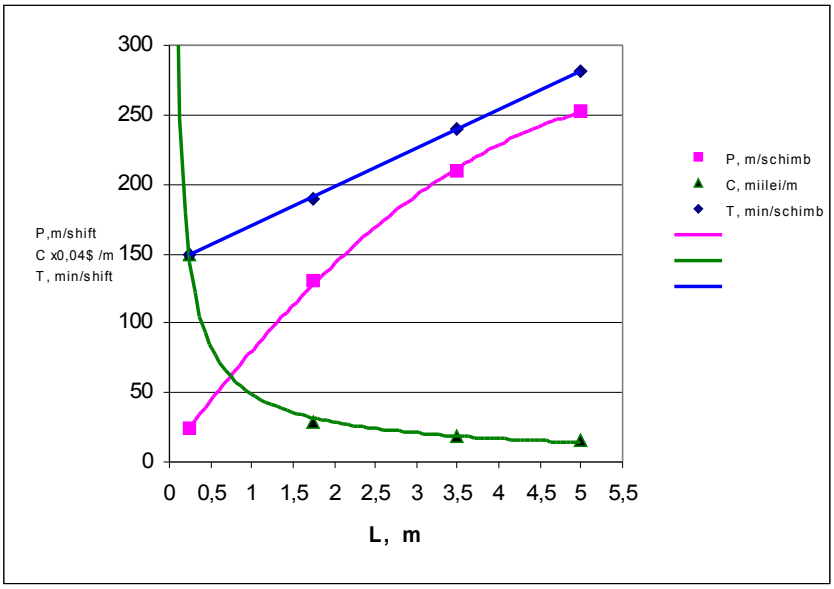

Figure 2. Calculated metrics for the jumbo ***MINIMATIC UNIVERSAL***

3. Comparison criteria and selection

The main criterion for selecting the drilling jumbo is the annual profit obtained in case of one jumbo compared with the second one, obtained using the formula:

$$B = \left(C_{an1} - C_{a2}\right) - \Delta Q_T \quad , \$ \tag{3}$$

in which :

C_{an1}, C_{an2} – annual operating costs using the two types of jumbos, $/year.

$$C_{an1} = C_1 \cdot L_{t1} \tag{4}$$

$$C_{an2} = C_2 \cdot L_{t2} \tag{5}$$

in which:

C_1 , C_2 – cost of drilling 1 meter of hole with each jumbo;

L_{t1}, L_{t2} – total length of holes drilled per year with each jumbo, m.

ΔQ_T - taxes paid .

The best variant is for the case in which capital costs and operating costs are smaller. For comparing the capital costs, the investment return period T_{rec} must be calculated as follows :

$$T_{rec2} = \frac{C_i \cdot K_i}{\left(C_{an1} - C_{an2}\right) + \Delta A_1} \quad , \text{years} \tag{6}$$

where:

ΔA_1 - annual capital recovery rate, $/year

C_i – capital cost of the equipment, $

$$K_i = \frac{Q_{an}}{Q_i} \tag{7}$$

Q_{an} - the amount of ore extracted by the mine plant in a year, t

Q_i - amount of ore extracted by a drilling jumbo in a year, t

4. Deriving the drilling regime parameters

In case of rotating-percussive drilling, the parameters are the drilling rate, the percussion frequency, the rod rpm. and the torque.

The initial mechanical drilling rate is the drilling rate at the beginning of drilling operation, when no looses of energy occurs duet o friction of rod on hole

(8)

walls. This one is a constant value and do not depends on the depth of hole. The relation for this drilling technique is :

$V_0 = 0{,}1(20 - f)$, m/min

For a hole with depth equal to L the drilling rate is :

$$V_p = \frac{V_0(1 - e^{-\alpha L})}{\alpha L} \text{ m/min} \quad (9)$$

in which :

α - decrement of percussive energy on hole length unit m^{-1}, (dependent on type of the drillhammer).

L – depth of the hole , m.

The frequency of percussions is given by:

$$f_p = 33{,}3 + \frac{5000 f}{E_p^2} \text{ , perc/min} \quad (10)$$

in which:

E_p –the percussive energy of the hammer, daJ.

The rpm. of the rod is depending on percussions frequency as follows:

$$n_{s1} = \frac{f_p}{f_{pr}} \text{ , rot/min} \quad (11)$$

in which:

f_{pr} – number of percussions to a rotation of the rod given by:

$$f_{pr} = \frac{360}{(0{,}5E_p + 0{,}5) - 0{,}7f} \quad (12)$$

The torque is given by:

$$M = 500 - 25f \text{ , N·m} \quad (13)$$

In case of percussive-rotating drilling, the drilling regime is characterized by initial drilling rate and rpm. of the rod.

The initial drilling rate in this case is given by:

$$V_0 = 0{,}05\frac{E_p \cdot f_p}{D_t^2 \cdot f} \text{ , m/min} \quad (14)$$

in which:

D_t – diameter of the bit , mm

The rational rpm. of the rod is given by:

$$n_{s2} = \frac{8700}{D_t} \text{ , rot/min} \quad (15)$$

The calculated parameters can be compared with the analyzed drillhammers ones. Up to date drillhammers allows the tuning of these parameters to be near to rational ones.

The methodology presented can be used for the rational design of drilling operation in ore mining using drilling-blasting technology.

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