BLASTHOLES DRILLING TECHNOLOGY USING POLAR MOVING EQUIPMENT

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Abstract: Using polar moving drilling equipment, as one of the many installations for gallery digging, requires the best correlation to gallery cross-section area, rock strength, timbering pace, system of transportation, the type of energy supply at the working face etc. For accomplishing a high drilling productivity when using polar moving drilling equipment, it is necessary a good timing of the operation, so that minimum periods for the drills maneuvering, preparation and conclusion to be obtained. This paper presents an example of optimizing the maneuvering operations to position the drilling equipment according to blasting scheme.

Key-words: drilling equipment, organizing blast hole drilling, gallery digging

1. INTRODUCTION

Replacing the hand and semi-mechanized blasthole drilling with a fully mechanized one, using polar moving equipment, is an essential factor to improving the gallery digging indicators.

Using the polar moving equipment for the above mentioned task requires the best correlation to gallery cross-section area, rock strength, timbering pace, system of transportation, the type of energy supply at the working face etc.

2. DRILLING EQUIPMENT

The most important sub-assembly of the drilling equipment is the manipulator, which consists of an arm and the guiding mechanism of the drilling installation (which sustain the drill). This arm is the determining element for the gallery cross-section area where the blastholes are to be drilled, and the trajectory to be followed when passing the equipment from one hole to another. The guiding mechanism of the drilling equipment provides the proper blasthole orientation as related to the gallery axis.

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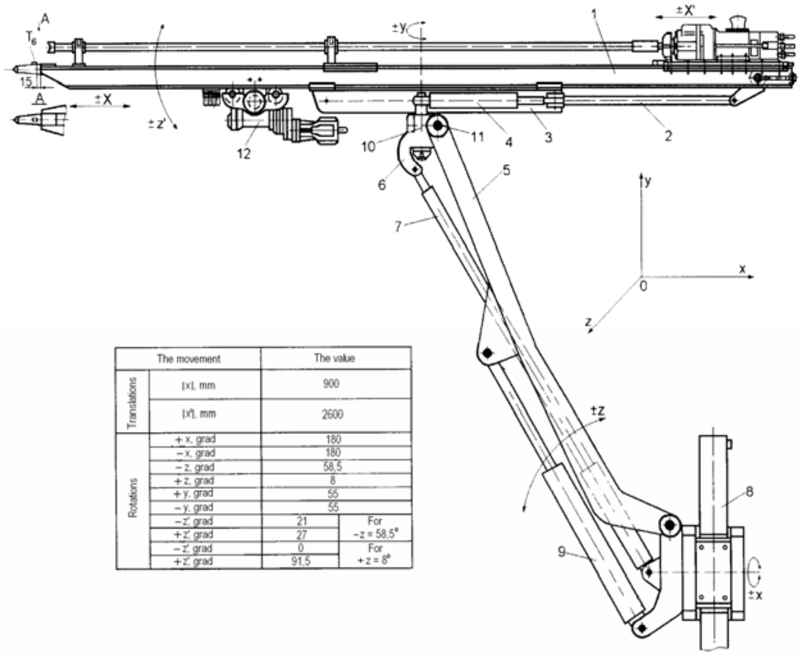
Figure 1 presents the manipulator type which outfits the polar moving drilling equipment, where:

1 - pull-rod (sliding beam) which moves the drill and includes the drill moving mechanism (±x translation);

2 - hydraulic cylinder for the pull-rod face fastening (during blasthole drilling, when the ±x translation takes place);

3 - pull-rod support and guide;



The movement		The value	
Translations	|x|, mm	900	
	|x'|, mm	2600	
Rotations	+ x, grad	180	
	− x, grad	180	
	− z, grad	58,5	
	+ z, grad	8	
	+ y, grad	55	
	− y, grad	55	
	−z', grad	21	For −z = 58,5°
	+z', grad	27	
	−z', grad	0	For +z = 8°
	+z', grad	91,5	

Fig.1. The polar moving manipulator with his degrees of liberty.

4 - fastening hydraulic cylinder that accomplishes the common ±y rotation of the 1, 2, 3, 12 and 13 elements pertaining to the drilling equipment;

5 - support arm of the drilling equipment;

6 - linking element between the arm 5 and drilling equipment;

7 - hydraulic cylinder that accomplishes the ±z' rotation of the drilling equipment;

8 - type gear wheel-rack mechanism, hydraulically driven, which accomplishes the ±x rotation of the manipulator;

9 - hydraulic cylinder, which accomplishes the ±z rotation of the manipulator arm (polar movement of the drilling equipment);

10. - horizontal rotation support;

11, 12, 13, 14, 15, 16 – cylindrical articulations;

17 - arm support.

The drilling equipment manipulator are of polar-circumferential type, as by ±x polar, respectively ±z circumferential moves, the drill can be brought to any point of the yz area (gallery surface). For a certain opening of the cylinder 7, it forms together with the elements 5, 6 and 17 a parallelogram that permits a parallel movement of the drilling equipment, when the there is a ±z polar movement by the cylinder 9. This possibility leads to eliminating the maneuvering times for bringing the drilling equipment to horizontal position, when drilling horizontal blastholes. Fig. 1 shows the possible movement (translations and rotations) values accomplished by manipulator mechanism. The structure of plane mechanisms that make up the manipulator was established in such a way that, for a constant driving flow, a speed of maximum 0.5m/s and minimum variations will be obtained at the front end of the pull-rod. This fact has been imposed by the precise drilling equipment positioning to the drilling height and direction. When digging galleries by drilling-blasting technology, the blastholes drilling operation is accomplished according to the blasting draft that represents the number and position of the blastholes required for the gallery profile. The blasting draft depends on the gallery cross-section area and the rock strength.

For increasing the drilling efficiency, we should diminish the blastholes drilling times, and therefore diminish the total duration of the drilling operation. This is possible by a better drilling timing, which is by establishing an optimal blastholes drilling order, so that minimum maneuvering times for drilling equipment positioning could be achieved.

3. DRILLING TECHNOLOGY USING POLAR MOVING EQUIPMENT

As an example, let it be the digging of a medium profile gallery (GDM-11, with a digging cross-section surface of 13.4 m^2), into medium strength rock (f = 6-7, according to the scale of prof. Protodiaconov).

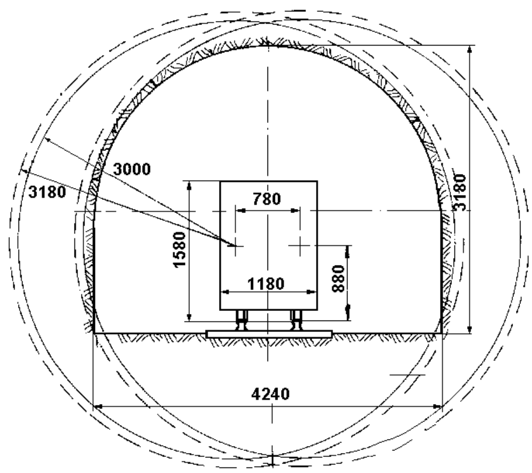


Fig. 2. The drilling equipment way of covering the cross-section of a gallery type GDM-11.

Figure 2 shows the drilling equipment on the background gallery taken into consideration, and the way the two manipulators cover the digging cross-section.

In this case, the blasting draft recommends a number of 41 blastholes distributed as follows:

N_s=5 (blastholes 1...5) representing the number of core blastholes;

N_r=17 (blastholes 6...22) representing the number of breaking blastholes;

N_p=19 (blastholes 23...41) representing the number of shaping blastholes.

The core blastholes are considered to be positioned according to a cylindrical core, and the blast timing is:

- stage I, blasthole 1;
- stage II, blastholes 2...5;
- stage III, blastholes 6...9;
- stage IV, blastholes 10...22;
- stage V, blastholes 23...34;
- stage VI, blastholes 35…39;
- stage VII, blastholes 40…41.

Fig. 3 shows the gallery digging profile in cross-section, and also the optimal recommended trajectory of passing from one blasthole to another. Thus, the starting points are: establishing trajectory described by the drilling equipments of the two manipulators, and the necessity of using a single manipulator for drilling the core blastholes N_s=5 in order to obtain a strict parallelism for these blastholes, according to the blasting draft.

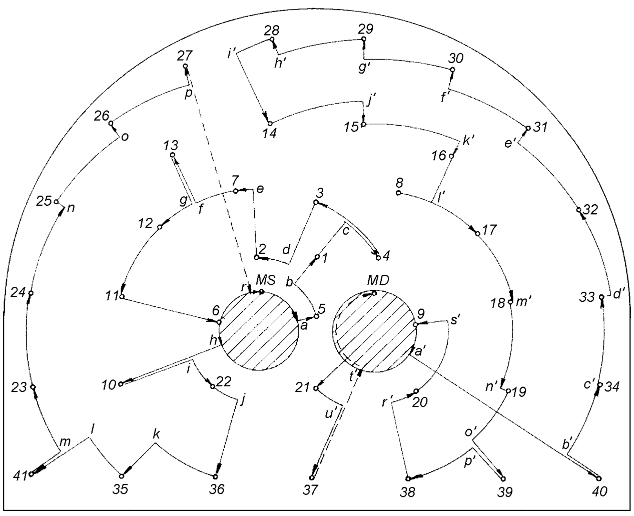


Fig.3. The optimal trajectory for a frequently used blasting scheme.

Moreover, figure 3 shows that the core blastholes drilling is accomplished by the left manipulator (*MS*), while the right (*MD*) one begins the drilling of the blasthole situated in the lower right corner. This way, excepting the period for core blastholes drilling, the two manipulators are situated symmetrically considering the vertical gallery axis and the rotation centers of the manipulators. These facts lead to better drilling equipment stability. The recommended order for blastholes drilling, as shown in fig. 3, is: for the left manipulator - 5, 1, 4, 3, 2, 7, 13, 12, 11, 6, 10, 22, 36, 35, 41, 23, 24, 25, 26, 27, and for the right manipulator - 40, 34, 23, 32, 31, 30, 29, 28, 14, 16, 8, 17, 18, 19, 39, 38, 20, 9, 21, 37, that is 20 blastholes for the left manipulator and 21 blastholes for the right manipulator.

According to the front peak of the drilling equipment, also shown in fig. 3, we can determine times used for different slopes of the manipulator, i.e. for different heights of its extremity ups and downs, and also the times for accomplishing the rotation movement; this is very helpful for determining the required time for blasthole positioning.

4. DETERMINING THE OPTIMAL REQUIRED TIME FOR BLASTHOLE POSITIONING

As for constant driving flow, the speed $\dot{z}$ of the hydraulic cylinder piston (which is a component of the polar movement mechanism) is constant, we obtain $z=\dot{z}\cdot t$, where z is momentary course of the raising hydraulic cylinder piston, expressed in mm, and t is time, in s. Thus:

$$t = \frac{1}{\dot{z}}\left[\sqrt{\left[x_A^2 + z_A^2 + R^2 + 2a\left(z_A \sin\alpha - x_A \cos\alpha\right)\right]} - r\right], \text{[s]} \tag{1}$$

where: x_A=150 mm; z_A=510 mm; a=1329 mm; r=1060 mm are dimensional values of the polar movement mechanism, and $\alpha \in$(-24°30'…42°) represents the momentary sloping angle of the polar movement mechanism.

For determining the raising and lowering times, we replace the hydraulic cylinder piston speeds by $\dot{z}_1$ for raising and $\dot{z}_2$ for lowering, corresponding to cylinder loading on small piston area, respectively large piston area.

Relation (1) leads to determining the variation diagram for the times taken at manipulator raising, respectively lowering, according to its slope α, within the limit of α variation, as shown in figure 4.

This diagram indicates that maneuvering times at polar movement are relatively small, so the time for manipulator maximum raise is 14.31 seconds and for lowering to its minimum height is 9.58 seconds.

Times required for radial (lineal) movements when positioning the drilling equipment can be directly obtained from the diagram 4, as function of blastholes current heights in blasting draft. For determining the required times regarding the circular positioning movements, we use:

$$t_{ij} = \frac{d_{ij}}{\omega \cdot R_{ij}} \quad , \text{[s]} \tag{2}$$

where: i, j are indexes (figures and letters) referring to the current blasthole and the next one on the trajectory in figure 3.

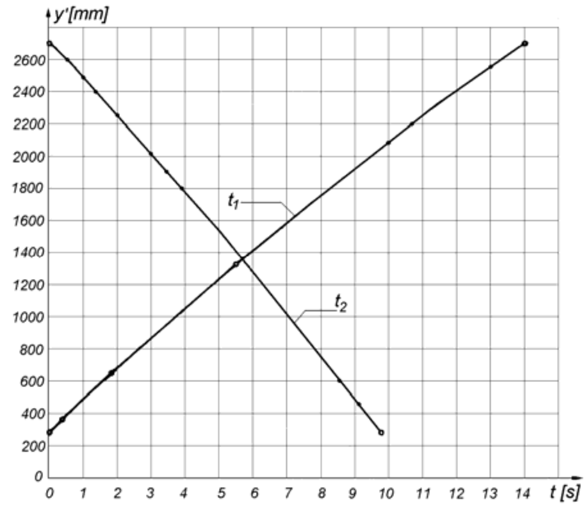


Fig. 4. The variation diagram of the time necessary for raising the manipulator according to it's α slope.

The figures represent blastholes numbering in blasting draft, and the letters represent intermediary points on the trajectory from one blasthole to another; t_{ij} [s] - time taken for arm circular movement between points i and j on trajectory; d_{ij} [m] -– distance between two any neighboring points on trajectory; ω [rad/s] - angular speed (constant) for arm rotating; R_{ij} [m] - radius of circular trajectory between points i and j.

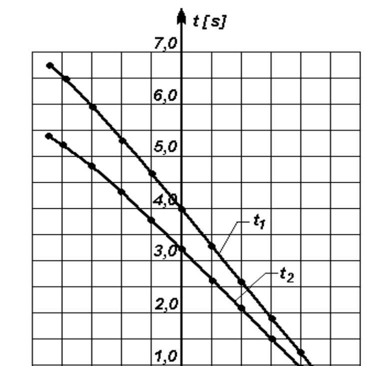


Fig. 5. The variation time for left, respectively right rotation of the drilling equipment.

Figure 5 presents the diagram of variation times for drilling equipment rotation to the left (t_1), and to the right (t_2), respectively.

Out of (1), (2) relations we can infer that for covering a certain distance, i.e. a $\sum d_{MS}$ = 15.27 m trajectory, the drilling equipment pertaining to the left manipulator requires a $\sum t_{MS}$ = 94.6 s time, and for covering a $\sum d_{MD}$ = 32.13 m the drilling equipment pertaining to the right manipulator needs a $\sum t_{MD}$ = 142.5 s, time.

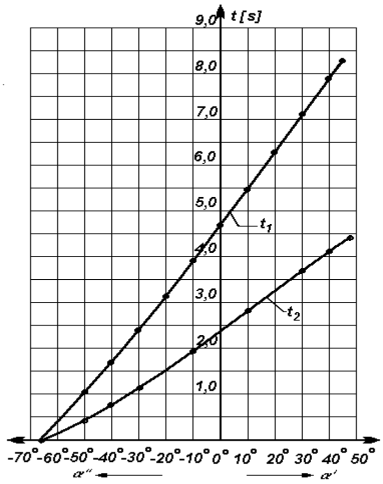


Fig. 6. The time variation for diverging, respectively converging sloping.

Figure 6 determines the time required for diverged sloping of the drilling equipment, when drilling shaping blastholes, and represents the time variation graph: t_1 for diverging sloping, and t_2 for converging sloping according to sloping angle α.

Thus, for a given value of the diverged sloping angle of the shaping blastholes α=8°, there is a time of t=1s. For the total shaping blastholes number N_p=19, there is a total required time t_p'=19s.

Moreover, for corrections brought to the drilling equipment direction related to gallery axis, we need to act on the rotation mechanism horizontally. Therefore, taking into account an average rotating angle value of α=30°, the required time for this rotation is t=2s. According to the total shaping blastholes number N_p=19, the total time is t_p''=38 s. These time values are theoretical ones and are related to actual movement of the drilling equipment manipulators within which it achieves the recommended trajectories, according to figure 3 blasting draft.

These times should be corrected by a coefficient that takes into account:

- preparing-finishing times for blastholes drilling that include time for face fastening of the drilling equipment at the beginning of the process and the time for retrieving it;
- times required for stopping the equipment into blasthole position and direction, which is subjectively appreciated by the worker;

- times required for certain technical interruptions;
- times due to the worker's skills in acting on certain levers and commands;
- influence of working simultaneousness for the drilling equipment manipulators;
- reacting times of the commands.

We will obtain the total maneuvering time by correcting the total theoretical time with a coefficient k_c=10, and this total maneuvering time is given by relation:

$$t_m = \left[\sum t_{MD} + t_p' + t_p'' \right] \cdot k_c \qquad , [s] \qquad (3)$$

For the considered case, digging of a medium profile gallery (GDM-11, with a digging cross-section area of 13.4 m^2), into medium strength rock (f=6-7), we will obtain a total maneuvering time t_m=1995 s=33,25 min.

If we also take into consideration the average drilling speed v_m =1 m/min, we have for a 2.6 m blasthole drilling, an average time of 2.6 min/blasthole, which multiplied by the total number of 41 blastholes for the entire work face, we come to a total drilling time of 106.6 min.

Taking also into account the preparing-finishing times for blastholes drilling, i.e. bringing the drilling equipment near the work face, putting it to work etc., and afterwards retrieving it which should be t_{pi} = 30 min, we can appreciate the total drilling operation period at t_{per} = 169.85 min = 2.83 hours.

5. CONCLUSION

After all, using polar drilling equipment for mechanizing drilling operations at gallery digging, we will obtain, apart for total reducing of the physical effort and improving the labour conditions, an important diminishing of the drilling operation period and therefore an increasing drilling productivity compared to the hand or semi-mechanized drilling.

Using the polar drilling equipment, also merge with the modern tendencies appeared in the mining industry of automatisation of more and more processes, in that way resulting a continuous increase of the productivity, reducing in the same time the costs of exploitation.

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