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THE EFFECT OF EXPLOSIVE PROPERTIES ON OPTIMISATION THE DRILL AND BLAST RING DESIGN[**]

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Abstract

The use of underground ring drilling and blasting holes is common, given their compatibility with various mining methods and use in the construction of underground structures like the ore draw bells. Working conditions and rock properties can vary significantly, making it essential to monitor and analyze the blasting results. If necessary, the adjustments and optimizations should be made to the drilling and blasting patterns based on the properties of the used explosives. The aim of this paper is to develop a stopping mining method model using the blastholes, as well as a unique drilling and blasting pattern for excavation the initial slot in the Datamine Aegis. The objective was to compare several types of explosives with different properties in this context, predict the blast outcomes in terms of break radius, and highlight the significance of all explosive parameters in selecting and optimizing a drill and blast ring pattern.

Keywords*: explosive properties, ring blastholes, optimization, Datamine Aegis*

1 INTRODUCTION

Explosive properties directly affect the rock fracturing and production of hazardous gases during blasting. These properties significantly affect the choice of explosives, used in mining operations. In theunderground mining, the mining method also plays a role in this selection, while the explosive properties have a big impact on determining the optimal drilling and blasting pattern [1]. Developement of a new explosive matter is not finished and the new compounds are still being discovered with a goal of aquiring the highly energetic and non sensitive explosives [2, 3]. The used explosive as the carrier of energy, used for task blasting, is the basic means by which the blasting is caried out and on which the success of blasting depends. The blasting geometry depends on energy of the used explosive, and all blasting calculations start fromcexplosive as a known parameter, i.e., they are carried out for known characteristics of explosives. All this means that at the beginning of planning any blasting, the choice of explosives must be made. The choice of explosives is made among those explosive products that can be provided on the market in a certain region. There is no simple formula for selection of explosives, but it is carried out on the basis of certain criteria according to a certain procedure [4].

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Every production blast in the underground mining must be meticulously planned and monitored. The results should be analyzed, and, if required, the adjustments to the drilling and blasting pattern should be made. This ensures the safety of workers and aims to achieve the optimal results, such as the desired granulation and planned excavation geometry, with minimal impact on the surrounding rock mass.

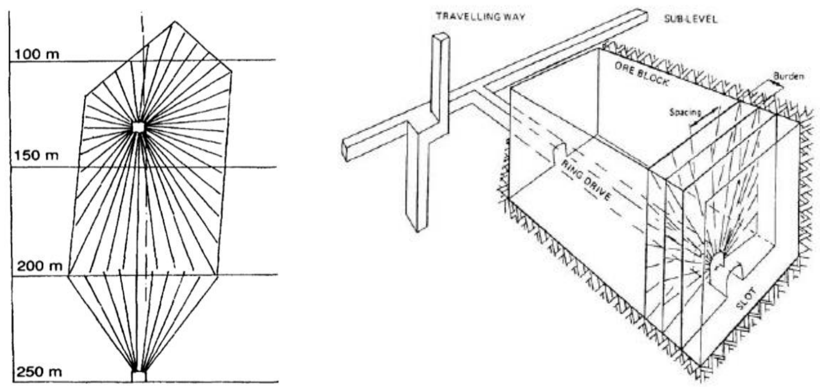
2 RING BLASTHOLES

The ring blastholes or rings, represent a production blasting in the underground exploitation. They can be drilled radially from one or more drilling points down or up, vertically or at an angle (Figure 1a) [1, 5].

The ring blastholes are used in many caving and open stope mining methods as the production blasting as well as during the construction of specific underground structures (e.g. ore extraction drawbells) [1].

The phases related to the drilling and blasting of these blastholes are shown in Figure 1b:

- Drift development (one or more) for drilling rings,
- Slot blasting at the end of drift,
- Drilling and blasting of the rings.[1]



a) *b)*

Figure 1 *Ring blastholes design around the drilling drifts (a) and ring development phases (b) [1, 5]*

2.1 Selection of explosives

Explosives can be described as the metastable chemical systems, encompassing both compounds and mixtures. They are capable of quickly transitioning to a more stable state under the external effects or impulses. During this transition, they release a significant amount of energy and gaseous products. As these gases expand, they exert force and perform work on their surroundings [3].

The fundamental properties of explosive substances are categorized into physical, chemical, thermochemical, and explosive properties. These characteristics not only determine the application of explosives, but also affect their production and handling processes [3].

Explosives can be classified by their aggregate state into the gaseous, liquid, and solid forms. Among these, the solid explosives are the most commonly used. When choosing explosives, three primary criteria come into play:

- Working conditions – specifically, the ability of the explosives to react effectively under certain conditions;
- Mining characteristics of texplosives, meaning their suitability for the specific blasting purposes;
- Cost implications of drilling and blasting.

The procedure for selecting explosives typically involves three steps:

- Firstly, one must choose from commercially available explosives that can reliably and effectively react under the given working conditions;
- Next, the selection is refined based on the blasting properties of explosives;
- Finally, a comparison is made on the basis of costs associated with using the selected explosives [4].

3 SLOT MODELING IN THE DATAMINE AEGIS SOFTWARE

The Datamine Aegis is one of the best software for modeling and optimization the drilling and blasting of ring blastholes. What sets it apart is an interactive and friendly interface, a multitude of tools and possibilities to improve efficiency [6].

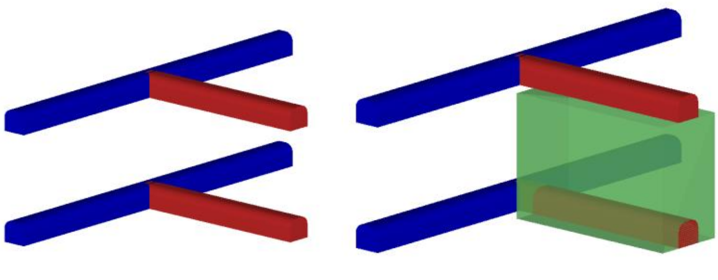
The Aegis software has its own database with collected experiences and parameters from ore deposits and rock enviroments around the world, drills, explosives, detonators and detonation amplifiers. This database allows the user to quickly and easily perform modelling in a similar environment. The user has the possibility to create his/her own database where later modeling or optimization will be even more precise [6].

3.1 Model making methodology

A model of the open stope excavation was created using the ring blastholes with a unique drilling and blasting pattern. Five types of explosives were applied and compared in slot blast simulation in the Datamine Aegis software. In this case, for the purposes of creating a model of drilling and blasting a slot, and in order to compare the results of blasting with several types of explosives, the following objects were created:

- Two main arched drifts with a mutual height distance of 20 m, dimensions of the cross-sections are 4.5 x 4 m (Figure 2a, blue),
- Two arched drifts with a mutual height distance of 20 m, dimensions of the cross-sections are 4.5 x 4 m, lenght 35 m (Figure 2a, red),

Stope model width 12 m, height 20 m and lenght 30 m (Figure 2b, green).



a) *b)*

Figure 2 *Appearence and position of the main drifts (a) and stope (b)*

3.2 Defining the input parameters

The input data is defined and selected in the database of the Datamine Aegis program. Based on experience, an Atlas Copco Simba 1354 drill with a drilling diametar of 76 mm was selected. The characteristics of a drill were already predefined in the software itself.

Characteristics of the surrounding rock environment were already predefined in the software and correspond to the altered andesite, Table 1. For the purpose of simulation, five different explosives were used: ANFO low strenght, ANFO high strenght, RU emulsion Dyno Nobel, Titan 7000 RU, Subtek Charge E1. Explosives are predefined in the software itself, and their characteristics are given in Table 2.

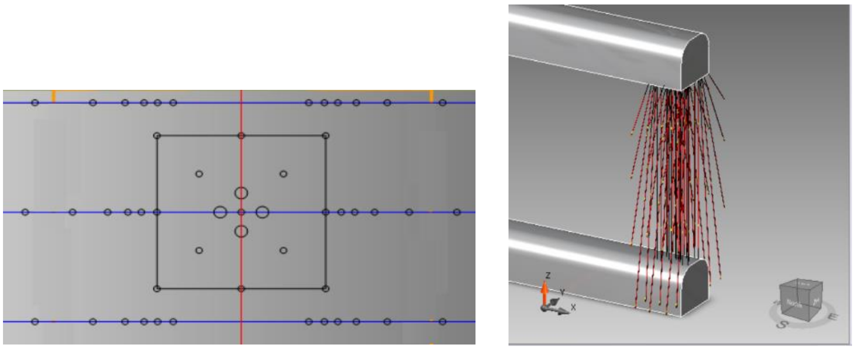
Table 1 *Properties of altered andesite*

Properties of altered andesite	
Density	2.403 g/cm³
RMR	51
RQD	23
JRC	17
P wave speed	3778.21 m/s
S wave speed	1943.87 m/s
Jung’s elasticity model	23.97
Poisson’s ratio	0.32

Table 2 *Explosives properties predefined in the Aegis software*

Name	**Description**	**Density g/cm³**	**Specific density cm³/g**	**Velocity of detonation m/s**	**Internal bulk energy MJ/m³**	**Thermochemical energy Cal/g**
ANFO Low strength	Mix of granular ammonium nitrate and diesel fuel	0.95	1.053	3654.4	1492.85	880
ANFO High strength	A mixture of emulsion matrix and ANFO explosive made of porous ammonium nitrate	1.2	0.833	4000	2135.83	1056
RU Emulsion Dyno Nobel	Pumped emulsion explosive	1.2	0.833	5931.2	3423.037	686.4
Titan 7000 RU	Pumped emulsion explosive	1.2	0.833	4427.7	2285.484	690
Subtek charge E1	Pumped emulsion explosive	1.2	0.833	5796	5574.65	1179.2

New parameters are defined for the 500 g pentolite detonation booster manufacured by TRAYAL in the Aegis database. Drilling and blasting pattern was optimized for application the ANFO low strength explosive and applied in further simulation for other types of explosives with the aim of showing the different impact of the explosives when using the same pattern and without its optimizing it (Figure 3).



a) *b)*

Figure 3 *Slot drilling and blasting pattern showed in the axonometry (a) and plan (b)*

In order to better understand the individual results and their effects on the stope a prism model was first created that represents the ideal result, that is, the ideal volume that should be crated after slot blasting. After defining all the input parameters and creating the model, a blasting simulation was performed for each type of explosive using the Analyzer option.

The model of the ideal volume was compared with the individual blasting results via the *Create comparison* option. In this way, it is possible to see the intersection of the two models, volume obtained by blast simulation and ideal volume (Figure 4).

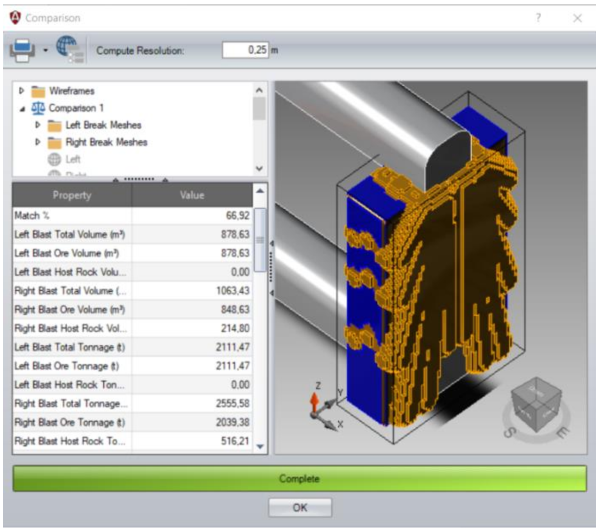


Figure 4 *Comparison of the two models, volume obtained by blast simulation (brown colour) and ideal volume (blue colour)*

4 RESULTS AND DISCUSSION

The following results were obtained by the blasting simulation, and presednted in tables below for each type of explosive.

The dependence of brake radius of the explosive on the characteristics of the explosives can be observed from Table 3.

Table 3 *Parameters affecting brake radius*

Explosive/Parameters	Density (g/cm³)	Thermochemical energy (Cal/g)	Internal bulk energy (MJ/m³)	Detonation speed (m/s)	Brake radius (m)
ANFO low strength	0.95	880	1492.85	3654.4	1.23
ANFO high strength	1.2	1056	2135.83	4000	1.59
RU emulsion Dyno Nobel	1.2	686.4	3423.04	5931.2	2.88
Titan 7000 RU	1.2	690	2285.48	4427.7	1.85
Subtek charge E1	1.2	1179.2	5574.65	5796	2.78

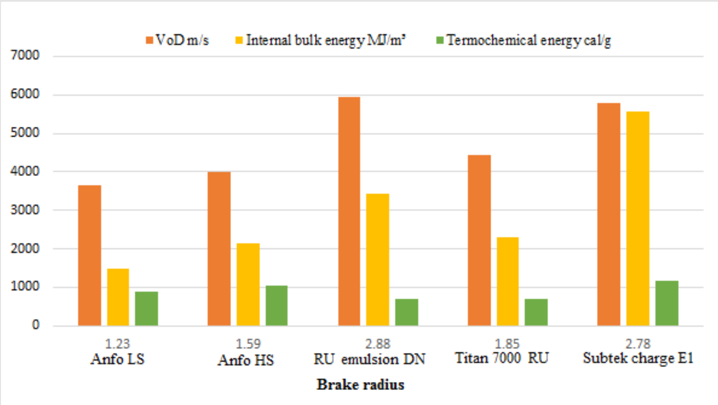


Figure 5 *Dependence of brake radius on explosive properties*

Table 4 *Model comparison results*

Name	ANFO Low strenght	ANFO High strenght	RU Emulsion Dyno Nobel	Titan 7000 RU	SUBTEK charge E1
Match (%)	66.92	63.06	35.26	56.28	33.87
Blast volume Vm (m³)	1063.43	1331.1	2561.71	1555.12	2422.63
Ideal volume model Vi (m³)	878.63	878.63	878.63	878.63	878.63
Total volume diference (m³)	184.8	452.47	1683.08	676.49	1544

Based on the obtained results, the ratio between the ideal volume model and volume, obtained by blasting simulation, was calculated as follows :

$$a = \frac{V_i}{V_m}$$

where :

a – ratio between the ideal volume and volume obtained by blasting,

V_i – ideal volume,

V_m – volume obtained by blasting.

Figure 6 shows the ratio of ideal volume model and volume of the blasting model as a function of the applied powder factor in order to determine the smalest powder factor.

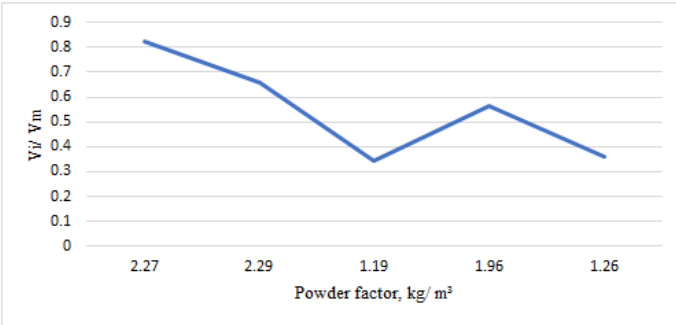


Figure 6 *The ratio of ideal volume model and volume of the blasting model as a function of the applied powder factor*

For the obtained minimum value of the powder factor of 1.19 kg/m^3, a volume of 2561.71 m^3 was obtained by simulation for the RU Emulsion Dyno Nobel explosive. For the obtained maximum value of powder factor consumption of 2.29 kg/m^3, a value of 1331.1 m^3 was obtained for the ANFO high strenght explosive.

It is shown that, although the internal energy of the Subtek charge E1 explosive is 5574.65 MJ/m^3 and that of the RU Emulsion Dyno Nobel is 3423.04 MJ/m^3, the RU Emulsion Dyno Nobel for a given blasthole diameter has a higher velocity of detonation of 5931.2 m/s and creates a larger brake radius compared to the others and is 2.88 m. This directly shows the importance of effect of each explosive parameter when calculating the radius of its effect and optimizing the drilling and blasting pattern.

From relation: $V_m : q_m = V_i : q_i$

follows: $q_i = \frac{q_m * V_i}{V_m}$

Calculation of the required powder factor is given in Table 5.

Table 5 *Required powder factor*

Name	Required powder factor for V_i, q_i (kg/m^3)
ANFO low strength	1.88
ANFO high strength	1.51
RU emulsion Dyno Nobel	0.41
Titan 7000 RU	1.11
Subtek charge E1	0.46

It can be seen from Table 5 that the minimum required powder factor for obtaining an approximately ideal volume is 0.41 kg/m^3 RU emulsion Dyno Nobel explosive. This can be obtained by adequately modifying the drilling and blasting pattern. Possible changes can be: changing the diameter of drillholes, changing the lenght and angle of drilling or by decking. From an economic point of view, the goal of every mining company is to achive the maximum profit and minimum costs. Bearing this in mind, the optimization of drilling and blasting operations may have different results compared to these if the cost price of explosives is taken in to account.

Due to this reason, during exploitation, it is important to take into account all factors and, if necessary, make the appropriate changes to maximize results and safe working conditions.

5 CONCLUSION

This scientific paper, using the five models in the Datamine Aegis software, demonstrated the impact of characteristics of five different explosives on blasting outcomes. It also emphasized the importance of considering all explosive parameters when optimizing the drilling and blasting patterns.

During the planning phase of drilling and blasting operations, it is crucial to account for the full spectrum of explosive characteristics. Moreover, if there is a change in drilling geometry or switch in the type of explosive used, the appropriate optimizations must be made. Poorly blasting operations can cause the significant risks to the personnel, equipment, underground infrastructure, and production processes. Such oversights can also lead to the adverse economic repercussions. Certainly, solving these tasks requiers a constant control of works, keeping work logs and own databases. One should never rely on a single approach to the problem solving. The most successful outcomes are typically achieved through a blend of hands-on experience, precise calculations, and advanced software simulations.

REFERENCES

[1] W. A. Hustrulid, R. Bullock, Underground Mining Methods – Engineering Fundamentals and International Case Studies, Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, Colorado USA, 2001, pp. 635 – 663 (in Serbian)

[2] D.Č. Kovačević, Mining Works in Construction Practice, Izgradnja, Belgrade, 2005

[3] Z. Bajić, Initial and High Explosives, AGM Book, 2015 (in Serbian)

[4] M. Savić, Blasting at the Open Pit, RTB Bor, Copper Institute Bor, Indok Center, 2000 (in Serbian)

[5] I. Onederra, G. Chitombo, Design Methodology for Underground Ring Blasting, Institute of Materials, Minerals and Mining, 2007

[6] https://iring.ca/knowledge-base/