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Determining parameters of blasting operations at coal open pit mines based on the results of production trial tests and studies

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Abstract. Nowadays, the role of physical and chemical processes in the mining industry is increasing. New mining technologies and advanced research methods have been developed and widely used, studying various properties of rock mass/ massif, such as structure, strength, elasticity, and acoustics etc. Rock massif of coal deposits, mostly presented by layered rocks of sedimentary origin is divided by various joints and fractures, that directly affects blasting results. This study aims to determine the basic parameters of blasting operations in specific mining-geological conditions based on the rock strength and average size of natural particles in the rock massif, since intensity of joint system and physical and mechanical properties of rock massif depend on thickness of natural particles in the rock massif.

Keywords. Rock mass/massif, geological structure, rock jointing, natural particles in rock mass, basic parameters of blasting operations

Introduction

The methodological studies, presently used in open pit mine practices for estimating parameters of blasting operations may be classified as follows: methodologies, based on a similarity laws; methodologies, based on distribution of explosion energy in the rock mass; methodologies, based on relationship between blasting parameters and final results of blasting operations etc. These methodologies have different purposes and specifics, because they aimed at estimating parameters of blasting operations that can use explosive energy more efficiently, taking into account different mining - geological conditions, rock mass structural features**.** For example, the methodologies, suggested by Professors N.Ya. Repin, V.T. Sorokin, and B.Laikhansuren more suitable for blasting layered rocks of sedimentary origin in coal mines, at the same time, methodologies, proposed by Professors V.N.Mosinets, A.E.Azarkovich, I. M.Yaltanets and B.Laikhansuren are recommended for blasting rock mass of ore and non-ore deposits.

Methodic for determining parameters of blasting operations

There is developed methodic for determining basic parameters of blasting operations , including burden distance (W), spacing between blast holes and distance between blast hole rows (a · b), taking into account explosives energy consumption per cubic meter of rock mass (q_t), average size of rock fragmentation (d_d), coefficient of fragmentation conditions (k) , based on rock strength factor (f) and size of natural particles in rock mass/massif ($d_m{}^x$), which mainly reflects mining and geological conditions of open pit coal mines.

Relevant production tests and studies were carried out by Prof. V.T.Sorokin (Irkutsk State Technical University of Russia) in blasting practices of coal mines of Kuzbass coal basin and by Professors B.Laikhansuren and L.Purev (School of Geology and Mining Engineering of Mongolian University of Science and Technology) and Dr. Kh.Jargalsaikhan (Mining Institute under Mongolian University of Science and Technology) in conditions of coal open pit mines of Mongolia.

Averaged data on size natural particles in rock mass (d_m) , rock strength factor (f) and powder factor or explosive energy (q) for open pit coal mines Sharyn gol, Baga nuur, Shivee-Ovoo of Mongolia is given in Table 1 and shown in Figure 1.

Table 1

1	Size of natural particles in rock mass/massif, dm, m	0.5	0.8	1.2	0.4	0.8	1.0	0.5	0.9	1.2
2	Rock strength factor, f	6	8	12	5	7	10	5	7	11
3	Powder factor, q, $кg/m^3$	0.43	0.54	0.74	0.3	0.4	0.5	0.3	0.44	0.65

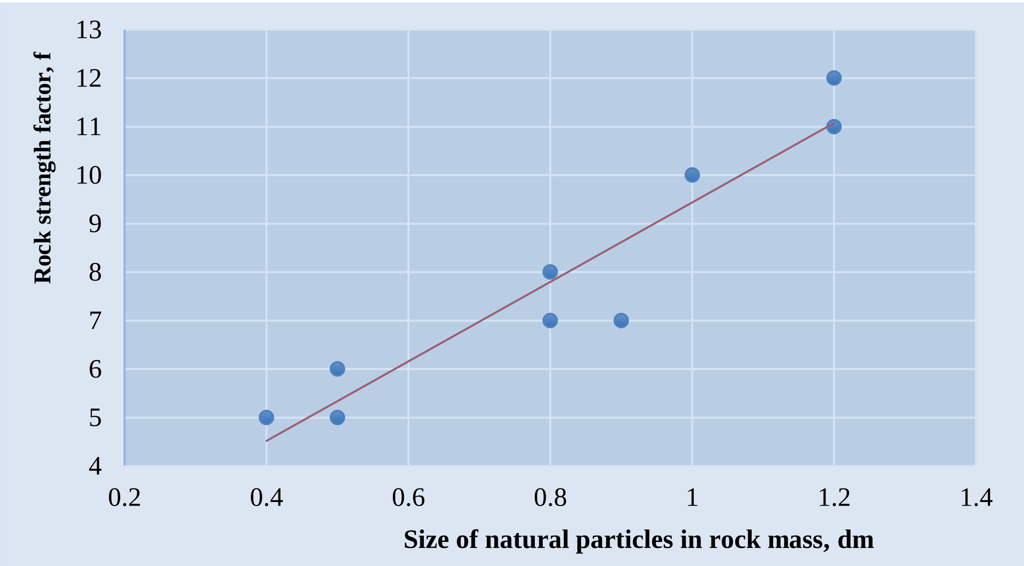

Figure 1. Relationship between size of natural particles in rock mass and rock strength factor

The relationship between these parameters was studied and the following correlations were identified.

1. Size of natural particles in rock mass and rock strength factor correlate well (r =0.94) . It can be expressed by below given equation (1) and shown in the Figure 1.

$$dm = 0.1098 \cdot f - 0.055, \;\; m \qquad (1)$$

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1. Powder factor – Rock strength factor relationship is also strong (r = 0.95), that is expressed by the equation (2) and shown in the Figure 2.

$$q_{т} = 0.055 \cdot f + 0.047, \quad кg/m3 \qquad (2)$$

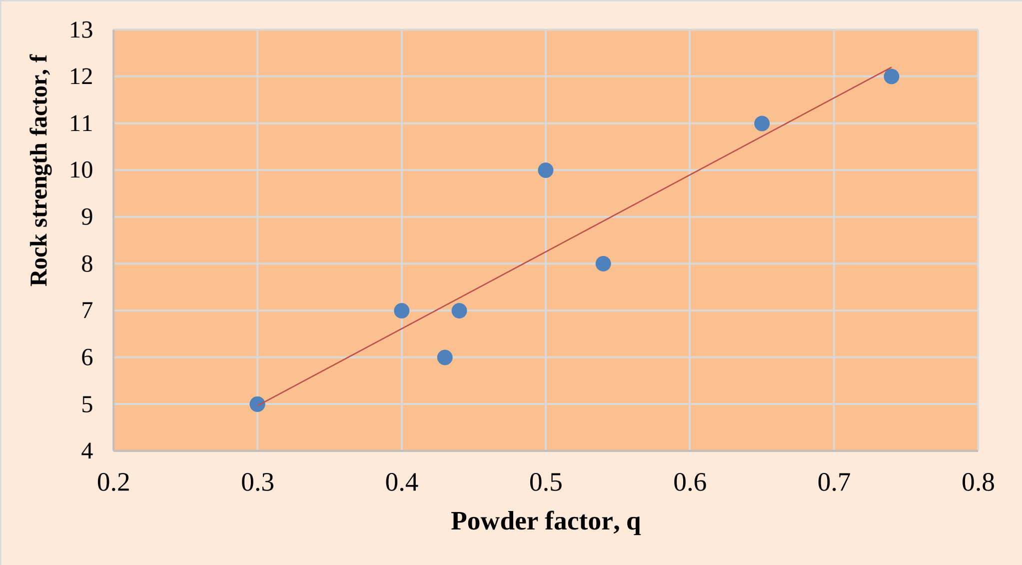

Figure 2. Powder factor – Rock strength factor relationship

Data, relating to size of natural particles in rock mass (dm) , explosive energy or powder factor (q), and average saze of rock fragmentation (da) ia presented in Table 2 and shown in the Figure 3.

Table 2.

1	Size of natural particles in rock mass/massif, d_m, m	0.4	0.5	0.55	0.7	0.8	0.84	0.9	1.0	1.4	1.7
2	Powder factor, q, $кg/m^3$	0.3	0.27	0.44	0.43	0.48	0.5	0.52	0.65	0.65	0.7
3	Average size of rock fragmentation,d_a, m	0.27	0.28	0.34	0.22	0.34	0.52	0.4	0.42	0.5	0.56

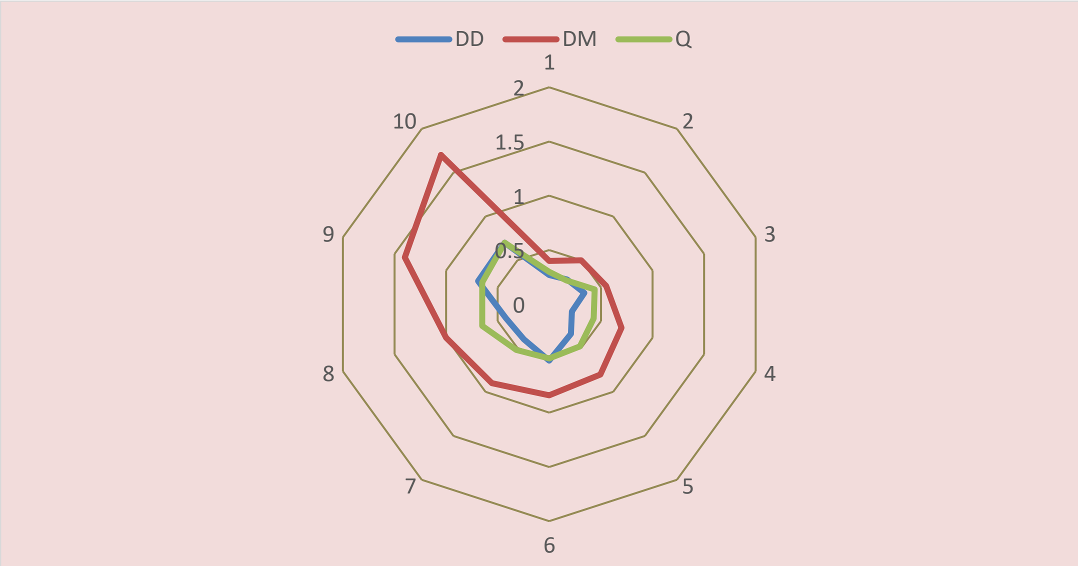

Figure 3. Relationship between powder factor, size of natural particles in rock mass and average size of rock fragmentation

Dependence between above mentioned parameters on the basis of trial test blastings can be approximated by the following equation. (See please Figure 3).

$$d_d = 0.15 \cdot d_m + 0.26 \cdot q + 0.12\,,\ \ m \qquad (3)$$

Correlation coefficient for average size of rock fragmentation – size of natural particles in rock mass relationship is r = 0.91 and r = 0.82 for average size of rock fragmentation – powder factor relationship.
Fragmentation degree can be evaluated by following relation of size of natural particles in rock mass and average size of rock fragmentation.

$$P = d_m : dd \qquad (4)$$

Coefficient of fragmentation conditions was determined by Prof.V.T.Sorokin, depending on size of natural particles in rock mass, spacing between blast holes and distance between blast hole rows, powder factor, explosive charge length and average saze of rock fragmentation, based on trial tests and studies, carried out at coal mines of Kuzbass coal basin, Russia.
Averaged data on coefficient of fragmentation conditions and fragmentation degree is given in Table 3 (See please Figure 4) [4].

Table 3

1	Fragmentation degree, P	1.4	1.5	1.43	1.25	1.08	1.17	1.54	1.33	1.61	1.38
2	Coefficient of fragmentation conditions, K_b	0.93	1.12	1.02	0.92	0.8	0.82	1.11	0.98	1.13	1.07

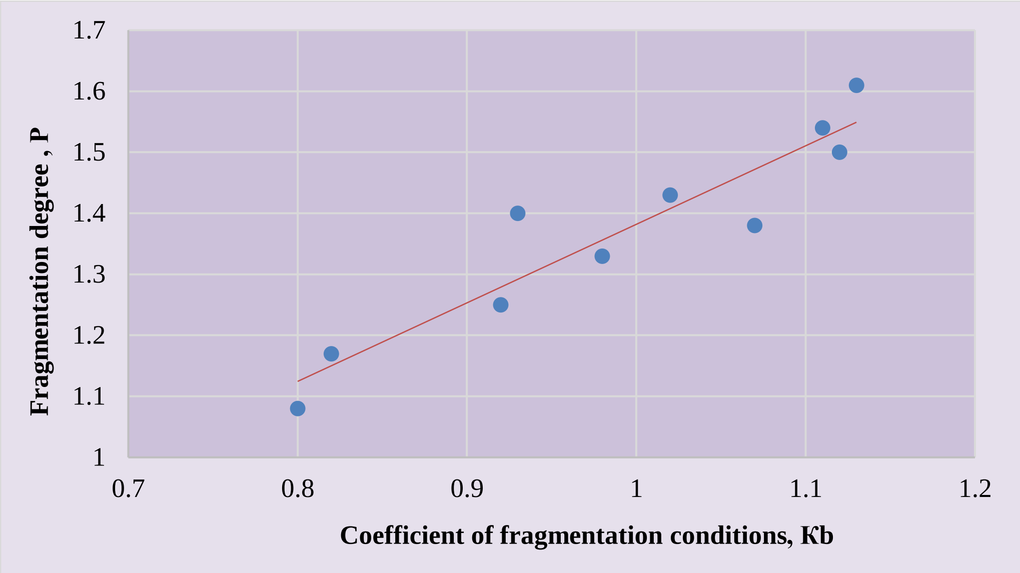

Figure 4. Relationship between coefficient of fragmentation condition and fragmentation degree

According to the results of above mentioned study, correlation between coefficient of fragmentation condition and fragmentation degree is expressed by the following equation (r = 0.94) .

$$K_b = 0.683 \cdot P + 0.054 \qquad (5)$$

Data in Table 4, as results trial blasting, conducted for good, medium and poor categories of rock materials blast ability in major coal mines of Mongolia shows the relationship between average size of rock fragmentation and spacing between blast holes. (See please Figure 5) [1-3].

Table 4.

№	Parameters	Parameters values								
1	Spacing between blast holes, a, m	5.0	4.5	4.0	5.5	4.5	4.0	5.0	4.5	4.0
2	Average size of rock fragmentation, d_d, m	0.22	0.36	0.41	0.2	0.32	0.36	0.3	0.35	0.4

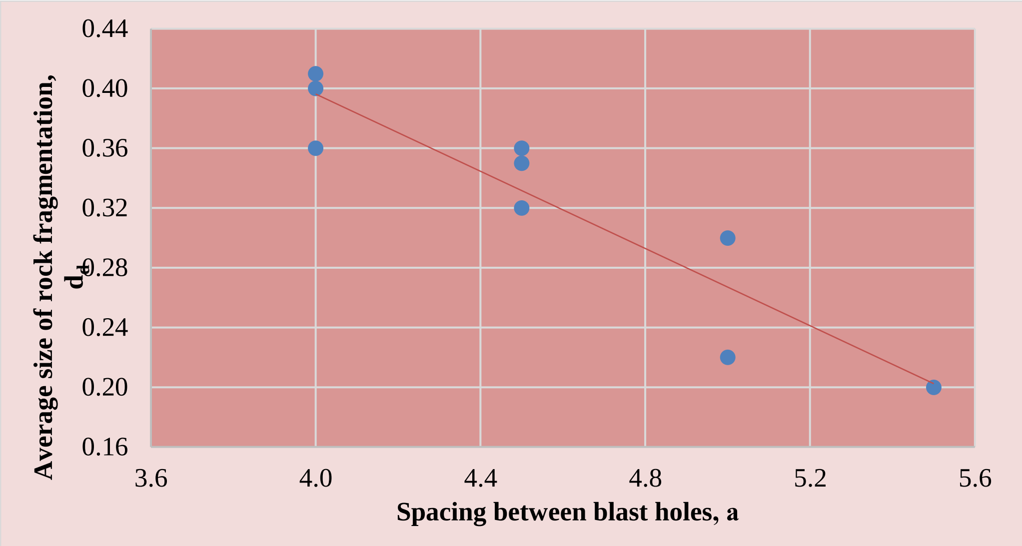

Figure 5. Relationship between average size of rock fragmentation and spacing between blast holes

Mathematical processing of experimental data (Table 4) provides following equation for spacing between blast holes – average size of rock fragmentation relationship and graph, illustrated in Figure 5.

$$a = 6.711 - 6.645 \cdot d_d, \text{ m} \qquad (6)$$

The relationship between burden distance and spacing between blast holes can be determined , using data in Table 5 .

Table. 5

№	Parameters	Parameters values								
1	Burden distance, W, m	6.5	5.5	5.0	6.0	5.5	5.0	7.0	6.5	6.0
2	Spacing between blast holes, a, m	5.5	5.0	4.5	6.0	5.0	4.5	6.0	5.5	5.0

In this case, correlation equation has following form: (r = 0,86)

$$W_t = 1.065 \cdot a + 0.326, \quad m \qquad (7)$$

Demermining coefficient of fragmentation conditions, dependent on structure of rock massif and basic parameters of blasting operations and identifying influence of spacing between blast holes have some interest for study. Accordingly, experimental data processing gives correlation coefficient r = 0.88 for burden distance – coefficient of fragmentation conditions relationship and r = 0, 86 for burden distance – spacing between blast holes relationship. The equation, expressing relationship between these three variables has following form and correlation coefficient r = 0.86.

$$W = 0.59 \cdot a + 2.01 \cdot K_b + 0.59, \quad m \qquad (8)$$

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Possibility of determining average size of rock fragmentation by explosive specific energy and estimating blast hole load (s = a · b) by basic parameters of blasting operation was considered and related data is given in Table 6 (See please Figure 6).

Table 6

№	Parameters	Parameters values								
1	Blast hole load $s = a \cdot b, m2$	24.8	22.5	18.0	33.0	22.5	18.0	52.0	38.0	24.0
2	Powder factor, q, $\kappa g/m^3$	0.43	0.54	0.74	0.3	0.4	0.48	0.27	0.44	0.65
3	Average size of rock fragmentation, d_d, m	0.22	0.36	0.41	0.2	0.32	0.36	0.3	0.35	0.42

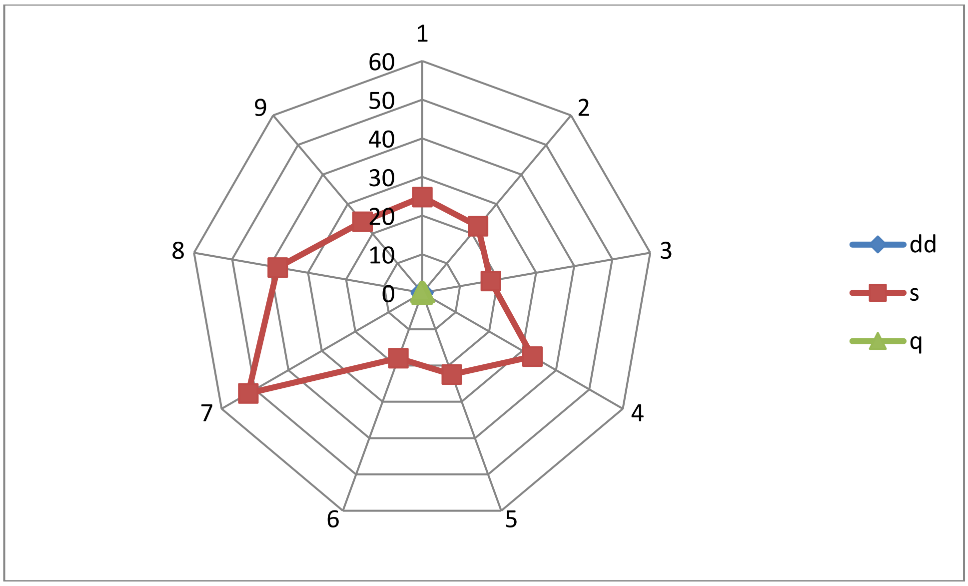

Figure 6. Relationship between powder factor, blast hole load and average size of rock fragmentation

The study shows that above said parameters have relationship, that can be expressed by following equation.

$$d_d = 0.002 \cdot s + 0.5 \cdot q + 0.016 , \ m \qquad (9)$$

Estimate results by formulas 1-9 will demonstrate rational idea or effective ways for practical application, illustrating dependence of average size of rock fragmentation from blast hole load and powder factor, influence of fragmentation degree and average fragmentation size on spacing of blast holes, determining coefficient of fragmentation condition dependent on fragmentation degrees, estimating burden distance by these parameters etc.

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Conclusion

Applied approaches for determining basic parameters of blasting operations: burden distance (w), spacing between blast hole and distance between blast hole rows ($a \cdot b$) , explosive energy consumption or powder factor (q), required size of rock fragmentation (d_t) for each category of rock blast ability based on production test and studies of average size of rock fragmentation, parameter of fragmentation conditions, rock properties, massif structure in coal open pit mines has contributed to resolving the factors, influencing within the scope of the study.

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