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Investigation and Analysis for the Selection of an Appropriate Method to determine Rock fragmentation from Experimental Data

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ABSTRACT

In the mining and construction industry, where explosive energy is used, rock fragmentation is a key parameter. It not only reflects the efficiency of a blast but also directly affects the entire production process, including drilling, blasting, loading, and transportation. Rock fragmentation is typically characterized by the mean particle size obtained from the particle size distribution. Currently, the mean particle size is often calculated from discrete particle size distribution data obtained through traditional sieve analysis. The accuracy of this method depends on the scale of the sieve experiment. In particular, the broader and finer the range of sieve sizes used, the more accurate the results. To address this limitation, this study conducted explosion experiments in the laboratory, used small-scale sieve analysis with only nine sieves, and applied analytical equations that establish continuous particle size distribution curves based on popular functional forms such as Gates-Gaudin-Schuhmann, Rosin-Rammler, and Swebrec, using only the data from discrete sieve analysis. The results showed that the differences between the mean particle size (D_{tb}) values calculated from the continuous functional models and those obtained from traditional discrete analysis were relatively small, with the best error being about 2%, demonstrating the reliability of the method. Furthermore, the relationships between explosive parameters, such as the powder factor (q), mean particle size (D_{tb}), and dispersion coefficients (a , b , c) corresponding to the three functional forms, were fully established. This resulted in a table that allows engineers to quickly assess blast quality from a small-scale sieve analysis, without requiring in-depth knowledge of statistics or complex machine learning techniques.

Keywords: Rock fragmentation; particle size distribution (PSD); Gate-Gaudin-Schumann (GGS); Rosin-Rammler (RR); Swebrec (SS); mean particle size (D_{tb}).

1. Introduction

According to explosion experts as Ho et al. (2010) and Dam et al. (2015), the effective explosive energy used to break rocks and soil accounts for less than 30%, which means that over 70% of the explosive energy is useless, negatively affecting the environment, such as causing dust, vibration, etc. Therefore, researching ways to increase the efficiency of breaking rocks and soil and reducing the negative impacts of explosions is always the goal of industries and fields using explosive energy, such as mining, irrigation, and underground construction.

Among them, the use of statistical methods to study explosions is one of the effective methods. In this research direction, scientists only consider the initial and final states of the destruction

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process without taking into account the nature of the dynamic process of crushing (Оксанич, 1982). The initial state can be considered as the experimental specimens and explosive parameters, and the final state is the rock fragmentation, represented by the particle size distribution or the average particle size (D_{tb}). This is an important criterion to evaluate the effectiveness of an explosion (Sanchidrián, 2007).

In the world, many authors have studied rock fragmentation by establishing the particle size distribution (PSD) functions in the form of the Rosin-Rammler (RR) function, the Gate-Gaudin-Schumann (GGS) function, and the Swebrec function (Osorio, 2014; Sanchidrián, 2014; Akinbinu, 2022). In general, these studies have shown that the RR and GGS functions find it hard to describe the expansion and contraction in different regions of the actual particle size distribution. In contrast, the Swebrec function possesses higher accuracy in describing the entire range of particle sizes from small to industrial scale, from large to fine-grain sizes. However, in these studies, the authors have not yet provided a method for finding the distribution function based on available data and its relationship with D_{tb} , causing difficulties for audiences who want to learn more.

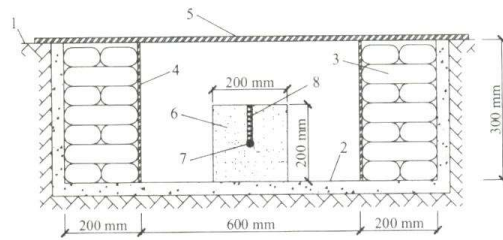
In Vietnam, the rock fragmentation has also been studied by many authors to analyze the influence of different factors on D_{tb} . Some of the influences that can be mentioned are the research of Vu and Dam (2015) on the number of open surfaces, the research of Le and Le (2017) on machinery and equipment, the research of Dam et al. (2018, 2019, 2020 and 2021) on the shape of the explosive charge, and even the distance from the center of an explosive charge (Dam, 2019). The common point of these studies is the use of D_{tb} parameters calculated from sieve analysis data according to Kuznetsov (1973) without considering the establishment of a full distribution function. This is famous for a famous quick analysis method commonly used in sieve analysis, but the accuracy is limited by the number of sieves and sieve size.

Within the framework of small experiments, partly inheriting the research of Vu and Dam [2019], Vu et al. (2024, 2025), this paper provides a direct method to determine the particle size distribution law according to the GGS function, RR function, and Swebrec function. This can also predict parameters such as the exponential coefficients of the distribution function (a , b , and c corresponding to the three aforementioned distribution functions), the average particle size D_{tb} , and the powder factor q , facilitating the rapid assessment of the blasting efficiency and the selection of appropriate blasting parameters.

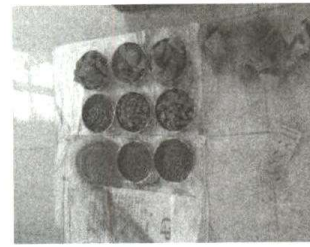
2. Experimental study

2.1. Experimental model

The experimental model is illustrated in Figure 1. In particular, the experimental model is a semi-submersible tank with a depth of 300 (mm), a width of 1000 (mm). Experimental specimens are cubic with a shape of 200x200x200 (mm), made of cement mortar and reach a grade of M100 (B7.5). The used explosives are TEN, which are detonated by electrical detonator No.8. The blasting machine MFB-200 is used. This study changes the total mass of explosives and detonators, ensuring to be appropriate to selected values of powder factors as 0.6, 0.9, 1.2, 1.5, 1.8, 2.1 kg/m³, respectively. To avoid secondary breakage caused by the impact of flying rocks, this study was also designed with two deceleration layers: the first layer consisting of a thin corrugated iron sheet surrounding the test sample, and the second layer consisting of sandbags placed around it.



(a)



(b)

Figure 1. Experimental model

1 – Surface, 2 – Concrete liner; 3 – sandbags; 4 – corrugated iron sheet; 5 – Steel cover; 6 – Specimens; 7 – Explosives charge and detonator; 8 – Stemming material

2.2. Experimental data collection

Blasting products are analysed using sieves with sizes of 2.5, 5, 10, 20, 30, 40, 50, 60, 70 (mm), respectively. Based on the number of sieve sizes, the obtained results are 10 groups of average particle size. Each group is then weighted as shown in Figure 1b; the information is summarized as a cumulative weight proportion. The data of six blastings is as follows:

Table 1. The table of cumulative weight proportion

STT	Sieve sizes x, mm										
	Range	<2.5	2.5÷5	5÷10	10÷20	20÷30	30÷40	40÷50	50÷60	60÷70	>70
	Average	1.25	3.75	7.50	15	25	35	45	55	65	80
1	q=0.6	0.026	0.055	0.096	0.138	0.196	0.266	0.394	0.490	0.659	1.000
2	q=0.9	0.045	0.088	0.164	0.246	0.337	0.431	0.555	0.691	0.833	1.000
3	q=1.2	0.108	0.139	0.191	0.274	0.398	0.510	0.616	0.742	0.880	1.000
4	q=1.5	0.176	0.271	0.385	0.493	0.586	0.682	0.787	0.863	0.949	1.000
5	q=1.8	0.151	0.283	0.408	0.530	0.623	0.775	0.838	0.894	0.976	1.000
6	q=2.1	0.166	0.324	0.438	0.606	0.771	0.859	0.912	0.947	0.979	1.000

The data in Table 1 is illustrated intuitively by a graph of the cumulative weight proportion

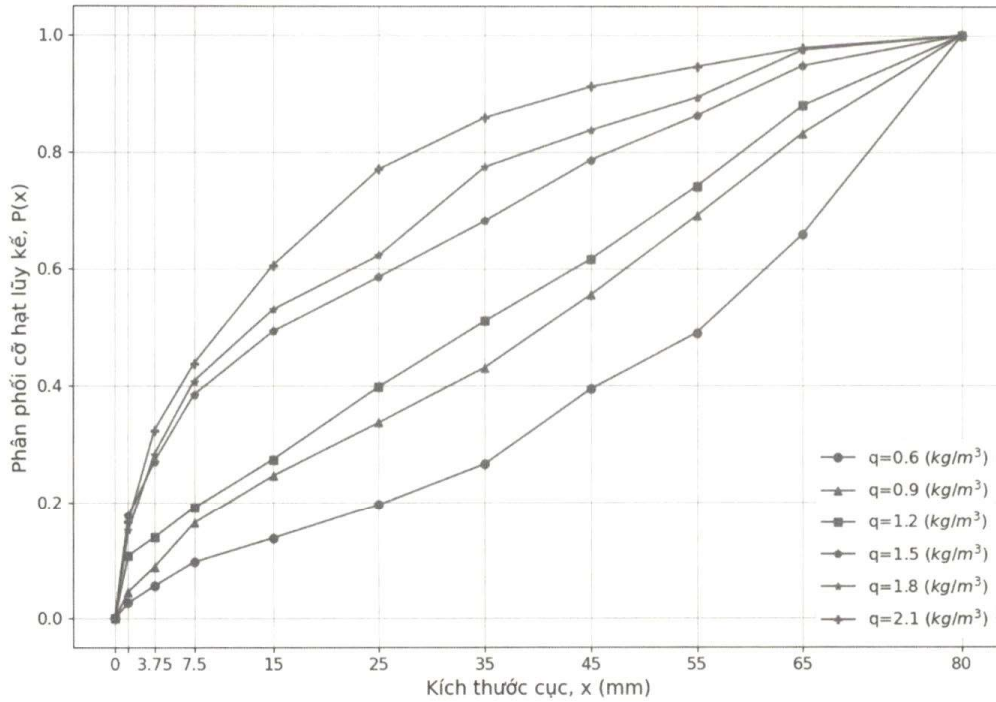


Figure 2. The graph of the cumulative weight proportion

3. Methodologies

This paper applies analytical solutions, which were figured out by Vu et al. (2024, 2025), to establish the forms of particle size distribution functions directly from sieving data.

For the GGS form, the particle size distribution is as follows:

$$P(x) = \left(\frac{x}{x_{max}} \right)^a \quad (1)$$

Analytical solution for the calculation of the dispersion coefficient a.

$$\sum_{i=1}^m P_i \bar{x}_i^a \ln(\bar{x}_i + \varepsilon) - \sum_{i=1}^m \bar{x}_i^{2a} \ln(\bar{x}_i + \varepsilon), \quad \text{với } \bar{x}_i = \frac{x_i}{x_{max}} \quad (2)$$

The average particle size of a muck pile after blasting, which is determined based on the GGS distribution function, is shown in the following equation;

$$D_{tb}^{GGS} = \frac{ax_{max}}{a+1} \approx \sum_{i=1}^m \frac{ax_i^a}{x_{max}^a} \Delta x, \quad \text{với } \Delta x = \frac{x_{max}}{iter} \quad (3)$$

For the RR form, the particle size distribution function is below.

$$P(x) = 1 - e^{-\left(\frac{x}{x_{63.2}}\right)^b} \quad (4)$$

The dispersion coefficient b is calculated as the following equation.

$$\sum_{i=1}^m \frac{P_i \bar{x}_i^b \ln(\bar{x}_i + \varepsilon)}{e^{\bar{x}_i^b}} + \sum_{i=1}^m \frac{\bar{x}_i^b \ln(\bar{x}_i + \varepsilon)}{e^{\bar{x}_i^{2b}}} - \sum_{i=1}^m \frac{\bar{x}_i^b \ln(\bar{x}_i + \varepsilon)}{e^{\bar{x}_i^b}} = 0, \quad \text{vóti } \bar{x}_i = \frac{x_i}{x_{63.2}} \quad (5)$$

Its average particle size is as follows.

$$D_{tb}^{RR} \approx \sum_{i=1}^{iter} \frac{bx^b}{e^{\left(\frac{x}{x_{63.2}}\right)^b} x_{63.2}^b} \Delta x, \quad \text{vóti } \Delta x = \frac{x_{max}}{iter} \quad (6)$$

For the SS form, the particle size distribution function is presented by an equation.

$$P_{(x)} = \frac{1}{1 + \left[\frac{\ln\left(\frac{x_{max}}{x}\right)}{\ln\left(\frac{x_{max}}{x_{50}}\right)} \right]^c} \quad (7)$$

The dispersion coefficient c of the SS function type is calculated below.

$$\sum_{i=1}^m \frac{P_i x_i^c \ln(\bar{x}_i + \varepsilon)}{\left(1 + \bar{x}_i^c\right)^2} - \sum_{i=1}^m \frac{\bar{x}_i^c \ln(\bar{x}_i + \varepsilon)}{\left(1 + \bar{x}_i^c\right)^3} = 0, \quad \text{vóti } \bar{x}_i = \frac{\ln\left[\frac{x_{max} + \varepsilon}{x_i + \varepsilon}\right]}{\ln\left(\frac{x_{max}}{x_{50}}\right)} \quad (8)$$

The average particle size of the SS function type is obtained.

$$D_{tb} = \sum_{i=1}^{iter} \frac{c \ln^2\left(\frac{x_{max}}{x_{58}}\right) \ln^{c-1}\left(\frac{x_{max}}{x_i + \varepsilon}\right)}{\left[\ln^c\left(\frac{x_{max}}{x_{58}}\right) + \ln^c\left(\frac{x_{max}}{x_i + \varepsilon}\right)\right]^2} \Delta x, \quad \text{vóti } \Delta x = \frac{x_{max}}{iter} \quad (9)$$

Finally, the average particle size according to the traditional sieving method (Kuznetsov, 1973)

$$D_{tb} = \sum x_i \bar{P}_{(x_i)} \quad (10)$$

In equations (1), (2), (5), (6), (7), (8): P_i or $P_{(x_i)}$ is the cumulative distribution of the i^{th} particle size of sieving analysis according to function types GGS, RR, or SS; x_{max} is the largest particle size, mm; x_i is the size of the i^{th} sieve, mm; a, b, c are dispersions of distribution functions GGS, RR, and SS, respectively; ε is an infinitesimal value; m is the total number of sieve sizes (consisting of the zero size); $x_{50}, x_{58}, x_{63.2}$ are the sieve sizes that have 50%, 58%, and 63.2% passing, respectively, for which $P_{(x_{50})} = 0.5, P_{(x_{58})} = 0.58, P_{(x_{63.2})} = 0.632$.

In equations (3), (6), (9), (10): D_{tb} is the average particle size, mm; x is the particle size, mm; x_{max} is the maximum particle size, mm, it goes to an infinite value for the RR function, chosen $x_{max} = 200$ (mm); $P_{(x)}$ is the particle size distribution function; $p_{(x)}$ is the probability distribution of particle size x , obtained by calculating the partial derivative of $P_{(x)}$ for x ; $\bar{P}_{(x_i)}$ is the probability of the occurrence of particle size x_i ; a, b, c are dispersions of distribution functions GGS, RR, and SS, respectively; $iter$ is the iteration number, chosen $iter = 1000000$.

4. Results, Discussions, and Conclusions

4.1. Results

Inheriting results from Vu et al. (2024, 2025) for Swebrec function type, and based on the value range between 1 and 4 from Ouchterlony (2005), Ouchterlony and Sanchidrián (2019), this paper carries out an expansion, and figures out relationships among parameters of an explosion, such as the powder factor q , the average particle size D_{tb} , dispersion coefficients a, b, c by three distribution function forms as GGS, RR, and SS.

In particular, this paper inherits the value range of the dispersion coefficient c and powder factor q for the SS function in the research of Vu et al. (2024). Meanwhile, the value range of the average particle size D_{tb} is recalculated by equation (9). The obtained results are shown in the following table.

Table 2. Summary table of values for the 3 parameters c - q - D_{tb} for the Swebrec function form

Value range of c	Value range of q (kg/m ³)	Value range of D_{tb} (mm)
1.00	0.411	62.668
1.15	0.525	57.855
1.25	0.633	53.635
1.35	0.832	46.599
1.50	1.741	24.582
2.00	2.090	19.225
2.50	2.277	16.850
3.00	2.415	15.287
3.50	2.528	14.124
4.00	2.624	13.200

The two remaining functions use equations from (1) to (6) to calculate, obtaining results according to GGS and RR distribution function types for six blastings in experiments. The calculated results are presented intuitively in Figure 3.

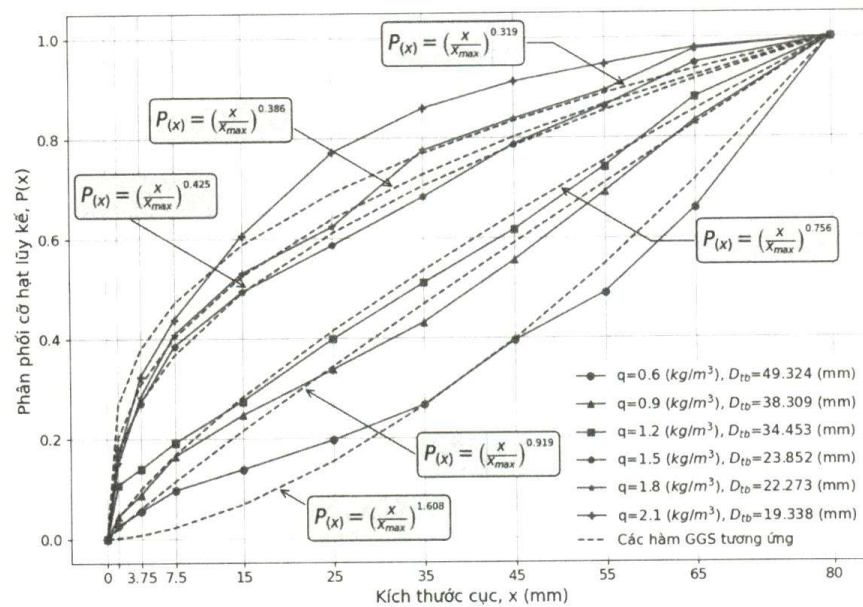


Figure 3. Particle size distribution of 6 blastings for the GGS function form

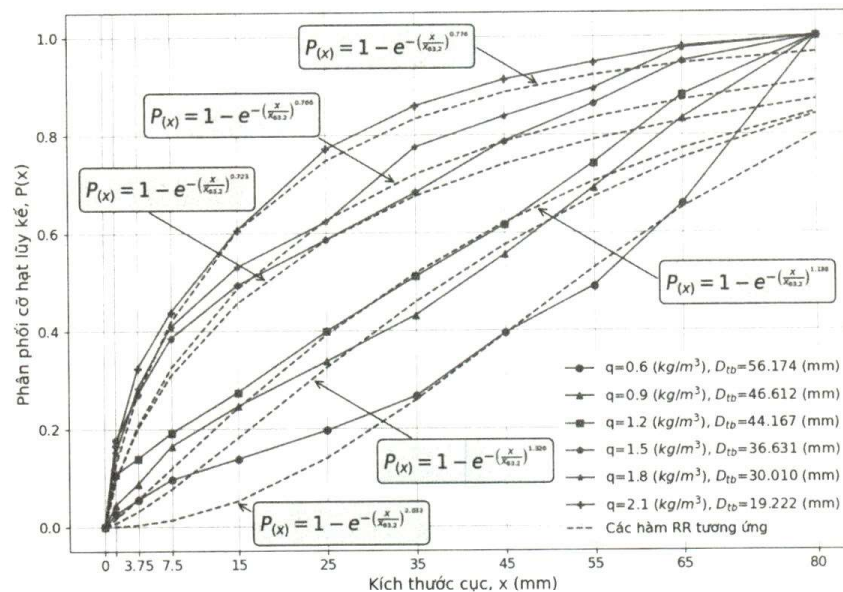


Figure 4. Particle size distribution of 6 blastings for the RR function form

The results of parameters for GGS, RR, and SS function forms are summarized in Table 3.

Table 3. Summary table of distribution functions as the forms of GGS, RR, and SS

STT	q (kg/m ³)	GGS			RR			Swebrec			D _{tb} sieve (mm)
		a	R ²	D _{tb} (mm)	b	R ²	D _{tb} (mm)	c	R ²	D _{tb} (mm)	
1	0.6	1.607	0.978	49.31 9.16%	2.023	0.935	56.17 3.47%	1.219	0.998	53.07 2.24%	54.28
2	0.9	0.918	0.993	38.28 11.46%	1.324	0.955	46.58 7.74%	1.375	0.998	42.95 0.65%	43.23

STT	q (kg/m ³)	GGS			RR			Swebrec			D _{tb} sieve (mm)
		a	R ²	D _{tb} (mm)	b	R ²	D _{tb} (mm)	c	R ²	D _{tb} (mm)	
3	1.2	0.756	0.992	34.45 12.08%	1.134	0.947	44.16 12.71%	1.374	0.999	39.22 0.10%	39.18
4	1.5	0.425	0.998	23.85 12.77%	0.721	0.947	36.62 33.93%	1.353	0.995	28.11 2.81%	27.34
5	1.8	0.386	0.991	22.27 8.31%	0.765	0.960	30.01 23.56%	1.580	0.993	24.72 1.75%	24.29
6	2.1	0.319	0.968	19.34 0.64%	0.776	0.992	19.22 1.26%	2.014	0.998	18.51 4.91%	19.46
Summary		Average		9.07%	Average		13.78%	Average		2.08%	

Based on calculated values, which are shown in Table 3, because the SS function form has the highest accuracy in almost 6 blastings so its parameters, such as q , c , D_{tb} , are considered as the basis, expanding to parameters a , b for GGS and RR function forms, respectively. Parameters a and b by input data of q and D_{tb} are calculated by the multivariable regression method, which is presented by Dam and Vu (2020) with three-dimensional data, corresponding to one dependent variable as a or b , and two independent variables as q and D_{tb} . The results are shown as follows.

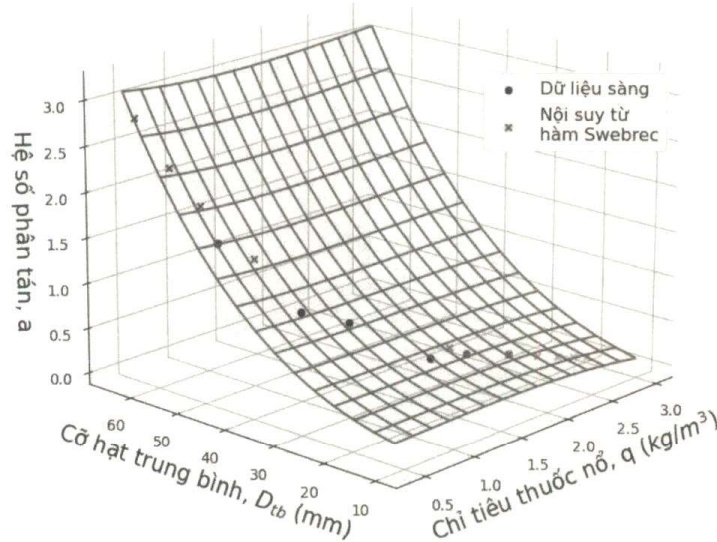


Figure 5. Dependence rule of dispersion coefficient a on q and D_{tb} in terms of GGS function

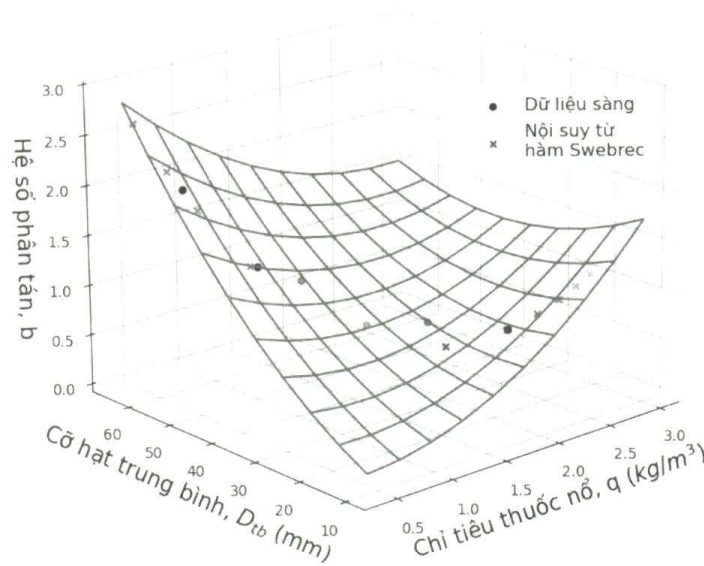


Figure 6. Dependence rule of dispersion coefficient b on q and D_{tb} in terms of RR function

In figures 5 and 6, the black points indicate data from the sieving process, the red points “x” indicate interpolation values of dispersion coefficients based on values of q and D_{tb} from the SS function form. From these relations, combined with calculated values in Table 2, all relationships among blasting parameters of the three distribution function forms are summarized in Table 4

Table 4. Summary table of relationships among blasting parameters according to 3 function forms

Powder factor q (kg/m ³)	Coefficient a in GGS function	Coefficient b in RR function	Coefficient c in SS function	D_{tb} (mm)
0.411	2.829	2.646	1.000	62.668
0.525	2.323	2.207	1.150	57.855
0.633	1.935	1.857	1.250	53.635
0.832	1.398	1.353	1.350	46.599
1.741	0.438	0.631	1.500	24.582
2.090	0.319	0.776	2.000	19.225
2.277	0.270	0.914	2.500	16.850
2.415	0.237	1.039	3.000	15.287
2.528	0.210	1.154	3.500	14.124
2.624	0.187	1.260	4.000	13.200

4.2. Discussions

From the experimental results obtained, the paper established the general relationship of all blasting parameters according to 3 distribution function forms: Gate-Gaudin-Schumann, Rosin-Rammler, and Swebrec.

In particular, the Swebrec particle size distribution almost perfectly matches the sieve analysis data, with accuracies greater than 0.99 for all 6 explosions. The errors between the average particle sizes calculated from the Swebrec distribution function form compared to that from the traditional sieve analysis data are also the smallest of all three forms, with an average

error of only about 2% over 6 explosions, while this figure for the GGS function form is about 9% and even up to nearly 14% for the RR function form. Thus, it can be seen that the Swebrec function form gives the most accurate results, the GGS function form has acceptable results, but also has an advantage because the formula is the simplest and easiest to use. In contrast, the RR function form has the largest error compared to the traditional sieve.

In terms of the Swebrec function form, it can be clearly seen that the $q - c$ relationship between the powder factor and the dispersion coefficient is a monotonically increasing function, that is, the larger the dispersion coefficient c , the more the distribution graph is skewed to the left, the larger the powder factor q , which is opposite to the GGS function form. Meanwhile, the $q - D_{tb}$ relationship between the explosive rate and the average particle size is a monotonically decreasing function; that is, the larger the powder factor q , the smaller the average particle size D_{tb} and vice versa.

Moreover, based on the range of values of the dispersion coefficient c , which is only between 1 and 4, it forms the basis for building a prediction system that can be extended to all blasting parameters according to all three distribution functions, as shown in Table 4. From this table, users can easily use the table lookup method to calculate intermediate values, helping to quickly assess the Rock fragmentation of an explosion.

4.3. Conclusions

The average grain size of the rock pile after blasting is an important criterion for evaluating the blasting efficiency. The paper has established a system for calculating and predicting the values of the blasting parameters a , b , c , q , D_{tb} for 3 common distribution functions suitable for experimental conditions using a lookup table. With this lookup table system, users can easily calculate interpolation when knowing one of the input data points, helping to visualize the explosion scale in advance. The methodology in the study can be applied to expand the lookup table system when adding other blasting conditions.

The final results show that the analytical solutions can be applied immediately to sieve data with high quantitative accuracy, especially with the Swebrec distribution function, when the average error is only about 2%. Henceforth, mining engineers will be able to directly apply the analytical solutions in this paper to immediately establish distribution functions for sieving data without having a deep understanding of data analysis.

Contributions of authors

Tung Lam Vu - methodology, writing, review & editing; Quang Hieu Tran - review & supervision; Trong Hieu Vu - experiment & data collecting works.

References

** Paper published in journal*

Ouchterlony, F. (2005). *The Swebrec© function: linking fragmentation by blasting and crushing*. Mining Technology: Transactions of the Institutions of Mining and Metallurgy, Vol. 114, Iss. 1, 29-44. DOI: 10.1179/037178405X44539

- Sanchidrián, J. A., Segarra, P., and López, L. M. (2007). *Energy components in rock blasting*. International Journal of Rock Mechanics and Mining Sciences, Vol. 44, Iss. 1, 130-147. DOI: 10.1016/j.ijrmms.2006.05.002
- Osorio, A. M., Menéndez-Aguado, J. M., Bustamante, O., and Restrepo, G. M. (2014). *Fine grinding size distribution analysis using the Swebrec function*. Powder Technology, Vol. 258, 206-208. DOI: 10.1016/j.powtec.2014.03.036
- Sanchidrián, J. A., Ouchterlony, F., Segarra, P., and Moser, P. (2014). *Size distribution functions for rock fragments*. International Journal of Rock Mechanics and Mining Sciences, Vol. 71, 381-394. DOI: 10.1016/j.ijrmms.2014.08.007
- Akinbinu, V., Oniyide, G., and Idris, M. (2022). *Assessment of rock fragmentation and strength properties using the Rosin-Rammler and extended Swebrec distribution functions parameters*. International Journal of Mining and Geo-Engineering, Vol. 56, Iss. 1, 53-60. DOI: 10.22059/ijmge.2021.281746.594811
- Vũ. T. H và Đàm. T. T. (2015). *Đánh giá ảnh hưởng của mặt thoát đến mức độ đập vỡ đất đá trong đường hầm từ kết quả thí nghiệm trên mô hình nổ điện*. Tạp chí Khoa học Kỹ thuật Mỏ - Địa chất, Số 49, 59-64.
- Lê. V. Q và Lê. T. H (2017). *Nghiên cứu, xác định mức độ đập vỡ đất đá hợp lý bằng nổ mìn cho điều kiện thực tế của mỏ than Đèo Nai*. Tạp chí Khoa học Kỹ thuật Mỏ - Địa chất, Tập 58, Kỳ 5, 424-430.
- Đàm. T. T, Nguyễn. T. T. và Vũ. X. B. (2018). *Nghiên cứu ảnh hưởng của hình dạng lượng nổ đến mức độ đập vỡ đất đá bằng phương pháp thực nghiệm*. Tạp chí Khoa học và Kỹ thuật, Vol. 13, No. 04, 113-121.
- Д. Ч. Тханг, В. А. Белин, и Ч. В. Зоань (2021). *Исследования действия кумулятивных зарядов с выемкой полусферической эксцентрической формы для разрушения горных пород*. Журнал Устойчивое развитие горных территорий, Т.13, №2, 281-291. DOI: 10.21177/1998-4502-2021-13-2-281-291
- Kuznetsov, V. M. (1973). *The mean diameter of the Fragments formed by blasting rock*. Soviet Mining Science, Vol. 9, 144-148. DOI: 10.1007/BF02506177
- Vũ. X. B và Đàm. T. T (2019). *Nghiên cứu thực nghiệm ảnh hưởng của chỉ tiêu thuốc nổ đến quy luật đập vỡ đất đá khi nổ lượng nổ tập trung*. Tạp chí Công nghiệp mỏ, Số 3, 24-28.
- Ouchterlony, F. and Sanchidrián, J. A. (2019). *A review of development of better prediction equations for blast fragmentation*. Journal of Rock Mechanics and Geotechnical Engineering, Vol. 11, Iss. 5, 1094-1109. DOI: 10.1016/j.jrmge.2019.03.001
- Đàm. T. T và Vũ. T. L. (2020). *Nghiên cứu xác định quy luật thực nghiệm về sự biến đổi của bán kính phễu nổ văng trong môi trường đất sét dưới nước theo phương pháp hồi qui đa biến*. Tạp chí Khoa học Kỹ thuật Mỏ - Địa chất, Tập 61, Kỳ 5, 77-87. DOI: 10.46326/JMES.2020.61(5).09
- Dam. T. T, Vu. T. L, and To. D. T. (2020). *The study on establishing the experimental dependence of the compressed zone radius and the observed height of the splashed funnel in the clay medium underwater*. Journal of Science and Technique - Section on Special Construction Engineering, Vol. 03, No. 02, 107-120. DOI: 10.56651/lqdtu.jst.v3.n02.157.sce

Vu. T. L, Vu. D. H, Vu. X. B (2024). *An approach to determine and predict the mean particle size of a muck pile after blasting according to Swebrec particle size distribution law based on the form of single spherical charge in laboratory scale*. Journal of Science and Technique - Section on Special Construction Engineering, Vol. 07, No. 02, 21-34. DOI: 10.56651/lqdtu.jst.v7.n02.879.sce

Vu. T. L, Vu. M. T, Vu. T. H, Nguyen. V. L (2025). *Building software for analyzing muck piles after blasting in laboratory conditions with integrated Artificial Intelligence*. Journal of Science and Technique - Section on Special Construction Engineering, Vol. 08, No. 01, 123-138. DOI: 10.56651/lqdtu.jst.v8.n01.970.sce

** Conference papers*

Dam. T. T, Tran. V. D, Tran. D. V, and To. D. T (2019). *Study on the reasonable parameters of the cylinder shaped charge with tapered liner funnel to destroy stone*. ISRM International Symposium on Rock Mechanics and Engineering for Sustainable Energy, Hanoi, Vietnam. ISRM-VCRES-2019-010

Dam. T. T, Bui. X. N, Nguyen. T. T, and To. D. T (2020). *Study on the reasonable parameters of the concentric hemisphere-style shaped charge for destroying rock*. International Conference on Innovations for Sustainable and Responsible Mining, Hanoi, Vietnam. DOI: 10.1007/978-3-030-60839-2_3

Dam. T. T, Nguyen. T. Ta, Vu. X. B, and Vu. T. H (2019). *Studying the rule of distribution of rock breaking size according to the distance from the center of concentrated charge*. ISRM International Symposium on Rock Mechanics and Engineering for Sustainable Energy, Hanoi, Vietnam. ISRM-VCRES-2019-029

** Book*

Hồ. S. G, Đàm. T. T, Lê. V. Q và Hoàng. T. C (2010), *Nổ hóa học lý thuyết và thực tiễn*. Nxb Khoa học tự nhiên và Công nghệ.

Đàm. T. T, Bùi. X. N và Trần. Q. H (2015). *Nổ mìn trong ngành mỏ và công trình*. Nxb Khoa học tự nhiên và Công nghệ, 2015.

И. Ф. Оксанич и П. С. Миронов (1982). *Закономерности дробления горных пород взрывом и прогнозирование гранулометрического состава*. Недра, Москва.