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Estimation of Safe Charge per Delay in Bench Blastıng

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Abstract

Prediction of maximum safe charge per delay (Q , kg) by Distance (D) from blasting point and adaptive Peak Particle Velocity (PPV) is a critical key for successful blasting. Safe charge per delay is calculated by using PPV estimators indirectly or Q estimator directly. This paper presents the results of ground vibration measurement induced by bench blasting in Sungun copper mine. The scope of this study is to evaluate the capability of different methods in order to predict maximum safe charge per delay. Conventional empirical models and two type of new non-linear direct estimator models are presented. An application of Imperialist Competitive Algorithm (ICA) has used to determine the Q estimator coefficients in Sungun bench blasting. A comparison between two ways of investigations including conventional empirical equations and ICA are done. It has been shown that the applicability of ICA-based equations is more promising than any selected traditional empirical equations.

Keywords: Blasting, safe charge per delay, PPV, ICA.

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Extended Abstract:

1. Introduction

Drilling and blasting is a typical method of rock excavation. The ground vibrations are an adverse effect of blasting which cannot be completely eliminated; but certainly can be minimized up to permissible level to avoid possible damages to surrounding structures (Mokhtarian Asl and Alipour 2020). Ground vibration is directly related to the maximum charge per delay and distance between blast face to monitoring station. To predict ground vibration, several empirical models have been developed by various investigators (Duvall and Fogelson 1962), (Ambraseys and Hendron 1968), (Langefors and Kihlström 1978). In the most of these models, the PPV is the parameter of concern. Various estimator equations have been proposed to determine PPV, a function of distance and maximum safe charge per delay. PPVs calculated by using these predictor equations give results close to observed values in the field. However maximum safe charge per delay calculated using these predictors does not give a satisfactory result, because Q is determined by back calculations (Rai, Shrivastva, and Singh 2005). So comparisons of Q values by direct statistical calculation and back calculation do not tally (Alipour, Mokhtarian, and Abdollahei Sharif 2012), (Hosseinzadeh Gharehgheshlagh and Alipour 2020). This paper presented the evaluation of Q by direct calculation (rather than back calculation) based on Rai et. al and ICA-based nonlinear models.

2. Materials and methods

In this paper, ICA (Atashpaz-Gargari and Lucas 2007) is proposed to get an appropriate equation for forecasting the maximum safe charge per delay in the Sungun copper mine. For comparison purposes, three empirical models were also used. Different Safe charge predictor models for Sungon mine are presented in Table 1.

Table 1. Safe charge pridictor models in Sungon mine.

Pridictor	Formulation
USBM	$Q = D^2\left(\frac{PPV}{302.07}\right)^{\frac{2}{1.561}}$
Ambraseys and Hendron	$Q = D^3\left(\frac{PPV}{1810.6}\right)^{\frac{3}{1.58}}$
Rai et al.	$Q = 0.0598(PPV \times D^2)^{0.7066}$
Alipour and Mokhtarian	$Q_{ICA_I} = 0.000121PPV^{01.3235}D^{2.2767}$
Alipour and Mokhtarian	$Q_{ICA_{II}} = -3136.4 + 2788.5PPV^{-0.436} + 16963.5D^{-0.456} + 0.0004275PPV^{1.294}D^{2.130}$

The proposed predictors are the function of PPV and distance. To evaluate the performance of Q predictor models, the correlation between the predicted and real measured values of Q was determined. Standard statistical evaluation criteria were used to evaluate the performances of different predictor models.

3. Results

The performance of the estimator models can be controlled by R, RMSE, VARE and VAF. The formulation of these indices can be found in Table 2. ICA_{II}-based model with higher coefficient of determination and VAF as well as lower RMSE and VARE shows better performance (Table 3). This gives better prediction of safe charge as compared to other predictors for case study.

Table 2. Statistical criteria for controling the performance of the pridictor models

Statistical criteria	Formulation
Correlation Coefficient, **R**	$CC=\frac{\sum_{i=1}^{i=n}\left[\left(Q_{Meas}^{i}-\overline{Q_{Meas}^{i}}\right)\left(Q_{Esti}^{i}-\overline{Q_{Esti}^{i}}\right)\right]}{\sqrt{\sum_{i=1}^{i=n}\left(Q_{Meas}^{i}-\overline{Q_{Meas}^{i}}\right)^{2}\times\sum_{i=1}^{i=n}\left(Q_{Esti}^{i}-\overline{Q_{Esti}^{i}}\right)^{2}}}$
Route Mean Square Error, **RMSE**	$RMSE=\sqrt{\frac{1}{n}\times\sum_{i=1}^{i=n}\left(Q_{Meas}-Q_{Esti}\right)^{2}}$
Variance Absolute Relative Error, **VARE**	$VARE=\mathrm{var}\left(\left\lvert\frac{Q_{Meas}-Q_{Esti}}{Q_{Meas}}\right\rvert\right)\times 100$
Variance Account for, **VAF**	$VAF=\left[1-\frac{\mathrm{var}\left(Q_{Meas}-Q_{Esti}\right)}{\mathrm{var}(Q_{Meas})}\right]\times 100$

Table 3. Results of statistical criteria for different pridictors

Model Name	R	RMSE	VARE	VAF (%)
USBM	0.76	534.98	0.2265	0.578
Ambraseys and Hendron	0.77	773.88	0.4382	0.500
Rai et al.	0.73	596.64	0.2135	0.510
Alipour and Mokhtarian (ICA_{I}-based)	0.8	502.1	0.227	0.626
Alipour and Mokhtarian (ICA_{II}-based)	0.88	397.2	0.191	0.764

3. Discussion

According to the calculated statistical error between the estimated and real measured values of safe charge, ICA_{II}-based model has the lowest values of VARE and RMSE, while these equations have the highest value of R and VAF, in comparison with the traditional empirical models. In other words, the new proposed equation gives a better prediction of safe charge compared to the use of back calculation from general predictor and Rai et al. direct calculator.

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