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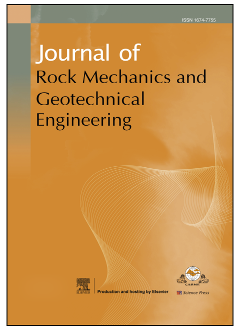

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Velocity of detonation measurement and fragmentation analysis to evaluate blasting efficacy

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Abstract: The velocity of detonation (VOD) measurement in holes helps in comparing and evaluating relative performance of explosives. The strength of explosives to cause a certain degree of rock fragmentation determines the efficiency of a blast. This paper analyzes the results of VOD measurements and degree of blast fragmentation carried out on a blast in a Zambia open pit mine. The study was conducted to measure VOD in five blast holes loaded with HEF100 emulsion explosives. In this trial, a resistance wire continuous VOD measurement system with SpeedVOD was used. The post blast fragmentation analysis was carried out using empirical fragmentation models and an image processing software. The steady state VOD from the holes varied from 4981 m/s to 5387 m/s and the values recorded were consistent with the published values under ideal conditions. The analyzed fragmentation results show that 90% of the blasted material is within 700 mm passing size.

Keywords: blasting; bulk emulsion; explosives; in-hole continuous measurement; velocity of detonation (VOD)

1. Introduction

This paper evaluates the performance of bulk emulsion explosives HEF100 through a velocity of detonation (VOD) measurement and fragmentation size distribution analysis. The VOD was measured in five blast holes using a resistance wire continuous VOD measurement system. The steady state VOD measured from the holes was compared with the published values under ideal conditions. It was concluded that the steady state VOD values were consistent with the published VOD values. The post blast fragmentation analysis carried out using empirical fragmentation models and image processing software showed that 90% of the blasted material was within 700 mm passing size.

1.1. Velocity of detonation measurement

Explosives with low VOD will have low impact on rock fragmentation than the ones with high VOD (Chiapetta, 1988; Heit, 2011). According to Cooper (1996), the explosive VOD is commonly used to approximate the detonation pressure and subsequently the explosive shock energy contained in an ideal explosive. The detonation pressure (P_d) of an explosive from the unreacted explosive density and VOD is given by

$$P_{\mathrm{d}} = \frac{\rho_{\mathrm{e}} C_{\mathrm{d}}^2}{\gamma + 1} \tag{1}$$

where P_d is the detonation pressure (GPa), ρ_e is the explosive density (g/cm^3), C_d is the VOD (m/s) and γ is the ratio of specific heats of detonation product gases ($\gamma \approx 3$). According to Cunningham (2002), γ may be approximately 2.6 for Ammonium Nitrate Fuel Oil (ANFO) to 3.2 for emulsion. Reduction in the VOD will produce a decrease in the P_d value as well as the shock energy of the explosive (Tete et al., 2013). VOD measurements indicate the performance of an explosive in real time. There are two common VOD measurement systems, i.e. the point-to-point system and continuous system. The former has limitation as compared to the latter used in this study (Crosby et al., 1991; Mishra and Sinha, 2003; Harsh et al., 2005). Pradhan and Jade (2012) carried out a study to investigate the performance of bulk emulsion explosive in a watery blast hole by measuring its in-hole VOD. The performance was found to be unsatisfactory due to reduction in VOD and failure of explosive column to detonate fully. Žganec et al. (2016) conducted a study to understand the influence of three different types of primers on the VOD of ANFO and complex ANFO blends. The VOD was measured in situ by a continuous method. It was concluded that ANFO or complex ANFO blends with the same percentage of added emulsion, density and borehole diameter had different steady VODs due to different primer properties. Mendes et al. (2014) compared the VOD for emulsion explosive sensitized with hollow glass micro-balloons and emulsion explosive sensitized with hollow polymer micro-balloons. They concluded that the nature of the sensitizing agent had no significant impact on the explosives detonation behavior.

1.2. Empirical fragmentation models

Kuznetsov (1973) suggested the following empirical equation to predict the mean fragmentation size resulting from rock blasting:

$$x_{\mathrm{m}} = AK^{-0.8}Q^{\frac{1}{6}}\left(\frac{115}{RWS}\right)^{\frac{19}{30}} \tag{2}$$

where x_m is the mean fragment size (cm); A is the rock factor (between 0.8 and 22, depending on rock hardness and structure and its derivation is given in Eqs. (3) and (4)) (Gheibie et al., 2009; Singh et al., 2016); K is the powder factor (kg/m^3); Q is the mass explosive in the hole (kg); and RWS is the explosive weight strength relative to ANFO (%). The relation between rock factor (A) and blastability index (BI), proposed by Lilly (1986), can be obtained from Eq. (3), where BI is determined from Eq. (4):

$$A = 0.06BI \tag{3}$$

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