A Numerical Approach for Simulation of Rock Fracturing in Engineering Blasting

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ABSTRACT

An approach for simulation of rock fracturing as a result of engineering blasting is presented in this paper. The approach uses element elimination technique within the framework of finite element method to capture the physics of engineering blasting. The approach does not require pre-placement of fracture paths which is the severe drawback of the other existing methodologies and approaches. Results of plane stress modelling for isotropic brittle rock behaviour are presented in this paper and these results are in good agreement with the existing knowledge base. The authors also review the existing approaches of numerical modelling to compare the efficacy of the element elimination technique. It is anticipated that the further developments with this approach can prove to be good experimental tool to improve engineering blasting operations.

Keywords: Continuum Approach, Discontinuum Approach, Element Elimination Technique, Explosive Energy, Finite Element Method, Rock Fracturing, Transient Load

1. INTRODUCTION

Rock fracturing by blasting can be best studied by understanding rock failure due to stresses under low confinement. Tensile failure (or extensile failure) is the primary mode of rock failure (Batzle et al., 1980; Blair & Cook, 1998; Kranz, 1983) whether stress loading is static or transient dynamic. In the case of rock failure by blasting, the violation to rock’s tensile strength near the blasthole periphery is overwhelming which lead to a crushing zone at the periphery of the blasthole and beyond the crushing zone, the violation results in discrete fracture network. The stress anisotropy, which is created by heterogeneity in rock properties and also the fracturing process are responsible for formation of the discrete fracture network. Stresses set out by the transient dynamic loading in a homogeneous rock mass can be understood from Figure 1. As per Figure 1, at any point in the rock mass, stress generated due to the transient loading from the circular blasthole will result in an equal amount of circumferential tensile and radial compressive stresses. Since the tensile strength of a rock is always much smaller than the compressive strength, fracturing at any point (whether in the form of crushing or discrete

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fracturing) can be understood from comparison of the tensile strength and the tensile stress values. Discrete fracturing takes place where the stress anisotropy has magnitude lower than the compressive strength but higher than the tensile strength.

Researchers still have wide differences in explaining fundamental operative mechanisms responsible for the rock fracturing by explosive energy despite its prevalent use at global scale and enormous experimental efforts made in the last half century. It can be seen from Table 1 that various theories are propounded in order to explain the failure mechanisms and there is no existence of a unified theory. The differences stem from observational difficulties associated with the prevalent experimental techniques. This is due to an extremely short duration of the explosive load on the rock (in the order of few micro-seconds), a very fast fracturing process covered under the explosive gaseous products, and rock debris (crack speed up to one third of the primary waves speed in rock) apart from the heterogeneous nature of natural materials like rock. Moreover, the prevalent experimental techniques can not have the complete control on the experiments. Continuous efforts are being made to evolve better experimental techniques in order to understand the fundamental operative mechanisms. Such an improvement will be a great aid in an effective application of explosive energy, development of better explosive products as well as safer and more economical mineral extraction procedures from mines.

Rapid advances made with numerical modelling tools and availability of faster computational resources at affordable costs make the numerical simulation as the most promising experimental method to study the dynamic rock fracturing processes. Use of the numerical simulation for dynamic rock fracturing is appealing, essential and most suitable due to a large number of complex variables are involved to deal with. This paper presents results of numerical modelling simulations, which are obtained from a newly developed numerical procedure for simulating dynamic fracturing by rock blasting (Saharan & Mitri, 2008; Saharan & Mitri, 2009). A critical review of the

Figure 1. Stress created by an explosion pressure (adapted from Timoshenko & Goodyear, 1969)
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