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Experimental and Numerical Analysis of Dynamic Fracture Processes in Rock and Rock-like Materials Using NRC Vapor Pressure Agent

Min[1] G, Fukuda[1] D, Di[2] W, Liu[3] H, Kawasaki[1] S, and *Cho[4,5]S
[1]*Graduate School of Engineering, Hokkaido University, Sapporo, Japan*
[2]*Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan, China*
[3]*School of Engineering, College of Science and Engineering, University of Tasmania, Hobart, Australia*
[4]*Department of Mineral Resources and Energy Engineering, Jeonbuk National University, Jeonju-si, South Korea*
[5]*Department of Energy Storage & Conversion Engineering of Graduate School, Jeonbuk National University, Jeonju-si, South Korea*
*Corresponding Author – Email: chosh@jbnu.ac.kr

Abstract

This study investigates the fracture characteristics of rocks and rock-like materials subjected to the Nonex Rock Cracker (NRC), a vapor pressure crushing agent. The NRC generates vapor pressure by instantaneously vaporizing a crystallized water mixture through the thermite reaction. Both experimental methods, using high-speed cameras and dynamic pressure gauges on Polymethyl methacrylate (PMMA) and granite blocks, and numerical simulations with a 3-D combined finite-discrete element method (FDEM) were utilized. Results indicate that gas pressure infiltrating pre-existing cracks primarily drives crack propagation. The study concludes that accurately modeling gas injection into initiated cracks during deflagration is essential for reasonable numerical simulations of rock fracturing processes using NRC.

Keywords: Nonex rock cracker(NRC); Vapor pressure crushing agent; Polymethyl methacrylate (PMMA); Fracture process of rock; 3-D combined finite-discrete element method (FDEM)

1. Introduction

In the field of rock blasting, controlling rock fracturing, vibration, and noise is crucial for safety, environmental considerations, and economic efficiency. Recently, the Nonex Rock Cracker (NRC) [1], a vapor pressure crushing agent, has been applied in urban areas, effectively managing these aspects while maintaining rock fragmentation efficiency. This study investigates the fracture characteristics of rocks and rock-like materials subjected to NRC, which generates vapor pressure by vaporizing a crystallized water mixture through the thermite reaction, utilizing both experimental methods and numerical simulation.

2. Analysis of Dynamic Fracture Processes in PMMA and Rock using NRC

Lab-scale tests were first conducted on a Polymethyl methacrylate (PMMA) block, a transparent artificial brittle material. High-speed cameras and dynamic pressure gauges captured vapor pressure generation and measured the pressure-time history. These tests demonstrated that main crack propagation in PMMA is driven by gas pressure infiltrating pre-existing cracks rather than dynamic loading along the borehole surface. The PMMA block fractured into two halves, displaying a simpler pattern compared to typical blasting fractures. Subsequent tests on granite blocks using NRC showed similar results, with the blocks splitting into two halves and exhibiting smooth fracture surfaces similar to those observed in the PMMA tests. To clarify the mechanism of rock fracturing by NRC vapor pressure, a 3-D numerical simulation tool specializing in the fracture process of rock based on a combined finite-discrete element method (FDEM) [2] was utilized. The rock fracture test was modeled in the 3-D FDEM by reproducing the vapor pressure applied to blast-hole of rock block based on the overpressure-time curve measured from the PMMA test, because the overpressure-time curve could not be obtained directly from the rock fracture test.

3. Results and Discussion

Figure 1 shows the resultant fracture pattern of a granite block induced by the NRC deflagration in both numerical simulation and experiment. In Figure 1(a), the numerical simulation resulted in five rock fragments, whereas the experiment showed the rock block separated into two halves. The difference in rock fracture behavior between numerical simulation and experiment may be due to the presence of gases in the experiment that penetrate the initiated crack. In the numerical simulation, the dynamic loading induced by the NRC deflagration is applied only to the blast hole surface. However, in the experiment, gases from the deflagration significantly affect rock fracturing by penetrating the initiated crack. Thus, it is concluded that gas injection into the initiated crack during deflagration should be modeled in the numerical simulation to achieve more reasonable results. This may crucial for accurately designing rock fracturing of rock masses or rock structures when a rock-crushing agent similar to the NRC is applied.

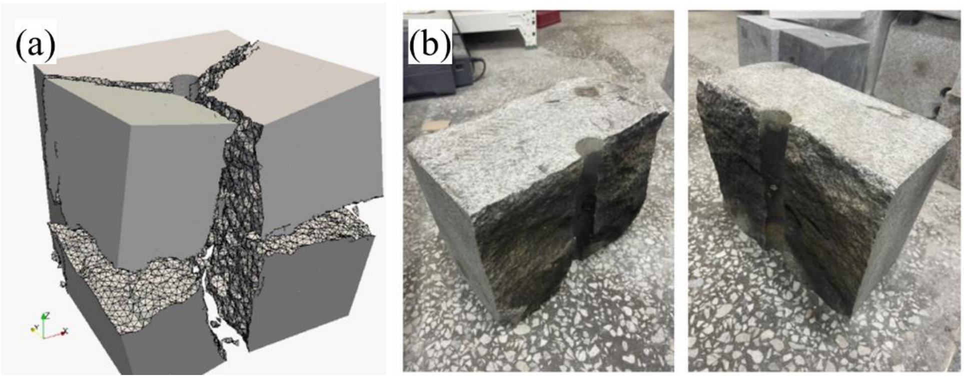

Figure 36 Resultant Fracture Pattern of Granite Block induced by the NRC deflagration in (a) Numerical Simulation and (b) Experiment

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