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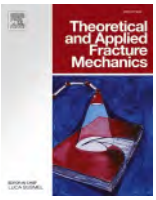

Investigating the impact of thermal treatment on fracture toughness and sub-critical crack growth parameters under mode II loading

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ABSTRACT

Studying subcritical crack growth is crucial to investigating the long-term behavior of rocks under applied loads and evaluating the long-term stability of underground and surface structures in rock masses. While considerable research has been done to determine subcritical crack growth parameters in mode I, Studies on subcritical crack growth under mode II loading are limited despite its important applications in rock engineering problems. The purpose of the study is to understand the thermal effect on the fracture behavior of hornfels rock, which were heated at 25 °C (without thermal treatment), 250 °C, 500 °C, and 750 °C, respectively. The subcritical crack growth parameters were determined using the constant stress rate test and one of the available fracture mechanics tests for mode II loading, namely, the four-point bending test. Experiments were conducted at three fixed displacement rates of 0.06 mm/min, 0.6 mm/min, and 6 mm/min, and three experiments were performed in each case to ensure repeatability. The results showed that the fracture toughness of hornfels samples increased with increasing temperature up to 250 °C and then decreased with increasing heat treatment temperature. The fracture toughness decreased drastically due to the thermal breakdown of the quartz crystal structure and the creation of wider intergranular fractures. The study indicated that for the hornfels samples, the subcritical parameter *A* decreased and beyond this temperature, parameter *A* began to increase while parameter *n* remained relatively constant as the temperature rose to 750 °C. The subcritical crack growth rate was calculated using the subcritical crack growth parameters and the stress intensity factor under mode II loading. For a certain value of the stress intensity factor K_{II}, the highest subcritical crack velocity occurred at the temperature of 750 °C (5.76×10^{-7}–2.47×10^{-1} m/s), and the lowest velocity of the subcritical crack occurred at the temperature of 250 °C (3.30×10^{-11}–6.84×10^{-5} m/s). The impact of inert strength, calculated at the highest loading rate, on subcritical parameters across various temperatures was examined. The findings indicate that the subcritical crack growth parameter A is reliant on inert strength.

1. Introduction

Fracture mechanics has gained widespread attention in the fields of science, such as geology, geophysics, and materials science, as well as in engineering, such as mining, civil, and mechanical engineering [1–4]. It is important to understand rock fracture mechanics as it can greatly contribute to the scientific development and safety of geo-structures and infrastructures [5]. To analyze various rock engineering phenomena, including blasting, hydraulic fracturing, and impact penetration, fracture toughness is a major characteristic used to indicate resistance to crack initiation and propagation. In rock fracture mechanics, cracks can expand rapidly when the stress intensity factor at the crack's tip reaches the material fracture toughness. However, if the stress intensity factor is lower than the fracture toughness, the crack grows at a slow velocity (10^{-9}–10^{-2} m/s), known as subcritical crack growth (SCG), which is responsible for brittle creep in rocks [6–8].

The growth of subcritical cracks is a significant factor affecting rock materials' mechanical behavior and long-term stability. Accurate predictions of rock behaviors in engineering applications, such as rock excavation, underground mining, and geotechnical engineering, rely on understanding the underlying mechanisms and factors that influence SCG. Managing and predicting SCG in rock slopes and underground mining operations can improve safety measures and minimize the risk of catastrophic failures [9]. Temperature, humidity, loading rate, and stress level are known to impact sub-critical crack growth in rock materials. Experimental investigations have revealed that an increase in

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