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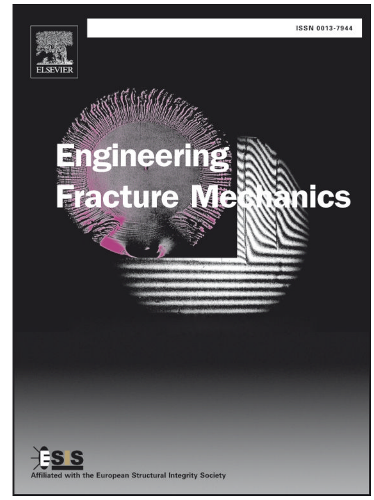

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A numerical estimate method of dynamic fracture initiation toughness of rock under high temperature

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Abstract: With the limitations of measuring techniques, limited investigation on dynamic fracture testing of rocks at high temperature is reported. In this paper, an effective measuring method of the dynamic mode I fracture toughness of high-temperature rocks, combined with laboratory tests with the Discrete Element Method (DEM), is proposed. Based on the laboratory experiments conducted, including uniaxial compressive tests under different temperature conditions, the Brazilian test and split Hopkinson pressure bar (SHPB) test, the micro-parameters of the numerical model are calibrated and the validity of the numerical model of specimens and the simulated dynamic load tests are examined. The results show that the DEM can truly reflect the mechanical properties of rocks at high temperatures, and the simulation test can capture the dynamic fracture parameters of rocks at elevated temperatures. The test data indicates that the fracture initiation toughness of specimens increases linearly with the loading rate, while the fracture initiation time detected by the measurement circle near the notch tip decreases. When the loading rate is higher than 130 GPa·m$^{1/2}$ /s, the fracture initiation toughness has a significantly negative relationship with the temperature within the temperature range of 25–400 ºC.

Keywords: Dynamic fracture toughness; High temperature; DEM; SHPB; Granite;

1. Introduction

As the depth of resource exploitation increases, the influence of temperature on rock is becoming more and more prominent. Further investigation of the dynamic failure characteristics of high-temperature rocks is critical for various engineering practices [1-3], such as core drilling, percussive and high-speed rotary drilling, and blasting produce transient mechanical and thermal loading onto rock[4]. Mode I fracture is the most commonly encountered failure mode of brittle rocks [5]. Dynamic mode I fracture toughness is the critical dynamic stress intensity factor (DSIF) of rock, which is an inherent parameter to characterize its resistance to tensile crack formation and propagation. The dynamic fracture toughness also serves as an index for rock fragmentation processes involving drilling, crushing and tunnel boring, or for the analysis of fracturing in rock blasting [6]. Therefore, an accurate determination of the dynamic mode I fracture toughness of high-temperature rocks is vital for characterizing the mechanical properties of thermal engineering materials.

Since the early studies of Tang [7], many scholars have studied rock fracture under dynamic loads with the test [8-10], and various kinds of samples, including Short Rod (SR) specimens[11], cracked straight-through notch Brazilian disc (CSTBD) specimens [12], holed-cracked flattened Brazilian disc (HCFBD) specimens [13], and notched semi-circular bend (NSCB) specimens [6], have been used to test the rock fracture toughness. Dai et al. [14] proposed a new method to measure the dynamic fracture toughness of rocks using a notched semi-circular bend specimen and investigated the inertial effect. They demonstrated that the dynamic fracture toughness can be calculated by substituting the experimental measured peak load into the quasi-static equation if the dynamic force balance is achieved. Iqbal [12] conducted dynamic testing to investigate the strain rate effect on rock strength and fracture toughness using the standard unconfined Brazilian disc and straight-through notch Brazilian disc respectively. Chen et al. [15] investigated the fracture initiation toughness of Heshuo granite under a pre-load of 0, 37 and 74 % of the maximum static load based on the split Hopkinson pressure bar system and finite element analysis method. Zhang et al. [16] employed micro-measurement techniques to identify the micrograph and surface morphology of fractured rock specimens under dynamic load. Zhang et al. [17] analyzed quantitatively the energy partitioning in the dynamic fracture process of a short rod (SR) rock

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