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Cracking behavior of three types granite with different grain size containing two non-coplanar fissures under uniaxial compression

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ABSTRACT

Granite, an excellent medium for deep geological disposal projects, geothermal systems and geological carbon storage, may be affected by its grain size and pre-existing flaws. Thus, three types of granite specimens with different grain sizes containing two non-coplanar fissures under uniaxial compression were investigated experimentally and numerically. Notably, the ligament angle had more effect on the peak strength than the grain size. With an increasing ligament angle, the angle between the crack and the principal stress did not show an obvious trend for $\beta \le 60^\circ$, whereas the angle between the crack and the principal stress increased when $\beta \ge 60^\circ$. This trend is similar to that for the peak strength. For the same ligament angle, the angle between the crack and the principal stress increased as the grain size decreased. Based on the micro-structure of the crack surface in the ligament ($\beta = 60^\circ$), the hypothesis that a shear crack is more difficult to initiate in coarse granite specimens than in fine granite specimens was presented and verified by experiments and numerical simulations.

1. Introduction

Granite, an excellent medium for deep geological disposal projects [1], geothermal systems [2], and geological carbon storage [3], has been investigated by many researchers [4–6]. Zhao et al. [7–9] studied the deformation, peak and post peak strength characteristics of Beishan granite and compared the strength between cylindrical and prism specimens under uniaxial compression. Shao et al. [10] detected that the failure modes of Strathbogie granite specimens changed from brittle fracturing to quasi-brittle shear fracturing and eventually to ductile failure with increasing temperature. Kumari et al. [11] found that the granite strength and shear parameters first increase and then decrease with increasing temperature. Zhao et al. [12] used 600 °C 200 MPa servo-controlled triaxial compression system to study the evolution of mesostructured granite specimens under high temperature and high pressure. Wang and Hu [13] measured the tensile strength and fracture

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toughness of granite on three-point-bend samples of a single size but with different notches. Tian et al. [14] carried out a laboratory program to investigate the mechanical behavior of diorite exposed to high temperatures up to 1000 °C.

Rock is a naturally occurring geological material that usually includes uneven flaws of various shapes [15], such as holes [16], fissures [17], joints [18] and inclusions [19]. In the past several decades, many efforts have been undertaken to better understand these natural flaws [20–26]. Wong and Einstein [27,28] studied cracking and coalescence behavior with prismatic laboratory-modelled gypsum and Carrara marble specimens containing two parallel pre-existing open flaws, and tensile cracking generally occurred more often in the marble than in the gypsum. Park and Bobet [29] presented a comparison between experimental observations made from gypsum specimens, with open and closed flaws, and observed three types of cracks. Lee and Jeon [17] used three materials (Poly Methyl MethAcrylate, gypsum and Hwangdeung granite) to investigate crack initiation, propagation and coalescence near flaws in specimens containing two unparallel fissures. Zhang and Wong [25] studied cracking and coalescence behavior in a rectangular rock-like specimen containing two parallel pre-existing open flaws under uniaxial compression by a bonded-particle model. Yang [30] and Yang et al. [15] presented crack coalescence behavior of brittle sandstone samples containing two coplanar and non-coplanar fissures.

It is well known that granite always has different grain size, and that grain size has an effect on the mechanical behavior of granite [5,31]. Therefore, investigating the crack coalescence behavior of granite specimens with different grain sizes is significant. In this paper, three types of granite with different grain sizes containing two non-coplanar fissures were carried out under uniaxial compression. First, the mechanical behavior of three types granite with different grain sizes containing two non-coplanar fissures were presented. Then, crack evolution was studied. Finally, a hypothesis to explain the different coalescence types for the same ligament angle with different grain sizes was put forward, and two cases and a particle flow code were cited to verify the hypothesis.

2. Rock specimens generated by PFC^{2D}

2.1. *The different granite materials*

Three types granite were adopted for testing to study the crack coalescence behavior of granites with different grain sizes containing two non-coplanar fissures under uniaxial compression. The microscopic structure of the three granite types are presented in Fig. 1, it is clear that the granites have a crystalline and blocky structure regardless of the type of granite. The enlargement factor of the granites is 50. The grain size of fine-granite range from 0.10 to 0.40 mm (Fig. 1a); the grain size of medium granite ranges from 0.24 to 0.89 mm (Fig. 1b), and the grain size of coarse-granite range from 0.77 to 1.16 mm (Fig. 1c).

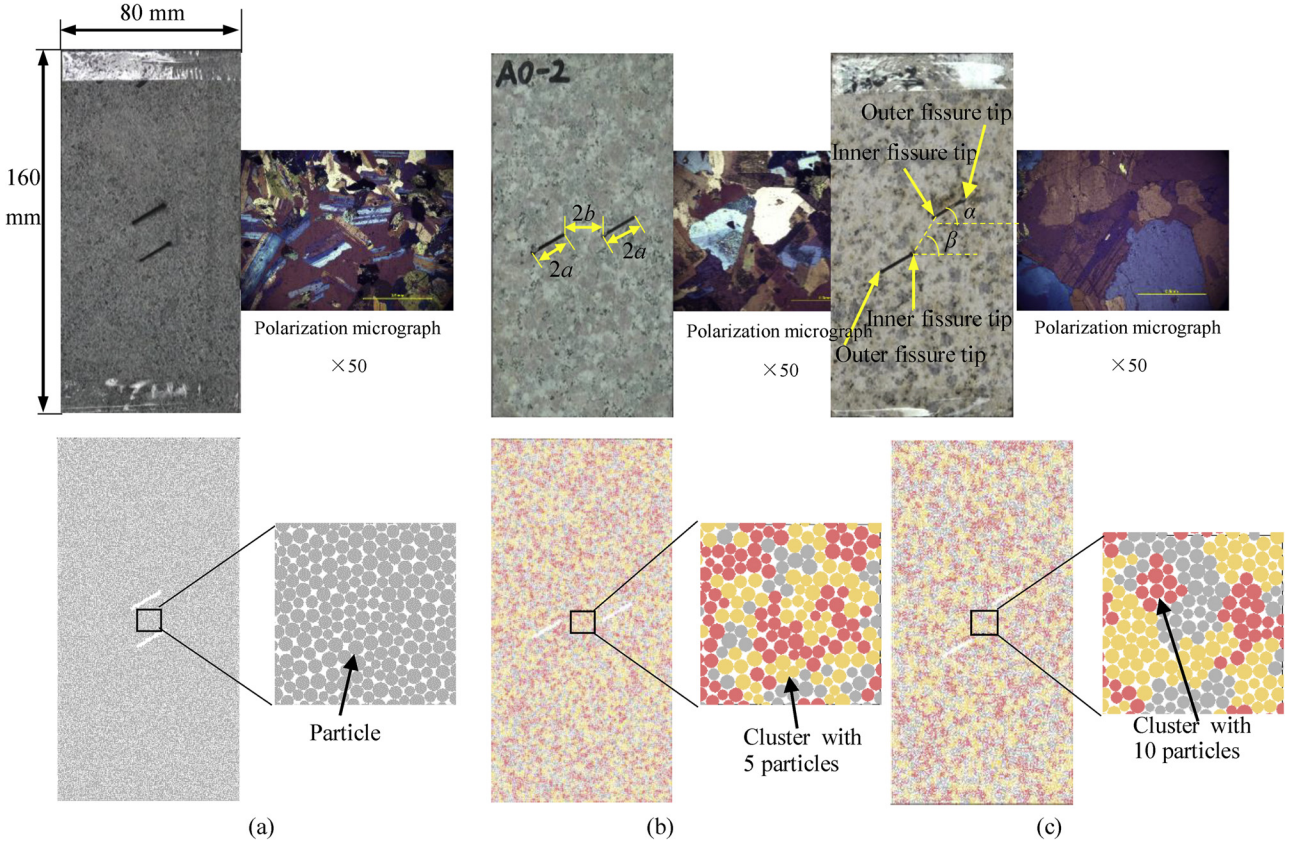

Fig. 1 – Microscopic structure of the different granites obtained by video microscope: (a) fine granite, (b) medium granite, (c) coarse granite.