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Digital features of main constituents in granite during crack initiation and propagation

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ABSTRACT

The purpose of this study is to investigate the digital features of various constituents on granite specimen in the crack initiation and propagation process. The test video image photographed during laboratory uniaxial compression test and digital image processing techniques were used to conduct this study. The video image was first converted into the format easily recognized in programming. A multiple-object tracking technique was then developed to detect the locations of the individual cracks at any time. The initiation of each crack was determined by the occurring instant of the bounding box including the cracks. The length, width and area of each crack at any time were thereafter recorded. The relation of the propagation process with digital features of the constituents in various locations was furthermore investigated. It shows that two cracks propagated respectively along the vertical and horizontal directions as uniaxial compression test was performed; a limit box technique can be used to determinate the initiation instants of the multi cracks on the specimen surfaces; during propagation, the width of the cracks increased quickly just after initiation, and then fluctuated around a magnitude until the completely failure of the specimen; the constituents near the crack would split as the crack initiated; the shape features of biotites, feldspar and quartz changed in different manners during crack's initiation and propagation. The technique presented herein may be referable in investigating the failure mechanism of rock materials.

1. Introduction

The process of the crack initiation and propagation in a rock is of great importance in understanding the deformation/failure process of the rock material. In conventional methods, this process is examined usually by the analysis of specimen appearances in the laboratory tests.

From the observations in the laboratory tests, it is known that the crack initiates in the matrix (Amann et al., 2014; Ündül et al., 2015) or in the contacts (Seo et al., 2002). The weakening zone may generate near the moving crack tips (Ghaffari et al., 2016). The crack propagation are much dependant on the stress magnitude, micro-damage localization (Seo et al., 2002; Manouchehrian and Marji, 2012) and mineralogical features such as type, percentage, and microstructure (Eberhardt et al., 1998; Diederichs et al., 2004; Rigopoulos et al., 2011; Lin and Labuz, 2013; Amann et al., 2014; Ündül et al., 2015), and eventually change the strength of rocks (Tugrul and Zarif, 1999; Suorineni et al., 2009; Heap et al., 2010). The orientation, velocity, and length of crack propagation are much related to the crack types (Rigopoulos et al., 2013).

To obtain more details in crack initiation and propagation, the image processing techniques were performed (Rigopoulos et al., 2013). The related displacements were exactly measured using digital image correlation (Lin and Labuz, 2013). Using the static digital image analysis, Åkesson et al. (2004) found that the new cracks occurred mainly within feldspar in granite and propagated parallel to a joint set. The SEM (Scan Electronic Microscopy) images were used to examine the propagation of cracks within different rock types (Wong, 1982; Bobet and Einstein, 1998; Sousa et al., 2005). The video images were also used to track the movement of crack by taking crack as tracking targets (Han et al., 2013).

Nevertheless, the details of crack initiation and propagation, as we know, are not clear. The test video images reflect these details and were used in the current study. Due to the universality and diversity of the granite (Eiler, 2007), the specimen of this rock under laboratory compression test would be used to investigate the initiation and propagation process of multi-cracks. The initiation instant and propagation of cracks were monitored by using the test video images photographed during the laboratory test. The changes in the digital features of the cracks and constituents at various locations and their relations with the initiation and propagation process would be also examined.

2. Tracking of multi cracks using test video image

2.1. Test video image and pre-processing

The rock type used in the current study is the Baishan granite, located in Gansu Province, China. The investigated rocks are composed of

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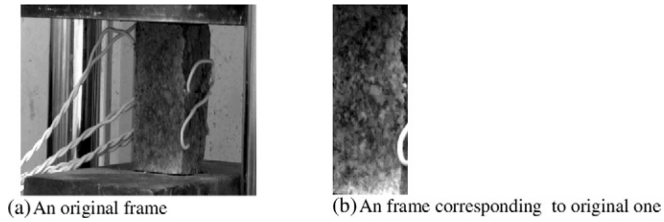

Fig. 1. The 2751st and corresponding 1st frame respectively in original and extracted video images.

feldspar, quartz and biotite. In laboratory, the rock was sliced and polished into the specimens with the size of around 50 mm × 50 mm × 100 mm. The uniaxial compression tests for the specimens were performed using the YE-2000 type of hydraulic machine, produced by the Zhejiang Jingyuan Machinery Company Limited, China. The external stress data on the plate were acquired using the SmartTest Computer-controlled System.

During the laboratory tests, the video images were photographed using a Sony Cybershot DSC-W5 digital camera with a sensor resolution of 5.0 mega pixels by leveling the camera normal to the specimen surface. The distances from the camera to the specimens were about 0.5 m. One of the video images was used to perform the following analyses. The total of the video image occupied 119.1 s with 2978 frames at a rate of 25 frames per second. One frame in the video image continued 0.04 s (1/25 = 0.04).

To shorten the later processing, the original video image was preprocessed using MATLAB codes, including: (1) decompression of the original video images into the 24 colorful ones with the AVI format; (2) selection of the frames if the cracks were included (or, the frame numbers of 2751–2850 were selected); and (3) selection of the areas with the cracks (or, with the area of 270 pixel × 790 pixel). The original video image was then transferred into one with 100 frames at an interval of 4.00 s. The 2751st frame in the original video image and corresponding 1st frame in the new video image were shown in Fig. 1.

2.2. Tracking of multi cracks

The crack initiation much reflects the local heterogeneity but there was no accepted method to define the crack initiation instant. In the current study, the cracks were treated as the moving objects and an image-based technique was proposed.

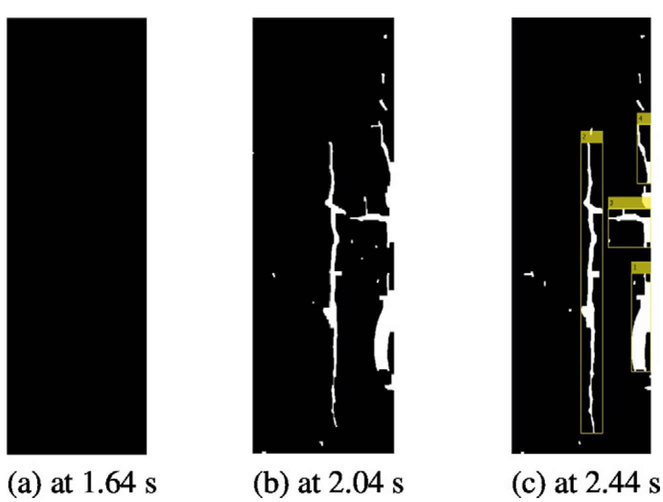

Fig. 2. Binary frames at different instants.

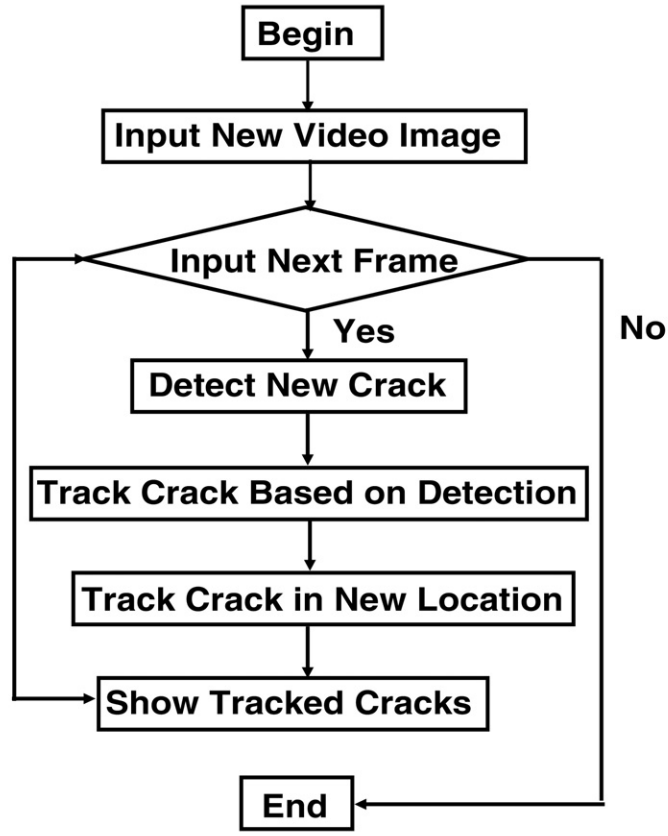

Fig. 3. Flowchart of multiple crack tracking.

For each frame in the test video image, the threshold segmentation, background subtraction, and morphological operation were used to remove the noises and extract the regions including multi cracks. The appearance of a crack was validated if it occurred in 8 successive frames. A super-position box out of the crack region was drawn out if the crack appeared.

The initiation instant of a crack was set as the time corresponding to the preceding 8th frame when a super-position box occurred. For example, if the time when the super-position box first occurred was at 2.40 s, the initiation instant would be 2.08 s (=2.40–0.32 s). The interval 0.32 s was used because each frame occupied 0.04 s (mentioned above) and the interval of 8 successive frames is 0.32 s.

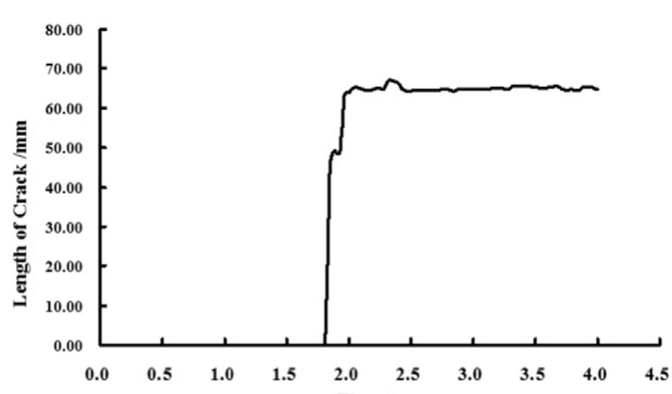

Fig. 4. Length with time of vertical crack.