EARTHQUAKE AND CRACK GROWTH PATH IN THE ROCK MASSES UNDER SHEAR LOADING

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The earthquake as a kind of loading may cause to fail the rock structures such as mines, oil and gas wells, tunnels, dams, etc. Since the rock masses have naturally enormous cracks and discontinuities, they are more vulnerable to damage and failure under earthquake loading. Therefore, the fracture of rock masses due to cracks under earthquake should be considered by mining and civil engineers. As an important issue for controlling the stability of cracked rock structures, the path of crack growth should be determined. For this purpose, the fracture mechanics concepts are used. Fracture mechanics is a branch of mechanical engineering science for analyzing the cracked structures and has been frequently used by civil and mining engineers and researchers to predict the onset of fracture and fracture path in the cracked rock structures. Because of arbitrary orientation of cracks relative to the loading directions, brittle fracture in rocks may occur due to a combination of two major fracture modes, i.e. crack opening mode (mode I) and crack sliding mode (mode II). The crack under pure mode I loading propagates usually in its original direction, while the fracture in cracked structures under mixed mode and pure mode II loading takes place from the crack tip along the curvilinear paths. There are several methods for predicting the fracture trajectory after the initiation stage. Using Cohesive elements (Lens et al., 2009), extended finite element method (Xu and Yuan, 2011) and incremental crack growth method (Aliha et al., 2010) are among the favourite methods for predicting the crack growth paths in mixed mode loading. The aim of this paper is to predict the fracture trajectory in rock specimen under pure mode II loading by using the incremental crack growth method. This method involves a large number of small crack extensions in appropriate directions. The direction of crack growth for each increment is assumed to be normal to the direction of maximum tangential stress according to the maximum tangential stress (MTS) criterion (Erdogan and Sih, 1963). In the present study, the direction of maximum tangential stress is determined by three methods: 1) using only the singular terms for characterizing the tangential stress component around the crack tip $\sigma_{\theta\theta}$, 2) using the second term in stress series expansion so-called T-stress term in addition to the singular terms for describing $\sigma_{\theta\theta}$, 3) using the third stress terms together with the singular and T-stress terms. Indeed, the effect of stress terms on the fracture trajectory is investigated in the present study. After calculating the direction of maximum tangential stress, the crack was remodelled with a small extension along the calculated direction and the same procedure was repeated for the next increment till the whole fracture path was predicted. In order to assess the effect of stress terms on the fracture path, the experimental results reported by Aliha et al. (2010) are considered here. They conducted several fracture tests on the center-cracked circular disk (CCCD) specimens made of Guiting limestone. The CCCD sample is a circular disk of radius R containing a center crack of length $2a$ as shown in Figure 1. The state of mode mixity in this specimen is controlled by changing the direction of crack relative to the load line, i.e. the crack angle α. The CCCD specimen is subjected to pure mode II loading when the crack angle a reaches to a specific value α_{II} according to the ratio of a/R. For example, the value of α_{II} fir tested specimen with a/R=0.3 is determined as 27° using finite element analysis (Ayatollhi and Aliha, 2007).

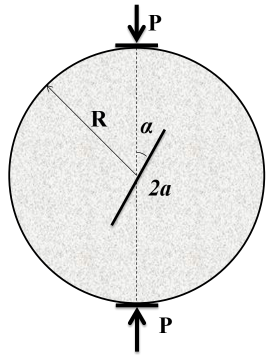

Figure 1. The schematic of CCCD specimen

Using the incremental crack growth method, the fracture trajectory of tested specimen is predicted by three mentioned methods as illustrated in Figure 2. As seen from this Figure, the stress terms affect significantly on the fracture path predicted by incremental crack growth method. It should be noted that the coefficients of stress terms are determined in each increment by employing the finite element over-deterministic method.

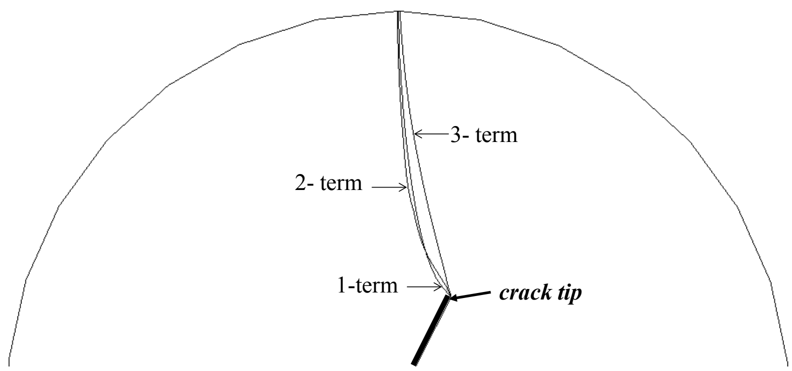

Figure 2. The fracture path predicted by incremental crack growth method

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