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Development of a Numerical Simulation Method for Complex Fracture Process of Rocks Based on 3-D ECZM-FDEM using GPGPU Parallel Computation

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Abstract

For the developments of surface and underground mines, numerical simulation has been regarded as a highly crucial approach in terms of mining design and safety. The combined finite-discrete element method (FDEM)[1] has attracted significant attention for reasonably simulating very complex fracture processes of rocks. FDEM is based on the continuum mechanics model considering finite-strain theory, the cohesive zone model (CZM)[2] by utilizing initially zero-thickness cohesive elements (CEs) and potential-based contact mechanics model. The FDEM based on the intrinsic CZM (ICZM), which inserts the CEs at the onset of the simulation, has been the mainstream of previous studies applying FDEM due to its simpler implementation. Although the FDEM is generally known as a computationally expensive numerical method for both two-dimensional (2D) and three-dimensional (3D) problems, the computational acceleration of the ICZM-based FDEM can be achieved with relative ease through parallel computation using general-purpose graphics processing units (GPGPUs). However, the accuracy of continuous deformation when rock is intact is significantly compromised in the ICZM. The FDEM based on the extrinsic CZM (ECZM), which activates CEs only when and where the local stress reaches the given activation criteria, is expected to overcome this issue. However, although the implementation of 2-D ECZM-based FDEM with the GPGPU parallel computation has been reported, its 3-D counterpart has not been achieved. Based on this background, this study proposes a novel master-slave algorithm to achieve the implementation of the GPGPU-parallelized 3-D ECZM-based FDEM. Figure 1 shows the examples results of GPGPU-parallelized 3-D ECZM-based FDEM for uniaxial compression test simulation and spalling test simulation [3]. These results indicate that the developed ECZM-FDEM can reasonably reproduce the fracture and failure patterns of rocks in both static and dynamic tests compared to laboratory tests. The significant advantage of the proposed approach lies in the fact that the precision of continuous deformation can compared to those of the parallelized ICZM-based FDEM. The proposed approach could be an important basis for the further developments of the ECZM-based 3-D FDEM for simulating very complex 3-D rock fracturing processes in the various rock engineering problems.

Keywords: 3-D Combined Finite Discrete Element Method (FDEM); Fracture process of rocks; Extrinsic Cohesive Zone Model (ECZM); GPGPU parallel computation

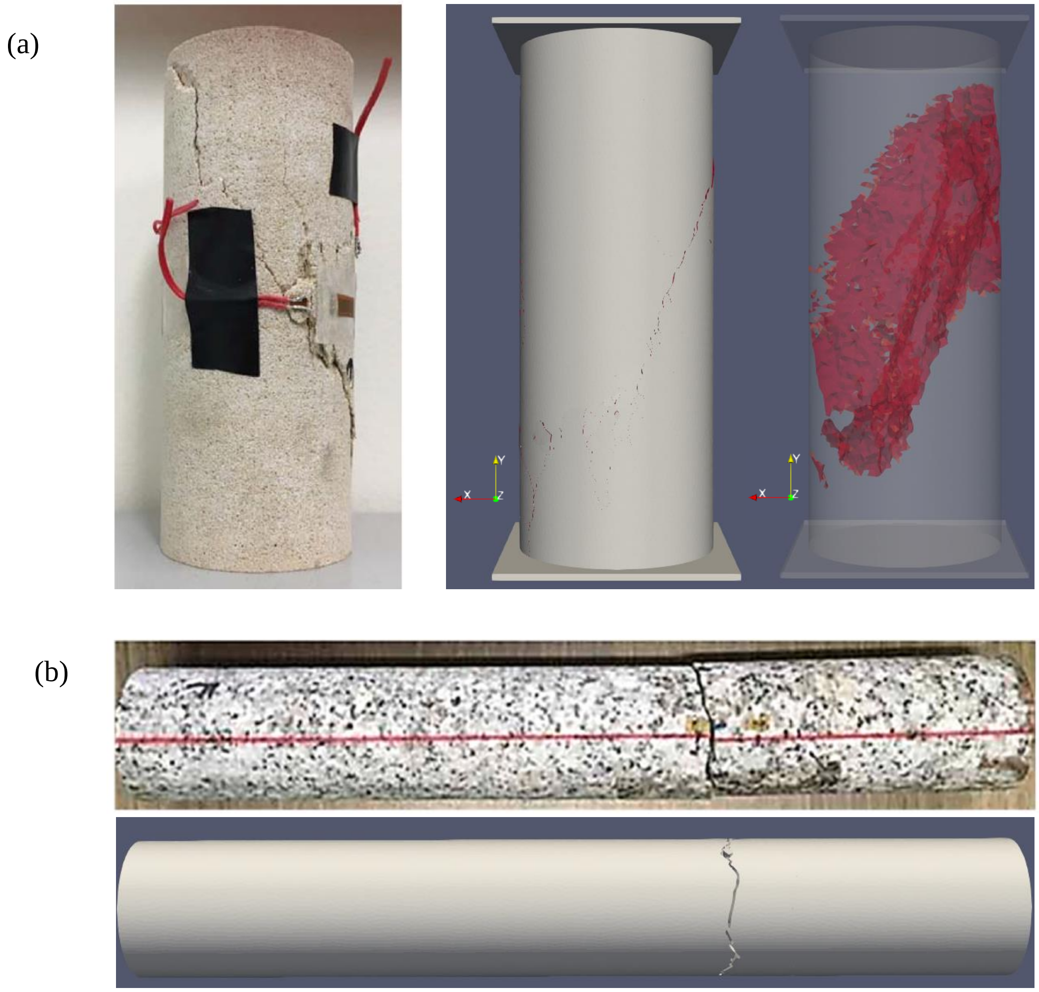

Figure 1. Comparison of the resultant fracture pattern in numerical simulation results with experimental results; (a) uniaxial compression test [1] and (b) spalling test [3]

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