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Elastoplastic Modified Stillinger Weber-Potential Based Discretized Virtual Internal Bond and Its Application to the Dynamic Fracture Propagation

Authors : Dina Kon Mushid, Kabutakapua Kakanda, Dibu Dave Mbako

Abstract : The failure of material usually involves elastoplastic deformation and fracturing. Continuum mechanics can effectively deal with plastic deformation by using a yield function and the flow rule. At the same time, it has some limitations in dealing with the fracture problem since it is a theory based on the continuous field hypothesis. The lattice model can simulate the fracture problem very well, but it is inadequate for dealing with plastic deformation. Based on the discretized virtual internal bond model (DVIB), this paper proposes a lattice model that can account for plasticity. DVIB is a lattice method that considers material to comprise bond cells. Each bond cell may have any geometry with a finite number of bonds. The two-body or multi-body potential can characterize the strain energy of a bond cell. The two-body potential leads to the fixed Poisson ratio, while the multi-body potential can overcome the limitation of the fixed Poisson ratio. In the present paper, the modified Stillinger-Weber (SW), a multi-body potential, is employed to characterize the bond cell energy. The SW potential is composed of two parts. One part is the two-body potential that describes the interatomic interactions between particles. Another is the three-body potential that represents the bond angle interactions between particles. Because the SW interaction can represent the bond stretch and bond angle contribution, the SW potential-based DVIB (SW-DVIB) can represent the various Poisson ratios. To embed the plasticity in the SW-DVIB, the plasticity is considered in the two-body part of the SW potential. It is done by reducing the bond stiffness to a lower level once the bond reaches the yielding point. While before the bond reaches the yielding point, the bond is elastic. When the bond deformation exceeds the yielding point, the bond stiffness is softened to a lower value. When unloaded, irreversible deformation occurs. With the bond length increasing to a critical value, termed the failure bond length, the bond fails. The critical failure bond length is related to the cell size and the macro fracture energy. By this means, the fracture energy is conserved so that the cell size sensitivity problem is relieved to a great extent. In addition, the plasticity and the fracture are also unified at the bond level. To make the DVIB able to simulate different Poisson ratios, the three-body part of the SW potential is kept elasto-brittle. The bond angle can bear the moment before the bond angle increment is smaller than a critical value. By this method, the SW-DVIB can simulate the plastic deformation and the fracturing process of material with various Poisson ratios. The elastoplastic SW-DVIB is used to simulate the plastic deformation of a material, the plastic fracturing process, and the tunnel plastic deformation. It has been shown that the current SW-DVIB method is straightforward in simulating both elastoplastic deformation and plastic fracture.

Keywords : lattice model, discretized virtual internal bond, elastoplastic deformation, fracture, modified stillinger-weber potential

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