A Non-ordinary State-based Peridynamics implementation of Ceramic Material Brittle Fracture

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Abstract

It is quite common used for ceramic materials in protective armor applications. They often encounter high-speed ballistic impacts in these situations, and may undergo quite dramatic deformation and high strain-rate. Damage and fracture play vital role in such kind of progress, and are very important to represent the realistic process by numerical simulations. Traditionally, such problems are handled by finite element method, which may inducing mesh distortion and mass loss, and need particle-converting technic to overcome such shortcoming [1].

In 2000, a new coarse particles-based method named Peridynamics was introduced by Silling from Sandia National Laboratory [2], and later being modified [3]. The latter one has been approved to be converged to the classic continuum mechanics [4]. This approach describes objects using material particles that carry physical properties, such like mass, velocity, acceleration. The interactions between particles are realized by their bonding. By utilized different force function on each bond, the material behaves different mechanical and physical properties. By breaking bonds between pairs of particles, crack and fracture are naturally formed within the Peridynamics framework.

In this work, the damage and fracture of brittle materials is remodeled and represented with a non-ordinary state-based Peridynamics theory. We first recall the state-based Peridynamic theory and its governing equation. Then, by utilizing the Cauchy-Born rule, we relate the strain state of a material point with the configuration of its surrounding neighborhood within the horizon. The surrounding configuration of a material point is described by its moment matrix [5]. The Johnson-Holmquist (JH) constitutive and damage model [6] is used to obtain the stress measure from the strain state of the material point, which taken into account of high strain-rate, effect of bulking, damage and fracture. Nevertheless, in current work, the damage is not only affected by the plastic strain accumulated in the material itself, but also linked with the bonding between the Peridynamic material points. The implementation is then validated by several cases as the same as those in reference [5]. One would expect the numerical results given by Peridynamic model for brittle materials comparable with that obtained from FEM. Moreover, Peridynamic model has the ability to form and represent the damage or fragment naturally without deleting elements or conversion to particles. At last, a few benchmark examples are carried out to demonstrate the ability of this model. The results show good agreements between the numerical simulations and the experimental results.

Keywords: Brittle Fracture, Johnson-Holmquist model, Peridynamics, Non-local model.

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