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Dynamic non-planar crack rupture by a finite volume method

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Seismic ruptures are usually modelled by finite difference (FDM), finite element (FEM) and boundary integral equation (BIEM) methods. These methods turn out to be efficient at the expense of simple medium description, or a loss of accuracy near the crack, or require many mesh points per wavelength and therefore a high computational cost. Other numerical methods, as the discontinuous Galerkin time-domain methods (DGTD), and particularly finite volume time-domain (FVTD) approach, have been succefully used for Maxwell's equations, and recently for wave propagation applied to the elastodynamic equations. We propose here an original finite volume approach, which we apply to the dynamic crack rupture problem for an arbitrary geometry of the crack surface. After transformations for building up the partial differential system following explicit conservative law, we design an unstructured bidimensional time-domain numerical formulation of the crack problem. As a result, arbitrary non-planar faults can be explicitly represented without extra computational cost. Through a careful analysis of total discrete energy, we specify boundary conditions on the crack in order to insure the correct discrete energy time variation and, therefore, the system stability. These boundary conditions are set on stress fluxes and not on stress values, which makes the fracture to have no thickness. The comparision with the Kostrov's analytic solution when rupture grows with predefinite constant velocity shows how it is important to refine the mesh nearby the crack surface. We also discuss the spontaneous dynamic crack rupture by considering a simple slip-weakening friction law. Since no theorical solutions are available, we study the influence of the mesh on numerical solutions and find out a minimal mesh segments that must be kept inside the cohesive zone to insure the accuracy of the results. We end up by two illustrations of

non-planar rupture evolution. The first shows the kink effect for the spontaneous rupture propagation where the mesh configuration has a strong influence while the second geometry handles smoothly curved fault propagating through a velocity discontinuity showing the influence in the rupture velocity regardless the mesh we are using as long as it is fine enough.