ABSTRACT

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A technique has been developed to couple the Finite Element Method (FEM) and the Smooth Particle Hydrodynamics Method (SPH) in the Lagrangian framework, named as "*Hybrid*" method. This method combines the capabilities of FEM and SPH together so that simulation of problems involving solids and structures under shock loading can be performed effectively. In geomechanics, one of the major applications of large deformations and large strains is the simulation of rock blasting phenomenon. For such problems FEM suffers from mesh distortion and thus requires numerical corrective measures such as element erosion or re-meshing to proceed with the solution. This causes artificial effects and a sufficient increase in the computational time. Mesh-less particle based methods such as Smooth Particle Hydrodynamics (SPH), on the other hand offers the flexibility to handle high-speed motion inherently. But the SPH method is more computationally demanding and requires special treatment for application of boundary conditions. For the simulation of certain process that involve high impact loads by fluid on solids or structures such as blasting, a coupled FEM-SPH procedure may be more efficient where regions of large deformations are modeled with SPH particles and unaffected regions are modeled with FEM. However, this requires an adaptive algorithm to declare the onset of element distortion or damage and then to convert elements into SPH particles. In this work, an adaptive procedure of coupling FEM-SPH is developed so that highly distorted or damaged elements in the model are replaced by SPH particles on the fly but remain linked to the model thus maintaining the compatibility in velocity and momentum at the FEM-SPH interface. Rock material is modeled considering Drucker-Prager plasticity with Grady-Kipp damage theory. The JWL equation of state is applied for the explosive burnt gas. The work provides the details of this adaptive procedure. Further, a few numerical stabilization schemes are also implemented in the hybrid code for simulating real problems. A detailed step-by-step outline of the developed algorithm is provided in the thesis. Validation of this coupling method is carried out by analyzing a simple 2-D elastic impact problem and a 2-D beam bending problem. The adaptive coupling is then applied for the 2-D simulation of fragmentation in brittle rocks under plain strain conditions in real-size model of a mining bench induced by high impact blast loads from explosions. An example of slope stability problem excited by ground motion is also solved and analyzed. Lastly, it is envisaged that this research will open up the doors for a new way of simulating fast transient problems in large scale geomechanics problems such as crack propagation in hydro-fracturing, blast simulation and others.

Keywords: Finite Element Method, Smoothed Particle Hydrodynamics, Hybrid Method, Element damage or distortion, High Impact Load