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Concrete fragmentation modeling using coupled finite element - meshfree formulations

Youcai Wu*, Hyung-Jin Choi and John E. Crawford

Karagozian & Case (K&C), 700 N. Brand Blvd., Suite 700, Glendale, CA 91203, USA

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Abstract. Meshfree methods are known to have the capability to overcome the strict regularization requirements and numerical instabilities that encumber the finite element method (FEM) in large deformation problems. They are also more naturally suited for problems involving material perforation and fragmentation. To take advantage of the high efficiency of FEM and high accuracy of meshfree methods, a coupled finite element (FE) and reproducing kernel (RK, one of the meshfree approximations) formulation is described in this paper. The coupling of FE and RK approximation is implemented in an evolutionary fashion, where the extent and location of the evolution is dependent on a triggering criteria provided by the material constitutive laws. To enhance computational efficiency, Gauss quadrature is applied to integrate both FE and RK domains so that no state variable transfer is required when mesh conversion is performed. To control the hourglassing that might occur with 1-point integrated hexahedral grids, viscous type hourglass control is implemented. Meanwhile, the FEM version of the K&C concrete (KCC) model was modified to make it applicable in both FE and RK formulations. Results using this code and the KCC model are shown for the modeling of concrete responses under quasi-static, blast and impact loadings. These analyses demonstrate that fragmentation phenomena of the sort commonly observed under blast and impact loadings of concrete structures was able to be realistically captured by the coupled formulation.

Keywords: Reproducing Kernel (RK); Finite Element (FE); coupled FE/RK; fragmentation; concrete

1. Introduction

Since its origination (Courant 1942), the finite element method (FEM) has been widely documented in the literature and a number of implicit and explicit FEM solvers, such as ANSYS, LS-DYNA, DYNA3D and ADINA, have been developed. The discretization of the problem domain in FEM is achieved by using elements, typically with very simple shape functions and high order quadrature rules. FEM has been proved itself to be a robust analysis method for numerous varieties of engineering and scientific problems. However, in applications, FEM is known to have difficulties with problems involving large deformations and moving discontinuities, such as the extremely large deformations incurred in some manufacturing processes, or the growth of cracks with arbitrary and complex paths present in failure (fragmentation) processes. For these kinds of problems, the finite element solution is highly mesh-dependent.

*Corresponding author, Professor, E-mail: wu@kcse.com

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