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MIXED TIME-STEPPING FOR COUPLED MESHFREE AND FINITE ELEMENT SIMULATIONS

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ABSTRACT

Over the last decade, meshfree methods have gained significant traction in the computational solid and structural mechanics community for simulation of complex physical phenomena [1-3]. One finds that conventional finite element methods suffer from several shortcomings when applied to problems involving extreme loads such as blasts and impacts. For instance, a strong mesh dependence of the crack path is observed in fracture simulations. For problems involving very large deformations, accuracy of the results is greatly influenced by the deterioration of the mesh with deformation. Implementation of other physical phenomena such as brittle fragmentation and capturing the post fragmentation response is also problematic with finite elements. Meshfree methods alleviate some of the difficulties associated with mesh dependence and mesh quality. However, depending upon the implementation, the computational cost associated with meshfree methods is usually significantly greater than that of finite element methods. In addition, special consideration is needed for the enforcement of essential boundary conditions [4] and for obtaining an accurate and stable numerical integration of the discrete meshfree formulation [5].

A natural solution that allows one to capitalize on the best of both methods is to couple meshfree methods with finite elements. Here, large parts of the problem domain are solved with finite elements and a meshfree discretization is used only in the regions where finite elements are insufficient to capture the desired response. These are usually regions with high spatial gradients, which often also warrant a finer temporal resolution. Thus, in addition to the coupling of meshfree methods and finite elements in space, a multi-time-step coupling [6] of the two is also required in the time domain. Some outstanding issues associated with such a multi-time-step coupled approach and their potential resolutions are explored in this study.

Several approaches for coupling meshfree methods and finite elements have been suggested in the literature [7]. These include the master-slave coupling of particles to finite element nodes, the use of blended discretizations using ramp functions, the *bridging domain* method with Lagrange multipliers and using hybrid discretizations by enrichment of an underlying particle or finite element discretization with higher-order shape functions. The performances of some of these approaches are evaluated in the present study. Particular attention is given to the effect of the presence of a numerical

interface between different discretizations, especially when using multiple time steps between them. Numerical artefacts such as wave reflection and refraction at such interfaces and methods to eliminate them are also explored.

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