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Hyperbolic phase field modeling of brittle fracture: part II—immersed IGA–RKPM coupling for air-blast–structure interaction

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Abstract

Part I of this series introduced a formulation of phase field fracture in which the inclusion of micro-scale inertia leads to a hyperbolic system of partial differential equations governing the coupled problems of nonlinear elasticity and material damage. This paper applies that formulation to a coupled isogeometric–meshfree discretization of compressible fluid–structure interaction that discretizes the damage field's governing equation using the reproducing-kernel particle method and the fluid–structure momentum balance equation using isogeometric analysis. The hyperbolic character of the coupled system permits efficient fully-explicit time integration of the entire system (not just the momentum equation, as in previous semi-implicit procedures for phase field analysis of dynamic fracture). Results for dynamic fracture problems match those computed in Part I using implicit time integration and standard finite elements. However, the isogeometric–meshfree discretization of this paper provides greater flexibility in representing structural fragmentation from blast loading. The blast loading computations at the end of this paper demonstrate the model's ability to represent extreme events involving air-blast–structure interaction.

Keywords: Phase field, Fracture mechanics, Air blast, Immersed methods, Isogeometric analysis, RKPM

1. Introduction

In Part I of this series, we introduced a hyperbolic partial differential equation (PDE) for phase field modeling of brittle fracture. We derived this model by extending the microforce balance theory of Borden et al. [1, Section 2.3] to include microscopic inertia. The properties of this new model were explored by simulating well-studied brittle fracture scenarios using a standard

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