Numerical Simulation of Underwater Explosions Using Unstructured Grids

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Abstract: The five-equation model for compressible two-phase flows has been extended to unstructured grids in order to model underwater explosions (UNDEX) close to complex geometries. The ideal equation of state (EOS) is used for air. The stiffened gas EOS is used for water. The Johnes-Wilkins-Lee (JWL) EOS is used for the high-explosive (HE) material to describe a simplified detonation process. A general formulation is written to include these different EOSs. A sharpening technique based on the hyperbolic tanget interpolation (THINC) is adopted to capture the transitioning interface. After verifying the accuracy of the numerical schemes against analytical and experimental results, 'best practice guidelines' have been developed to assure reliable results.

Keywords: Computational Fluid Dynamics, UNDEX, THINC limiter.

1 Introduction

Underwater explosions (UNDEX) have always been of interest for both military and civilian applications. The aim of the current work is to establish a mathematical model that is suitable for this class of problems. Any such model must take into account the three fluids that interact: air, water and HE. Although a large body of work has been published for two-phase problems, publications for three fluids are less common, especially with HE. This work aims to establish a simple and robust numerical method for UNDEX problems on vertex-centered unstructured grids.

The regarding governing equation for the three-fluid model is a system of eight equations: the continuity and transport equation for air, water and HE material, respectively, the momentum and total energy equation for averaged flow. In this model, the pressure needs to be determined from a general formulation of EOS with mixed parameters. This numerical model is used for underwater explosions because of its simplicity and robustness. The spatial discretization is based on unstructured grids due to their flexibility to deal with complex geometries. An explicit multi-stage Runge-Kutta method is used for the temporal discretization. The interface capturing method (THINC) used for two-phase fluids is extended here to three-fluid problems.