Numerical Modeling of Fluid-Structure-Debris Interaction during a Tsunami Event

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1. Introduction

Major tsunami events in recent history, such as those which occurred in the Indian Ocean in 2004, Japan in 2011, and Indonesia in 2018, have resulted in widespread damage to infrastructure due to fluid impact forces as well as debris impact and damming forces. Engineers have developed new standards to provide methods for designing structures to resist both types of tsunami-related loads in an effort to avoid future losses of the same degree as those observed in the past. For example, ASCE 7-16 has added a new tsunami load chapter and commentary that provide design equations for static and dynamic fluid forces as well as debris impact. However, further development of robust fluid-structure-debris interaction models is needed to give clearer insight to designers in the future, which is feasible with today's efficient solution algorithms and ever evolving computer capabilities.

2. FSI and Wave Generation using OpenFOAM

The most recent releases of OpenFOAM offer a wide array of dynamic mesh motion tools, the overset grid method, and adaptive mesh refinement (AMR), which can be used to simulate the rigid body motion of objects floating in water. Additionally, two fundamental classes of wave generation methods, wave theory-based generation and absorption boundary conditions versus moving boundaries, have been incorporated into OpenFOAM, which allows for accurate recreation of tsunami wave conditions. Using these tools together, a suitable model for simulating the motion of debris objects in tsunami inundation flows can be developed and used to perform a validation study.

3. Estimation of Wave Impact Forces

Experimental data for both wave and debris impact forces was gathered using the large wave flume at the NHERI Coastal Wave/Surge and Tsunami Experimental Facility (NHERI CWST-EF) at Oregon State University [Alam et al. 2018, Winter et al. 2018]. Using this benchmark data set for model validation, an OpenFOAM model was developed and calibrated to accurately reproduce the maximum wave impact forces measured during experiments. By adding dynamic mesh or overset grid functionality to this model, a suitable tsunami debris motion model can be developed and validated using both the ordered and random debris object configurations that were tested during the aforementioned experiments.

4. Proposed Collaboration Approach

Moving forward with this research topic involves developing a robust model that can simulate debris motion and impact forces in addition to accurately modeling tsunami inundation behavior. During this workshop, the goal of collaborating on this topic would be to identify a sufficient set of numerical tools that can be combined either entirely within the framework of OpenFOAM or by coupling it with a finite element method (FEM) software such as OpenSees or Abaqus to achieve the structure-structure interaction occurring between buildings and debris objects. Researchers from other numerical modeling groups could combine their expertise in these fields with those of the University of Washington with the aim of creating a useful engineering modeling software toolset and increased numerical modeling knowledge base that would benefit all parties involved in the collaboration as well as for future similar studies.

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