An Enhanced ISPH-SPH Coupled Method for Incompressible Fluid-Elastic Structure Interactions

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Abstract: Precise evaluation of highly interactive fluid-structure systems (e.g. hydrodynamic slammings of marine vessels, tsunami/storm surge impact on onshore structures) has been a substantial challenge for reliable design of coastal/ocean structures. In the view of the intrinsic difficulties, usually encountered in numerical modeling of FSI (Fluid-Structure Interaction) problems associated with coastal/ocean engineering (e.g. existence of violent free-surface flows as well as large/abrupt hydrodynamic loads and consequently large structural deformations), Lagrangian meshfree methods including Smoothed Particle Hydrodynamics, SPH, are potentially robust and appropriate candidates.

In this study, a projection-based particle method, namely, Incompressible SPH (ISPH), is coupled with a SPH-based structure model in a mathematically-physically consistent manner via a careful attention to the mathematical concept of ISPH, namely, Helmholtz-Leray decomposition. The ISPH-based fluid model is founded on Navier-Stokes and continuity equations, while the SPH-based structure model is based on conservation laws for linear and angular momenta corresponding to an elastic solid. A set of previously developed enhanced schemes [1] are incorporated in the ISPH fluid model. Hence, the developed coupled method is referred to as Enhanced ISPH-SPH. **To the best of our knowledge, this study presents the first ISPH-SPH FSI solver for computational modeling of incompressible fluid flows interacting with deformable elastic structures**.
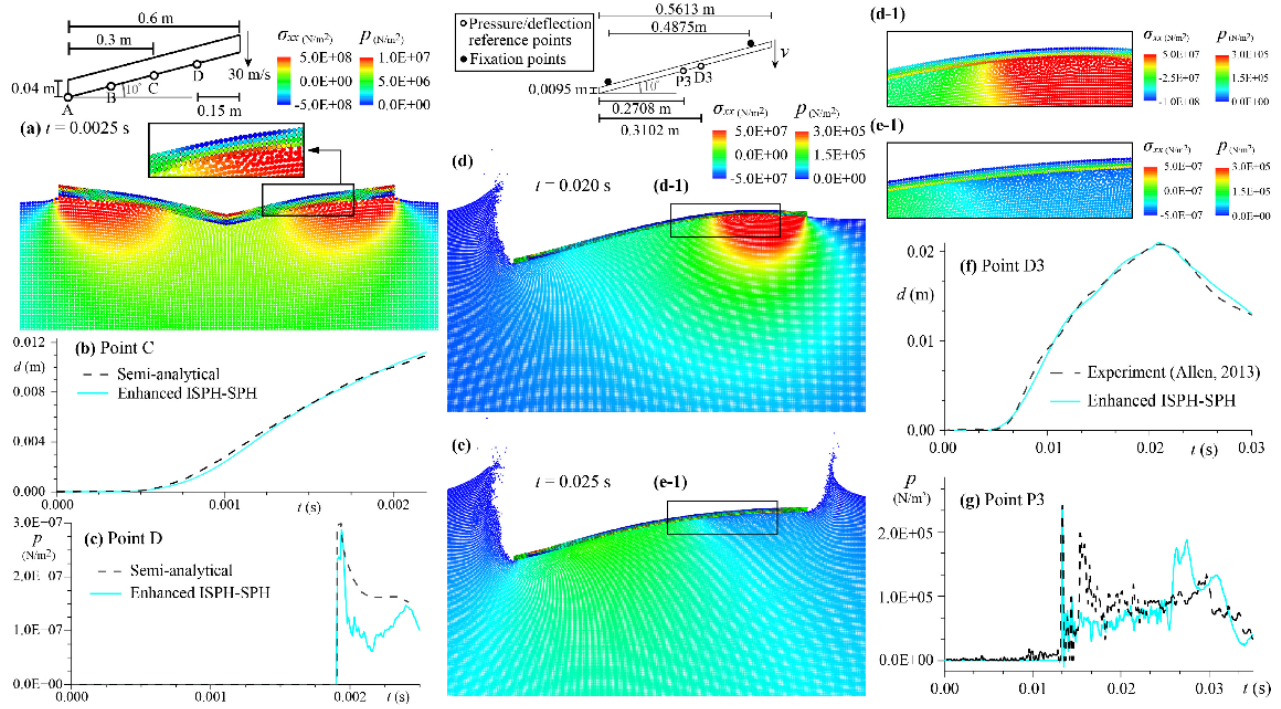
Figure 1: Representative results related to (a-c) high velocity impact of an elastic aluminum beam [2] and (d-g) hydroelastic slammings of a marine panel [2, 3], illustrating the performance of the developed Enhanced ISPH-SPH FSI solver

Followed by validation of the SPH structure model, the performance of Enhanced ISPH-SPH FSI solver is verified through a set of benchmark tests, namely, high velocity impact of an elastic aluminum beam [4] and hydroelastic slammings corresponding to a marine panel [2, 3]. Fig. 1(a) presents a snapshot corresponding to high velocity impact of an aluminum beam, illustrating smooth and qualitatively acceptable pressure/stress fields. Fig. 1(b-c) present a quantitative validation of the accuracy of proposed FSI solver by considering the deflection and pressure time histories at two reference points. Fig. 1(d-e) portray typical snapshots related to hydroelastic

slammings of a marine panel (for $v = 4$ m/s), illustrating qualitatively accurate pressure/stress fields. Fig. 1(f-g) present quantitative validations by considering time histories of deflection and pressure at reference points D3 (for $v = 4$ m/s) and P3 (for $v = 3$ m/s), respectively. From the figures, the Enhanced ISPH-SPH FSI solver has provided quite accurate results corresponding to a hydroelastic slamming phenomenon.

References

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