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

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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.**

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 [2] and hydroelastic slammings corresponding to a marine panel [3,4]. **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.

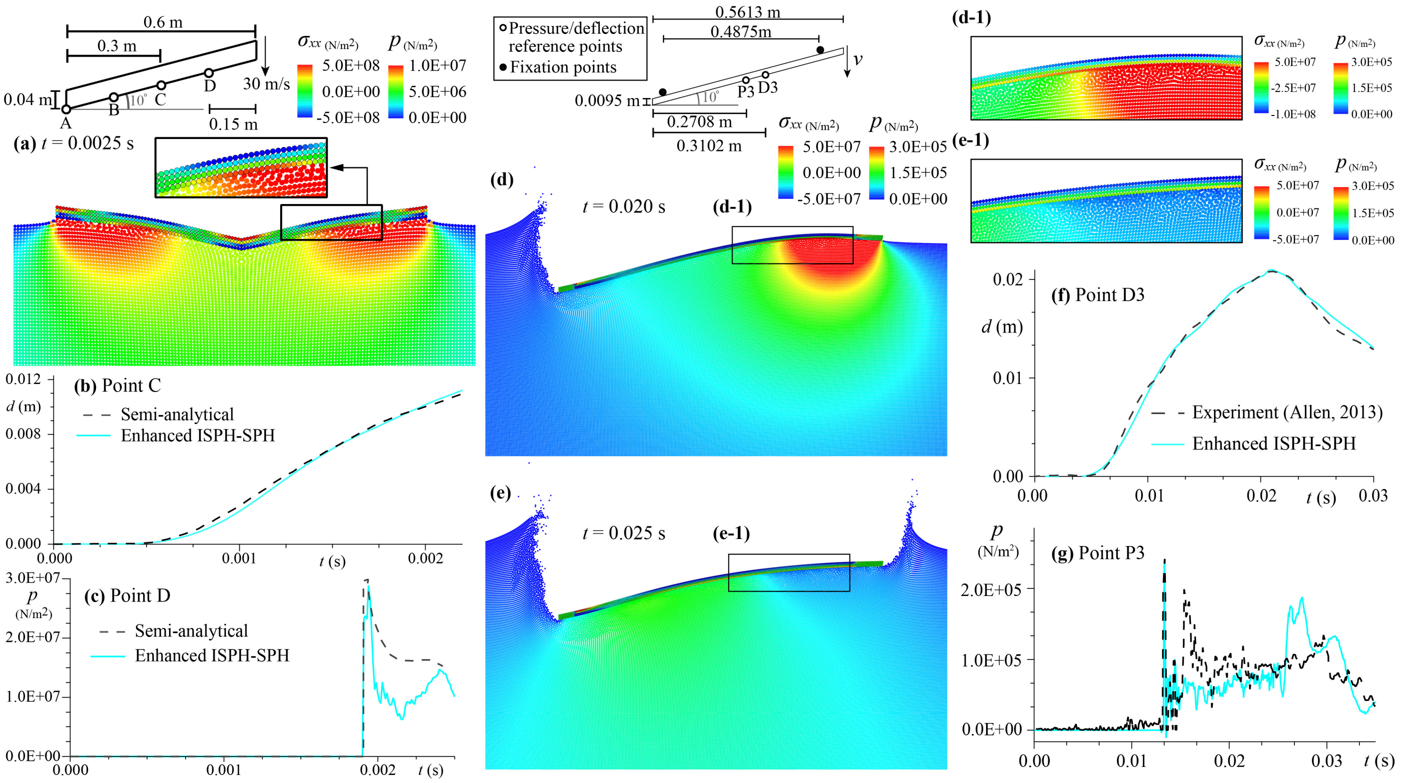

Fig. 1 Representative results related to **(a-c)** high velocity impact of an elastic aluminum beam [2] and **(d-g)** hydroelastic slammings of a marine panel [3,4], illustrating the performance of the developed Enhanced ISPH-SPH FSI solver

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