A finite element particle method (FEPM) for modeling fluid-structure interaction problems with large fluid deformations

Z. L. Zhang[1, 2, 3+], T. Long[1, 2, 3+], J. Z. Chang[4], M. B. Liu[1, 2, 3*]

[1] BIC-ESAT, College of Engineering, Peking University, Beijing 100871, China
[2] State Key Laboratory for Turbulence and Complex Systems, Department of Mechanics and Engineering Science, Peking University, Beijing 100871, China
[3] Institute of Ocean Research, Peking University, Beijing 100871, China
[4] Shanxi Institute of Energy, Taiyuan 030006, China

Abstract

Fluid-structure interaction (FSI) problems with large fluid deformations can be a great challenge for numerical simulations using conventional methods. In this paper, a novel finite element particle method (FEPM) is proposed for modeling FSI problems. The edge-based smoothed finite element method (S-FEM) is developed in Lagrangian frame and is used for the first time to model both elastic structures and incompressible flows. For fluid regions with large deformations, the associated finite elements are adaptively converted into particles and the corresponding regions are then modeled using the decoupled finite particle method (DFPM), which is an improved smoothed particle hydrodynamics (SPH) method suitable for modeling incompressible flows with free surfaces. A ghost particle-based interface algorithm to couple existing S-FEM elements and DFPM particles is developed in FEPM to implement the modeling of FSI problems. As the smoothed FEM and decoupled FPM are enhanced FEM and SPH respectively and DFPM is only used for local fluid regions with large deformations, it is expected that FEPM is more accurate and more efficient than the existing coupling approaches of conventional FEM and SPH. Five numerical examples are tested using the proposed FEPM and the comparative studies with results from other sources reveal that FEPM is an effective approach for modeling FSI problems with large fluid deformations.

Keywords: Finite element particle method (FEPM), Smoothed finite element method (S-FEM), Smoothed particle hydrodynamics (SPH), Decoupled finite particle method (DFPM), Fluid-structure interaction

+ These authors contributed equally to the work
*Corresponding author (M.B. Liu): E-mail address: mbliu@pku.edu.cn Tel: +86-10-62766982