FSI simulation with coupled incompressible material point finite element method

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Abstract

Fluid structure interaction problem is one of ship hydrodynamics and hydraulic engineering applications of free surface flow. This issue involves the interaction between fluid and structure that is a strong nonlinear problem, especially for moving structures or deformable solid. In traditional one-way coupling or two-way partitioned coupling scheme, the velocity of solid is used to prescribe velocity boundary conditions on the fluid, and the fluid to provide force boundary conditions on the solid. In the special case for static solid or prescribed velocity rigid, there is no need to update the state of solid body in the next step. But for elastic and unconstrained rigid body, the pressure from the fluid domain can be both stiff and noisy as compared to the velocity field.

In this talk, a coupled incompressible material point finite element method is presented for fluid structure interaction. This method can be divided into three sub-steps: Firstly, it is assumed that the fluid domain takes a predicted velocity by excluding pressure, and the solid domain takes a predicted velocity from next time step without considering the contact force at the interface nodes; Secondly, a unified velocity field is established where both fluid and solid can be treated as a mixed density fluid. The interface interaction is embodied by solving the pressure Poisson equation, and a smoothed force from pressure Poisson equation is applied on the body of structure to predict the velocity and deformation in time n+1. In this sub-step, the fluid velocity doesn't satisfy the divergence free condition; Lastly, the solid velocity from the above sub-step is used to satisfy the divergence free condition for fluid domain by another pressure Poisson equation. In this sub-step, the velocity and position of fluid and position of solid are updated. Generally speaking, the fluid velocity and interface interaction are predicted in first two sub-steps, and in the third sub-step, the fluid velocity is corrected to satisfy the divergence free condition. Our new scheme takes full advantages of incompressible material point method in solving fluid and finite element method in solving deformable structure. The proposed method is verified by various test examples such as water entry, dam break with interacting with a rubber gate which shows that the proposed FSI scheme of incompressible material point method coupling with finite element method is a powerful tool for solving fluid structure interaction problems.

Keywords: Fluid structure interaction, Incompressible material point method, Operator splitting, Water entry.

References

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