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# Large Scale Simulation of Fluid-Structure Interaction using an Incompressible Smoothed Particle Hydrodynamics

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Numerical simulations for free surface flows models, which are water entry of several rigid bodies free falling, fluid tank sloshing and flood disaster over several rigid bodies were conducted by using an Incompressible smoothed particle hydrodynamics (ISPH) method. In the current ISPH algorithm, a stabilized incompressible SPH method by relaxing the density invariance condition is introduced as Asai et al. [1]. The governing equations are discretized and solved with respect to Lagrangian moving particles filled within the mesh-free computational domain and the pressure was evaluated by solving pressure Poisson equation using a semi-implicit algorithm based on the projection scheme to ensure divergence free velocity field and density invariance condition. The main concept in an incompressible SPH method is solving a discretized pressure Poisson equation at every time step to get the pressure value. In this work, we used the following equation:

$$< \nabla^2 P_i^{n+1} > = \frac{\rho^0}{\Delta t} < \nabla \cdot \mathbf{u}_i^* > + \alpha \frac{\rho^0 - < \rho_i^n >}{\Delta t^2} \tag{1}$$

where, $\left(0 \le \alpha \le 1\right)$ is relaxation coefficient, $\mathbf{u}^*$ is temporal velocity, triangle bracket <> means SPH approximation.

In this study, we modeled the structure as a rigid body motion corresponding to Koshizuka and Oka [2]. They proposed a passively moving-solid model to describe the motion of rigid body in a fluid. Firstly, both of fluid and solid particles are solved with the same calculation procedures. Secondly, an additional procedure is applied to solid particles:

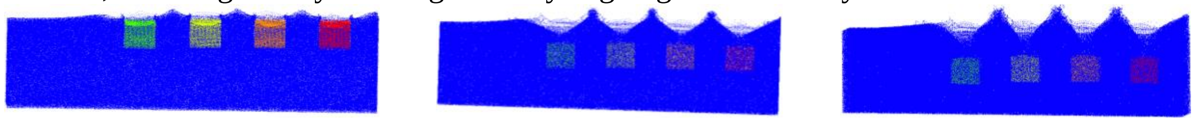
The velocity of each particle in the solid body is replaced by:

$$\mathbf{u}_k = \mathbf{T} + \mathbf{q}_k \times \mathbf{R} \tag{2}$$

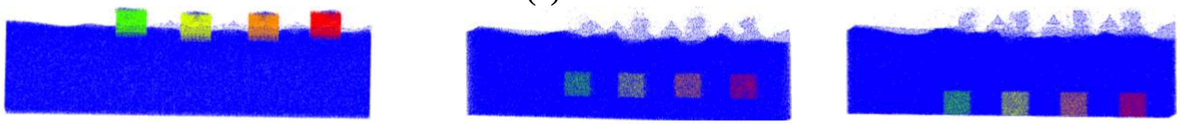
with $\mathbf{R} = \frac{1}{I}\sum_{k=1}^{n} \mathbf{u}_k \times \mathbf{q}_k ; \mathbf{T} = \frac{1}{n}\sum_{k=1}^{n} \mathbf{u}_k ; I = \sum_{k=1}^{n} \left|\mathbf{q}_k\right|^2 ;\ \mathbf{q}_k = \mathbf{r}_k - \mathbf{r}_c ;\ \mathbf{r}_c = \frac{1}{n}\sum_{k=1}^{n} \mathbf{r}_k$

where, the number of solid particles is $n$ with location $\mathbf{r}_k$ for each particle, the center of solid object at $\mathbf{r}_c$, the relative coordinate of a solid particle to the center $\mathbf{q}_k$ and the moment of inertia $I$ of the solid object.

In this study, three different simulations for the fluid-structure interactions have been introduced and discussed. The structure is taken as a rigid body and is modeled by ISPH method. In the first model, free falling of several rigid body over water in tank is simulated with three diferent densities cases. Fig. 1 shows the snapshots of free falling of several rigid bodies over water in tank at times 0.5 and 1.0 sec for three different density ratios 0.5, 1.0 and 1.5, respectively. The rigid body with small density is still floating over fluid and at the case of similar density, the rigid body is going down to the fluid centre and it still moves inside the fluid, while rigid body with high density is going down directly to the bottom of fluid tank.



(a) Time 0.5 sec

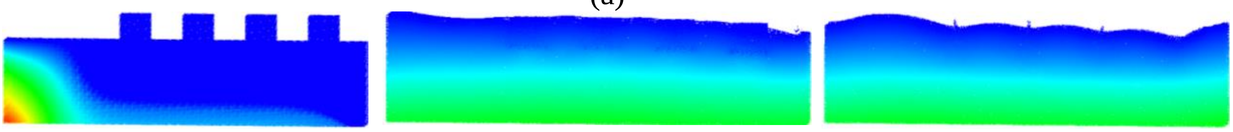


(b) Time 1.0 sec

Fig. 1 shows the snapshots of free falling for several rigid bodies over water in tank at times 0.5 and 1.0 sec for three different density ratios 0.5, 1.0 and 1.5, respectively

Fig. 2 shows the snapshots of pressure distribution for fluid tank sloshing. Here, the fluid sloshing problem in a rectangular tank under a sway excitation are introduced with external excitation applied on the tank $x = A(\sin \omega t)$, where A=0.004 m and $\omega = 7.3996$ rad/s. In this figure, the pressure distribution shows the efficiency of the current ISPH method in stabilizing the evaluated pressure and keeping the total volume of fluid during the whole simulation.

(a)



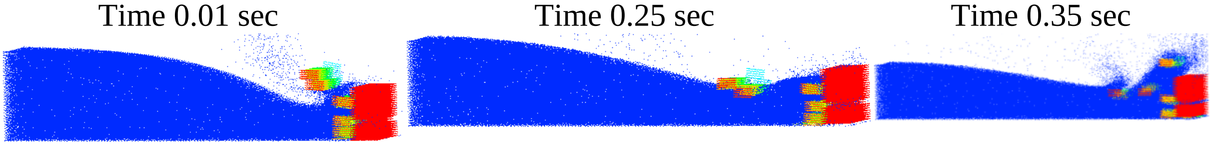
(b)

Time 0.05 sec Time 1.25 sec Time 2.5 sec

Fig. 2 shows the snapshots of pressure distribution for fluid tank sloshing including rigid body motion with two density ratios (a) 0.5 and (b) 1.0, respectively at times 0.05, 1.25 and 2.5 sec.

In the third model, we simulated flood disaster by introducing fluid column collapse impacts rigid bodies as shown in figure 3.

Time 0.01 sec Time 0.25 sec Time 0.35 sec



Time 0.5 sec Time 0.75 sec Time 1.0 sec

Fig. 3 shows the time histories for the flood disaster impacts several rigid bodies.

## REFERENCES

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