CFD Lab Project:Free Surface flow and Sloshing Dynamics

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Abstract

In this project the goal is to extend Finite Difference Solver for the Navier-Stokes Equation to include the phenomenon of Free Surface flows. This phenomenon is applied to study the sloshing dynamics in a road tanker. We have tried to simulate sloshing in a tank taking into consideration body forces caused by various maneuvers and studied the effect of various parameters on sloshing.

1 Issues

The free surface flows can't be treated exactly with the help of marker and cell method only because the cells can't capture the free surface accurately. So we have to introduce particles in each cell. Furthermore, the flags and the boundary conditions at free surface have to be updated in each loop since the particles are moving. We also have to handle the particle tracing in the visualization of the simulation.

2 Implementation

To solve the above mentioned problems we initialize particle and particle lines using function INIT_PARTICLES. We then proceed on to segregate the type of cells in a free surface flow into Obstacle cells, Empty cells, Fluid Cells, Surface cells etc in MARK_CELLS depending on the availability of particles in the cell and vicinity to obstacle boundary or empty cells. Surface cells are those cells which lie in the fluid domain but are next to the empty cells. Other fluid cells are marked as interior fluid cells.

Next we set the boundary conditions for the surface cells using continuity equation and the normalization equations at the free surface for all the possible 15 cases in SET_UVP_SURFACE. We then advance the particles and particle lines using the function ADVANCE_PARTICLES. For the advance particle function we don't know the velocity at all points in the Marker and Cell grid and hence we use bilinear interpolation of the individual components of velocity to find the new position of the particles.

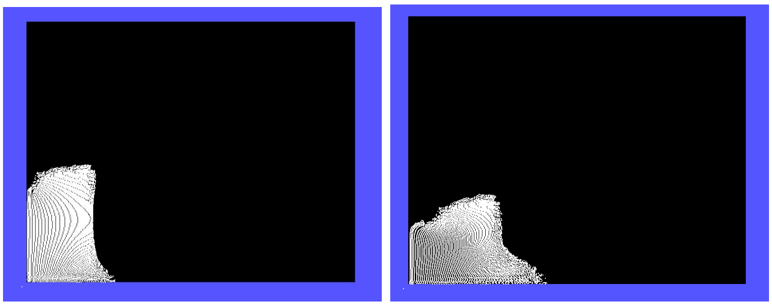
In visualization we visualize particles as unstructured grid points and only visualize particles lying inside the domain.

We then use the code to simulate the application of Tank sloshing. In this we studied the effects of sloshing due to sudden braking, banking and lateral excitation (uneven roads) in a full sized tank with liquid filled upto 50 percent and 80 percent of total volume. We have also considered the effects of baffles on sloshing in the above mentioned cases.

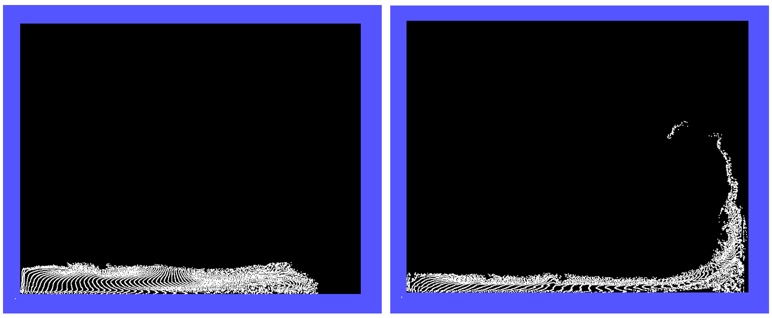
3 Results

The code is tested for the standard free surface problem of free surface flows. The results (Fig 1.) look satisfactory and in agreement with other benchmarked codes such as LS-DYNA.

Figure 1: Breaking dam at different time steps.



(a) time = 1sec (b) time = 2sec



(a) time = 4sec (b) time = 7sec

A tank model of rectangular size 10 X 2.5 is used for the front view of the tank. A braking maneuver is performed with a constant deceleration of 0.8g for 3 seconds, after which it reduces to 0. Figure 2 shows the pressure and particle distribution in the tank at 2 seconds. The specific kinetic energy dissipates quickly with time.

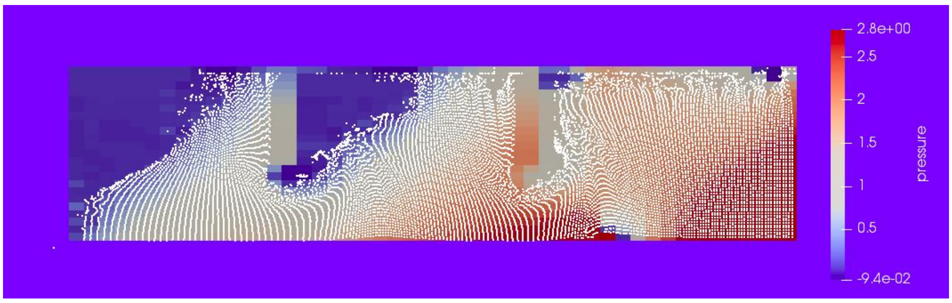


Figure 3: Tank Front section with baffles- Braking maneuver(0.8g) at 2 sec

Simulations were run for a tank without any baffles. Figure 3 shows the pressure and particle distribution at 2 seconds after a braking maneuver of 0.8g (similar to above). The specific kinetic energy shows slower dissipation as compared to tank with baffles. Similar analysis as above was done for side section of the tank corresponding to banking maneuver and the behavior is similar.

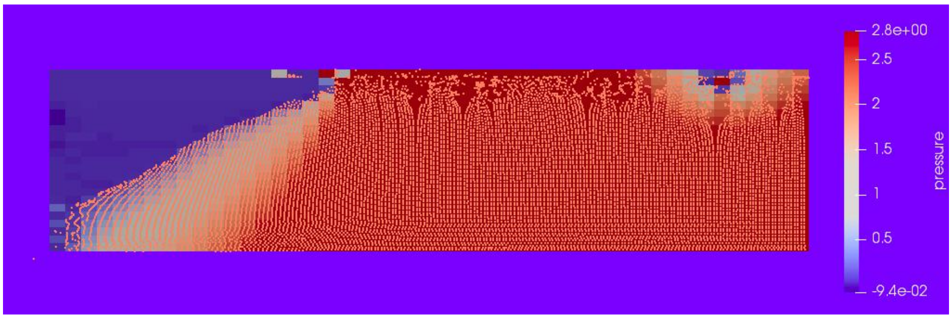
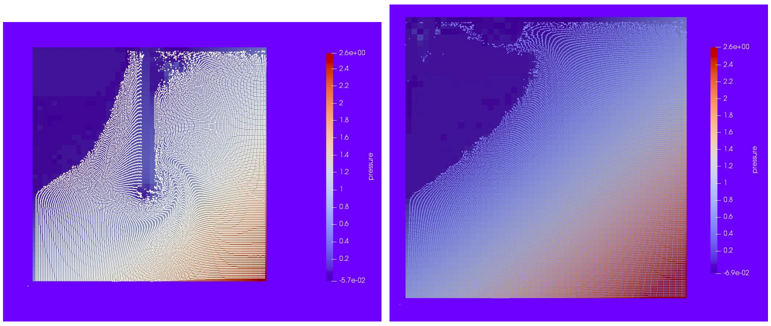


Figure 4: Tank Front section without baffles- Braking maneuver(0.8g) at 2 sec



(a) With baffle

(b) Without baffle

Figure 5: Tank Side section- Banking maneuver(0.8g) at 2 seconds

References

[1] Griebel, M., Dornsheifer, T., Neunhoeffer, T.: *Numerical Simulation in Fluid Dynamics: A Practical Introduction*. SIAM, **1998**.

[2] Vincenzo D'Allesandro,:*Modeling Of Tank Vehicle Dynamics By Fluid Sloshing Coupled Simulation*.Doctoral Dissertation**2011**