# Analysis of Free-falling wedge onto water using OpenFOAM

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***Abstract*—This case study aims to simulate and calculate the forces on the surface of a free-falling object into water using OpenFOAM v1806. It also aims to implement 6-DoF (Degrees of Freedom) model to calculate the motion of the free-falling object. Overset Mesh methodology is used to handle the dynamic of the object. An multi phase simulation with dynamic overset mesh will be performed in 2-D with 2DoF (only 2 translations allowed) model. Finally the force plot and motion of the wedge are visualized.**

***Index Terms*—overset grid, 6-dof, water entry**

## I. Introduction

Numerical Simulation of dynamic problem which includes large amplitude motion or topology change of component meshes is very difficult using traditional methodology like mesh deformation, mesh regeneration, and Arbitrary Mesh Interface (AMI). To overcome difficulties like need of larger computational power in case of regeneration, and error-prone mesh deformation, overset grid methodology is employed to numerically simulate the dynamic problem.

Test case of free-falling wedge of different interior angle such as 30 degree, under gravity onto the surface of water is solved using overset grid method to prove its effectiveness. The software used for the numerical simulation is OpenFOAM v1806 by ESI-OpenCFD.

### *A. Geometry*

The geometry for the wedges are modeled in salome-meca. The wedge of 30 degree has a longest edge with length 0.6 m and the two angles of the triangle are 30 degree each respectively as in figure 1. The wedge is created by extruding the triangle. The background domain is a simple 5m x 5m square extruded to required thickness.The geometry of the stable wedge is modeled also in salome meca, the modeled design is presented in figure 2. The profile the wedge is modified to minimize force generated during slamming of wedge on water and to have better stability while floating on water .

### *B. Meshing*

The mesh of the wedge for the simulation is created using salome-meca meshing software as in figure 3 and the fluid domain mesh is created using blockMesh utility. The mesh for the wedge and fluid domain mesh is created separately and overlapped

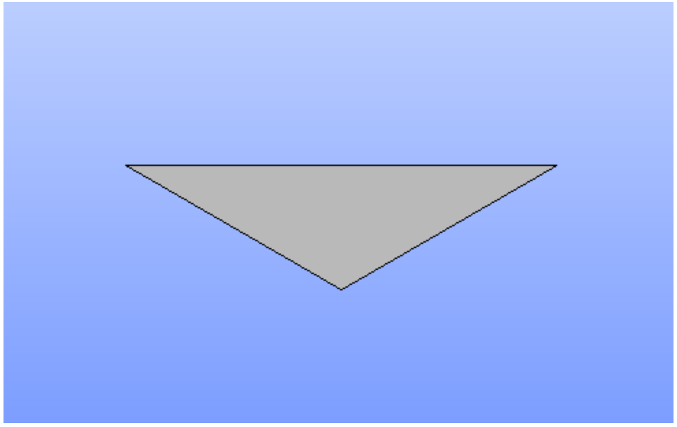

Fig. 1. Wedge of 30 degree and largest side 0.6 m

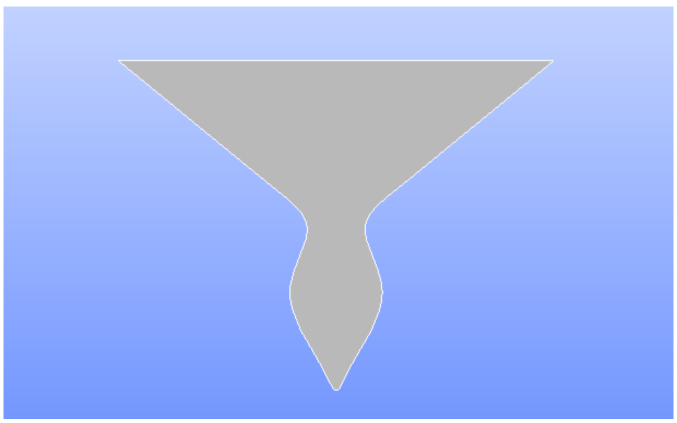

Fig. 2. Stable design of wedge for water entry

onto other using 'mergeMeshes' utility as in figure 4. The overset mesh for the stable wedge is also created similar to the above mentioned methodology as given in figure 5.

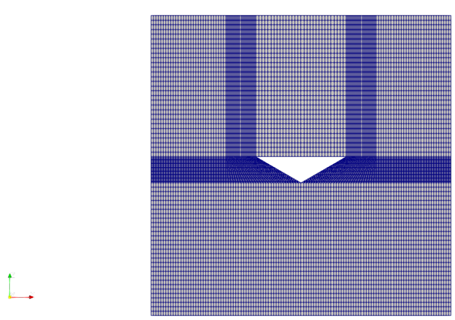

Fig. 3. Background Fluid Domain mesh

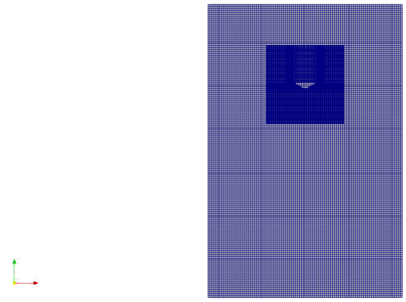

Fig. 4. Overlapped wedge mesh onto fulid domain mesh.

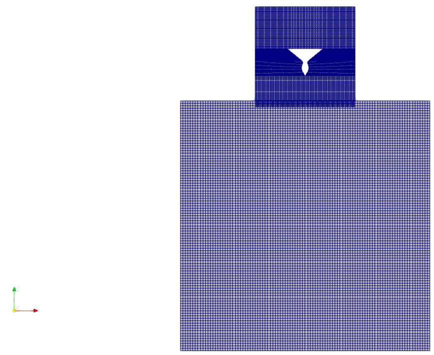

Fig. 5. Overset Mesh for stable wedge

## II. Analysis

### A. Case Setup

The case setup includes the initial condition, boundary condition, properties of fluids and the dynamic motion controls are given. The properties of the wedge are also given in dynamicMeshDict file, density of the solid wedge is 999 kg/m3 and moment of inertia for the wedge is calculated and given in the dynamicMeshDict, rotational and linear constrains are provided in the same file. Turbulence is turned off for the simulation. Gravity acts on the -y direction with 9.81 m/s$^2$. The values are given in table 1 and table 2.

### B. Solver

Since we have to simulate a multi phase model with dynamic motion of patches using overset mesh. so overInterDyMFoam solver is chosen for the simulation of the case. Multi phase is handled using Volume of Fluid (VOF) method.

TABLE I
SIMULATION CONTROL VALUES

| Sl.No. | Description | Inference/value |
|---|---|---|
| 1 | Solver | overInterDyM-Foam |
| 2 | Start Time | 0 s |
| 3 | End Time | 10 s |
| 4 | Time Step | 0.001 s |
| 5 | Write Interval of field variables | 10 |

TABLE II
PROPERTIES OF FLUIDS FOR SIMULATION

| Sl.No. | Description | Value |
|---|---|---|
| 1 | Kinematic viscosity of water | 1e-06 $m^2/s$ |
| 2 | Density of water | 998.2 $kg/m^3$ |
| 3 | Surface Tension | 7.34e-02 N/m |
| 4 | Kinematic viscosity of air | 1.48e-05 $m^2/s$ |
| 5 | Density of air | 1 $kg/m^3$ |

## III. Result and Discussion

The force on the wedge is the important feature to be noted as they result in failure of wedges. The plot of average force on the surface of the wedge against simulation time is given in figure 6 for stable wedge and figure 7 for wedge 30 degree

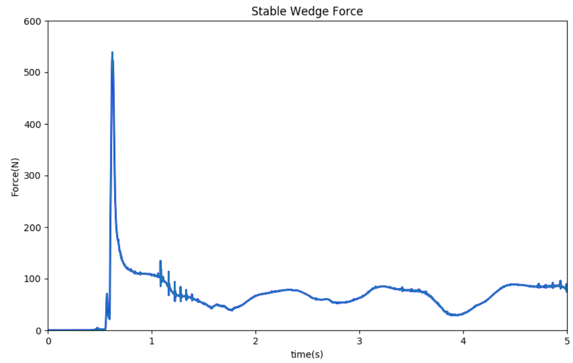


Fig. 6. Force plot against time for stable wedge

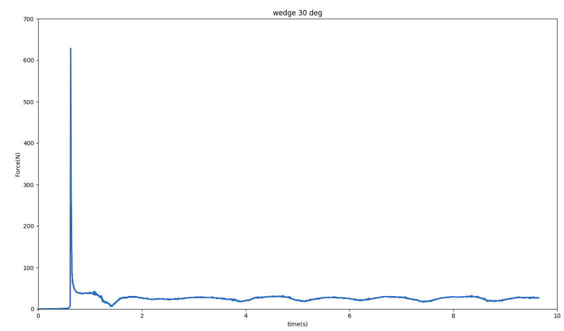


Fig. 7. Force plot against time for wedge 30

From the plots we can infer the spike in force during slamming of wedge and a 15 % decrease in force is seen when compared to 30 degree wedge.

### A. Visualization

we can also visualize the motion of the wedge and the behaviour of water in accordance to the wedge. The volume fraction of water in each cell determines the behaviour of water. Figure 8 and Figure 9 represents the volume fraction of water at different simulation time for stable wedge and 30 degree wedge.

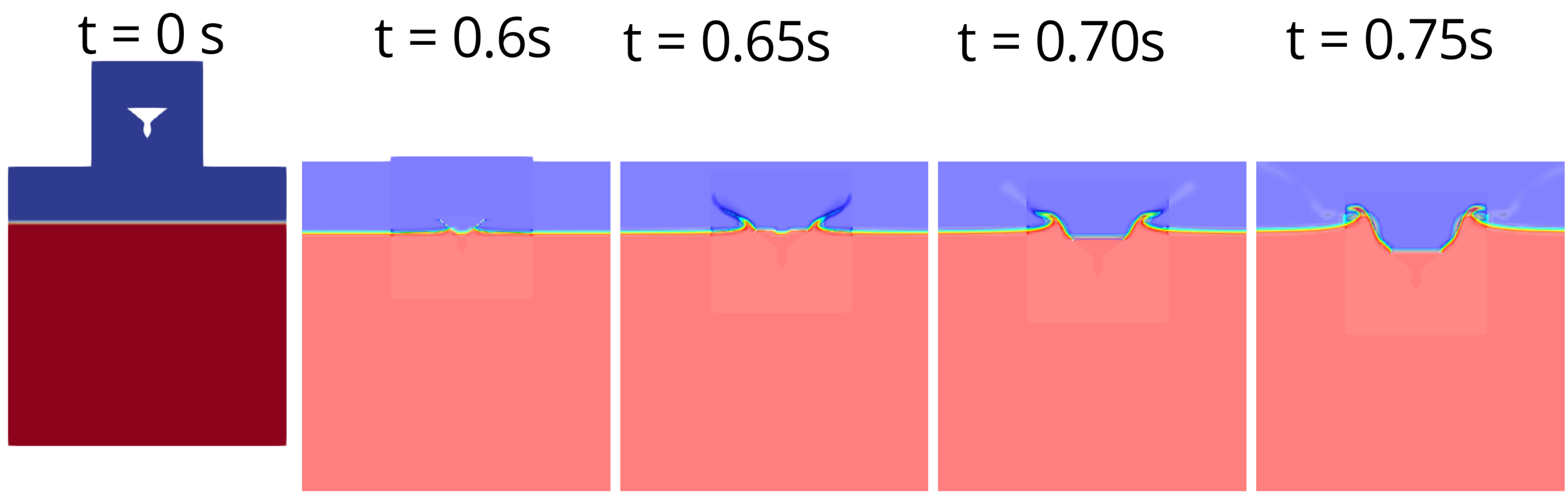


Fig. 8. Volume fraction of water of stable wedge at different time step(range 0-1)

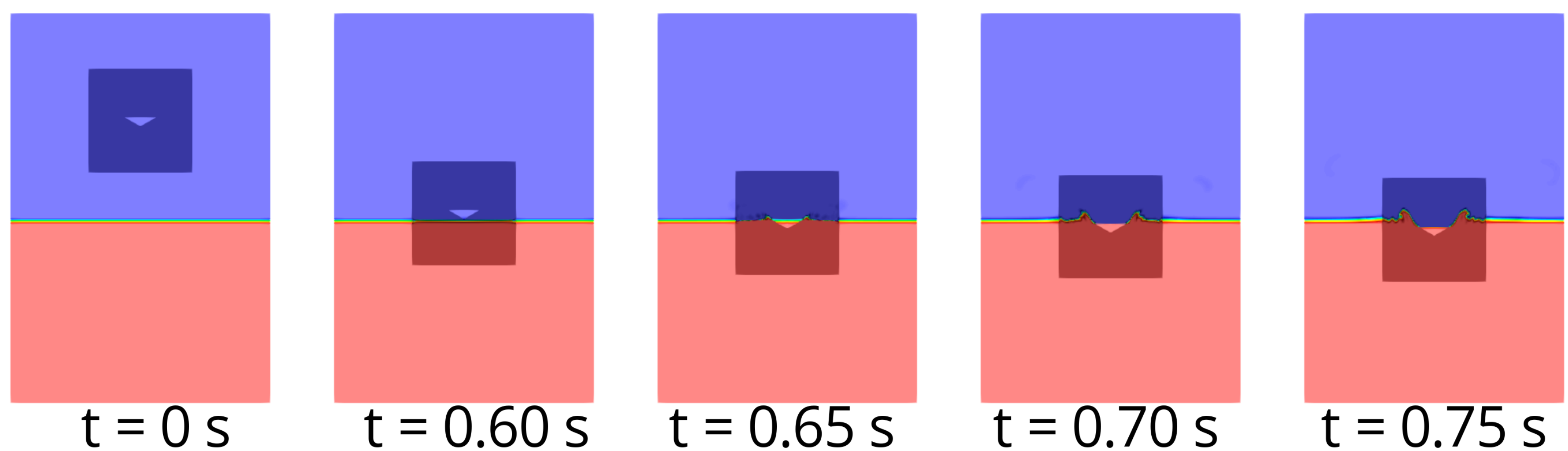


Fig. 9. Volume fraction of water of wedge 30 at different time step(range 0-1)

## IV. Conclusion

This report concludes that oveset grid method can be used to handle large amplitude motion or topology changes of the object and numerical simulaiton of the free-falling wedge under gravity onto water.

## V. Reference

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