Wave Generation and Propagation in an Underwater Energy Release

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Overview

Introduction to Underwater Energy Release

- Underwater Energy Release is an phenomena which occurs due to detonation under water surface
- The energy release is classified into two type, depending on $\frac{d}{W^{\frac{1}{3}}}$:
  $\rightarrow$ Amount of TNT or explosive 'W' (lbs)
  $\rightarrow$ Depth 'd' (ft) at which the energy release has taken place
- Deep water energy release : $\frac{d}{W^{\frac{1}{3}}} > 16$
- Shallow water energy release : $\frac{d}{W^{\frac{1}{3}}} < 3$
- Now depending on the depth at which the energy release takes place the nature of the water waves varies

Initial Condition

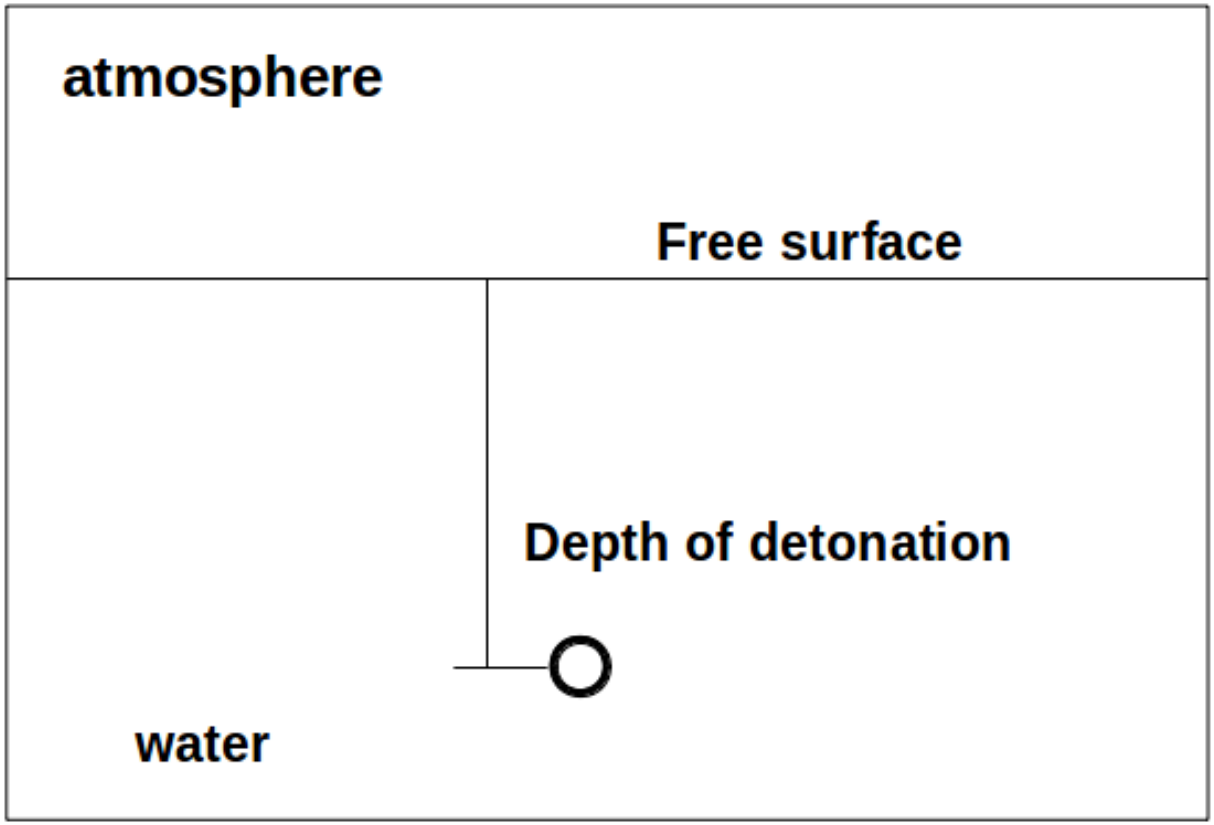

Figure: Schematic representation of initial condition of underwater energy release

Shock Wave generation

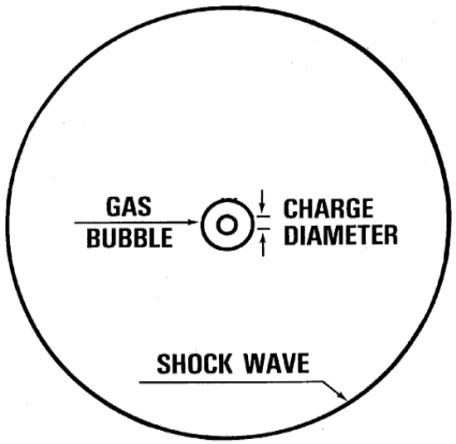

Figure: Shock wave and center gas bubble after detonation

- In majority of underwater energy release the shock wave is the main cause of damage
- Initial shock wave is propagated in milliseconds and the corresponding bubble contraction and expansion is occurs in seconds
- Due to the reflection of the shock waves from the free surface, a change in the pressure field is also observed.

Cavitation

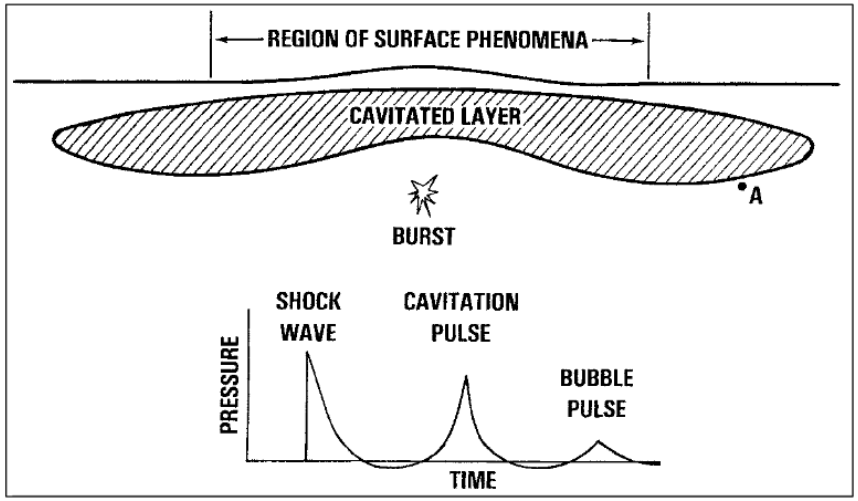

Figure: Cavitation after energy release

- As the shock wave is generated it travels to surface and reflects back as a tensile wave
- Since water cannot sustain this large amount of tensile force it leads to cavitation
- Due to the effects of gravity and atmospheric pressure this region of cavitation and bubble from the bottom surface collide and give rise to a **Water Hammer Effect**

Gas Bubble Dynamics

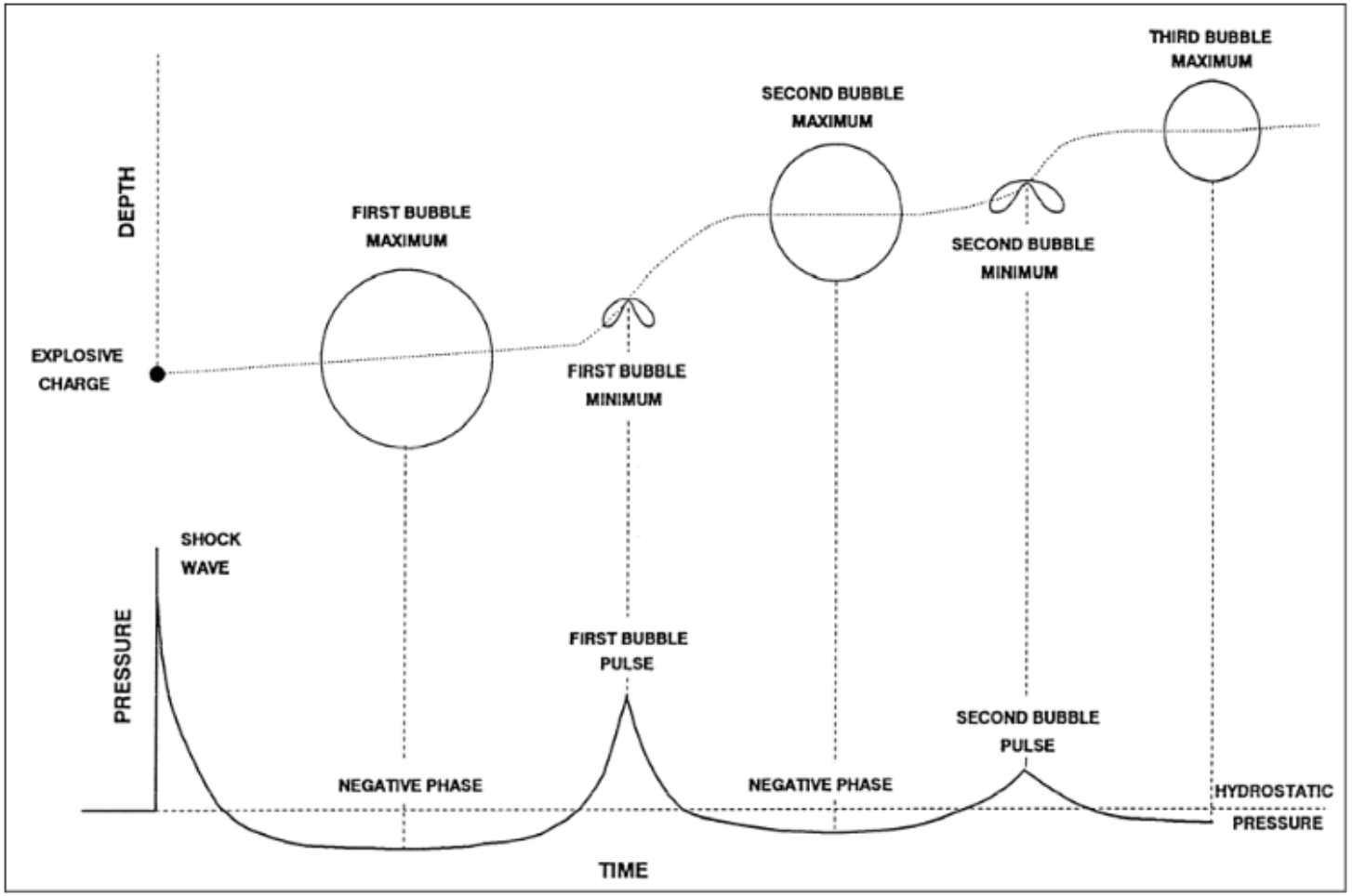

Figure: Different phases of Explosion bubble with pressure-time graph

Governing Equations

- Pressure on bubble surface $\rightarrow$ $\boxed{P_R = 7.8\frac{W}{V}^{\gamma} + \sigma}$
- Initial radius of the bubble $\rightarrow$ $\boxed{R_m = 3.38(\frac{W}{H+10})^{\frac{1}{3}}}$
- We neglect viscosity and surface tension effects
-

Governing Equations

Volume of Fluid

- Volume of Fluid (VoF), is one of the numerical technique for tracking and locating free surfaces or a two fluid interface
- Type of advection scheme which is used to track the motion and shape of the interface

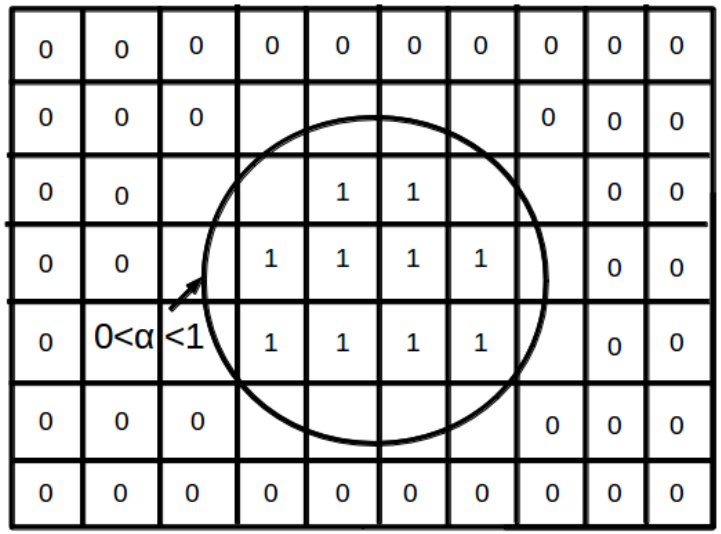

Figure: Volume fraction α for a Fluid-gas interface

- $\alpha = \frac{V_k}{V_T}$

Volume of Fluid- Interface reconstruction

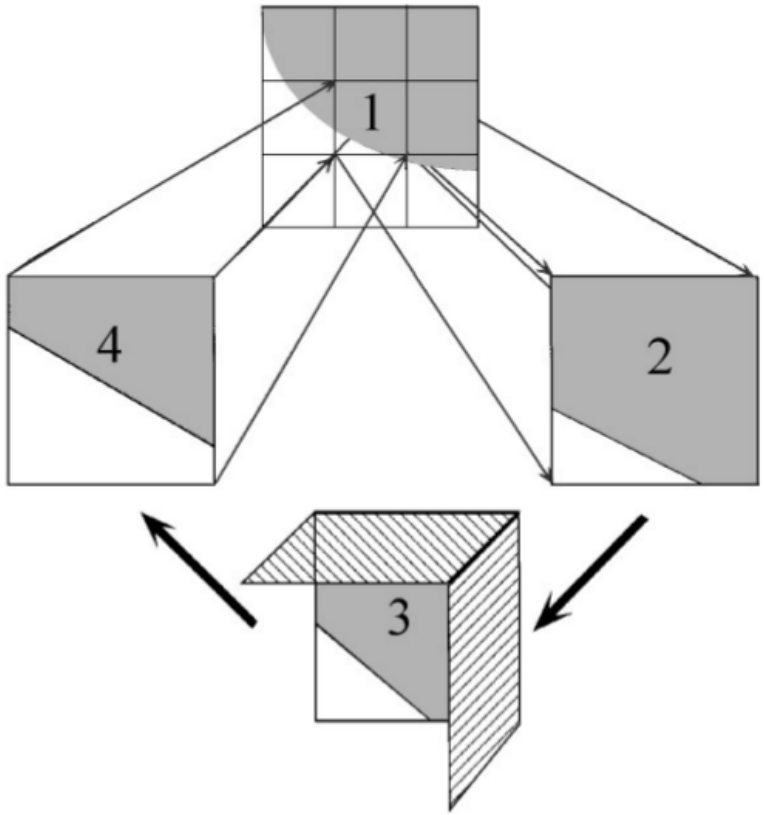

Figure: VoF interface reconstruction

OpenFOAM

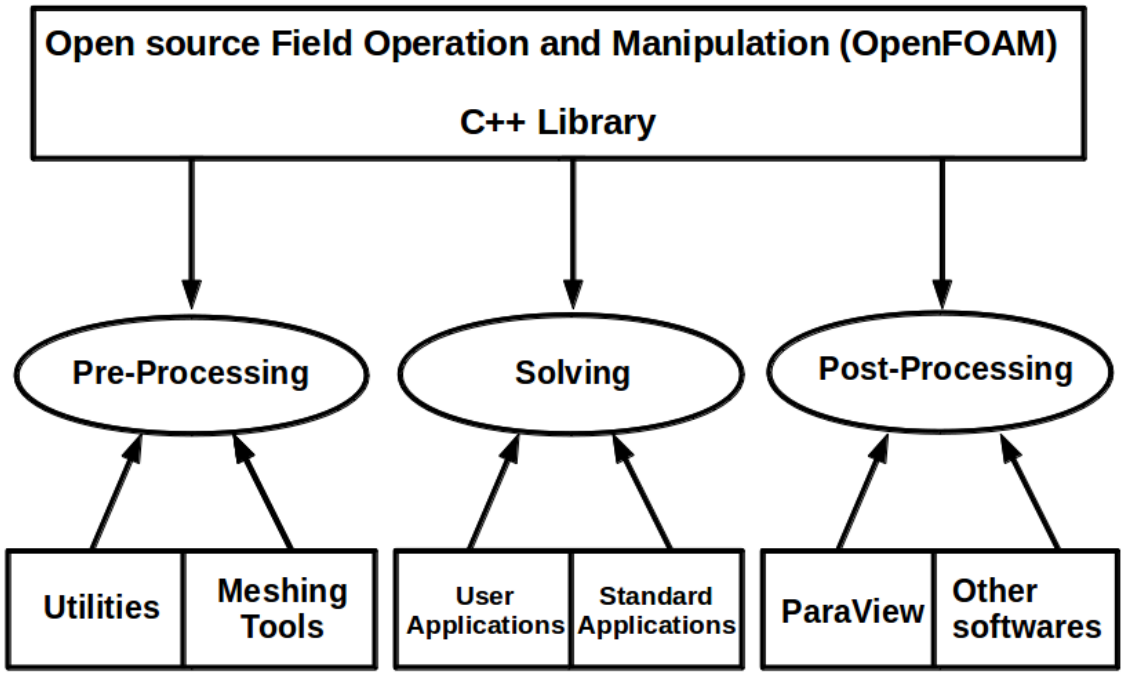

Figure: Overview of OpenFOAM

OpenFOAM- File structure

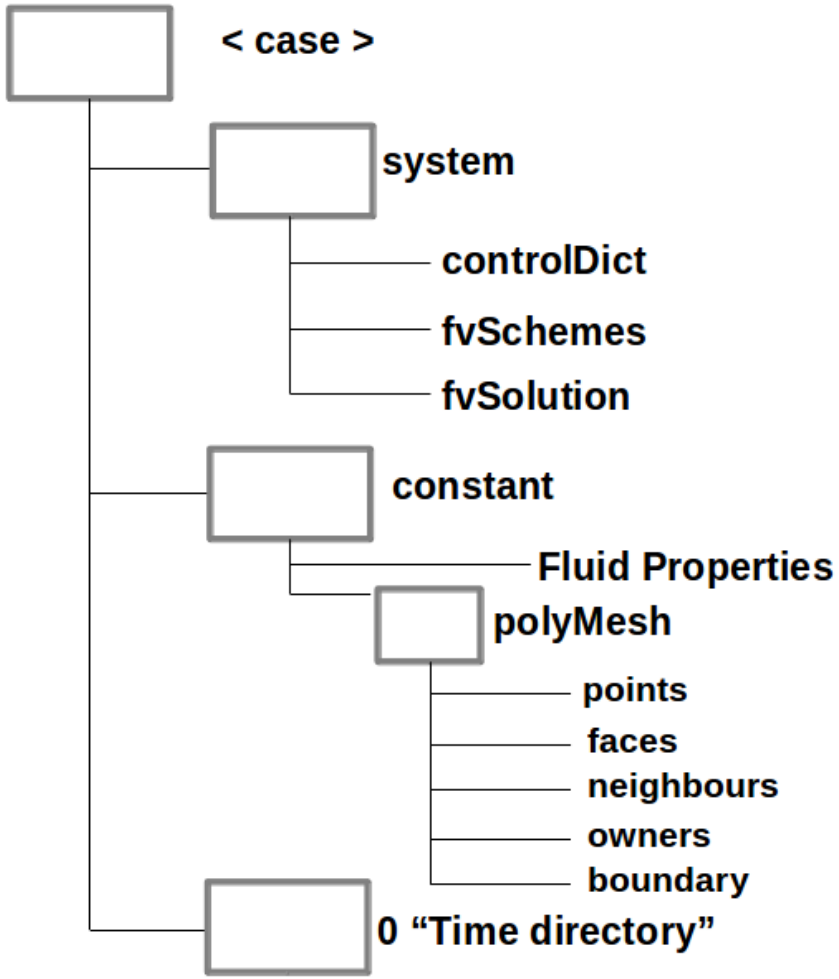

Figure: File structure of OpenFOAM

Conclusion

- Physics behind underwater energy release is both fascinating and challenging
- From literature it was found that there is scope for implementation of non-conservative form of the equations
- Quantify the resulting errors for energy release in free/ compact surfaces as well as in deep and shallow water depths

Future Work

- Using OpenFOAM solve the test case given below and validate the results with the paper published by S.T.Miller et.al

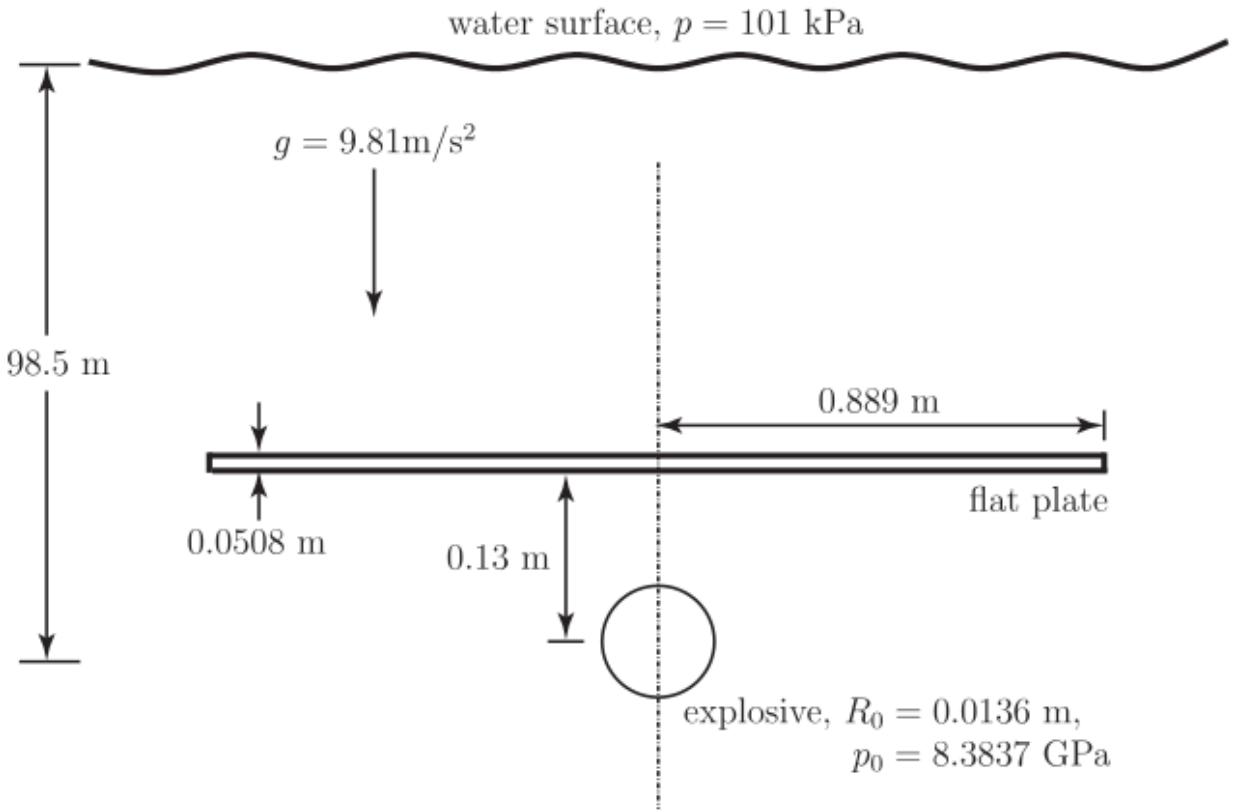

Figure: Test case for validation,S.T. Miller et.al

Refrences