Summary of the deliverable D1.3: Coupled Fluid-Structure Interaction model for bubble collapse

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The motivation behind this research lies in understanding the physical mechanism of cavitation erosion in compressible liquid flows, with applications in the field of aerospace, hydrodynamics, diesel injectors etc. The area of interest is the physical process of cavitation where phase transition takes place due to local decrease in pressure below vapor pressure in a continuum liquid flow. As a consequence, vapor cavities are formed and can lead to high pressure impact loads during violent collapse of the cavities. These pressure loads are believed to be responsible for the erosive damages on solid surface observed in most applications. For our investigation, the initial geometry is a single vapor bubble collapse in an infinite medium, due to the pressure difference between the bubble and surrounding liquid. The bubble collapse is usually characterized by the shrinking of bubble surface, acceleration of liquid flow towards the centre of bubble and shock propagation during the collapse. An accurate, efficient numerical methodology is developed to model the fast, unsteady flow characteristics. The numerical approach couples a fully compressible finite-volume fluid solver with a solid mechanics code in order to predict the material response to cavitation bubble collapse. In the fluid two phase modelling, simplified homogenous mixture or '*single fluid*' model with barotropic assumption is employed. The model uses a single set of governing equations for the phases with the assumption of thermal equilibrium. The single fluid phase transition model couples the governing equations and different phases by consistent equation of state and shock propagation speed for compressibility. The resulting model implemented in the CFD code $YALES2$ can efficiently model small and large scale cavitating structures. For the problem of interest, the resolved fluid domain is coupled with a solid mechanics code to model the evolving dynamics of collapsing bubble with resulting surface deformation. The pressure loads are computed at the fluid domain with the resulting surface deformation estimated in the solid domain from the fluid pressure loads as boundary condition. The resulting solid surface deformation is assigned back to the fluid domain as domain boundary condition at the fluid-solid interface, thus effecting the nearby flow dynamics. An Arbitrary Lagrangian-Eulerian (ALE) formulation is employed in the fluid domain for fluid mesh deformation in order to have a conforming mesh to the fluid-solid interface at every time step. The two-way coupled iterative method can accurately predict the evolution of impact loads in space and time in response to resulting surface deformation and material behaviour. The dynamics of the collapsing bubble is validated with the established theoretical Rayleigh-Plesset model and surface plastic deformation obtained will be validated with other numerical and experimental work.

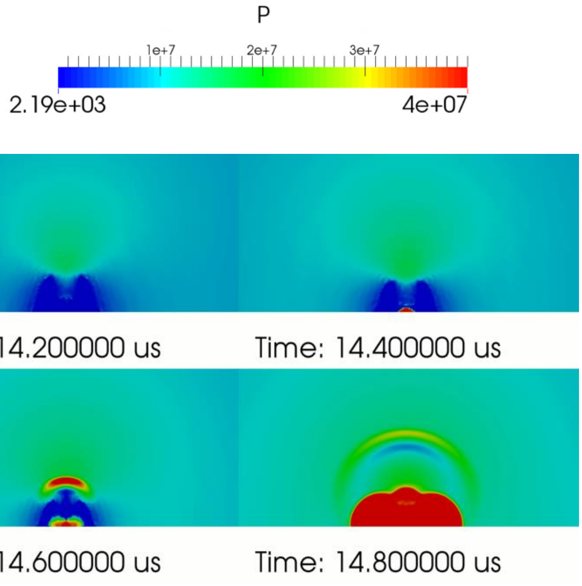

Figure 1: Pressure evolution during the end of bubble collapse at different time instances showing the liquid jet impact and subsequent shock impact on the solid wall, R_{max} *= 600* μ*m,* γ *= 0.8,* P_∞ *= 10 MPa*

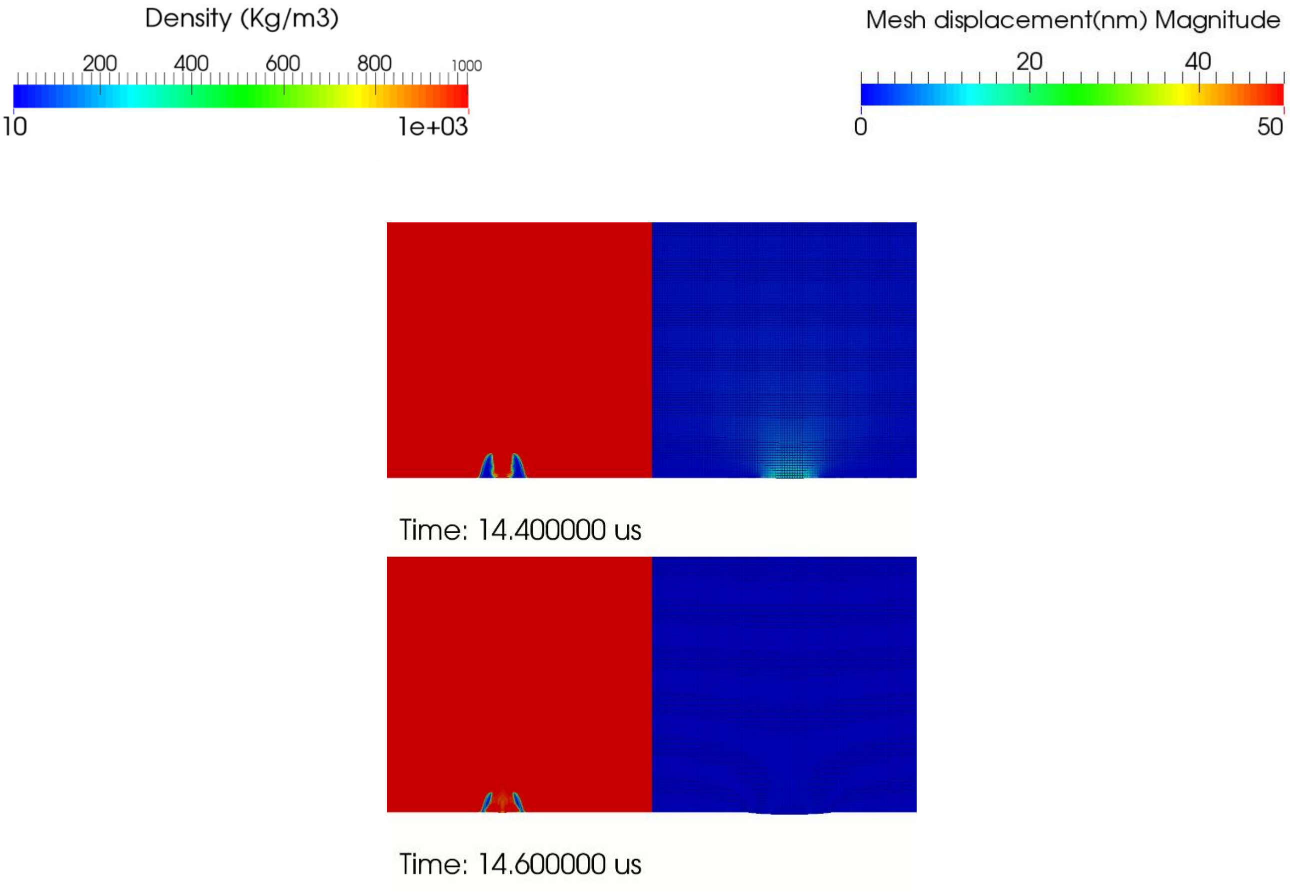

Figure 2: Fluid structure interaction simulation showing the deformation of the solid wall under the influence of impacting pressure loads, R_{max} = 600 μm, γ = 0.8, P_∞ = 10 MPa, (left contour) density evolution, (right contour) mesh displacement due to pressure loads