Summary of Deliverable D 1.5: Development of Smoothed Particle Hydrodynamics solid solver to estimate mass loss in materials

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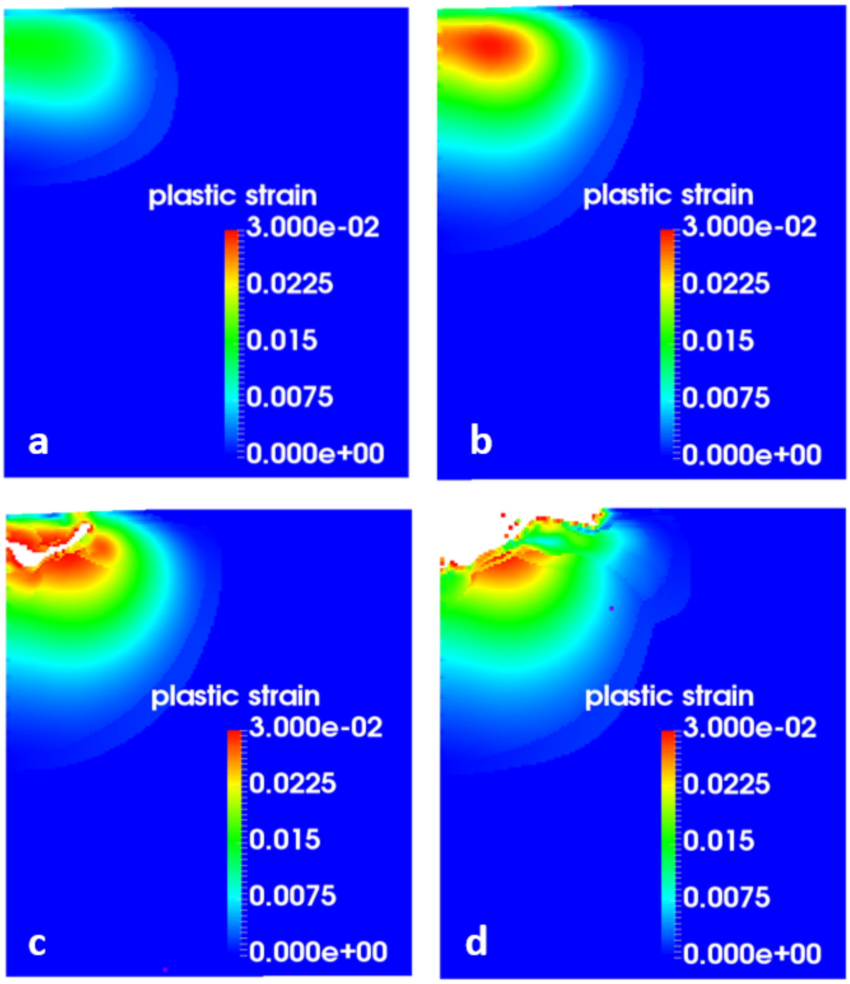
The present study is focused on developing a 2D and 2D-axisymmetric Smoothed Particle Hydrodynamics (SPH) cavitation erosion solver. The existing cavitation solvers generally use conventional Finite Volume Method for fluid coupled with a Finite Element Method for solid. The fluid SPH-solid SPH solver offers significant advantages over the existing methods. Firstly, due to the mesh-less nature of SPH there is no mesh re-construction required as the solid is deformed (and no need for an Arbitrary Lagrangian-Eulerian formulation for the fluid) which saves substantial amount of computational time and work. Secondly, the fluid/solid solvers use the same method (SPH) for both fluid and solid making it much easier to couple the two.

A 2D fluid solver SPHYSICS [1] is used as a starting point for the development, where a 2D SPH solid solver is developed from scratch and added to the above fluid solver. The two solvers are then coupled together to give a Fluid-Structure Interaction solver capable of solving bubble collapse over a solid surface and predict damage and mass loss. However a 2D solver has its limitations in terms of predicting mass loss since it does not represent the exact geometry of a spherical bubble but rather a cylindrical bubble.

To predict mass loss and material erosion accurately for different materials a 2D-axisymmetirc solver is developed. Starting with the 2D solver, the equations and schemes are modified to cylindrical coordinate system. The fluid part of the 2D axisymmetric SPH solver is then validated in the case of a spherical bubble collapse in a large domain against analytical results from Rayleigh-Plesset equation. The solid solver is developed by deriving a novel scheme that relies on correcting density near the symmetry axis due to the limitation of the standard kernel function to reproduce the density near the axis. The solid behaviour is added into the solver with features like elasticity, plasticity, hardening and strain-rate dependence. A simple damage criterion is introduced to calculate the damaged particles and mass loss. The solid in axisymmetric SPH solver is validated using FEM solver CAST3M on a case of spherical indenter indenting the specimen.

The first deliverable is satisfied by developing an SPH solver capable of mass loss simulations, a sample mass loss simulation is shown in the figure below. The mass loss curves for different materials can now be obtained directly from the 2D-axisymmetric SPH Fluid-Structure Interaction solver. The use of more complicated and realistic damage criteria that includes plasticity, triaxiality and Lode parameter will be used with the FSI SPH cavitation solver.



Sequence of images from 2D axisymmetric damage simulation of a stainless steel A-2205 specimen under spherical indentation, (a) Shows the plastic strain accumulation in material without damage, (b) Shows high plastic strain zone just beneath the top surface, (c) damage initiation from the point of highest plastic strain, (d) Material loss due to a single indent.