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Cavitation erosion is a major concern in many industrial applications such as water pump, marine propellers, hydroelectric turbines, fuel injectors, or even in health science like for hearth valves. Cavitation erosion is the consequence of mass loss of a solid material subjected to multiple impacts of collapsing bubbles in the fluid. The bubbles are generally nucleated in the flow at locations where the local pressure decreases below vapour pressure, i.e. in the regions of high velocity. They will later collapse when the velocity will decrease. In the case the collapsing bubble is located close to a solid interface, the dynamics of the collapse is not symmetric and a liquid microjet is formed toward the solid interface as depicted in Figure 1b. When the microjet hits the opposite side of the bubble (Figure 1c), a shock wave is generated in the fluid. The liquid microjet will then reach the solid surface (Figure 1d) at a velocity of several meters per second leading to high strain rates in the material. With time, the solid/liquid interface will experience a large number of impacts that will cumulate plasticity in the material. This will finally lead to the nucleation of a crack at the origin of mass loss.

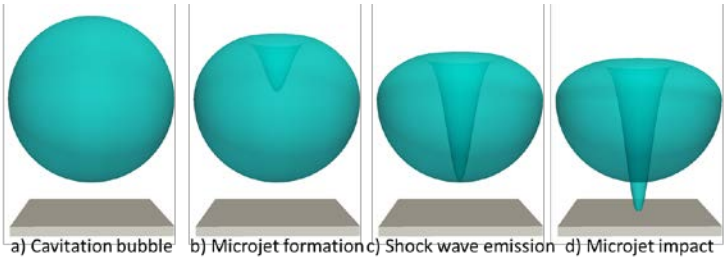

Figure 1: Snapshots of the dynamics a cavitation bubble collapse near a solid interface.

The objective of this paper is to simulate the plasticity induced in the solid material by bubble collapses. Very few attempts have been conducted so far. Typical simulations consists of using a Finite Element (FE) solver where the load corresponding to the bubble collapse is introduced via a pressure distribution at the solid boundary. However, it is extremely difficult to measure experimentally such a load distribution. Indeed, measurements based on PVDF only give an integration of multiple bubble collapses on the entire sensor area with a poor temporal resolution. An alternative solution consists of realizing Computational Fluid Dynamics (CFD) simulations but a key point is to accurately account for the deformation of the solid interface. This could be done within a classical fluid/structure interaction framework, for example using an Arbitrary Lagrangian Eulerian description of the fluid domain and a strong coupling between the CFD code and the FE solver [1]. In the present paper, we chose to use a meshless method in order to solve both the fluid and the solid domain in the same code. Smoothed Particle Hydrodynamics (SPH) method is a Lagrangian meshless method for which the dynamics of particles representative of an infinitesimal part of the continuum domain is computed based on a set of constitutive equations [2]. Although originally developed to numerical studies of planetary collisions [3], SPH is nowadays mostly dedicated to fluid mechanics for which the code can easily handle compressibility and subsequent wave propagations.

Starting from the 2D open-source software SPHysics dedicated to fluid mechanics and jointly developed at Johns Hopkins University and the University of Rome, La Sapienza [4], we have modified the code so that it could account for elasto-visco-plastic media within axisymmetric conditions. The solid solver has been validated by comparisons with FE simulations in simple situations such as the case of indentation. The fluid solver has been verified by computing the velocity field during a spherical bubble collapse in an infinite fluid domain and comparing the result of the analytical Rayleigh-Plesset solution.
The code has then been applied to the case of a spherical bubble collapsing near an Al-2205 aluminum alloy sample for which the constitutive parameters have been identified experimentally. Different standoff positions of the bubble have been tested. Namely, we have investigated the case of a detached cavity for which the standoff ratio, SR, defined as the distance to the wall divided by the bubble radius is greater than 1 and the case of an attached cavity for which SR<1.

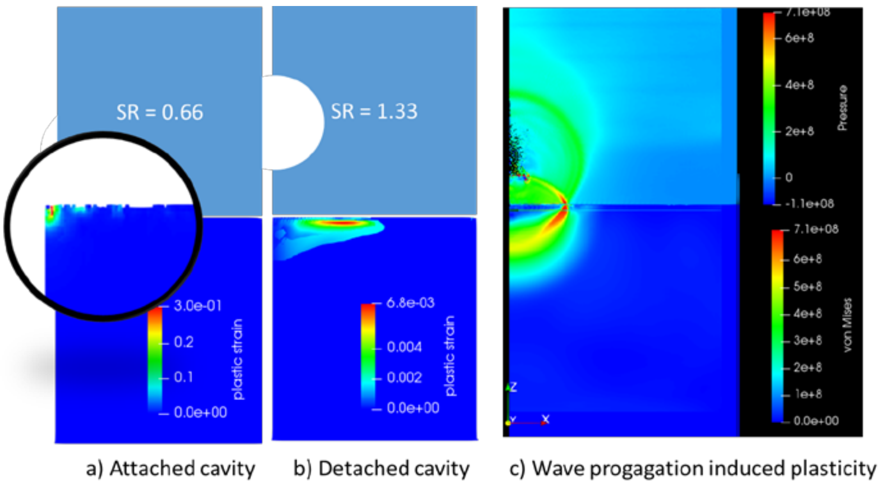

Figure 2: SPH results of plasticity induced by an attached cavity (a) compared to a detached cavity (b). Illustration of the Von Mises stress induced by the wave propagation in the case of a detached cavity (c).

It is observed that the attached cavities induce a much more localized plastic zone precisely located along the symmetry axis (Figure 2a). The detached cavity behaves differently because of the shock wave generated during the bubble collapse which cumulates plasticity outside the symmetry axis (Figure 2b) although it is not the location of the highest pressure induced by the fluid. The plasticity expansion process is attributed to inertial effects induced by the elastic wave traveling in the solid (Figure 2c).
It is concluded that numerical investigations of cavitation erosion should not be limited to pressure distribution at the interface.

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