Fluid-Structure Interaction (FSI) simulation for Thermo-elasto-plastic treatment

Joe Khalil[1*], Ramy Nemer[1], Aurelien Larcher[1], Rudy Valette[1] and Elie Hachem[1]

[1] Computing and Fluids Research Group, MINES Paris, PSL – Research University, CEMEF – Centre for material forming, CNRS UMR 7635, 06904 Sophia-Antipolis, France.
joe.khalil@mines-paristech.fr, aurelien.larcher@mines-paristech.fr, rudy.valette@mine-paristech.fr and elie.hachem@mines-paristech.fr

Key Words: *Phase Transformation, Phase Change, Immersed method, Level Set, Anisotropic mesh Adaptation, Thermo-elasto-plasticity.*

Fluid-Structure Interaction (FSI) is used in many industrial applications, in particular automotive, aerospace and nuclear industries. In the present work, we are interested in the interaction between a deformable structure during its cooling surrounded by gas and water issue from evaporation and boiling phenomena. In other terms, the present work aims to tackle the complexity of the involved physics and the complexity of the numerical methods used to achieve such a simulation.

Indeed, the solid materials will undergo several complicated phenomena as thermal expansion, elastic and plastic deformations, as well as phase transformation. It requires a high fidelity elasto-plastic model to give a real description of the deformation combined with a phase transformation model affecting the temperature change as well as on the stresses and deformation [1][2].

An adaptive Eulerian framework will be used for the simulation of both boiling and evaporation phenomena occurring at the interface of the heated solid immersed in a liquid tank [3]. It simultaneously considers the gas-liquid phase changes, the vapor formation, and their dynamics, and consequently the quenching or cooling of a heated solid. It uses a Level Set method to separate and to track each phase and a Variational Multi Scale (VMS) stabilization method to deal with the two-phase flow Navier Stokes solver [4].

Finally, the coupling is handled by the new Adaptive Immersed Mesh (AIM) method for FSI. It incorporates the independent results of a time accurate solid dynamics solver onto a fully Eulerian Monolithic framework. This is done by immersing the solid mesh, onto the fluid-solid mesh [5]. This approach allows us to work on two different domains simultaneously: a Fluid-Solid domain to understand all the physics and the interaction between the fluid and the solid, and a Solid domain to have a better resolution on the solid. 2D and 3D benchmarks results will be presented to highlight the accuracy and robustness of the hybrid proposed method as well as a 3D industrial real test case will be presented to highlight the applicability of the framework.

REFERENCES

[1] S.-H. Kang and Y.-T. Im, “Three-dimensional thermo-elastic–plastic finite element modeling of quenchingprocess of plain-carbon steel in couple with phase transformation,”International Journal of MechanicalSciences, vol. 49, no. 4, pp. 423–439, 2007

[2] R. Nemer, A. Larcher, and E. Hachem (2021). “Stabilized finite element method for incompressible solid dynamics using an updated Lagrangian formulation.” arXiv preprint arXiv:2101.07057.

[3] M. Khalloufi, R. Valette, and E. Hachem, “Adaptive eulerian framework for boiling and evaporation,”Journal of Computational Physics, vol. 401, p. 109 030, 2020,issn: 0021-9991

[4] E. Hachem, B. Rivaux, T. Kloczko, H. Digonnet, and T. Coupez, Stabilized finite element method for incompressible flows with high Reynolds number. Journal of Computational Physics, Vol. 229, pp. 8643-8665, 2010.

[5] P. DesJardin, B. Bojko, and M. McGurn, Initialization of high-order accuracy immersed interface CFDsolvers using complex CAD geometry. Int. J. Numer. Meth. Engng, Vol. 109, pp. 487-513, 2016.