XVIII International Conference on Computational Plasticity, COMPLAS 2025
September 2-5, 2025, Barcelona, Spain

RECENT ADVANCES IN THE PARTICLE FINITE ELEMENT METHOD FOR FLUID-STRUCTURE INTERACTIONS AND MULTI-PHYSICS PROBLEMS

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ABSTRACT

Particle Finite Element Method (PFEM) is a still rather young discretization method that seeks to merge the advantages of the classical FEM with those of modern particle-based methods, such as SPH. To this end, PFEM is designed as a Lagrangian method that combines computations over one time step using FEM with a fast remeshing algorithm, thereby avoiding mesh distortions consequent to very large deformations, such as those encountered in fluid flow with free surfaces. The method is thus quite flexible and can be applied to both solid and fluid material behavior (see e.g. [1] as a sample of the state of the art).

PFEM has proven to be a very versatile method that not only allows tracking free evolving boundaries but also take into account thermo-mechanical coupling and thus tackle more complex multi-physics problems. For instance, thanks to its Lagrangian character and its ability to automatically track evolving free surfaces and interfaces, PFEM allows handling phase change due to solidification, melting and vaporization, as well as capillary and Marangoni effects from surface tension [2]. These physical ingredients are highly valuable for simulating melt pool dynamics, for example, in the context of additive manufacturing.

Multiphysics problems can lead to models that are inherently incompatible or highly difficult to combine within the same numerical implementation. In such a case, it is convenient to split the physical models and solve them separately using dedicated software. Although this approach has been used mostly to address fluid-structure interaction problems in PFEM, it has also been used to couple thermo-mechanical models, for example, in the simulation of welding processes.

This work gathers recent advances in the PFEM with special attention to the incorporation of multi-physics models and their applications. In addition, numerical examples of the PFEM will illustrate fluid-structure interaction problems including contact between different solid parts and plastic deformation of some components of the system. These advances will be complemented by new remeshing proposals to further improve the PFEM strategy, which aim at reducing numerical artifacts and improving the continuity and smoothness of the free surface on which complex physical phenomena take place.

REFERENCES (maximum 2 references)

[1] Cremonesi M, Franci A, Idelsohn S & Oñate E. (2020). A state-of-the-art review of the particle finite element method (PFEM) Archives of Computational Methods in Engineering 27, 1709–1735.

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