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PFEM formulation for thermo-coupled FSI analysis. Application to nuclear core melt accident.

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Abstract

The aim of this paper is to present a Lagrangian formulation for thermo-coupled fluid-structure interaction (FSI) problems and to show its applicability to the simulation of hypothetical scenarios of a nuclear core melt accident. During this emergency situation, an extremely hot and radioactive lava-like material, the corium, is generated by the melting of the fuel assembly. The corium may induce collapse of the nuclear reactor devices and, in the worst case, breach the reactor containment and escape into the environment. This work shows the capabilities of the proposed formulation to reproduce the structural failure mechanisms induced by the corium that may occur during a meltdown scenario. For this purpose, a monolithic method for FSI problems, the so-called Unified formulation, is here enhanced in order to account for the thermal field and to model phase change phenomena with the Particle Finite Element Method (PFEM). Several numerical examples are presented. First, the convergence of the thermo-coupled method and phase change algorithm is shown for two academic problems. Then, two complex simulations of hypothetical nuclear meltdown situations are studied in 2D as in 3D.

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