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TOWARDS NUMERICAL MODELLING OF CAVITATING INTER-WRAPPER LIQUID SODIUM IN SUPPORT OF PHYSICAL STUDIES OF SODIUM-COOLED FAST REACTORS

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In the context of the development of the next generation of nuclear reactors within the Generation IV International Forum (GIF), design studies of the Advanced Sodium Technological Reactor for Industrial Demonstration (ASTRID) have been carried out since 2010 by the French Nuclear Energy and Alternative Energy Commission (CEA). Those studies have considered cases performed by means of numerical simulations where a movement of the fuel assemblies of a Sodium-Cooled Fast Reactor (SFR) core is assumed [1].

Within this framework, recent activities have shown that cavitation in the inter-wrapper space of a SFR core may appear in case of high mechanical excitation of the internal structures [2].As a consequence cavitation phenomenon which may have a strong influence on the coupling between fluid and structure is considered in this paper to be taken into account in the evolution of the resulting reactivity transient by means of an existing Neutronics-Mechanics code chaining in the software Cast3M [3].

Thus this paper aims at presenting the perspectives of the ongoing work which consists at the current step in building a simplified problem between two parallel plates which are moving from another. By now, we have assumed filling the gap with liquid water at laminar state and subjected to a certain movement of the top-bottom boundaries. In this way, all the terms constituting the Navier-Stokes equation for momentum conservation are considered. By the way, pressure is imposed at the inlet and outlet of the channel. In our context considering a high ratio between the length and the height of the channel, a parabolic parallel velocity profile in the streamwise direction is assumed. A vertical velocity component is either assumed to be neglected or in the opposite taken into account. Regarding these assumptions it is indeed possible to reach the theoretical saturation pression of water at the channel center (where the minimum of the pressure field is reached) as well as providing a characteristic curve depicting the evolution of the required minimum intial gap value versus movement frequency to reach the saturation pressure in case of symmetric and sinusoidal movement of the plates. This work also shows that the spanwise velocity component has a negligible effect on the evaluation of the minimum pressure value.

The case previously described constitutes a first approach for us in order to prove analytically that reaching the saturation pressure value of liquid sodium or water at typical temperature and initial pressure conditions is possible depending on the inital gap between those two plates. Subsequently this basic work aims to serve us for the formulation of a two-phase flow averaged modelling especially dedicated to simulate cavitating flow at the scale of a nuclear reactor core and also compatible within a mobile mesh of the inter-wrapper space geometry. The purpose of this numerical development is therefore to take advantage of a code coupling Thermohydraulics and Mechanics able to provide relevant physical outputs in a large scope of complex scenarios involving fluid-structure interactions in the context of SFR design activities.

In parallel of those computational fulfillments, the work also aims at adapting an experimental mock-up PISE-2C [4] located at CEA's LATF lab in order to reproduce a specific mechanical scenario in a inter-wrapper space filled with water medium. An appropriate setup of that equipment is intended to be built taking into consideration to what extent the initial conditions provided by the simulation can be easily implemented. This step is also dedicated to studying the practical feasibility for measuring the physical parameters characterizing the cavitation phenomenon.

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