PhD topic:

Study of ultrasound wave propagation in an inhomogeneous fluid medium for the continuous monitoring of an operating sodium-based nuclear reactor

Context:

Inspection and monitoring of nuclear reactors cooled with liquid sodium (SFR) relies heavily on acoustic methods, the medium being opaque. For future reactors, and for the ASTRID reactor, extensions of current implementations of acoustic processes are being considered in relation to those of the Phenix and Super Phenix reactors (Visus, Sonar): thermometry in the output of assemblies, core compactness measurement, telemetry, visualization...

The development of devices and estimation of their performance under various operating conditions of the reactor as well as different conditions of heterogeneity and non-stationarity of the medium requires the development of methods and modeling tools suitable for the topics that will be studied: geometry, propagation medium, acoustic frequency,...

Main goals of the PhD thesis:

The flow of sodium out of the assemblies in the core of the reactor is an inhomogeneous and turbulent fluid medium. The equations governing the propagation of acoustic waves in inhomogeneous turbulent media are known, in particular in aeroacoustics where the intensity of the wave can also lead to non-linearities.

The first part of the thesis will focus on defining the state of the art about media such as a flow of sodium above the core of the reactor, taking into account recent developments in Computational Fluid Dynamics conducted in particular at CEA. A second part will consist in considering different scenarios of ultrasonic measurement in the context of ISIR and of continuous monitoring because the flow regime changes depending on the location of the measurement (inside the core, on its edges ...) and on the operating mode of the reactor (stopped or in operation, taking engagement into account, ...). Scenario analysis and knowledge of the propagation medium will lead to making simplifying assumptions that will allow the PhD candidate to select the numerical models to be studied.

Previous studies have shown that the right numerical modeling tool to use in this thesis will be the SPECFEM software package (http://www.geodynamics.org/cig/software/specfem3d). Two cases have already been selected: when the variability of the velocity field is weak, current equations governing SPECFEM can be used with small changes, otherwise the equations will need to be more significantly modified. The simulation will be carried out in 3D to predict phenomena such as deviations of the acoustic beam due to the environment and interpret the results of physical tests. The thesis will also include experimental developments that will validate the numerical approach. Several experimental benches are already available or planned to simulate turbulent flows with vortices, for instance the IKHAR experimental bench. Scenario analysis in the first part of the thesis will define the most relevant experimental conditions. Modeling of the acoustic source characteristics (the
transducer) should also be considered in order to better compare and fit SPECFEM numerical simulations with experimental measurements.

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