Next Generation Fluid Flow Solver for Nuclear Reactors using Automatic Code Generation

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Overview: Thermal-hydraulic analysis of LWR nuclear reactor cores and primary systems is currently performed using a hierarchy of codes:

- System Codes: used to model the flow in the whole primary system on a coarse mesh (e.g. RELAP5, TRACE, APROS).
- Sub-channel Flow Codes: used to model the flow in individual channels in a reactor core (e.g. ARTHUR).
- Computational Fluid Dynamics Codes: used to model detailed effects, such as detailed flow patterns in the lower or upper head etc (e.g. FETCH, CFX, OpenFoam).

The aim of this project is to develop a fast-running finite volume porous medium flow solver [1] that can perform most of the above roles for a wide range of nuclear reactor cores, see figure 1. The solver will be developed using Imperial College’s Devito technology [2, 3] for the automatic generation of finite difference solvers from the differential equations and associated boundary and initial conditions. Internal structures within the Reactor Pressure Vessel (RPV) will be introduced using the immersed body approach pioneered at Imperial College (IC). This will allow complex internal structures to be introduced into the RPV using IC’s super-meshing and conservative interpolation technologies. The new code will be benchmarked against existing technologies for a typical LWR core. It is envisaged that this project may form part of a larger programme of work to develop a porous medium flow solver with capable of modelling the entire reactor system, and include sensitivity analysis and uncertainty quantification.

Figure 1: SUPO nuclear reactor (left). CAD and immersed body method of representing its internal dynamics [4]. Notice that the mesh is focused around the control rods and the guide tube.

References