Developing an Automated Fluid Activation Residence Time CFD Database

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Fluids exposed to neutron irradiation can become activated. Fluid activation is of critical importance to fusion power plant design, as it can impact dose rates to maintenance personnel, heating in sensitive components, and waste. The levels of fluid activation in a system are dependent on the neutron flux spectrum and the exposure time of the fluid. Accurately modelling the fluid residence time requires computational fluid dynamics (CFD). However, performing CFD on whole pipe systems can be computationally expensive and inflexible to design changes.

To address this concern, a new code was developed: FARBASE (the Fluid Activation Residence time dataBASE). This talk details the development and functionality of FARBASE, focusing on its two key features:

- An automated CFD pipeline which accepts a parametric description of a pipe component under given flow conditions, generates the pipe geometry, runs a steady-state OpenFOAM simulation, and returns the resulting residence time distribution.
- A Gaussian Process Regression (GPR) surrogate model which can be trained on the CFD database and queried to provide uncertainty quantified predictions of residence time distributions. Where the uncertainty of the GPR prediction exceeds a given threshold, FARBASE can automatically perform additional CFD to update the database, improving the accuracy of future predictions.

FARBASE is being utilised in UKAEA's GammaFlow fluid activation code, providing residence time distributions which are used to determine the production and decay rates of key radionuclides in each component of a basic water circuit. This will be extended in future to model benchmark experiments and validate the combined tool, which aims to provide an efficient and standardised approach to modelling activation in complex fluid circuits.