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High Resolution Temperature and Flow Measurements in Wire-Wrapped Fuel Assemblies

PIs:
Rodolfo Vaghetto, Texas A&M University
Yassin A. Hassan, Texas A&M University
Thien Nguyen, Texas A&M University
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Collaborators:
Brian Jackson, TerraPower
Michael Steer, TerraPower
Katrien Van Tichelen, SCK•CEN (Belgium)

ABSTRACT:

Fuel rod assemblies of fast reactors are characterized by a high power density and a tight lattice of the rods in the fuel element with narrow gaps between adjacent rods. A high coolant mixing rate is necessary for these configurations to reduce the local maximum temperatures during normal operation of the reactor. Helically wound spacer wires are provided over each fuel pin to avoid pin-to-pin contact and to guard the pin bundle against flow induced vibration. The helical spacer wires also promote mixing of coolant among various sub-channels. In view of thermal and hydraulic design of liquid metal fast reactor cores, it is of paramount importance to investigate the coolant mixing and the heat transfer behavior due to wire spacers. In this type of fuel bundles, rods are tightly disposed with helically wound spacer wire, forming narrow gaps among adjacent rods and between an outer rods and containing walls. Change in the fuel bundle geometry may also occur during the reactor operation due thermal-mechanical stresses.

Wire wrapped rod bundles present challenges to advanced modelling and simulations tools (such Nek5000, currently in development under NEAMS program) as little available high resolution experimental data is suitable for the validation of such advanced computer codes.

Project Objectives

The objective of the proposed work is to develop high spatial and temporal resolution temperature and flow datasets in a wire-wrapped rod bundle geometry, targeting the validation of Nek5000. The proposed experimental work will include concurrent measurement of:

- Three-dimensional velocity fields within exterior (near wall) and interior sub-channels, and the first and second order flow statistics
- Wall and fluid temperatures at selected sub-channels
- Time-dependent wall shear and pressure (dynamic)

The experimental procedure intends to combine advanced imaging techniques (the 3D Time-Resolved Particle Image Velocimetry (3DTR-PIV), and the Matched Index of Refraction (MIR) to perform high spatial and temporal resolution measurements of the flow structure within the bundle. The data will be also complemented with Laser Doppler Velocimetry (LDV) measurements. Laser Induced Fluorescence (LIF) technique will be combined with the use of optical fiber to measure walls and fluid temperature fields. A wide range of Reynolds numbers will be investigated to cover the laminar, laminar-transition, transition-turbulent, and turbulent flow regimes. We propose to investigate the heat transfer mechanism using Low Prandlt Number fluids within a heated bundle, and produce concurrent flow and heat transfer experimental data.