Project ID: **60144**

Project Title: **Flow Visualization of Forced and Natural Convection in Internal Cavities**

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RESEARCH OBJECTIVE

The goal of this program is to develop innovative flow visualization methods and predictive techniques for energy, mass and momentum transfer in the presence of chemical reactions in the drying and passivation of spent nuclear fuel (SNF) elements.

RESEARCH PROGRESS AND IMPLICATIONS

This report summarizes work after roughly one and a half years of a three year, collaborative project. At the University of Idaho (UI), an experimental apparatus has been designed in which a flow passes over a specific surface reaction that can be controlled , and the effect of this surface reaction on the flow can be observed and measured. The system capitalizes on the strong reaction between water and sodium. A mineral oil/water mixture flows over a test section containing metallic sodium, causing a reaction to occur between the water in the mineral oil and the sodium. Efforts to date have focused on construction of a test apparatus, and installation of the image capture capabilities.

To visualize the occurrence of an exothermic reaction, thermochromic liquid crystals (TLCs) are being employed. TLCs are being used to indicate the occurrence of an oxidation reaction on the surface of spent nuclear fuel elements. In the complex geometry created by the honeycomb of spent fuel rods and canisters, it is desirable to directly determine what surfaces are exposed to, and thus react with, the oxygen and which surfaces do not. The initial tests have consisted of pumping water of varying temperature through piping coated with a layer of TLCs and have shown that the effect can be clearly and easily captured on video or film.

The INEEL is obtaining basic flow field measurements using a scale water-flow apparatus. Its purposes are to obtain initial indications of the gross flow behavior and to investigate the circumferential periodicity of the flow. It was demonstrated that prototypical perforated support plates (4 and 8% open area) caused significantly different flow patterns compared to plates in typical aerodynamics experiments (about 50% open area). Slight flow oscillations were observed in the array of elements. Quantitative velocity vector plots show very complicated flow patterns with a wide range of velocities. It appears that the flow is roughly periodic around the circumference, implying that numerical predictions and detailed measurements can concentrate on a sector of the geometry rather than the full cross section.

A scale model, designed to measure velocity and turbulence fields, is being fabricated for use in the INEEL Matched-Index-of-Refraction (MIR) flow system. The initial hole pattern has approximately 5% open area. The traversing system for the Laser Doppler Velocimeter is being modified for operation in the forward-scattering mode and computer control has been upgraded to three directions. An experiment was performed to investigate the suitability of using uncoated hollow glass spheres and silver-coated hollow glass spheres for Particle Tracking Velocimetry (PTV) in the MIR flow system. Preliminary results suggest that, in design of such drying/passivation systems, bypass flow routes should be avoided and flow distribution should be controlled. Design assumptions of uniform flow would be misleading. Modification of the basket support plates and bottom region of canisters could be desirable.

Over the last 12 months, the efforts at Ohio State University (OSU) have been concentrated on the imaging and computer processing end of the flow visualization. The focus has been on developing a Windows 95 imaging program and interface to implement the imaging and processing needs of the project. It was decided that due to the wide angle stereoscopic imaging needs of the project, 3-dimensional PTV (3-D Particle Tracking Velocimetry) and 3-dimensional IPT (3-D Individual Particle Tracking) would be the ideal hardware for the project. This hardware architecture was recognized as being the most versatile platform for the demanding applications associated with simultaneous acquisition of good resolution stereoscopic images over substantial lengths of time, as required for the 3-D IPT imaging needs. The implementation of this system hardware in a seamless fashion has proven to be a challenging system integration and software project.

Efforts by Clarksean and Associates (C&A) focused on the development of a three-dimensional model to predict the flow through the perforated plate and past the simulated fuel rod. The model simulates the flow from the exit of the pipe that impinges on the lower plate, spreads out between the perforated plate and the bottom plate, and then flows up through the perforated plate past the simulated fuel rod. A two-dimensional turbulent profile for a long pipe was simulated, which was used as the inlet boundary condition for the pipe in the three-dimensional geometry. Time was also spent on developing an appropriate finite element mesh to correctly capture the flow near and through the plate. The three-dimensional flow analyses are in progress and will be compared to the flow visualization work being conducted experimentally.

PLANNED ACTIVITIES

At the UI, once the sodium/water apparatus is finished and tested, we will conduct flow visualization experiments, studying the effects of the reaction on the flow. This flow will be compared with fully developed flow as it passes over an area where no sodium is present. The next series of tests involving the TLCs will use a scale model of a spent fuel passivation chamber that was used previously in dye-injection type flow visualization tests. In the coming year, a series of tests using TLCs in conjunction with an exothermic surface reaction is planned. The exact configuration of these tests is not finalized, but the concept consists of flowing a slurry of TLCs and water or mineral oil over a plate that will react with the fluid, giving off heat.

The experiments in the INEEL MIR flow system will concentrate on the fundamental problems of turbulent transport and laminarization in semi-confined flow of a low Reynolds number impinging jet using a two-component Laser Doppler Velocimeter. This region determines the turbulence levels incident on the perforated plate and, hence, entering the fuel element array. These measurements should occur during the latter part of the present award year and during the third year. It is expected that the traversing Particle Tracking Velocimeter will be available during the third year. This capability will permit following individual particles (simulating motion of an oxidant) as well as determination of the three-dimensional flow field.

At OSU preliminary work has been performed merging the 2-dimensional information from the two (extensible to many more) views/cameras/computers to reconstruct the 3-dimensional particle trajectories as a function of time. In the coming months, this system will be outfitted on the INEEL MIR system. These images will be available through a user-friendly computer interface, which does not require any specific knowledge of computer imaging.

The C&A computational group will expand their current numerical studies by performing additional three-dimensional modeling and will complete the direct numerical simulations of the flow within the passivation chamber.

INFORMATION ACCESS

Updated information is available at the following web site:
http://teton.if.uidaho.edu/emsp/index.html