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Experimental Investigation on the Thermal Mixing Characteristics of the Wire Wrapped 37 Rods Using a Laser Induced Fluorescence Technique

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1. Introduction

The Nuclear Power Committee has established the objectives of the construction and the operation of the 4th generation LMFBR (Liquid Metal Fast Breed Reactor). To meet these goals, one of the subjects which is performing the production of the experimental data and also is estimating the uncertainties of the results of the CFD analysis should be undertaken. In other words, it is important to evaluate the accuracy of the model and the thermal hydraulic analysis code used to evaluate the safety of the SFR reactor core and quantify uncertainty. For the preliminary test before the 127 pin model test, the test loop for the wire wrapped 37 pin fuel assembly (FIFFA, Flow Identification for Fast reactor Fuel Assembly) was constructed to establish measurement technique [1].

The heat transfer associated with the flow exchange between rod bundles was related with the diffusion coefficient. To identify a mixing characteristics among rod bundles, the optical measurement technique was adopted. To visualize and quantify the mixing characteristics between each rod bundle, the laser induced fluorescence (LIF) technique is one of suitable measurement technique. The CFD-grade experimental results will contribute to provide the benchmark data for validating the CFD analysis [2].

2. FIFFA Test Facility

Figure 1 shows the FIFFA test loop diagram constructed in KAERI. FIFFA has been designed with a geometric and dynamic similarity of prototype plant for a low temperature and low pressure conditions. The flow distribution is estimated to be preserved with same flow path shape, 1/1 of Euler number, and 1/1 of Reynolds number of SFR flow condition. The desired flow rate is obtained by regulating pump speed installed in main line. An electrical heater with 40 kW is installed to regulating the desired loop temperature in the water tank. Main loop parameters are the flow rate, loop pressure, loop temperature, differential pressure of the rod bundle. For the mixing characteristic test, the injection flow rate is also measured. The rated loop flow rate is 5.49 kg/s and loop temperature is 60 °C in this study. A 3” coriolis mass flowmeter is used to measure the flow rate of FIFFA. The differential pressure transmitters measure the differential pressure of rod bundle produced by the flow rate. The resistance temperature detectors measure the fluid temperature. The pressure transmitters also measure the fluid pressure of the upstream/downstream of the test section. The temperatures and pressures of the fluid are used to determine the fluid density.

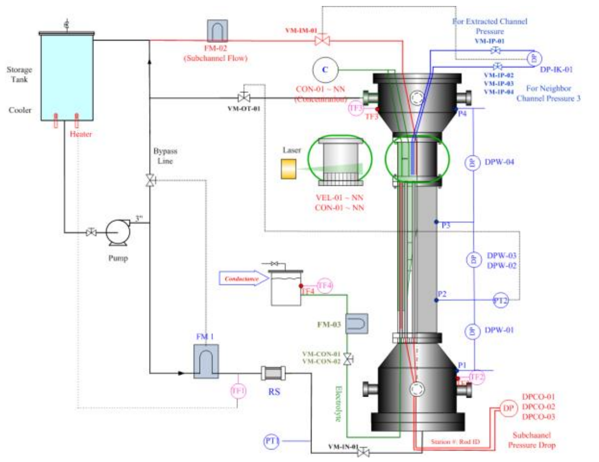

Fig. 1. FIFFA test loop diagram

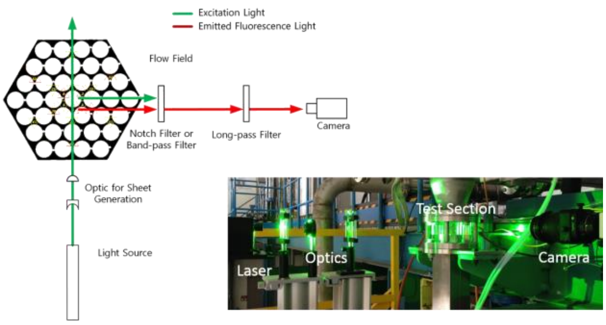

Fig. 2. Experimental configuration for LIF measurement

3. LIF Technique

LIF (laser induced fluorescence) technique is an optical measuring technique used to measure instant whole-field concentration or temperature field in flows [3]. Figure 2 shows the schematic diagram of experimental setup for LIF measurement. It consists of 5 W Nd:YAG continuous laser, 2K×2K CCD camera and a few optics. The laser light sheet illuminates the test flow section through the left side of the tempered glass as shown in figure 1. Working fluid used for LIF measurements is de-ionized water with 60 °C.

Rhodamine B is used ad fluorescent dye. A long pass filter (λ>550 nm) and notch filter are used to eliminate the scattered light except the fluorescence light and block the 532 nm wavelength, and they are installed in front of a digital recording device. LIF technique has the following disadvantages. (a) uniformity of laser sheet (b) the laser power changing between the calibration test and experiment (c) absorption effect of the fluorescent dye. In this study, dimensionless method is adopted to resolve the LIF technique disadvantage, and dimensionless LIF results are compared with CFD analysis results. Figure 3 shows the instantaneous fluorescence image for the case of P01QQ100T60 test case.

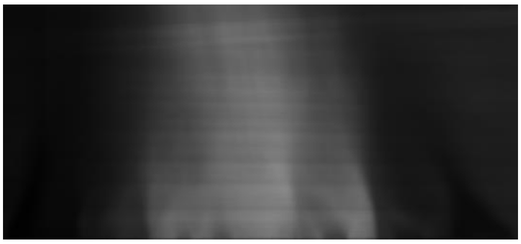

Fig. 3. Raw fluorescence image for P01UQ100T60

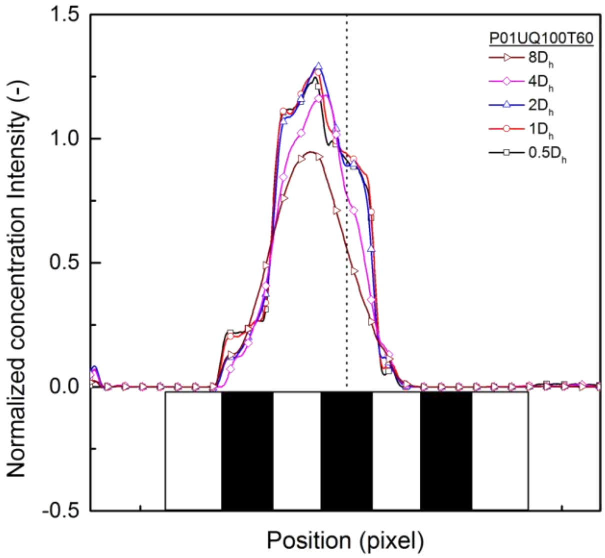

Fig. 4. Concentration profile for P01UQ100T60

4. Experimental Results

In order to remove the influence of background noise, the background image (I_{bg}) obtained by averaging 10 images is acquired before injecting a fluorescent dye. The background images has a lower intensity than test images, so the image obtained by subtracting the background image from the raw test images (I_{raw}) is acquired and the calculated image ($I_{raw} - I_{bg}$) is normalized by the median value ($I_{avg,median}$) of the intensity for 50 average test images as expressed in equation (1).

$$I_r = \frac{I_{raw} - I_{bg}}{I_{avg,median}} \quad (1)$$

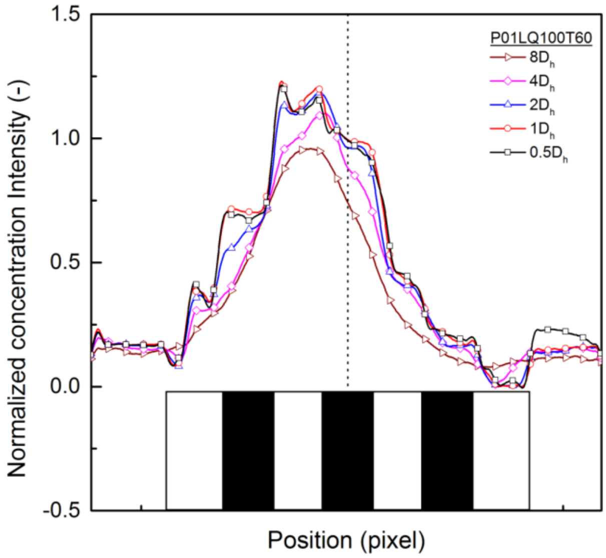

Fig. 5. Concentration profile for P01LQ100T60

In this study, the Rodamine B (fluorescent dye) is injected into the upper and lower location of the rods (#1 and #36). Figure 4 and figure 5 show the average concentration profiles with different injection location for the case of P01UQ100T60 and P01LQ100T60, respectively. In this study, the hydraulic diameter (D_h) is 2.7 mm. In case of lower injection location as shown in fig. 5, the width of mixing zone is bigger than the case of upper injection location. The concentration intensity along the center axis continues decreasing like a jet flow. This CFD-grade experimental results will contribute to provide the benchmark data for validating the CFD analysis.

5. Conclusions

LIF technique is adopted to visualize and quantify the mixing characteristics between each rod bundle in this study. The mixing characteristics data of reactor flow distribution will be utilized to evaluate and to validate the thermal margin analysis of the SFR reactor.

ACKNOWLEDGMENTS

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