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PIV Measurements of Lateral Flow on Fuel Subchannel

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1. Introduction

There have been many experimental attempts to measure the flow structures in a rod bundle array. In the early stage during two decades from 1970, fundamental studies on the flow mixing in a bare rod bundle have been frequently performed. Rehme [1] has been measured the axial velocities and the shear stresses in a four rod bundle array by using the Pitot tube and the hot wire anemometry. Neti et al. [2] performed the LDV measurements for a 3x3 rod array and presented the lateral fluctuations were about 1% magnitudes of the axial flow. From the beginning of eighty, the effect of the vaned spacer grid on thermal hydraulic behavior in a rod bundle array was widely studied as being required the better performance of the heat transfer in a nuclear reactor. Yao et al. [3] have suggested the predictive formulation of the heat transfer by analyzing the physical mechanism and compared with experimental data. Yang et al. [4] have performed the experiments for the measurement of the axial and lateral velocities and their turbulence intensities in a 6x6 rod bundle array with different spacer grids.

Some useful knowledge and insight of the thermal hydraulic behavior in a rod bundle array was obtained from the above extensive experimental works. However, the data resolution in a subchannel is insufficient to get the information of the channel-wise detailed flow structure. Moreover, precise experimental data in a rod array with various flow promoters is increasingly required from the workers in the field of CFD (Computational Fluid Dynamics).

This work presents the detailed measurements of the lateral velocities in a rod bundle array. The measurement was performed by using the PIV (Particle Image Velocimeter) technique. There has been similar experimental work in a rod bundle array (McClusky et al. [5]) by using the PIV system. But the measurement method was advanced and the data resolution was improved.

2. Experimental Method

2.1 Test Facility

The experimental study has been conducted at the cold test loop in KAERI which can perform the hydraulic test at normal pressure and temperature conditions for a rod bundle array in water. The loop consists of a water storage tank, circulation pump and test section (Figure 1). Heater and cooler are contained in the water storage tank for maintaining the experimental temperature conditions during the test. The loop conditions are monitored and controlled by electric signals from instruments likewise, thermocouples, pressure transmitters and flow-meters. During the experiments, the loop temperature was maintained at 35 ºC and the system pressure was 1.5 bar. Experiments were performed at the condition of the *Re* = 50,000 (equivalent to W_{avg} = 1.5 m/s) at the test rig.

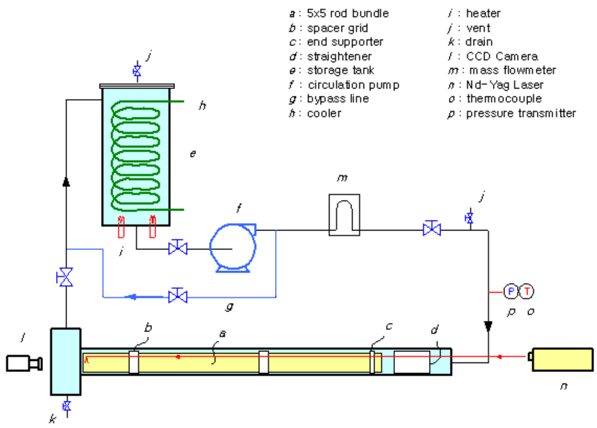

Figure 1. Schematic diagram of the test loop

The spacer grids which were used as the specimen in this work are two types, i.e., the split and the swirl vaned. The detailed information of the specimen is described in earlier work (Chang et al. [6]) which was performed by using the LDV system.

2.2 PIV System

PIV is a measurement technique for obtaining instantaneous whole field velocities based on the particle displacements in a specified time interval. To get the image of the particles in a flow, illumination of the investigating plane and camera are essential. In this study, Nd-Yag laser (Continuum, Surelite, 450mJ) was used as a light source. Particle images were obtained using a CCD camera (Kodak, MegaPlus, 1Kx1K). Seeding particles of hollow glass spheres with a 10 μm diameter were used for the flow tracers. A commercial arm-type beam delivery system was not available because the metallic rod bundles do not pass the sheet beam to the interior of the investigating plane in a subchannel. Special beam delivery tool was designed for the illumination of the investigating plane in a subchannel. The optical array which is comprised of cylindrical lenses and a prism was packed into a tube diameter of which is identical to that of the rod. This tool can deliver the circular beam from the laser generator along the rod center. The circular beam is converted to the sheet beam through the lens array. The direction of the sheet beam is changed to the perpendicular by the mirror in a tube at the investigating plane. Figure 2 (a) shows the tip of the beam delivery tool and (b) shows the operation of the tool in the flow system.

(a) (b)

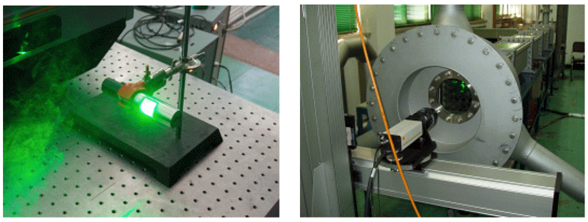

Figure 2. Laser beam delivery system and its operation

Figure 3 shows the schematic of the test rig with optic rod and the bundle cross section in an investigating plane. Optic rod is located as shown in the figure and four subchannels (#1,2,3,4) can be illuminated by rotating this optic rod. In the present experiment, the time delay between pulses was 100 ms and the laser sheet width was 3.0 mm.

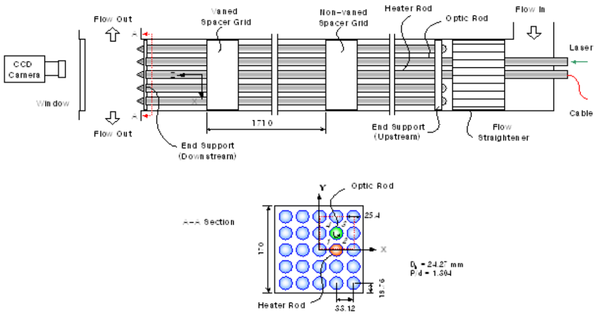

Figure 3. Test rig and the investigating subchannel

Figure 4 shows the example of the illumination of a subchannel by the sheet beam through the optic rod.

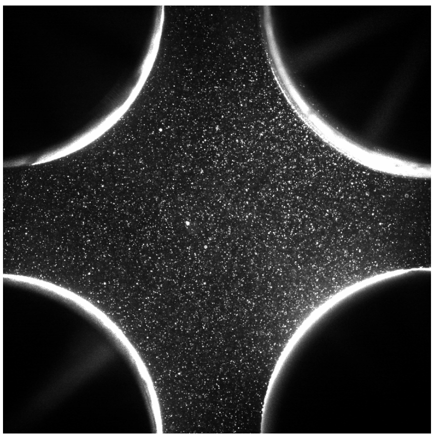

Figure 4. Particle illumination in a subchannel

3. Experimental Result

Typical flow profiles in subchannels are illustrated in figure 5. Upper figure shows the cross flow vectors in channel 1 and 2 at 1 D_h in the case of the split type. Lower one is for the case of the swirl type.

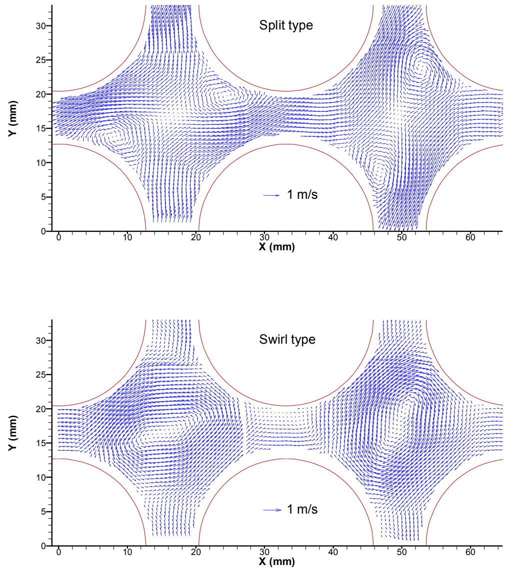

Figure 5. Typical lateral flow configurations with different spacer grid

3. Conclusion

Detailed lateral flow measurement was performed in subchannels at 5x5 rod bundle array using PIV system. To get clear particle images in a subchannel, a special optic rod was designed for the optimum sheet beam generation. Using this optic rod, lateral flow profiles in subchannels were successfully obtained with typical experimental conditions.

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