Experimental Study on Flow Mixing in a Bundle Array with Vaned Spacer Grid

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1. Introduction

In PWR-type reactor core, there are many spacer grids for supporting fuel rod bundles. With this primary purpose, the spacer grids also have a substantial role of thermal mixing of the coolant for improving reactor performance by attaching various types of mixing vanes on their strips. For the purpose of evaluating the flow mixing in a 5x5 rod bundle array with vaned spacer grid, detailed flow velocities are measured by using a laser Doppler velocimetry. The axial and lateral velocities and their turbulent intensities have been measured through the lateral positions and along the axial flow direction in a 5x5 rod bundle array. The distributions of velocities and turbulent intensities are presented along the distance from the spacer grid.

2. Experimental Apparatus

2.1 Experimental Facility

The experimental works have 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 experimental loop conditions are monitored and controlled by electric signals from instruments likewise, thermocouples, pressure transmitters and flow-meters. During this experimental work, the loop temperature was maintained at 27 °C and the system pressure was lower than 4.3 bar.

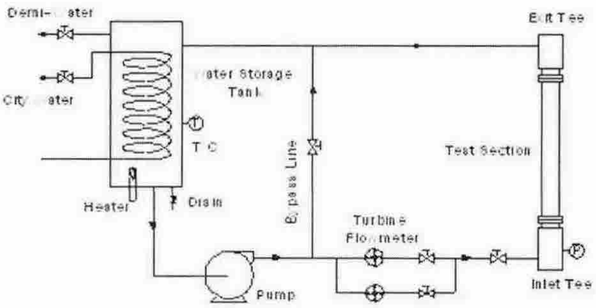

Figure 1. Schematic diagram of the test loop

A 2-component laser Doppler velocimetry was used to measure the turbulent velocities in a rod bundle. It comprises Argon-ion laser source, optics and 2-D probe.

2.2 Test Section

Figure 2 describes the cross sectional configuration of the 5x5 rod bundle array and its LDV measuring coordinates. The rod array is installed in the 68x68 mm acrylic square duct. The principal dimensions are rod dia., D=9.5mm, rod pitch, P=12.8mm and wall pitch, W= 8.4mm, respectively. The dotted area is the location for the LDV measurement. Based on the center line along the z-direction on this area, four lines are selected on both sides with same intervals (0.36mm). Right side in figure 2 describes the vane patterns of the spacer grid on the measurement area.

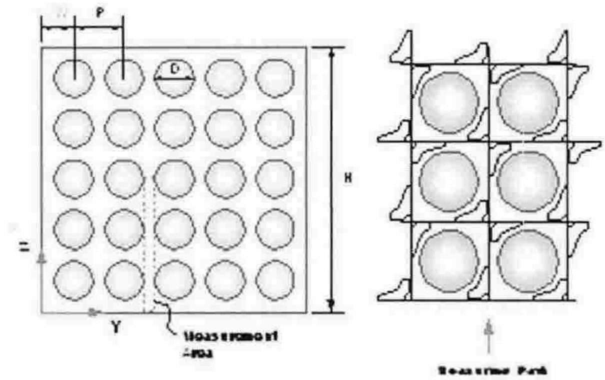

Figure 2. LDV measurement location and coordinates

3. Experimental Results and Discussion

3.1 Velocity Profiles

For our overall understanding of flow structure on a rod bundle array with vaned spacer grid, LDV measurements were performed for one span, where from just behind one spacer grid to just before the next spacer grid. Figure 3 shows the contour of the axial velocity along the flow direction. From this figure the flow profile is converged to the shape of fully developed flow on bare rod bundle array [1] from about x/D_h=16.

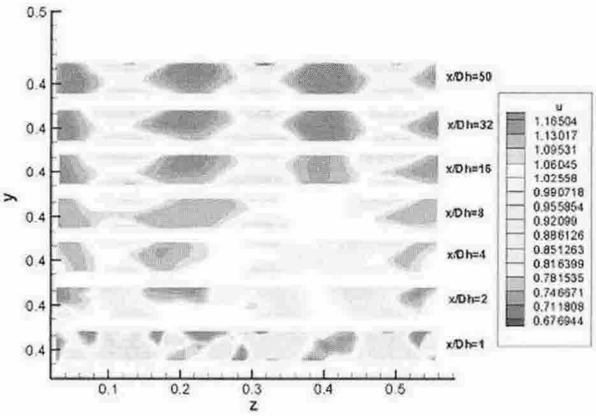

Figure 3. Axial velocity contours along the axial flow direction

Figure 4 shows the axial and lateral velocity profiles (b) and (c) on gap center line and partly compared to the axial velocity profiles (a) of non-mixing vane spacer grid case. From this figure, A and C line of figure 4 (a) and vertical solid lines of figure 4 (c) are the locations of rod center. The axial velocity profile at $x/D_h=2$ on figure 4 (b) is flat and complicated by the vane effects, while on figure 4 (a) is defected (at B and D) sine wave shape which is caused by the strips. Lateral velocity profile is presented in figure 4 (c) and it depicts the vane patterns (region a, b) exactly. Thus, the split vanes have an important role of momentum transfer from axial to lateral component [2]. The axial velocity profiles are agreed well with published experimental results [3].

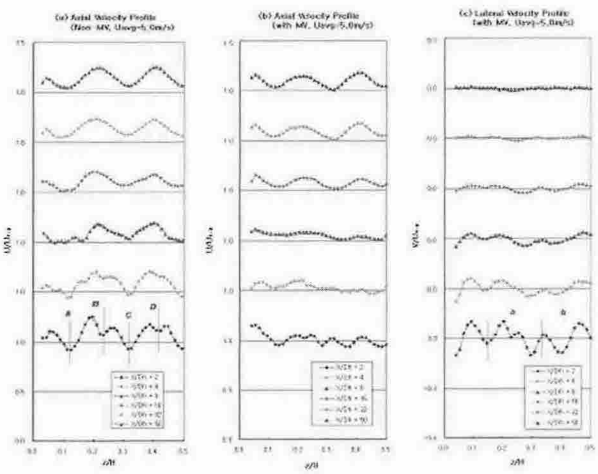

Figure 4. Axial and lateral velocity profiles at centerline in sub-channels along the axial flow direction

3.2 Turbulent Intensity

Figure 5 represents the development of the axial turbulent intensity contour along the axial flow direction. The high turbulent intensity generated by mixing vanes at near spacer grid is rapidly decayed until the distance of $x/D_h=16$ and after that the value is almost constant. At the developed turbulent intensity contour, the high values are distributed near rod walls as was already known from other literature [4,5] and the lowest is located at sub-channel centers.

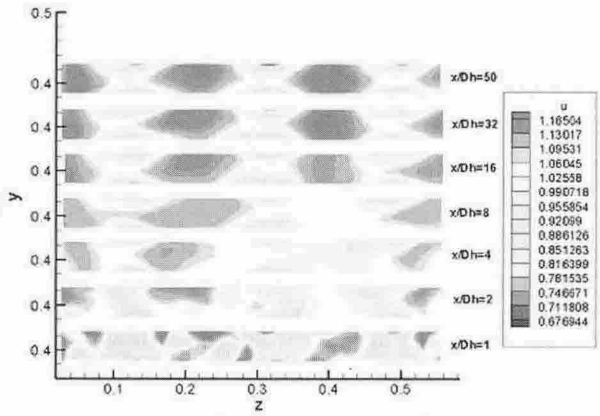

Figure 5. Axial turbulent intensity contours along the axial flow direction

4. Conclusion

Flow structures on a rod bundle array with vaned spacer grid were experimentally investigated using 2-D LDV system. The split vanes on spacer grid have an important role of momentum transfer from axial to lateral flow direction. The axial and lateral velocity fluctuations caused by the mixing vanes are generally disappeared after the distance of $x/D_h=16$, but the developed axial flow profile is flatter than that of the non-mixing vane spacer grid case. The decay of turbulent intensity is also same as the characteristics of the lateral flow disappearance.

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