Experimental Study on the Flow Characteristics in a Bare Rod Bundle Array

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1. Introduction

Structure of a rod bundle array in thermal-hydraulic environment is widely used and very important issues in the industrial field. Especially, in nuclear power plant, this structure is essential in the reactor and steam generator. Because of such an industrial importance, there have been many experimental studies on the flow characteristics in a rod bundle array. During two decades from 1970, fundamental studies on the flow mixing in a bare rod bundle have been frequently performed. Rowe et al. [1] measured the axial and some lateral velocities and their turbulence intensities by using 2-D LDV system. They found the existence of the longitudinal macro-scale and the dominant frequency of turbulence in a sub-channel mixing. Neti et al. [2] also performed the LDV measurements for a 3x3 rod array and presented the lateral fluctuations were about 1% magnitudes of the axial flow. Renksizbulut et al. [3] measured the shear stress of the rod surface and estimates the secondary flow in a sub-channel and Vonka [4] also confirmed the secondary flow in his experimental work.

In spite of many experimental studies on the flow mixing in a sub-channel geometry on a bare rod bundle, there were no full measurement information in a sub-channel. This study attempted to the detailed full measurement of the lateral velocities as well as the axial velocities in a sub-channel geometry on a 5x5 rod bundle.

2. Experimental Method

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.

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

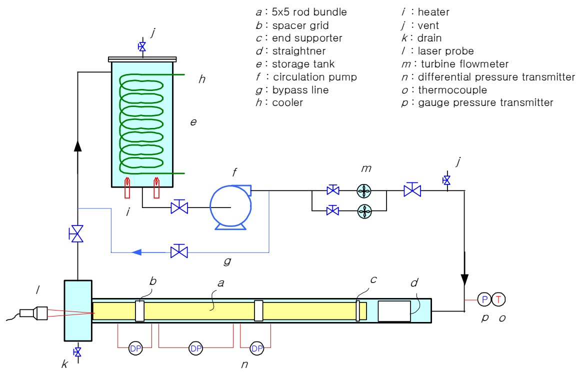

Figure 1. Schematic diagram of the test loop

Figure 2 shows the cross sectional configuration of the 5x5 rod bundle array (170x170mm) and the investing region (enclosed with dotted line). The rod dimensions are D=25.4mm (dia.), P=33.12mm (pitch), respectively. The right figure presents the lateral velocity measuring points. There are 2,412 points of lateral velocity measurement and the space resolution is 0.75mm. The axial velocity measurements were performed in the gaps between two rods (770 points).

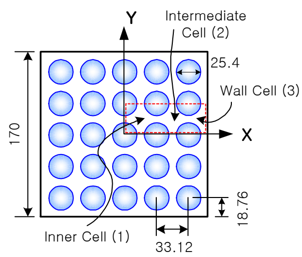

Figure 2. Cross section of the rod bundle array and the investigating region

3. Measurement Results

Figure 3 shows the LDA measurement result of the axial velocity vectors in the rod gap region at the level of 71 D_h apart from the non-vaned spacer grid. Upper figure presents the map of the axial velocity profiles. Velocity peaks are located at cell centers but one peak in cell 2 is biased to the left because of the wall effect. This velocity map is compared to the published data [1,2,3] in a lower figure. Since the flow and geometric conditions are somewhat different each other, these were normalized with rod pitch for comparison. This shows the qualitative similarity in their profile shape but the magnitudes are different according to the flow and geometric conditions.

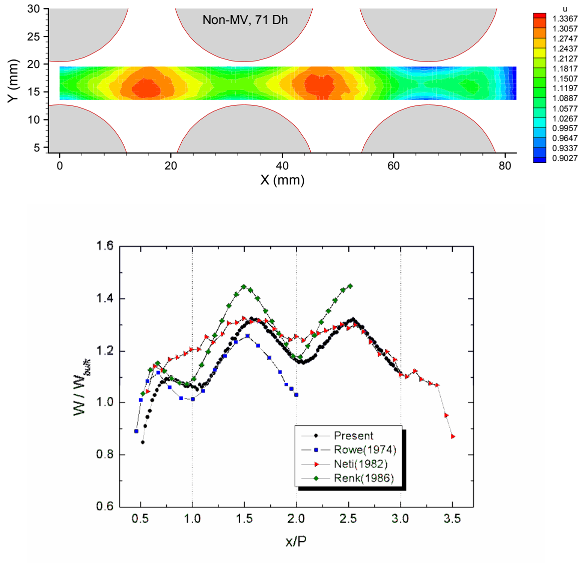

Figure 3. Axial velocity distribution in rod gaps

Figure 4 shows the full structure of lateral velocities in an investigating region at the same cross section of the bundle. Upper figure represents the map of the streamlines from the velocity vectors. There are no closed stream lines in this 5x5 rod bundle array which are expected to be existed in a condition of the symmetric sub-channel geometry. The velocity profile at the gap centerline was compared with the data [2] and shows the well agreement.

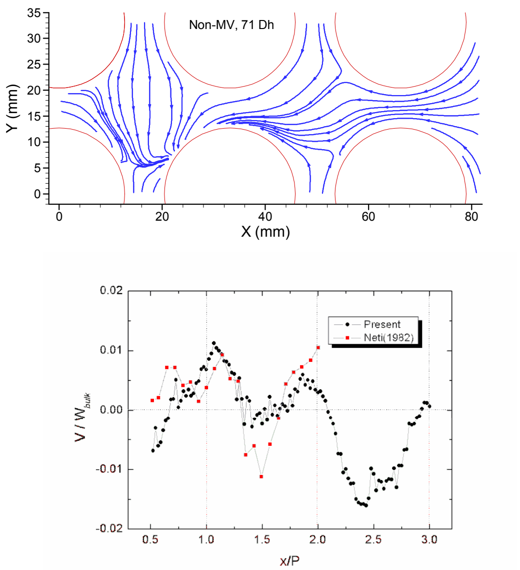

Figure 4. Lateral flow structure in the investigating region

Figure 5 shows the axial and lateral turbulence intensities in the investigating region. Upper figure depicts the map of the u-component lateral turbulence intensities. Intensities are higher at gap regions and lower at cell centers. At the gap regions, intensities are higher at rod surfaces than gap centers. Lower figure shows the three component turbulence intensity profiles in a gap centerline. It was found that the axial turbulence intensity is about 3% higher than that of the lateral components.

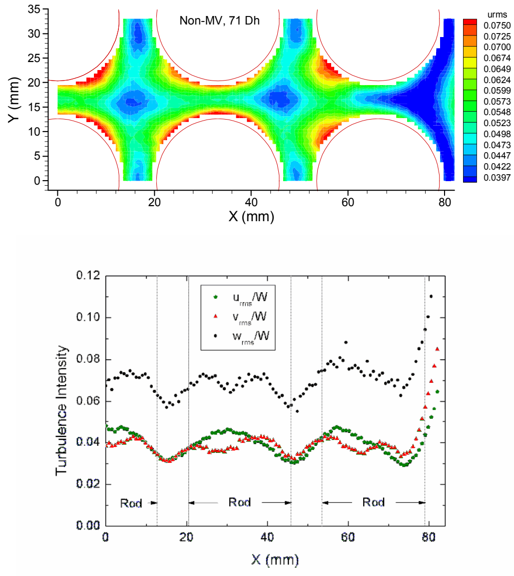

Figure 5. Turbulence intensity distributions

4. Conclusion

Detailed flow structures in a bare rod bundle have been measured by using LDA system. Measurements of the axial velocities were limited in a region of rod gaps. Lateral velocities were measured at full sub-channel region. The axial velocity profile shows qualitive agreement with the conventional data. The closed secondary flow was not found in this bundle array but the magnitudes of flow fluctuations and the map of turbulence intensities were confirmed quite reasonable.

REFERENCES

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