Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Comparisons of the Flow Structure in a Rod Bundle Array with Different Types of the Mixing Devices

Seok Kyu Chang,[a] Bok Deuk Kim,[a] Sang Ki Moon,[a] Won Pil Baek,[a] Young Don Choi,[b]
a Korea Atomic Energy Research Institute, 105, Dukjin-Dong, Yusong-Ku, Daejon, 305-353, Republic of Korea
skchang@kaeri.re.kr, bdkim@kaeri.re.kr, sychun@kaeri.re.kr, wpbaek@kaeri.re.kr
b Korea Univ., Mechanical Engineering Dept., 1, 5Ka, Anam-Dong, Sungbuk-Ku, Seoul, Korea, ydchoi@korea.ac.kr

1. Introduction

In a nuclear power plant, an optimum heat removal from the surface of the nuclear fuel elements in a reactor is very important for the viewpoint of a reactor thermal margin and safety. The spacer grids which support the fuel assembly are used as the effective thermal mixing devices by attaching various types of flow deflectors. The mixing devices cause the swirling flow in a sub-channel and/or the interchanging flow through the gaps between sub-channels by generating the various lateral fluctuations.

There have been attempts to examine the flow mixing in a sub-channel with the vaned spacer grid. Rowe and Chapman [1] investigated the flow perturbation with a grid spacer experimentally. Shen et al. [2] performed experiments of the cross flow mixing effect caused by spacer grids in a 4x4 rod array by using a Laser Doppler Velocimeter. Langford et al. [3] employed a Particle Image Velocimetry (PIV) to measure the lateral velocity field in a 5x5 square-pitch rod bundle. Chang et al. [4] have performed the detailed flow measurements in magnified sub-channel geometry.

Continuing the last experimental work [4] the comparisons of the flow characteristics of the two types of the mixing device in sub-channels have been performed. In a 5x5 rod bundle array with vaned spacer grid, detailed flow velocities were measured by using a laser Doppler velocimetry. The axial and lateral velocities and their turbulence properties were presented.

2. Experimental Method

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. During this experimental work, the loop temperature was maintained at 35 ºC and the system pressure was lower than 2.0 bar.

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.

Figure 1 shows the schematic of the test channel which contains a rod bundle and the test spacer grid and the arrangement of the LDA probe. Experiments were performed at the condition of the Reynolds number 50000. The average velocity in the flow channel is 1.5 m/sec.

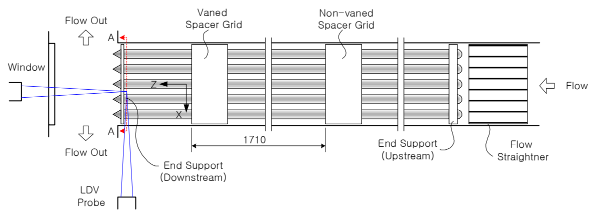

Figure 1. Schematic diagram of the test channel

Figure 2 (a) shows the cross sectional configuration of the 5x5 rod bundle array (170x170mm) and the interesting 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. These are 2,412 points and the measurement resolution is 0.75mm. The axial velocity measurements are performed in gaps between two rods (770 points). Figure 2 (b) shows the split (left) and the swirl (right) type vane patterns in the interesting region.

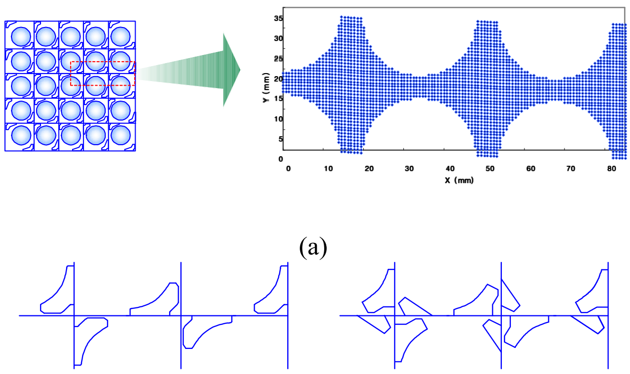

Figure 2. LDV measurement locations (a) and the mixing devices in the interesting region (b)

3. Measurement Results

Figure 3 shows the LDA measurement result of the lateral velocity vectors in the investigation region for two types of the spacer grid at the level of 1 D_h apart from the tip of the mixing vanes. The velocity profiles are differentiated between the types of the spacer grid according to the configurations of the mixing devices.

In the upper figure for the split type, there is a couple of symmetric vortices generated by the split vanes within a sub-channel at the inner and intermediate sub-channels. These localized small vortices contribute to a thermal mixing in a very limited region within a sub-channel. The cross-flow at four gaps in a sub-channel is vigorous and mostly contributes to the energy exchange between the adjacent sub-channels

Meanwhile, in the lower figure for the swirl type, one large vortex of elliptic shape is generated by the swirl vanes within a sub-channel at the inner and intermediate sub-channels. This large swirling flow makes flatten the temperature profile caused by the heat flux from the fuel rod surfaces in a sub-channel. The magnitudes of the lateral peak velocities in this investigation region are about 30% of the axial bulk velocity (1.5 m/s) in both cases.

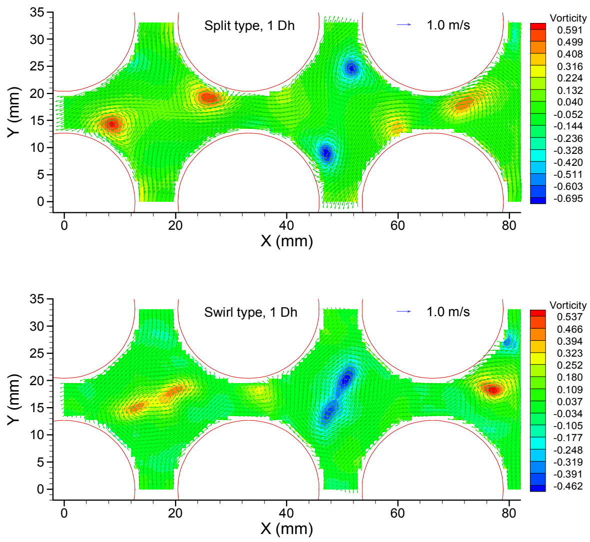

Figure 3. Lateral velocity vectors and vorticities at the level of 1 D_h (Upper : split type S/G, Lower : swirl type S/G)

Figure 4 shows the comparisons of the axial and lateral velocity profiles between the two types along the gap centreline as a flow passes through the downstream.

In the left figure, the axial velocity fluctuates in a complicated manner at $z/D_h = 1$ due to the existence of the mixing vanes just upstream. As the flow moves downstream, the velocity fluctuations decrease gradually. At the level of $z/D_h = 16$, the velocity profile of the split type becomes almost flat while the velocity profile of the swirl type shows a wavy form.

In the right figure, the fluctuations of the lateral velocity profiles in both cases represent the flow characteristics due to the vane patterns, exactly. From the points C1 and C2 at $z/D_h = 1$ which mean the centre of the sub-channels, the symmetric fluctuations in the case of the swirl type allude to a swirling, while in the case of the split type they suggest a splitting flow.

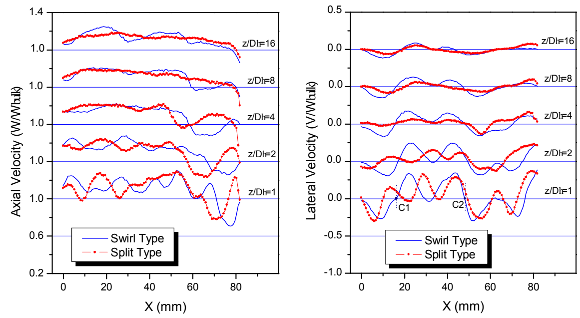

Figure 4. Axial and lateral velocity profiles at the rod gap

4. Conclusion

Detailed turbulent flow profiles have been measured by using LDA in magnified square sub-channel geometry with two types of mixing devices. The experimental results are summarized as follows.

In the case of the split type, a couple of symmetric small vortices were generated in a sub-channel just after the split vanes and it disappeared as the flow moves downstream while the cross-flow at four gaps in a sub-channel was vigorous. The split type spacer grid is considered to be more effective for a mixing between neighboring sub-channels rather than a mixing within a sub-channel.

In the case of the swirl type, one large vortex of an elliptic shape was generated in a sub-channel just after the split vanes and it was maintained until the flow moves downstream. The cross-flow at four gaps in a sub-channel was relatively weak. The swirl type has a better performance for a thermal mixing within a sub-channel when compared to the split type.

REFERENCES

[1] Rowe, D. S. and Chapman, C. C., Measurement of Turbulent Velocity and Scale in Rod Bundle Flow Channels Containing a Grid Spacer, BNWL-1757, 1973

[2] Shen, Y. F. Cao, Z. D. and Lu, Q. G., An Investigation of Crossflow Mixing Effect Caused by Grid Spacer with Mixing Blades in a Rod Bundle, Nucl. Eng. & Design, 125, pp.111-119, 1991

[3] Langford, H. M., Armfield, M. V. and Beasley, D. E., Particle Image Velocimetry of Swirling Flow in a Subchannel of a Rod Bundle, Proceedings of the 2001 ASME Fluids Engineering Division Summer Meeting, New Orleans, May 29-June 1, 2001

[4] Chang, S. K. and Moon, S. K., Detailed Lateral Flow Structure in a Square Sub-channel Geometry, Proceedings of the 2005 Korea Nuclear Society Autumn Conference, Oct. 26-28, Busan, 2005