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Measurements Comparison of Cross Flow on Fuel Subchannel

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1. Introduction

Many experimental studies have been performed by using LDV to measure the velocity field in a fuel rod subchannel with spacer grids. Ikeda and Hoshi [1] performed axial and lateral crossflow measurements in a 5x5 rod bundle by using a specially designed rod-embedded LDV. Chang et. al. [2] have performed detailed axial and lateral velocity measurements in an enlarged 5x5 rod bundle array with two types spacer grids. Recently, the PIV technique was adopted for the full measurement of a subchannel by McClusky et. al. [3]. They observed the generation of vortices from the mixing vanes and its development further downstream. McClusky et. al. [3] showed a comparison with other measurements [1] but it was difficult to obtain clear information because of the rare data and the different experimental conditions.We have performed the PIV measurements of the lateral velocity field in a 5x5 rod bundle array. This work is an extension of the LDV measurements [2]. We compared the PIV measurement results with the earlier LDV data.

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. 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 shows a schematic of the test rig of which the sizes of the cross section and the length are 170x170 and 4,900 mm, respectively.

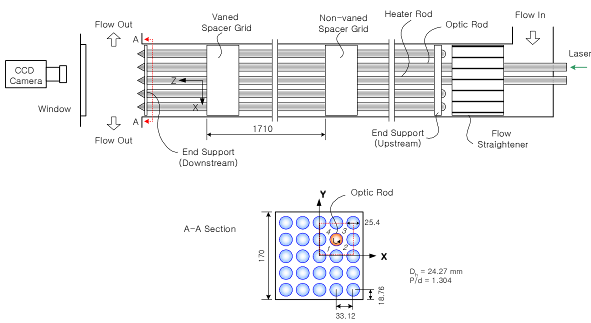

Figure 1. Schematic of the test rig

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. [2]) which was performed by using the LDV system.

For the measurement of the crossflow field in the subchannels (A-A section), a CCD camera (Kodak, MegaPlus, ES 1.0, image resolution = 1,008 x 1,016 pixels) is placed in front of the view window. Four subchannels (#1, 2, 3, 4) were selected as the investigative region. We designed a special rod-embedded optical array. The circular laser beam from the double-pulsed Nd-Yag laser is guided to the rod center which is extended to the outside of the test rig. Figure 2 (a) shows the sheet beam translation by the optic rod from the original circular laser beam. Figure 2 (b) shows a typical particle image in a subchannel. Particle images were divided into an interrogation area of 32 x 32 pixels with a 50 % overlap option and the velocity vectors were processed using the cross-correlation algorithm

(a) (b)

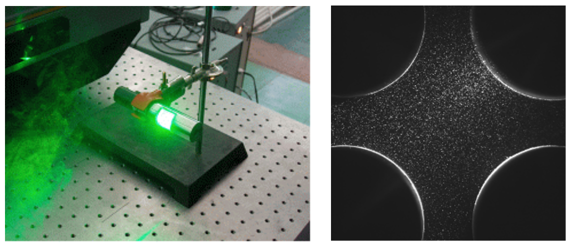

Figure 2. Laser beam delivery system and particle image

3. Experimental Result

From the eighty frames of the instantaneous velocity vector field in a subchannel, averaged crossflow profiles for each of the four subchannels which are in the investigative region were obtained. Thus, one subchannel had 1,740 velocity vectors (resolutions of 0.6 mm). Meanwhile, the resolution and the distributed velocity vectors in a subchannel were 0.75 mm and 1,036, respectively in the LDV measurements [2].

Figure 3 shows the PIV measurements of the lateral velocity profiles in the subchannels at the investigative region in the case of z/D_h = 1 from the spacer grid for both vane types.

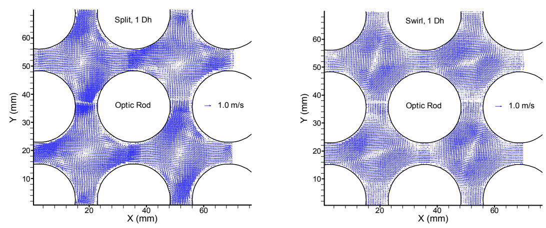

Figure 3. Lateral velocity vectors for $z/D_h = 1$ (PIV results, left : split type, right : swirl type)

Figure 4 shows the LDV measurements in subchannels #1 and #2 which had been performed earlier [2].

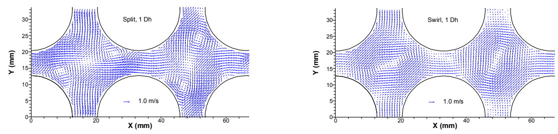

Figure 4. Lateral velocity vectors in subchannel #1 and 2 for $z/D_h = 1$ (LDV results [2], left : split, right : swirl)

Figure 5 shows the comparisons of the velocity magnitudes of the v-component between the PIV and LDV measurement results at the horizontal gap center in subchannel #1 and #2. The velocity profiles along the horizontal gap center line generally agree well but in details, there are some differences of the velocity magnitudes between both measurement results.

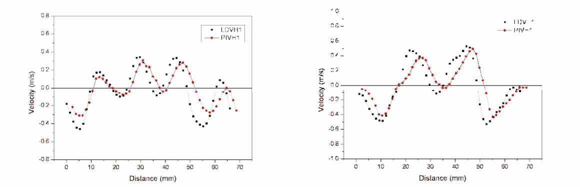

Figure 5. Comparisons of the vertical velocity profiles at horizontal gap center line (left : split, right : swirl)

The vorticity distributions which are shown in Figure 6 were evaluated from the velocity fields in Fig. 7 at $z/D_h = 1$ for both vane types. Most of the vorticity distributions in the subchannels are physically reasonable but at the vicinity of the rod surfaces they may have large uncertainties because of the incorrect evaluations of the velocity vectors as mentioned above.

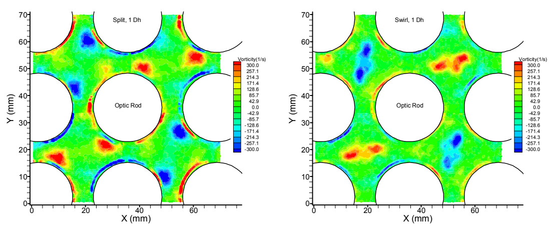

Figure 6. Vorticity distributions for $z/D_h = 1$ (PIV results, left : split type, right : swirl type)

For the comparison, the vorticity distributions in subchannels #1 and #2 from the result of the LDV measurements [2] are presented in Figure 7.

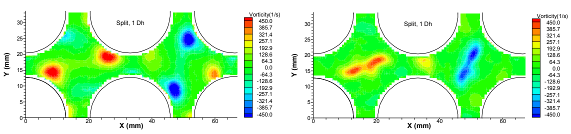

Figure 7. Vorticity distributions in subchannel #1 and 2 for $z/D_h = 1$ (LDV results [2], left : split, right : swirl)

Figure 8 shows the comparisons of the vorticity distribution between the PIV and LDV measurement results. The differences are about a maximum of 48 % in the case of the split type and a maximum of 61 % in the case of the swirl type based on the local vorticity magnitudes from the LDV measurements.

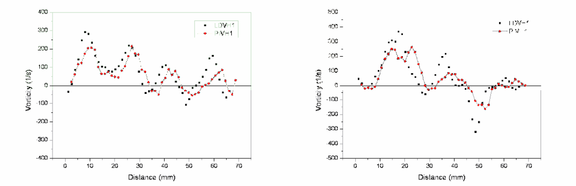

Figure 8. Comparisons of the vorticity profiles at horizontal gap center line (left : split, right : swirl)

3. Conclusion

The lateral crossflow on subchannels in a rod bundle array was investigated to understand the flow characteristics related to the mixing vane types on a spacer grid by using the PIV technique. For more measurement resolutions, the 5x5 rod bundle was fabricated as 2.6 times larger than the real rod bundle size in a pressurized water reactor. A rod-embedded optic array was specially designed and used for an illumination of the inner subchannels. The measurement results were compared to the results which had been performed with the LDV technique earlier [2] at the same test facility.

The crossflow field in a subchannel was characterized by the type and the arrangement of the mixing vanes. At a near downstream location from the spacer grid ($z/D_h = 1$) in the case of the split type, a couple of small vortices were generated diagonally in a subchannel. On the other hand, in the case of the swirl type, there was a large elliptic vortex generated in the center of a subchannel. These intrinsic flow features according to the vane types were confirmed by comparing them with the result of the LDV measurements.

REFERENCES

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