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Heat Transfer Measurements in a 5x5 Rod Bundle with Vaned Spacer Grids

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1. Introduction

In pressurized water reactor, the core has many fuel assemblies and these assemblies contain many fuel rods that are supported by spacer grids. The spacer grids have an important role of mixing coolant flowing in subchannels by attaching various flow promoters at strap edges as well as supporting the rods in right positions. It can be generally deduced that the heat transfer is drastically activated just after the spacer grid which has mixing vanes and as flow passes axially along the fuel rods the heat transfer would decrease gradually.

KAERI has been performed a series of experiments [1] of flow mixing in subchannels in conditions of various vaned spacer grids. In the experiments, the flow structures in subchannels were measured by non-intrusive measurement method such as LDV or PIV technique. Recently, during these works, the heat transfer experiment in a rod surface was also performed. For this experiment, a short rod heater is equipped in a rod which is one among the 5x5 rod bundle.

Such experimental studies have been performed in nuclear field. Yao et al. [2] have suggested the predictive formulation of the heat transfer by analyzing the physical mechanism in a rod array with various flow promoters. The predictions were compared with experimental data. Holloway et al. [3] performed an experimental work of heat transfer and pressure drop in a rod bundle downstream of support grid designs with and without flow enhancing features. They suggested a heat transfer correlation which is considering the effects of the flow blockage and the pressure drop of the flow enhancing features.

This study presents the heat transfer measurements in a 5x5 rod bundle with two types of spacer grids. From the temperature measurements in a rod surface, the heat transfer coefficients along the downstream of the rod bundle were obtained.

2. Experimental Method

2.1 Test Facility

We used the cold test loop 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. 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 the electric signals from thermocouples, pressure transmitters and flow-meter. The loop temperature was maintained at 35 ºC and the system pressure was 1.5 bar during operation. Experiments were performed at the condition of the *Re* = 50,000 (equivalent to W_{avg} = 1.5 m/s) at the test rig.

A short heater is embedded in one fuel rod among the 5x5 rod bundle as shown in figure 1. The experiments were performed as moving a couple of spacer grids axially along the rod bundle.

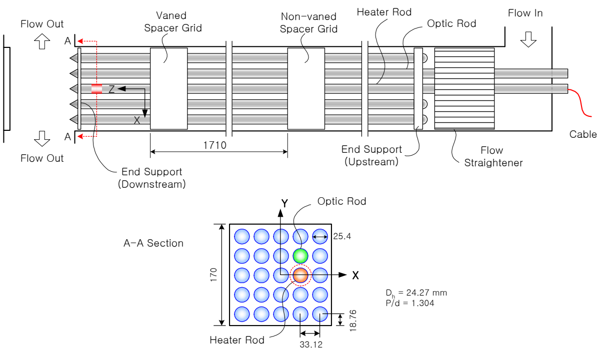

Figure 1. Schematic of the test rig

2.2 Heater Rod

Figure 2 shows the rod heater installed in a 5x5 rod bundle. This heater rod is comprised of a heater which has insulating parts at both ends and a connecting rod extended to the outside. There are eight thermocouples embedded at the surface of the heater. The power and signal cables of the heater passes inside of the connecting rod and are linked to the power and the DAS system.

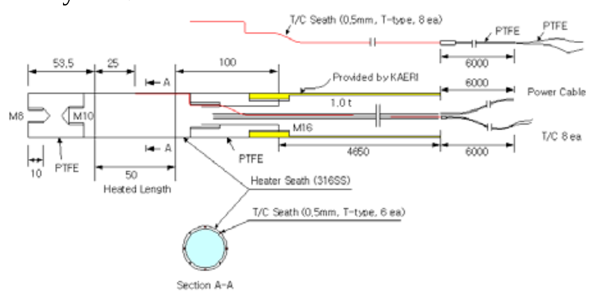

Figure 2. Schematic of the heater rod

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. [1]) which was performed by using the LDV system. A typical vane patterns in a subchannel for each type are shown in figure 3.

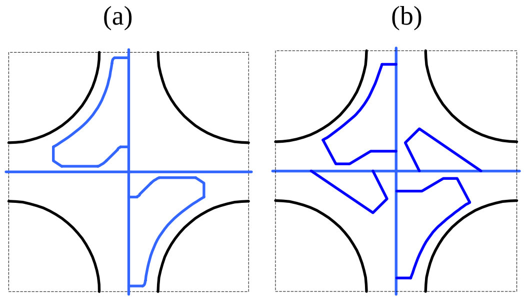

Figure 3. Typical vane patterns in a subchannel ((a) split vaned, (b) swirl vaned)

3. Experimental Result

Temperature measurements at the surface of the heater rod were performed as changing the position of the test spacer grids from -0.57 to 38.4 D_h. The input power to the heater is maintained at 600 Watt. Figure 4 shows the averaged temperature profiles at each locations of the T/C for each vane types.

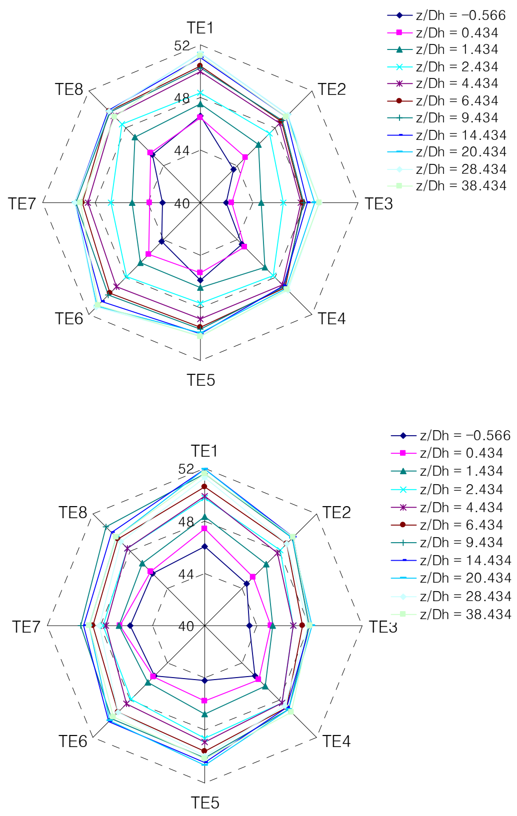

Figure 4. Temperature profiles at the rod surface for each vane types (upper: split, lower: swirl)

From the above measurement results, the local heat transfer coefficients were evaluated with the simple relation, i.e., $h = q''' / (A \cdot \Delta T)$.

q''' and A is a heat flux and a peripheral heater surface, respectively. ΔT is a difference between the heater surface and the loop system temperature. Figure 5 shows the decay of the local heat transfer coefficients for both types as flow goes downstream. The HTCs at TE2,3,4 locations are higher than other locations because of the vane effects. Although the HTCs are higher in split type at near spacer grid, averaged HTCs at remaining downstream are almost same for both types.

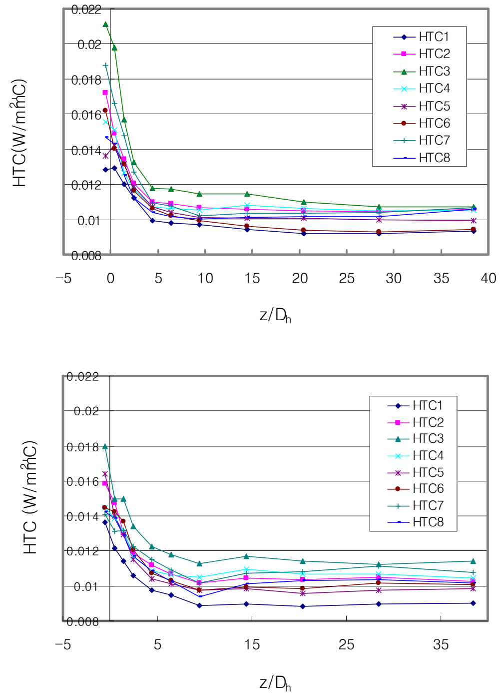

Figure 5. Profiles of heat transfer coefficients (upper: split, lower: swirl)

3. Conclusion

Heat transfer experiments were performed at a 5x5 rod bundle array with two types of vaned spacer grids. A short heater was equipped in one rod and eight thermocouples were embedded at the heater surface. The local heat transfer coefficients were evaluated from the measurements. More information would be acquired from further investigation of the measurement results.

REFERENCES

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