Heat Transfer Enhancement by a Spacer Grid

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1. Introduction

The spacer grids affect the hydrodynamics of flow through the fuel rod bundle and the heat transfer to the flow from the fuel rods. They reduce the fuel assembly flow area by contracting the flow and then expanding it downstream of the spacer grid. Thus, the flow and thermal boundary layers are disrupted and re-established by the spacer grid. This enhances the local heat transfer within and downstream of the spacer grid. The previous studies[1-4] suggested heat transfer correlations that are a function of flow blockage ratio only. However, a recent study revealed that the heat transfer coefficients are affected by the Reynolds number as well[5]. The objective of this study is to develop a correlation to predict the heat transfer behind the spacer grids.

2. Experimental setup

KAERI holds rod bundle test facilities: 2x2 and 6x6 rod bundles. Figures 1 shows the 6x6 rod bundle. The diameter and pitch of rods are 9.5mm and 12.85mm, respectively. The axial length of rods is 3.81 m. 30 rods are heated with an axially chopped cosine power profile. The spacer grids are the plus 7 type.

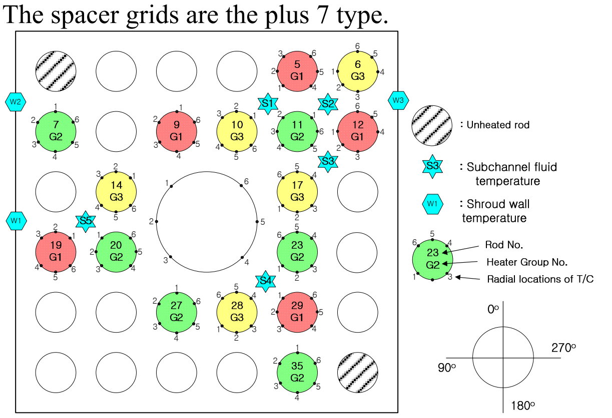

Fig. 1. 6x6 rod bundle

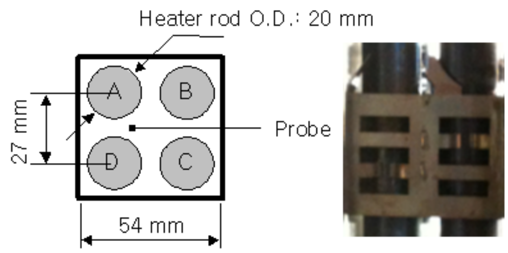

Fig. 2. 2x2 rod bundle and spacer grid

Table I: Spacer grid used in 2x2 rod bundle.

	Vane	Vane angle	ε
Type 1	X	-	0.17
Type 2	O	60°	0.35
Type 3	O	67°	0.41

Figure 2 shows the 2x2 rod bundle. The axial length of the rods is 1.8 m. An Axially-uniform power is applied to the rods. Three types of spacer grids are considered in this study, as listed in Table I. The major parameter of spacer grids is the flow blockage ratio depending on the mixing vane angle. This paper however deals with type 3.

3. Result

3.1 2x2 rod bundle

In general, the Nusselt number is maximized at the exit of the spacer grid and decreases as going downstream. Figure 3 shows the variation of the temperature with the axial position when the steam flow rate is 0.0149 kg/s (Re=9283 at SG2 and Re=0.8235 at SG3). In the graph, x is the distance from the bottom of the heated section. One can see that the wall temperature is greatly reduced near the spacer grids.

Figure 4 shows the variation of Nu_{max} with Re. Nu_0 is the experimental Nusselt number at the location ahead of the spacer grid (x=200mm for SG2 and x=600mm for SG3). Nu_{max} decreases with Re, as follows:

$$\frac{Nu_{max}}{Nu_0} - 1 = 15.316\,Re^{-0.391} = 91.1\,Re^{-0.391}\,\varepsilon^2 \qquad (1)$$

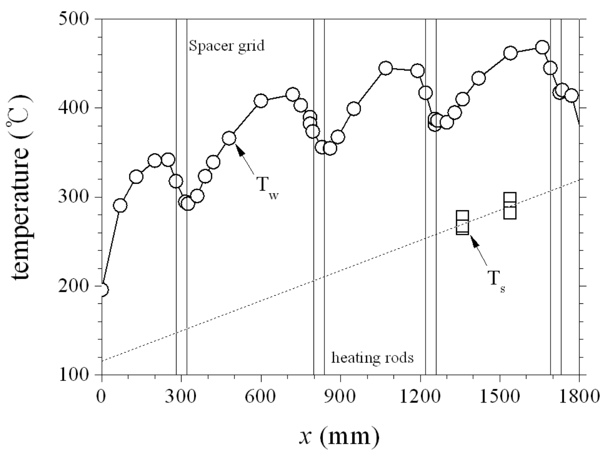

Fig. 3. Temperature profile

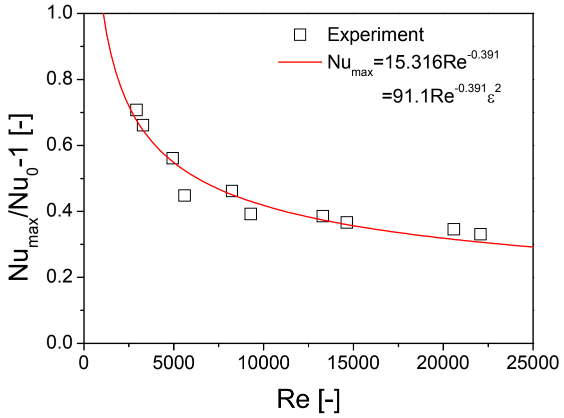

Fig. 4. Nu_{max} vs Reynolds number

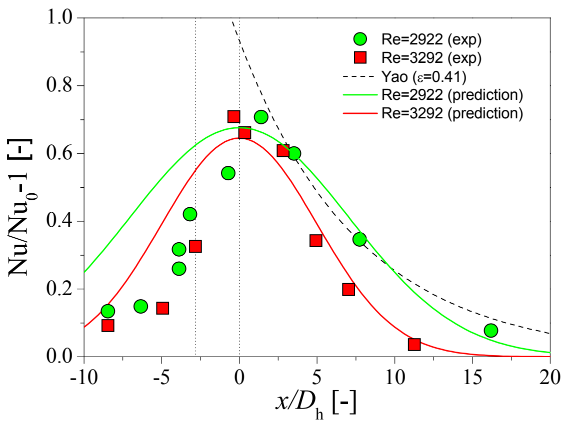

Fig. 5. Nu (Re=2922, 3292)

Most previous studies adopted an exponential decay function to predict the heat transfer coefficient behind the spacer grid[1-5]. We found that a Gaussian function is more appropriate for the present experiments.

$$\frac{Nu}{Nu_0} - 1 = A\exp\left(-b\left(\frac{x}{D_h}\right)^2\right) \tag{2}$$

The variable x is the distance from the trailing edge of the spacer grid main body, not from the mixing vane tip. The parameters A and b should be determined from experiment. It was assumed that A and b are a function of the Reynolds number as well as the blockage ratio and. The parameter A equal Nu_{max}/Nu_0-1 in Fig. 4. Figure 5 shows the results for low Reynolds numbers. The downstream data can be fitted with Eq. (2). A=Nu_{max}/Nu_0-1 decreases with the Reynolds number.

3.1 6x6 rod bundle

A similar analysis was applied to 6x6 rod bundle test. Two different total powers were considered. Four steam flow rate were considered for each total power. Unlike the 2x2 test facility, the temperature points are axially sparse because of long and many rods. Figure 6 shows the analysis results for the spacer grid located at 2050 mm from the bottom of heating rods. One can say that

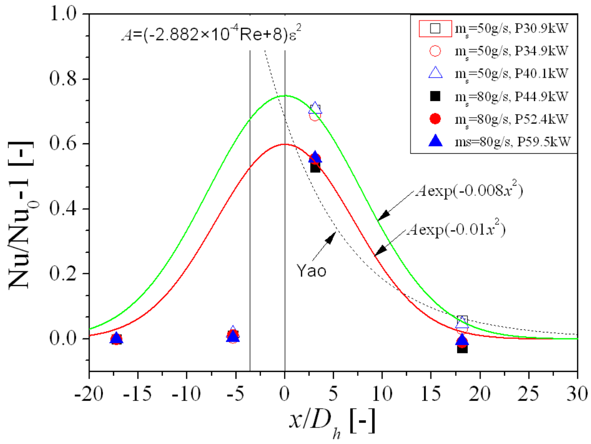

Fig. 6. Nu (Re=6500, 10750)

the total power applied does not affect the result. On the other hand, the vapor flow rate changes the result. The steam flow rates 50g/s and 80g/s correspond to Re=6500 and Re 10750, respectively. A=Nu/Nu_0-1 decreases with the Reynolds number. This behavior is also observed in the 2x2 rod bundle test. Due to the limitation of the axial data points, A was fitted with a linear function of the Reynolds number.

$$\frac{Nu_{max}}{Nu_0} - 1 = (-2.882\times10^{-4}\,Re + 8)\varepsilon^2 \tag{3}$$

The variable b is not much different in two fitting curves. Since the spacer grids in 2x2 and 6x6 rod bundles are not the same, A and b may be different. However, general trends are the same.

Acknowledgments

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4. Conclusions

Experiments have been done to find a proper correlation to predict the heat transfer behind the space grid. As a result, we derived the correlation that is a function of the Reynolds number. The work is going on at this moment. The flow blockage ratio will be incorporated into the correlation.

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