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Effect of Mixing Vane on Critical Heat Flux in 2x3 Rod Bundle with R-134a

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1. Introduction

The mixing vane, a major component of the nuclear fuel assembly, plays a role of enhancing the critical heat flux. It is the cause to increase the power in the nuclear power plant. Hence, the development of mixing vane with good performance is an important part in design and development of the nuclear fuel assembly.

The mechanisms of the CHF enhancement by mixing vane were discussed in Cheng et al. (1996) [1].

Table 1 Mechanisms effective to the CHF

Region	Effecting Mechanism	CHF
General	Increase of enthalpy mixing	Increase
Low quality	Breakup of bubble crowding	Increase
	Centrifugal acceleration	Increase
High quality (Annular Flow)	Directing entrained liquids from core to the wall	Increase
	Breakup of liquid film	decrease

And many researchers developed CHF correlations for bundle geometry from the effect of mixing vane. The CHF correlations for bundle geometry consider heating type (uniform or non-uniform), spacer grid and mixing vane effect, the location of guide thimble and non-heating area (EPRI correlation, CE correlation, B&W correlation, etc) [2]. In additions to these works, some researchers develop the CHF correlation in bundle geometry from CHF data in circular using correction factor. [3, 4]

The objective of this study is estimation and analysis of the CHF performance of various mixing vanes in 2x3 rod bundle geometry.

2. Experimental Works

In this study, the CHF experiment was performed in 2x3 rod bundle with and w/o mixing vane. The working fluid was R-134a.

2.1 Test Loop and Test Section

The test loop is composed of the pump, the condenser, the chiller and the accumulator. The cooling system is capability of removing the heat up to 60kW. The maximum mass flux is 1425kg/m^{2}s about 2x3 rod bundle. The detailed features are referred on [5].

In the test section, the distance between rods is 12.65 mm and each rod has 9.5 mm in diameter. The gap of rod-to-wall is 1.575 mm. The heating length is 1.125 m. The spacer grid with mixing vane is located 150 or 300 mm downward from upper end of heating part.

2.2 Test mixing vane

Test mixing vanes are three different types of mixing vane: Split vane, Hybrid vane, and Swirl vane. Split vane was developed by W/H Company and Hybrid vane and Swirl vane was developed by KAERI. Split vane generate the cross flow between the subchannels and Swirl vane generates the swirl flow in a subchannels. Hybrid vane generates the cross flow and swirl flow at the same time.

2.3 Test Condition

This experiment was performed at the high pressure conditions over 90bar (water equivalent pressure). And the mass flux ranges include the low and high mass flux. The test conditions are as follows;

- Pressure: 15 bar ~ 25 bar
- Inlet subcooling: 40 kJ/kg ~ 80kJ/kg
- Mass flux: 300kg/m2s ~ 1400kg/m2s

The number of total data is 234 points.

3. Results

In the experiment without mixing vane, CHF trends were similar to the CHF trends in round tube. That is, the value of CHF increased as the inlet subcooling and mass flux increased and the pressure decreased. The data was compared with the Bowring correlation [2] after the data was converted to the water data using fluid-to fluid model with Katto's equation [6]. The correlation underestimated up to 25%.

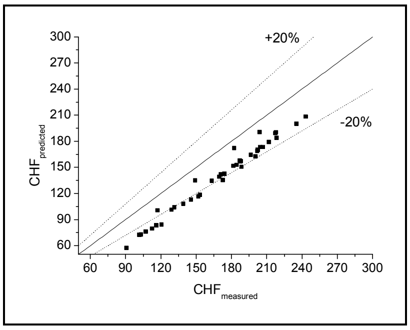
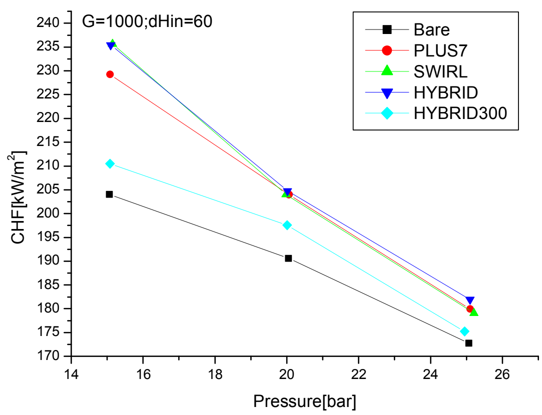


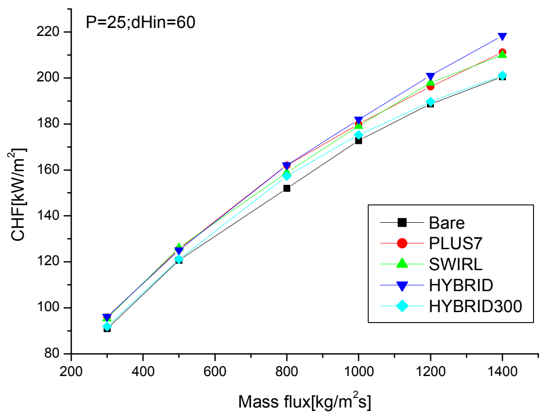
Figure 1 Comparison of the CHF data with Bowring correlation

Figure 2 shows the effect of mixing vane on the value of CHF. In this figure, the effect of mixing vane (q_{MV} - q_{Bare}) was enlarged at low pressure, high mass flux. But the variation of the inlet subcooling didn't affect the difference of the heat flux.

Generally, the reason of the CHF enhancement by mixing vane is due to the swirl flow and cross flow. In this result, CHF enhanced largely at the relatively low pressure and high mass flux. It means that the effect of the swirl and cross flow reduced at that condition. It guessed that the reasons of the reduction is the decrease of the centrifugal force by the decrease of density ratio at low pressure and the reduction of the magnitude of the swirl and cross flow at low mass flux.



(a) CHF with variation of the pressure



(a) CHF with variation of the mass flux
Figure 2 Effect of mixing vane on critical heat flux

The performance of three types of mixing vane was also compared in this study. In entire region, the CHF enhancement ratio between mixing vanes didn't have a big difference. But, at the low pressure, Swirl vane show a relatively large enhancement and Hybrid vane is superior at high pressure and high mass flux. It will be discussed later.

4. Conclusion

In this study, the effect of mixing vane and the comparison of three types of mixing vane on CHF enhancement was investigated. The main conclusions are as follows;

(1) In the experiment without mixing vane, CHF trends were similar to the CHF trends in round tube.

(2) In the experiment with mixing vane, the effect of mixing vane was enlarged at low pressure, high mass flux. But the variation of the inlet subcooling didn't affect the difference of the heat flux.

(3) At the low pressure, Swirl vane show a relatively large enhancement and Hybrid vane is superior at high pressure and high mass flux. It will be discussed later.

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