CHF Experiment and CFD Analysis in 2*2 Rod Bundle with Swirl-Type Mixing Vane

B.S. Shin,a S.H. Chang,a
a Department of Nuclear and Quantum Eng.,KAIST, 373-1, Guseong-dong, Yuseong-gu, Daejeon, 305-701,Korea, byungsoo@kaist.ac.kr

1. Introduction

In commercial PWR fuel assembly, mixing vane is one of important components for improvement of thermal performance. Up to now, many researchers have studied on the effect of mixing vane on CHF and the cause of CHF enhancement. But, it was not clear region. Nowadays, there are efforts to study the mechanism of CHF enhancement by mixing vane using CFD analysis. In spite of limited memory, it is economical and useful method to understand the mechanism. But, it need more studies.

2. Methods and Results

2.1 CHF Experimental Work

The test loop and test section was described in Ref. [1]. Working fluid is R-134a. The test mixing vane is shown as Figure 1. It was developed by KAERI. (U.S. Pat. No. 6236702) The angle of mixing vane varies as 20, 30 and 40. The experimental conditions are as follows: mass flux is from 1000 to 1600 kg/m^{2}s, inlet temperature is from 35.05 to 90.93 kJ/kg, inlet pressure is from 15 50 25 bar. The experiments are performed with or without mixing vane.

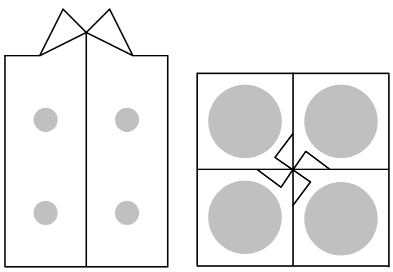


Figure 1. Test Mixing Vane (U.S. Pat. No. 6236702)

Firstly, CHF experiment without mixing vane was performed. The results had a good agreement with look-up table despite a little error. To compare the experimental data with look-up table of round tube, the fluid-to-fluid model was used [2]. Then, Katto's model was selected as fluid-to-fluid model [3]. Figure 2 shows the comparison.

Figure 3 shows the variation of CHF with inlet subcooling on mixing vanes, which have various vane angles. From figure 8, Mixing vanes enhance the value of CHF up to 20%. And the ratio of CHF enhancement changed with an angle of mixing vane. In the figure, S30 enhance the value of CHF most effectively except the case of 1000kg/m^{2}s.

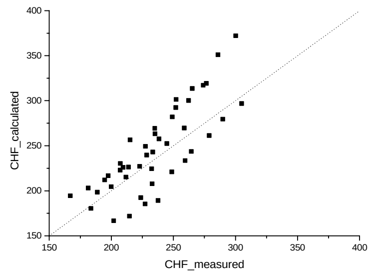
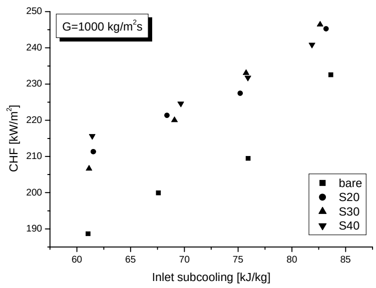
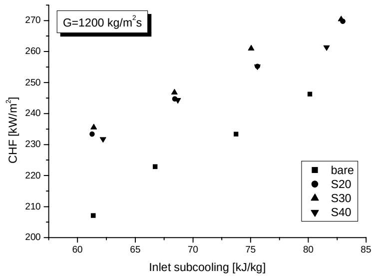


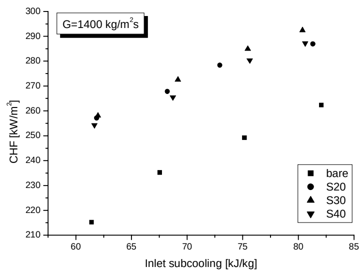
Figure 2. Comparison of experimental CHF and 1995 Groeneveld look-up table



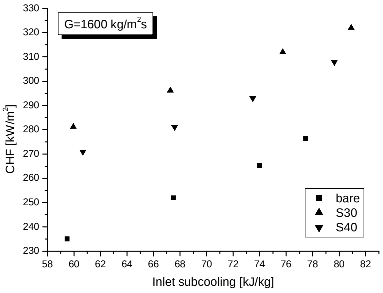
(a) G=1000kg/m^{2}s



(b) G=1200kg/m^{2}s



(c) G=1400kg/m^{2}s



(d) G=1600kg/m^{2}s

Figure 3. Variation of critical heat flux with inlet subcooling on mixing vanes, which have various angle (a) G=1000kg/m^{2}s (b) G=1200kg/m^{2}s (c) G=1400kg/m^{2}s (d) G=1600kg/m^{2}s

Figure 4 shows the variation of CHF enhancement ratio on the position of mixing vane with the inlet subcooling and the mass flux. Karoutas(1994) measured the decay of swirl flow using LDV [4]. From figure 4 we could know that, due to the decay of swirl flow, CHF enhancement ratio was reduced as the position of mixing vane was far from the position at which the CHF occurred.

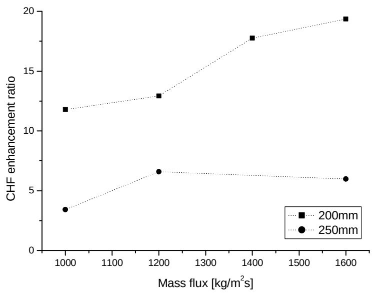


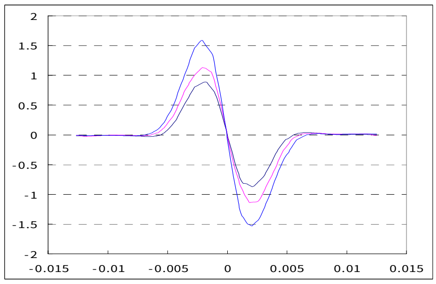
Figure 4. Variation of CHF enhancement ratio on the position of mixing vane with the mass flux

2.2 CFD Analysis Method

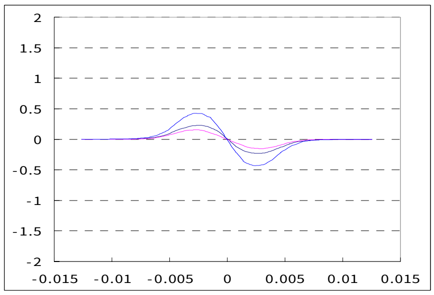
3-D numerical analysis model is set up. In this model, a thickness of strap and blade is 0.5mm and other geometry is same as that of test mixing vane used in experimental work. The 3-D model is composed of 2375229 elements and has 477634 nodes.

Inlet boundary condition is defined as uniform velocity (3m/s) and outlet boundary condition is defined as static pressure. No slip and no roughness conditions are defined as wall, rod surface and spacer grid. “k-e model” is applied as turbulent model. When RMS residual is below 10^{-4}, it is defined that CFD analysis converges. The CFD analysis is calculated using CFX-5.

From the CFD analysis, tangential velocity profiles at the centerline of cross section is compared between the location and mixing vane angle. It is shown as Figure 5. Contrary to the results of CHF experiment, S40 generated swirl flow stronger than S30.



(a) z=10mm



(b) z=70mm

(Black:S20, Red:S30,Blue:S40)

Figure 5. Tangential velocity vectors at centerline of the cross section of which the position is (a) 10mm (b) 70mm

3. Conclusion

CHF experiment was performed in 2*2 rod bundle with R-134a. And CFD analysis was also done on single phase flow. In CHF experiment, we could know the effect of mixing vane angle and location on CHF. In case that the angle is 30^o, the ratio of CHF enhancement was largest. The CFD analysis did not agree with the CHF experimental results. We need more studies on the methods of CFD analysis.

REFERENCES

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