Evaluation of MARS code on CHF with Fluid-to-Fluid Method Under Inlet Flow Fluctuation

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1. Introduction

The marine reactor is influenced thermal hydraulically by various ship motions such as heaving, rolling and pitching. In particular, the heaving is the most important factor to the safety design and operating. So that, it must consider effects of acceleration oscillation induced by ship motion on the performance of the power plant. It is especially important to be able to predict critical heat flux (CHF) in an oscillating acceleration field, which limits the maximum power extractable from nuclear reactors. Otsuji et al. [1] found that CHF ratio was proportional to the 1/4th of acceleration factor. In this paper, only the heaving condition is considered to evaluate acceleration effects on the CHF. To verify this characteristic, the fluid scaling methods suggested by Coffield [2], Katto [3] and Ahmad [4] were used to compare Otsuji's Freon CHF data with CHF correlations for water in the system code.

The main objective of this study is to assess capability of MARS code [5] using the fluid-to-fluid scaling with comparing Otsuji's experimental data and to evaluate the fluid-to-fluid modeling method with MARS code calculation between R-113 and water. To analyze the result of experiment data followed Otsuji's experiment procedure and model. However, there was a critical problem to apply experimental data to water-based marine reactors since the data was obtained from R-113 flow. Therefore, a fluid to fluid modeling should be used to examine the applicability of the MARS code to simulation of moving motions for marine reactors.

2. 3. Result and Discussion

2.1 Stationary CHF

MARS calculation with fluid-to-fluid scaling and fluid-to-fluid method CHF as a function of inlet subcooling (1-27K) is shown in fig. 1. Preliminary analysis was performed effect of inlet subcooling on CHF at different flow condition for estimating the method of compatibility of MARS CHF calculation. The results are obtained at the pressure 24.4 bar and at mass flux of 728, 681, 1110 corresponding to Otsuji's test 510 kg/m^{2}s and 1398, 1309, 2133 corresponding to Otsuji's test 980 kg/m^{2}s. The CHF increase almost linearly with the inlet subcooling, but the effect decrease with decreasing mass flux. In stationary condition, fluid-to-fluid method of Coffield is predict well than others method.

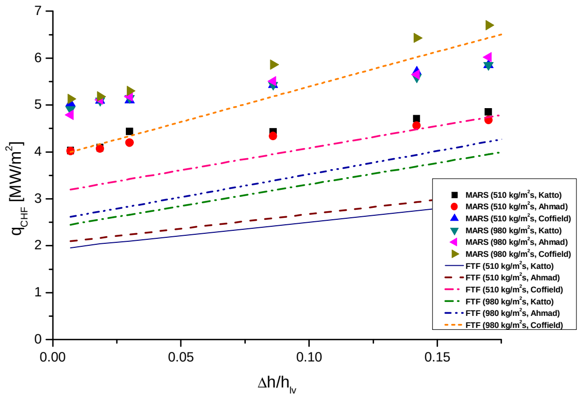

Fig. 1. Comparison of MARS calculation and fluid-to-fluid scaling (FTF) result on stationary CHF as a function of inlet subcooling.

2.2 CHF and inlet subcooling variation under oscillating condition

The results in fig. 2 represent that the ratio of the CHF under oscillating condition to the steady (non-oscillating) CHF decreases as the inlet subcooling increases. Especially, at around 20 and 27 K of subcooling, the amount of decrease becomes maximum, which was also observed in the experiment. As the inlet subcooling increases at a given mass flux, the CHF ratio reduction comes close to proportional to 1/4th power of gravity. This is due to fluctuation of the void fraction as the inlet subcooling increase.

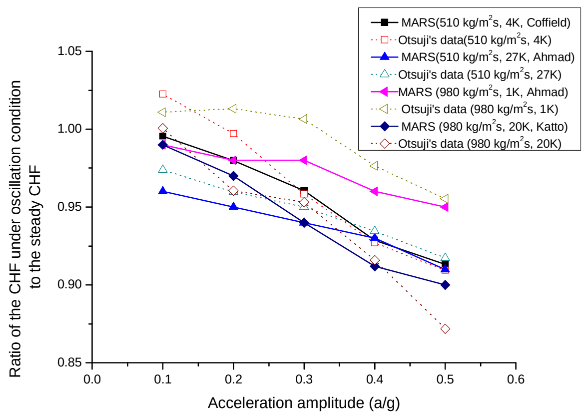

Fig. 2. Reduction of water CHF ratio under oscillating condition.

3. Conclusions

When the marine reactor suffers from heaving in the ocean, the mass flow rate and void fraction might change vertically, and thus can seriously affect on CHF. Therefore, the Freon-based CHF data from Otsuji's experiment was assessed by the Ahmad, Katto and Coffield fluid-to-fluid modeling to extend its applicability on the water-based analysis and design. Also, we examined the thermal-hydraulic system code for land-base reactor design, MARS, with an artificially fluctuation of the inlet flow to have a same effect on acceleration change.

The results of code calculation predicted well the Otsuji's Freon CHF data. CHF decreases quantitatively with the oscillation of gravity acceleration in a vertical direction as the previous researches concluded. As results, the CHF for water in the scaling calculation, multiplied by CHF scaling factor to CHF for R-113, was nearly similar to the results of MARS code within ±14 % of error and 7.6 of RMS. The ratio of the CHF under oscillating condition to the steady (non-oscillating) CHF decreases as the inlet subcooling increases. In additional calculation, the void fraction increases as the flow rate decreases during the heaving. In conclusion, the prediction of CHF for given flow oscillation is good agreement with Otsuji's data and analysis using the methodology of this study is reasonable.

REFERENCES

[1] T. Otsuji, and A. Kurosawa, Critical Heat Flux of Forced Convection Boiling in an Oscillating Acceleration Field, Nuclear Engineering and Design, Vol. 71, pp. 15-26, 1982.
[2] R. D. Coffield, Jr. et al., A Subcooled DNB Investigation of Freon-113 and its Similarity to Subcooled Water DNB Data, Nuclear Engineering and Design, Vol. 11, pp. 143, 1969.
[3] Katto, Y., A Generalized Correlation of Critical Heat Flux for the Forced Convection Boiling in Vertical Uniformly Heated Round Tubes, International Journal of Heat and Mass Transfer, Vol. 21, pp. 1527-1542, 1978.
[5] S. Y. Ahmad, A Fluid to Fluid Modeling of Critical Heat Flux: A Compensated Distortion Model, International Journal of Heat and Mass Transfer, Vol. 16, pp. 641-662, 1973.3
[4] MARS3.1 Code Manual, Korea Atomic Energy Research Institute (KAERI), Korea, 2007.