CFD Analysis on Critical Void Fraction in Round tube under CHF Conditions

Byungsoo Shin*, Soon Heung Chang

Korea Advanced Institute of Science and Technology, Republic of Korea
**Corresponding author: Byungsoo@kaist.ac.kr*

1. Introduction

Generally, the critical heat flux under any circumstance is predicted from the correlation based on experimental data. But this prediction method demands high cost and effort. Recently, through the development of CFD technique, it is possible to calculate the two phase boiling flow with reasonable prediction error.

Weisman and Pei [1] suggested the DNB model at 1983. They insist that CHF occurs when the wall void fraction exceeds 0.82 as critical void fraction. But in their model, the value of critical void fraction was not decided by mechanistic analysis but just regression method for correlation fitting.

In this study, the CHF criteria for DNB region were suggested through the CFD analysis. From the results, the critical void fraction depends on the averaged void fraction but not a constant value.

2. Numerical Methods and Validation

2.1 Numerical Methods

Two-fluid model in used commercial code, CFX version 11.0, was applied as a two-phase flow simulation. The flow was treated as non-homogeneous flow. And the interfacial mass, momentum and energy transfer was also considered. Especially, interfacial momentum transfer was included with drag forces and non-drag forces. And non-drag force was composed of lift force, wall lubrication force, virtual mass force and turbulent dispersion force.

Generally, DNB occurs at subcooled flow boiling as well as saturated flow boiling. To cover the minus range of local quality, subcooled boiling phenomena was also considered in this CFD analysis. The concept of wall partitioning was applied to the wall boundary condition. The wall partitioning model means that the wall heat flux is partitioned to three heat flux: convective heat flux, quenching heat flux and evaporation heat flux. The variables related to each heat flux were defined with former researcher's equations or correlations. [2]

2.2 Validation

To validate the applicability of numerical methods referred previously, the numerical analysis about a simple round tube was performed. Semicircle with symmetric surface was treated for economical calculation. Test case was determined based on the experiments of Bartolomei and Chanturiya [3]. In these experiments subcooled convective flow boiling was considered in axis-symmetric vertical heated pipe.

Typical averaged void fraction along equivalent quality for validation is presented in figure 1. Application of numerical method shows the plausibility of the calculated results.

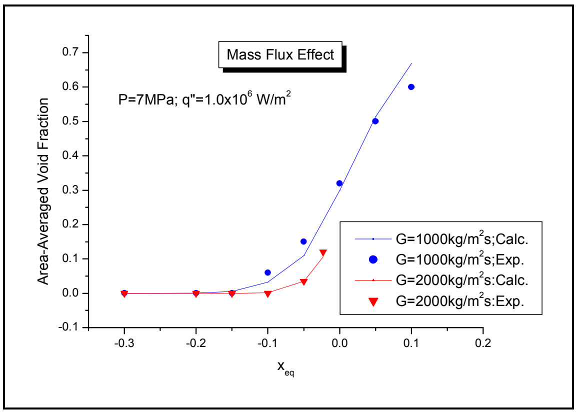

Figure 1 Comparison of CFD results with experimental data

3. Results and Conclusions

Kataoka et al. [4] suggested new critical void fraction for bubble crowding model. Their critical void fraction dependent on the averaged void fraction was expressed as

$$\alpha_{wall} = 0.9 \cdot \alpha_{avg}^{0.28} \qquad \text{Eq.1}$$

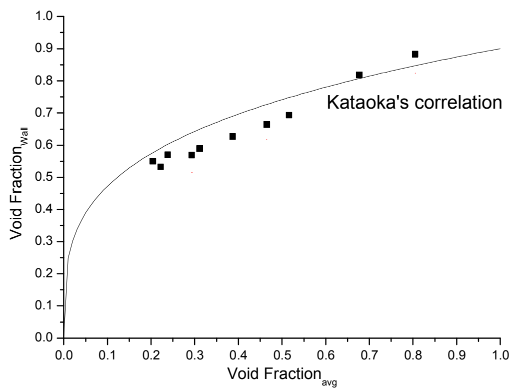

Figure 2 Comparison of CFD results with Kataoka's correlation

Here, the averaged void fraction is a function of heat flux and flow parameters. Therefore, it is possible to predict the CHF with bubble crowding model, new CHF criteria and an equation on averaged void fraction.

In this study, the critical void fraction achieved by CFD analysis was not a constant: Weisman and Pei suggested 0.82. The critical void fraction achieved by the CFD analysis was a function of the average void fraction and agreed well with Kataoka's critical void fraction correlation. And bubble crowding model with critical void fraction achieved by this study predicted well with more improvement.

REFERENCES

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