Survey of the Heat Transfer Correlations for Helically Coiled Tubes to Analyze the Performance of the SMART Steam Generator

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1. Introduction

Helically coiled tubes are widely used for making compact heat exchangers. In the nuclear industry, once-through helically coiled heat exchangers are one of the options for small and medium sized reactors. SMART, which has been designed at KAERI, has 12 cassettes of once-through type heat exchangers using helically coiled tubes as a steam generator [1]. To analyze the performance of the steam generator, information on the heat transfer characteristics of the helical coil tubes is required.

2. Heat Transfer Correlations

Literature survey was conducted to get the heat transfer correlations (HTC), and many HTCs were gathered.

2.1 Shell Side-Single Phase

There is no shell side HTC for helically coiled tubes. Instead of the helically coiled tubes' HTC, horizontal tube bundle correlations are widely used for the shell side correlations. Zukauskas correlation is one of the well known correlations. Miheev correlation is a Russian correlation. Applicable range is unknown. Churchill and Bernstein correlation for a horizontal tube can be used as an option.

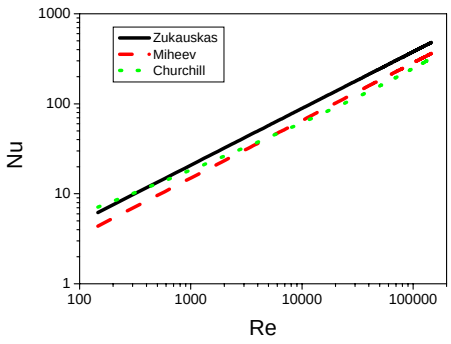

Figure 1. HTC for the shell side of a helical tube.

2.2 Tube Side-Single Phase

A set of Mori-Nakayama's correlations [2] is widely used for a single phase region. Those correlations are derived theoretically and experimentally. A set of Russian correlations, which are called the Kutateladze's correlations, is applicable for a whole range of Reynolds number. It shows a good predictability in the laminar region. A Seban-McLaughlin correlation is a widely used correlation. It has a similar form to the Dittus-Boelter correlation, which is used for a single phase fluid in a tube. Rogers and Mayhew made a modification to the Seban-McLaughlin correlation. Guo et al. suggested a number of correlations for vertical and horizontal helically coiled tubes. These correlations can be applicable to P = 0.5 ~ 3.5 MPa, Re = 6,000 ~ 180,000. Guo et al. insisted that the direction of the helix axis is not important. In addition, Schmidt, Gnielinski, Naitoh et al., Yildiz et al., Modified Bishop , Jeschke have suggested correlations.

For a laminar flow, Manlapaz-Churchill, Janssen-Hoodendoorn and Acharya et al. have suggested correlations. These correlations are derived from a theoretical study. Calculation results with them shows a higher Nu number than the other larger-range correlations within a low Re number range.

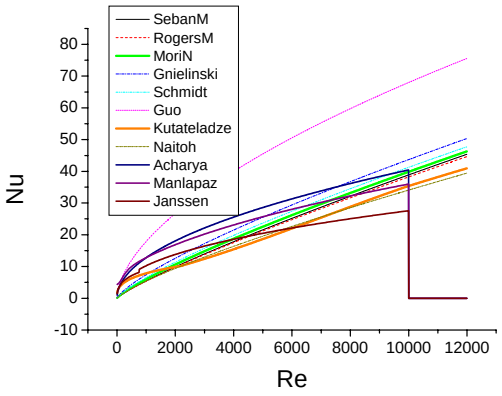

Figure 2. HTC for a tube side, single phase liquid.

2.3 Tube Side-Boiling

The correlations of Miheev and Campolunghi et al. are a similar type to the Thom correlation. They can be applied in all the boiling regions. Kozeki et al performed some experiments, and found that the local heat transfer coefficient of a convection boiling is a little affected by the steam quality, mass flow, pressure and location of the coiled tube section [3].

Kaji et al. and Guo et al. suggested a correction factor type correlation to be used in the single phase correlation of helical tubes. Modified Schrock-Grossman correlation is another correction factor type

correlation. The Chen correlation is also used. In the Chen correlation, usually the Seban-McLaughlin correlation is used as a single phase liquid HTC.

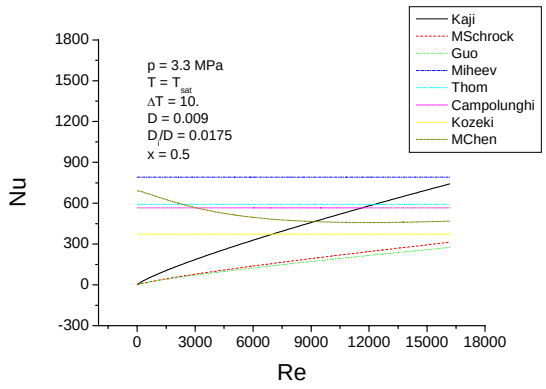

Figure 3. HTC of a nucleate boiling depending on the Re number.

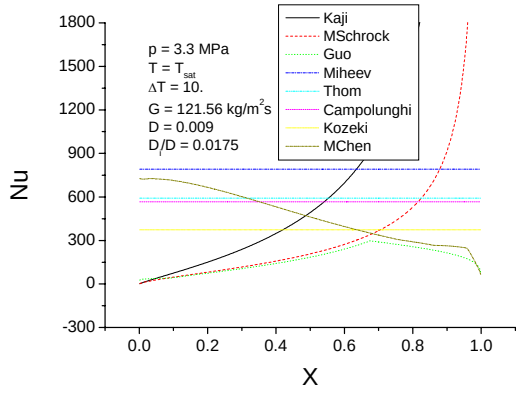

Figure 4. HTC of a nucleate boiling depending on the quality.

For a transition boiling, Miropolski-Pikus suggested a correlation. The Bishop et al. correlation was used in some researches. Both correlations show a different behavior to the quality change.

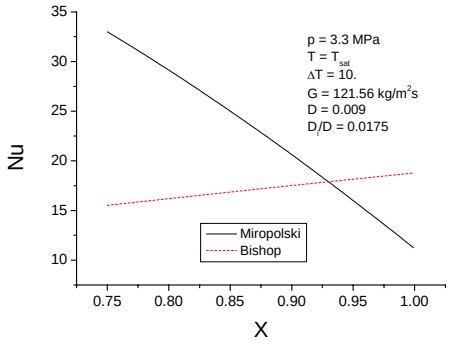

Figure 5. HTC of a transition boiling

3. DNB Correlations

By the secondary flow effect in a helical tube, it is considered that a dry out occurs in a higher quality than in a strait tube.

Jensen-Bergles, Kaji et al., Jayanti and Berthoud, Bein and Yahalom, Naitoh et al and Guo et al. have suggested CHF correlations. The Biasi correlation is used in some researches.

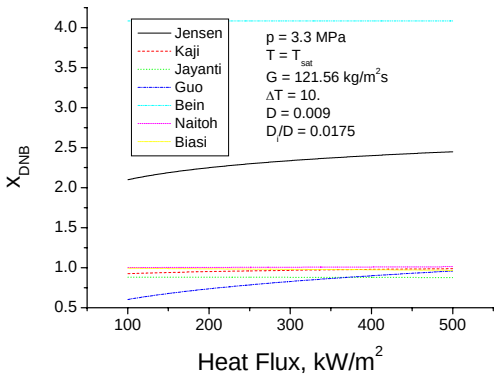

Figure 6. Comparison of the CHF correlations.

4. Conclusions

Heat transfer correlations and CHF correlations are collected from a literature survey for the thermo hydraulic performance analysis of a helically coiled once-through steam generator of the SMART. It was possible to obtain many correlations for a tube side. For a single phase region and a nucleate boiling region, the collected correlations show a similar tendency. However, the heat transfer correlations in the transition boiling region and the CHF correlations show scattered results. There is a need for an experiment related to these regions.

REFERENCES

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[3] M. Kozeki, H. Nariai, T. Furukawa and K. Kurosu, A Study of Helically-Coiled Tube Once-Through Steam Generator, Bulletin of JSME, Vol. 13, p. 1485, 1970.