Modification of SPACE code for the Safety Analysis of the HANARO

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1. Introduction

KAERI has a plan to use the SPACE code for the safety analysis of research reactors including typical open-pool type research reactors using plat-type fuel as well as the HANARO (Highly Advanced Neutron Application Research reactOr) using finned rod fuel element. In order to extend the applicability of the SPACE code to safety analysis of the HANARO, thermal-hydraulic models and/or correlations for the HANARO fuel and operational conditions should be additionally implemented on SPACE code. In this study, single-phase thermal-hydraulic correlations, such as friction factor and heat transfer, for finned rod fuel elements were implemented on SPACE code and verified to improve predictive capability for thermal-hydraulic phenomena in the HANARO core as the first step for the modification of SPACE code.

2. Correlations for a finned rod fuel

2.1 Single-phase Friction Factor

The frictional pressure drop experiments of 18 and 36 finned fuel elements were performed at KAERI [1]. Test fuel elements without spacers were used and the pressure drops were measured at the various axial positions under the expected flow rate ranges. As the experimental results, it was found that the pressure drop characteristics in 18- and 36-finned fuel assemblies were different according to mass flow rate. Therefore, two different friction factor correlations for each finned fuel element were suggested for the low (Re<7,000) and high (Re>7,000) flow regions as below.

<u>18 finned fuel assembly</u>

$$f_{18,low} = 7.9271\,\mathrm{Re}^{-0.6236} \tag{1}$$

$$f_{18,high} = 0.3357\,\mathrm{Re}^{-0.2731} \tag{2}$$

<u>36 finned fuel assembly</u>

$$f_{36,low} = 3.6903\,\mathrm{Re}^{-0.5415} \tag{3}$$

$$f_{36,high} = 0.2217\,\mathrm{Re}^{-0.2327} \tag{4}$$

2.2 Single-phase Heat Transfer

The single-phase heat transfer experiments for finned rod fuel were performed at AECL because the existing correlations did not considered the effects of fins on heat transfer [2]. The electrically heat fuel element simulator (FES) was used and the surface temperatures and coolant bulk temperatures were measured at three locations along the FES. As experimental results, it was found that the Dittus-Boelter (D-B) correlation overpredicted fuel surface temperatures of FES. Therefore, the new correlations for single-phase heat transfer coefficient were suggested based on experimental results as below.

<u>Laminar flow</u>

$$h_{lam} = 3.656\left(\frac{k}{d_e}\right) \tag{5}$$

<u>Turbulent flow</u>

$$h_{tub} = 0.009388\left(\frac{k}{d_e}\right)\mathrm{Re}^{0.9109}\,\mathrm{Pr}^{0.536} \tag{6}$$

3. Code Assessment

3.1 Single-phase Friction Factor

The calculations were performed for the frictional pressure drop experiments to verify and validate the Space code with newly implemented frictional factor correlations of the finned fuel elements. The nodalization for the code calculations is shown in Fig. 1. A flow channel of finned fuel assembly was modeled using a pipe component (Pipe #200). The experimental conditions were specified with boundary conditions at the inlet and outlet of the test section. The temperature and flow rate were specified at the inlet TFBC #100, and the pressure was fixed at the outlet TFBC #300. The calculated results are shown in Fig. 2 and Fig. 3. The friction factors of finned fuel deduced from the experiments is different from that of circular tube (Churchill) because of the assembly and fin effects. However, the code calculations using friction factor correlations for HANARO finned fuel show good predictions.

3.2 Single-phase Heat Transfer

The calculations were performed for the single-phase heat transfer experiments to verify and validate the Space code with newly implemented single-phase heat transfer correlations for single finned fuel. The nodalization for the Space code calculation is shown in Fig. 4. A flow channel of the test section including FES was modeled using a pipe component (Pipe #200). The experimental conditions were specified with boundary conditions at the inlet and outlet of the test section. The temperature and flow rate were specified at the inlet TFBC #100, and the pressure was fixed at the outlet TFBC #300. The calculated results are shown in Fig. 5. The D-B correlation used in the SPACE code predicted lower heat transfer than the experiments. This lead to overprediction of the fuel surface temperature as shown Fig. 5. However, implemented heat transfer correlation developed based on experiments for HANARO single finned fuel predicted with good accuracy the surface temperatures.

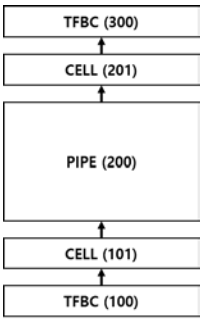

Fig. 1. SPACE nodaliztion for single-phase pressure drop

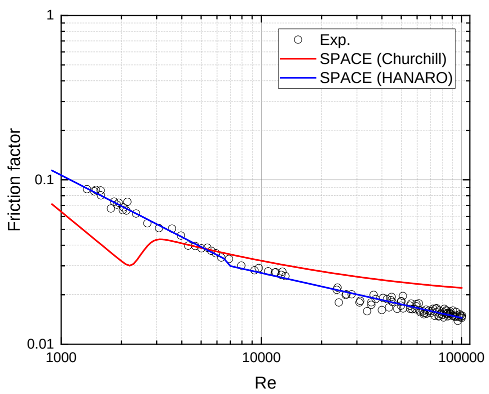

Fig. 2. Single-phase friction factor for 18 finned fuel assembly

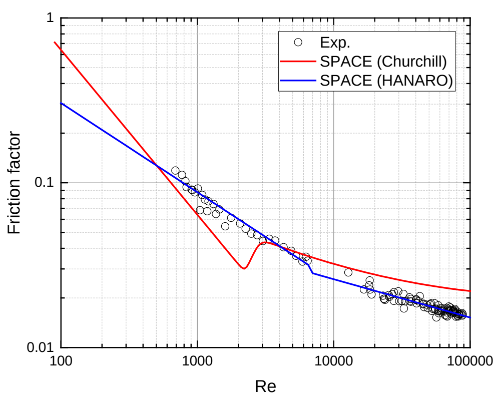

Fig. 3. Single-phase friction factor for 36 finned fuel assembly

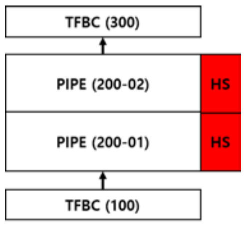

Fig. 4. SPACE nodaliztion for single-phase heat transfer

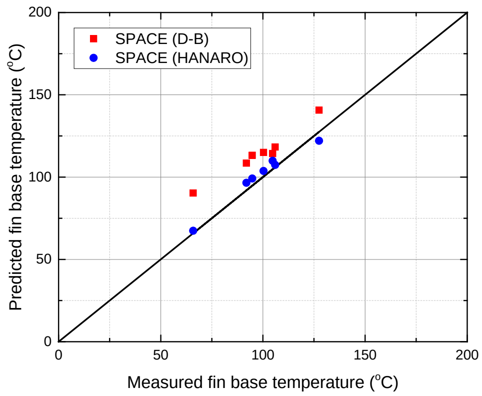

Fig. 5. Surface temperature for single finned fuel

4. Conclusions

The modifications and assessments of SPACE code were conducted to extend predictive capability for thermal-hydraulic phenomena in the HANARO core. It was concluded from the calculation results that the SPACE code implemented with friction factor and single-phase heat transfer correlations for HANANO finned fuel showed good prediction with experiments and can be applicable to the analysis of the HANARO.

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