Modification of Laminar and Transition Single Phase Heat Transfer Model in SPACE Code for Research Reactor Application

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1. Introduction

As the SPACE code is developed for the safety analyses of nuclear power plants, suitability should be checked for the application to the research reactor thermal-hydraulic conditions. One part is heat transfer calculation for the fuel flow channels of research reactors in the laminar flow and transition regions where the flow speed is low. However, there are considerable errors between the analysis and the experimental result, since the SPACE code treats that region as the maximum value among the laminar and turbulent heat transfer coefficients. In addition, the different shape of the nuclear fuel of the research reactor from that of the power plant should be considered in the calculation model.

In this research, in order to apply the SPACE code to the safety analysis of research reactors with plate type fuels, appropriate heat transfer models for laminar and transition regions have been selected and applied to the code. In addition, in order to validate the selected models, validation calculation was performed for heat transfer experimental data of a plate-type fuel.

2. Laminar and Transition Heat Transfer Correlations

- **Correlations in SPACE 3.0**

- $Nu_{lam} = 4.36$
- $Nu_{tur} = 0.023 Re^{0.8} Pr^{0.4}$
- $Nu = max\,(Nu_{lam}, Nu_{tur}, Nu_{nc})$

- **Modification of Correlations**

- Laminar region : Shape effect (Rectangular shape)

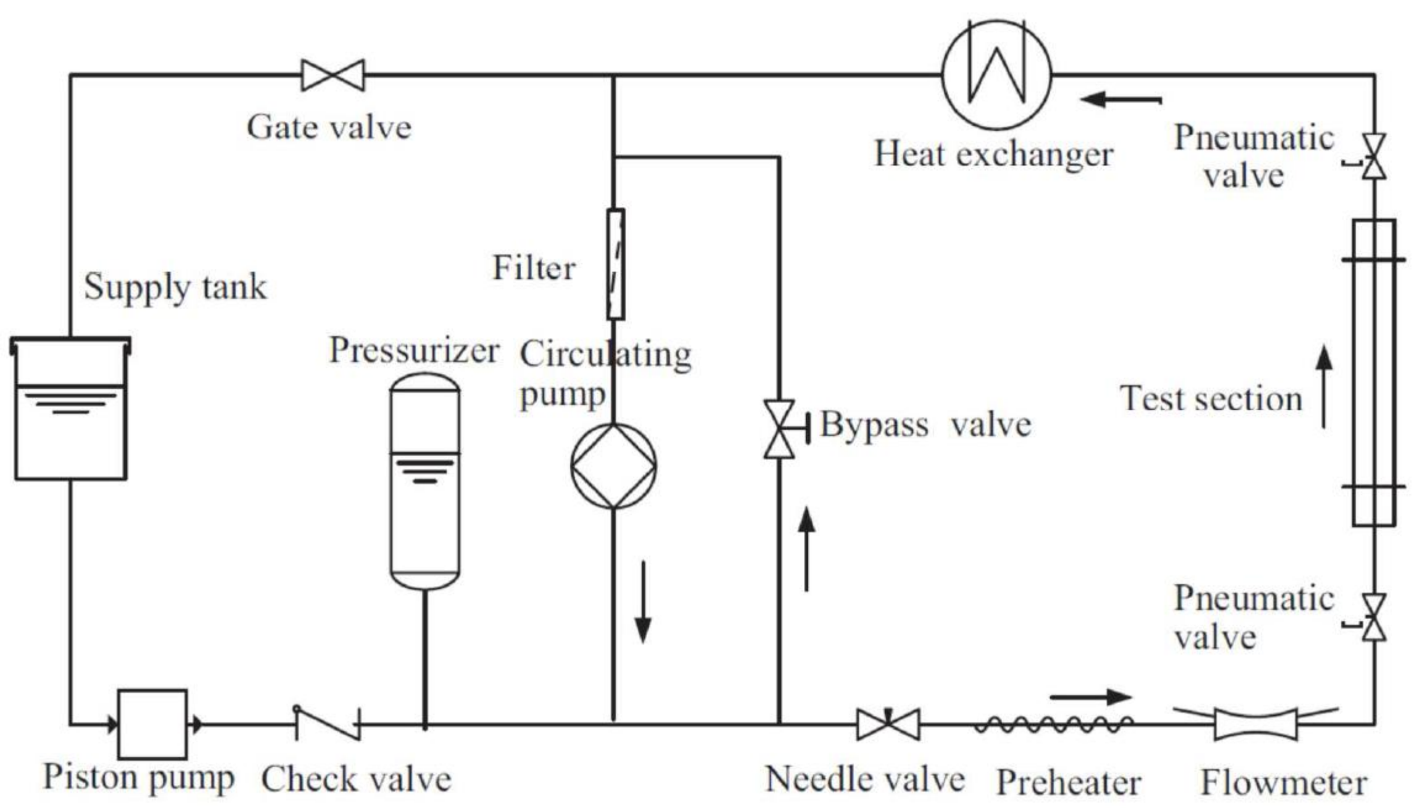
$$Nu_{lam} = 8.235\left(1 - 2.0421\left(\frac{t}{w}\right) + 3.0853\left(\frac{t}{w}\right)^2 - 2.4765\left(\frac{t}{w}\right)^3 + 1.0578\left(\frac{t}{w}\right)^4 - 0.1861\left(\frac{t}{w}\right)^5\right)$$

- Transition region : Interpolation method

$$Nu = Nu_{lam} + \left(\frac{Nu_{turb} - Nu_{lam}}{Re_{turb} - Re_{lam}}\right)(Re - Re_{lam})$$

3. Description of CNNC Experiment

- **Schematic diagram of the CNNC test loop**



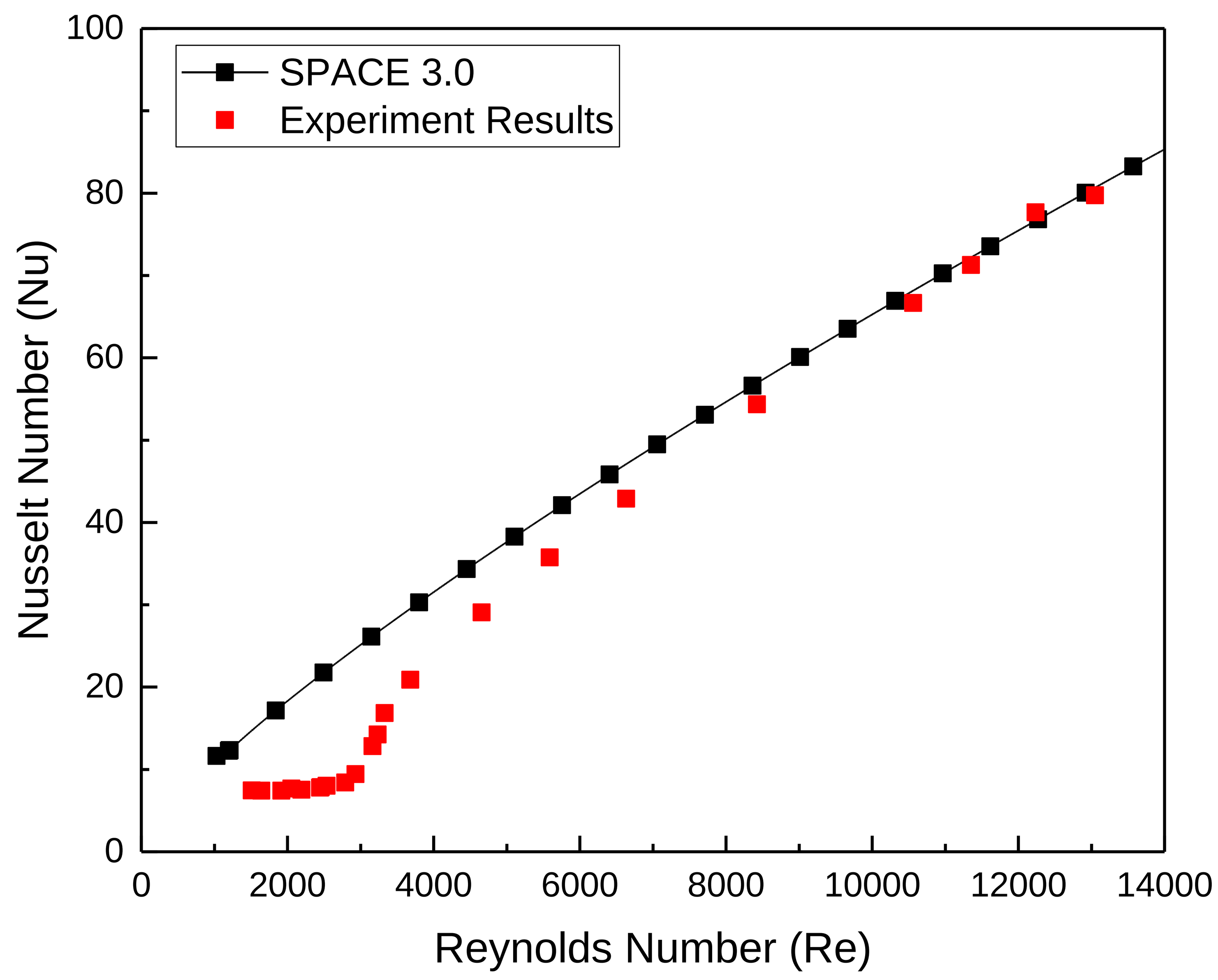
- **Design parameters of the CNNC experiment apparatus**

Parameter	Data
Flow direction	Upward
Channel gap	2 mm
Channel span	40 mm
Heater block thickness	3 mm
Hydraulic diameter	3.64 mm
Roughness	3.09E-03 mm
Channel length	1092 mm
Heated channel length	1037.4 mm

- **Experimental parameter of CNNC tests**

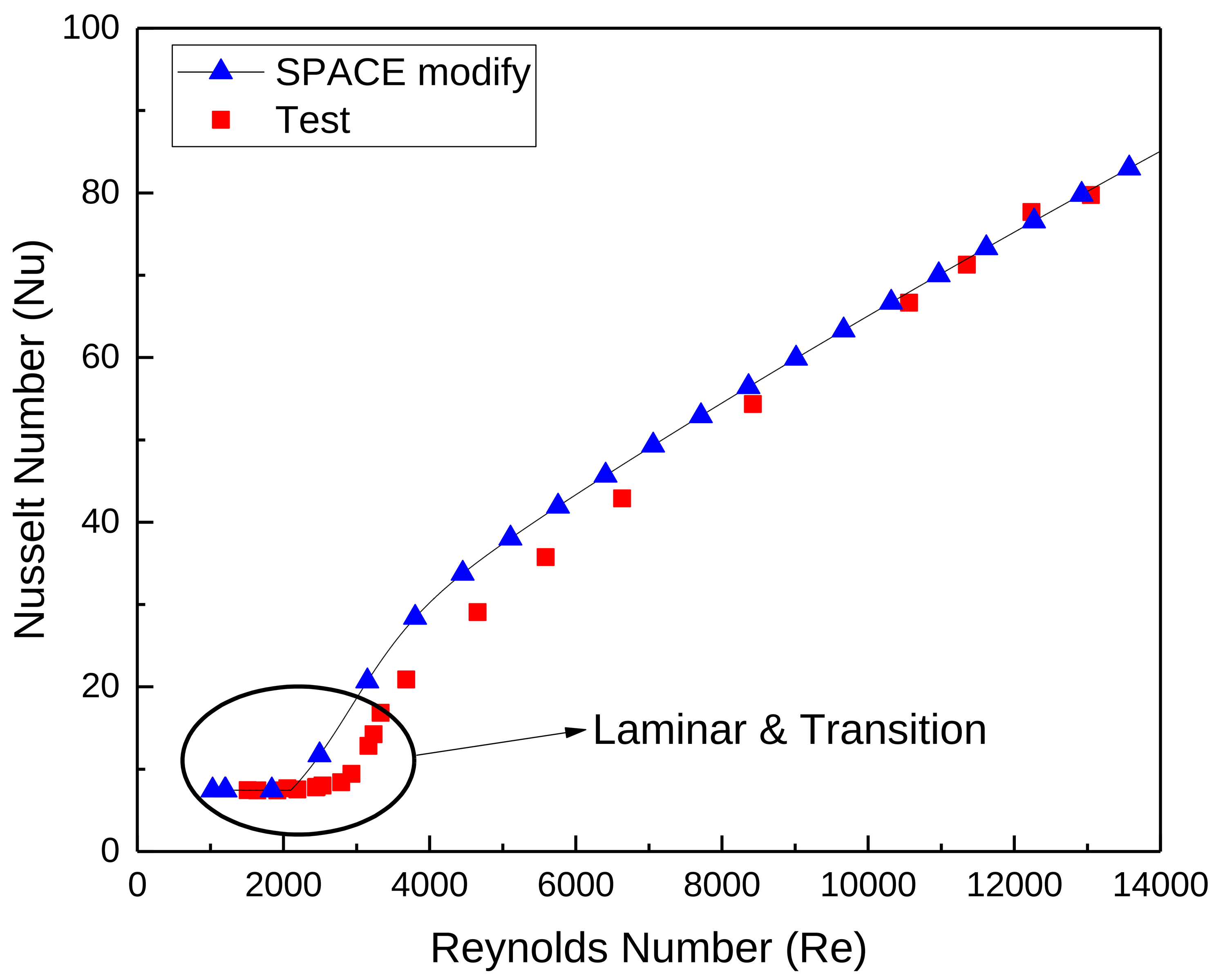
Parameter	Data
Inlet temp.	24 ~ 37.5 ℃
Mass flux	285 ~ 2000 kg/(m2s)
Heat Flux	14 ~ 214 kW/m2
Prandtl number	4.6 ~ 6.2

4. Results



[Validation Calculation using SPACE 3.0]

- Over prediction in laminar & transition flow region
- Turbulent heat transfer correlation is applied to all flow region



[Validation Calculation using Modified Model]

- Good prediction in laminar & Transition flow region

5. Conclusion

In order to apply the SPACE code to the safety analysis of the research reactor, a study on the improvement of the heat transfer model for laminar and transition regions has been performed. As a result of validation calculation using the modified model, it is confirmed that the heat transfer predictions in the laminar and transition regions is improved.