Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

RELAP5/Mod3.3 and SPACE 2.17 Simulation of a Narrow Rectangular Channel Experiment

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1. Introduction

A thermal hydraulic characteristic in a narrow rectangular channel is an important issue in a research reactor fuel cooling because many of research reactors adopt a flat-plate-type fuel element. Therefore, a series of experiments for establishing hydro-thermal characteristics of a narrow rectangular channel was conducted. The China National Nuclear Corporation (CNNC) also conducted this kind of experiment to evaluate wall friction and forced convection heat transfer in narrow rectangular channel [1].

In order to simulate the research reactor using a flat-plate-type fuel, a series of numerical simulations using thermal hydraulic system analysis code based on the experiment data is needed and the accuracy of the simulation results should be validated. For this reason, this paper contains the simulation results of thermal hydraulic characteristics in narrow rectangular channel using RELAP5/Mod3.3 and SPACE 2.17, and a comparison of simulation results with experiments results.

2. Description of the CNNC Experiment and Modeling

2.1 Description of the CNNC experiment

The CNNC experiment loop was constructed to simulate heat transfer of single phase flow in a rectangular channel [1]. The design parameters of the CNNC experiment loop are shown in table 1.

In CNNC experiment, isothermal and non-isothermal experiments were carried out with various mass flow rate and heating power. In the isothermal experiment, flow rate was controlled without heat into the test section. In the non-isothermal experiment, the heater in the test section was turned on and controlled on the corresponding flow rate. Total 24 sets of experiments were performed for varying with inlet temperature, heat flux and flow rate. The experimental parameters of isothermal and non-isothermal test are listed in table 2.

Table 1. Design parameter 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
Channel length	1092 mm

Table 2. Experimental parameter of CNNC tests

Parameters	Data
Isothermal case	
Inlet Temp.	24 ~ 37.5 ℃
Mass Flux	285 ~ 2000 kg/(m^2s)
Prandtl Number	4.6 ~ 6.2
Non-Isothermal case	
Inlet Temp.	24 ~ 37.5 ℃
Mass Flux	285 ~ 2000 kg/(m^2s)
Heat Flux	14 ~ 214 kW/m^2
Prandtl Number	4.6 ~ 6.2

2.2 Modeling of the CNNC experiment

Figure 1 shows the node diagram of RELAP5/MOD3.3 for modeling the CNNC experiments. The test section is modeled as a pipe (150), which has the 22 sub-volumes, and the pump flow is modeled as a time dependent junction (155). The inlet and outlet of the test section were modeled as time dependent volumes (140, 160).

The node diagram of SPACE 2.17 is same as the modeling used in RELAP5/MOD3.3.

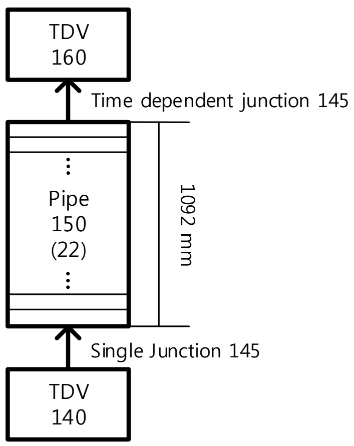

Fig. 1 Node diagram of RELAP5/MOD3.3 modeling

3. Results

3.1 Prediction of the isothermal experiment

The hydrodynamic results of rectangular channel flow in the isothermal experiment are represented by using dimensionless numbers; Reynolds number (Re) and friction factor (f). Figure 2 shows the friction factor calculated in CNNC experiment, RELAP/MOD3.3 and SPACE 2.17 versus Reynolds number. In all cases, the friction factor sharply decreases in laminar region, and slightly increases in transient region, then slowly decreases in turbulent region. The friction factors calculated by RELAP and SPACE are similar to the experiment results in turbulent region. However, the friction factors in laminar and transient region are quite different between RELAP and SPACE. The reason of this phenomenon is that the calculation results using RELAP are considered the shape factor for a rectangular narrow channel. However, the SPACE calculation results are not considered the shape factor. Therefore, the friction factors of the RELAP calculation results are more accurate than that of the SPACE calculation results in laminar region.

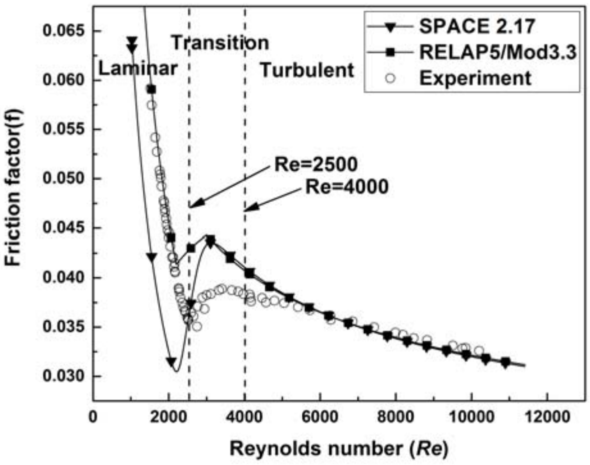

Fig. 2 Friction factors of isothermal experiment, RELAP/MOD3.3 and SPACE 2.17 simulation

3.2 Prediction of the non-isothermal experiment

The thermal hydraulic characteristics results of rectangular channel flow in the non-isothermal experiment are represented by using dimensionless numbers; Reynolds number (Re) and Nusselt number (Nu). In order to simulate the CNNC non-isothermal experiment results, RELAP and SPACE calculations were performed by using 101 correlation set and default set in wall heat transfer option, respectively.

Figure 3 shows the Nusselt number of the CNNC experiment, RELAP and SPACE calculation results as a function of Reynolds number. The simulation result using RELAP software is same as SPACE result because they use the same correlation equations in both laminar and turbulent region. These simulation codes use the Sellars (Nu=4.36) and Dittus-Boelter correlations in laminar and turbulent region, respectively.

In comparison with experiment result, the simulation results are highly estimated than experiment results, especially in low Reynolds number. In high Reynolds number, Re>10000, the simulation results well predict the experiment results. Therefore, in rectangular narrow channel, Dittus-Boelter equation is recommended correlation for calculating the wall heat transfer in turbulent region.

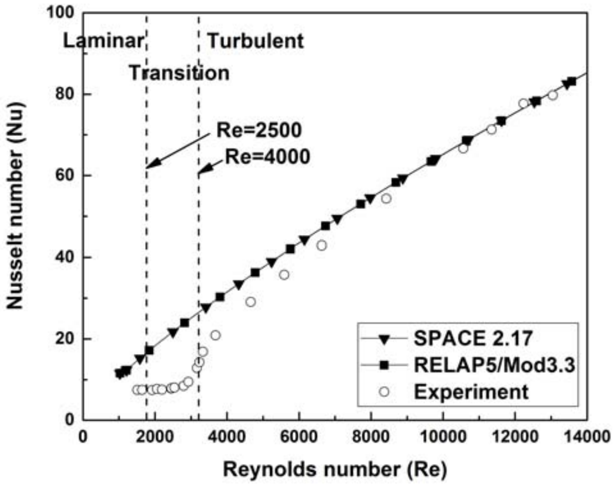

Fig. 3 Nusselt numbers of non-isothermal experiment, RELAP/MOD3.3 and SPACE 2.17 simulation

4. Conclusion

The simulations of rectangular narrow channel experiments were performed using RELAP/Mod3.3 and SPACE 2.17. In isothermal and non-isothermal experiment, both codes well predict the experiment results in turbulent region. In isothermal experiment case, the SPACE 2.17 code does not well predict the friction factor in laminar flow region because of shape factor. In non-isothermal experiment case, the prediction results of the wall heat transfer coefficient in laminar flow region are not successful for both codes.

Acknowledgement

This work was supported by the Korea government (MSIP: Ministry of Science, ICT and Future Planning).

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