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Simulation of a Flow Excursion in a Narrow Flow Channel by using the MARS Code

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1. Introduction

Flow instability is one of the important interests in the thermal hydraulic safety analysis of a research reactor with plate type fuels, which can cause a sudden reduction of the flow rate due to a large pressure drop and can lead to an abrupt damage of the fuel. In order to assess the applicability of the MARS code for the analysis of research reactors, some experiments for flow excursions and void distributions in a heated channel have been simulated by the MARS code.

2. Simulations and Results

2.1 Simulation of Flow Excursion

2.1.1 Description of Experiments

Forgan & Whittle experiment [1] on the pressure drop characteristics along with the flow rate has been used for the separate effect assessment of the MARS code in order to confirm the applicability of the code to the T/H analysis of research reactors. The schematic of the test section is presented in Fig. 1. In this work, the test data for 3 different geometries of rectangular channels as in Table 1 were selected and simulated. The coolant in the flow channel is directly heated by an ac current through the walls, and the heat generation is uniform along the sectional length. The pressure drop across the test section was measured by manometers. Detailed descriptions of the test and test procedures can be found in the references [1, 2].

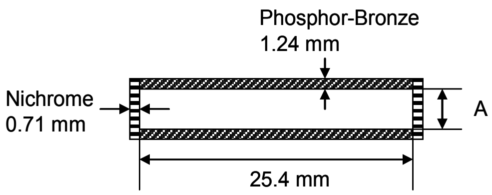

Fig. 1 Schematic of the Test Section

Table 1 Parameter Ranges of the Test Sections

No.	Channel gap (mm)	Channel Width (mm)	Heated Length (mm)	L_h/D_h
TS 1	3.226	25.4	610	94.5
TS 2	2.44	25.4	406	83
TS 3	2.032	25.4	406	100

Several data of the Thermal Hydraulic Test Loop (THTL) tests to support the development of the ANS research reactor with a high power of 200 MW have been simulated as well [3].

2.1.2 Modeling and Nodalization

Only the test section part was modeled with a boundary condition. For the MARS simulation, the test section was modeled with a pipe component of 20 cells and the connected single and time dependent volumes at the top and bottom as shown in Fig. 2. Test conditions are specified with boundary conditions at an inlet and outlet (TMDPV 100 & 300). The flow channel and heating walls of phosphor-bronze and nichrome were modeled with two heat structures, respectively (PIPE 200). The properties of the test section were not sensitive to the results.

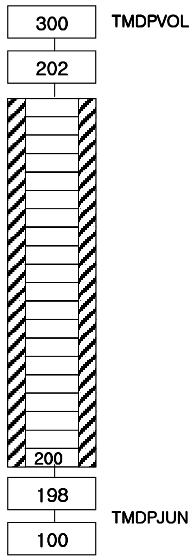

Fig. 2 Nodalization

2.1.3 Simulation Results

a) Cold case (without power)

In order to check the suitability of the nodalization, a cold case with a zero power to the test section was simulated for each type of the test section and the typical result for TS 2 is compared with the test data in the Fig 3. MARS code shows good and more accurate predictions for a narrower channel, but it has a tendency of slightly over-predicting the experimental data as the mass flux decreases. In this task, no tuning was made for the hot case simulations.

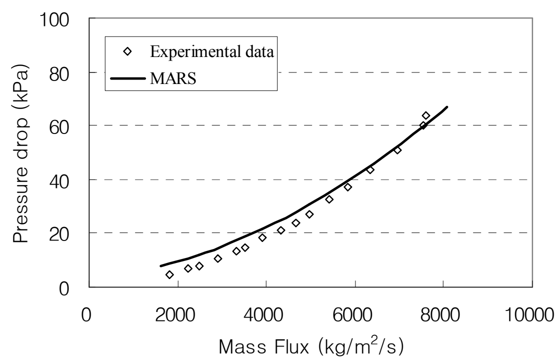

Fig. 3 Pressure drop vs Flow rate for TS 2 Cold case

b) Hot case (with power)

Typical calculated results for TS 2 are compared with the test data in Fig. 4. The MARS code generally provides reasonable predictions and shows the right trends of the OFI (Onset of Flow Instability) conditions, i.e., the OFI point is shifted to a higher mass flux as the heat flux increases. The predicted void fractions at the channel exit are around 0.2~0.27 at the OFI points, and this seems reasonable when considering the void fraction at the OSV(Onset of Significant Void) points. From the simulation results, it is thought that better results will be provided if the initial difference between the predicted to measured one in the cold case is smaller. The void fraction at the channel exit is slightly larger for a higher heat flux, but the difference will be more obvious for much higher heat fluxes. However, the predicted mass fluxes at an OFI had a different tendency in accordance with the test section geometry. Fig 5 shows the ratio of the predicted to measured mass flux at an OFI along with the channel width. A tendency of underprediction is shown for a narrower flow channel while there is overprediction for a wider flow channel.

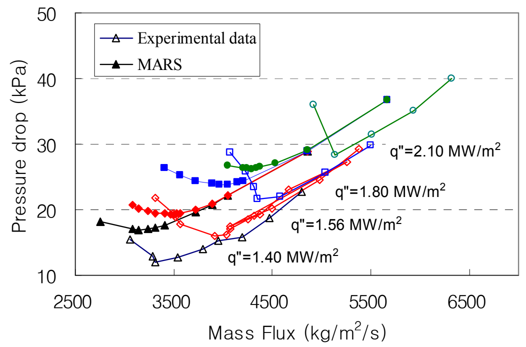

Fig. 4 Pressure drop vs Flow rate for TS2 hot case

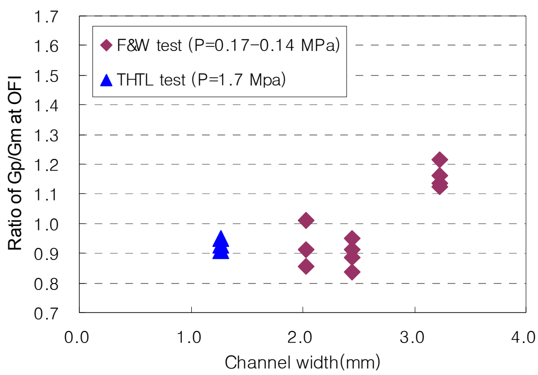

Fig. 5 Pressure drop vs Flow rate for TS2 hot case

2.2 Simulation of Void Distribution

2.2.1 Experimental Data and Simulation

As a flow instability is closely related to the void generation in a heated channel, void distribution measurements have also been simulated. Some data were obtained from references [4, 5]. The modeling for the simulation is quite similar to that described in section 2.1.2.

2.2.2 Simulation Results

A typical calculation result is depicted in Fig. 6. It can be generally said from the results that the calculated void is slightly under-predicted in the upstream part of the test section and shows a quite good agreement in the downstream of the test section at near and above the saturation temperature of the coolant. But one thing to note is that the predictions by the code are changing more rapidly in a range of around 0.1~0.4 of the void fraction. than the measured ones.

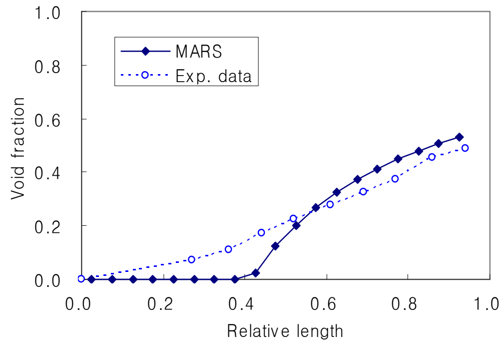

Fig. 6 Comparison of Axial Void Profile

3. Conclusion

a) MARS code provides reliable predictions for the simulated cases and the agreements between the predicted and the measured flow rates at an OFI are within ±20%.

b) MARS code has a tendency of under-predicting the flow rate at an OFI for narrower channels while it shows an over-prediction for wider flow channels.

c) More simulations are necessary for the MARS code before it is applied to a research reactor with low pressure operating conditions, in particular, for the medium quality ranges at a low pressure.

d) The void profile predictions by the MARS code show a quite good agreement in the downstream of the test section at near and above the saturation temperature, but it is slightly under-predicted in the upstream part of the test section.

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