Assessment of Prediction Capability on Two-Phase Flow Pressure Drop Using MARS-KS

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1. Introduction

Natural circulation type - PSSs (Passive Safety Systems) such as PAFS (Passive Auxiliary Feedwater System) and PRHRS (Passive Residual Heat Removal System) are widely introduced in the advanced nuclear power plants. The performance prediction of the PSSs has been mainly conducted by using the system analysis codes such as RELAP5, MARS-KS, and SPACE. For the reliable prediction of the PSS heat removal capability, the system analysis codes should produce the heat transfer coefficient on the heat exchanger and the pressure drop in the natural circulation loop accurately. A lot of researches have been carried out so far to improve the prediction capability of the heat transfer model in the system analysis code; however, there are insufficient studies regarding the prediction of the pressure drop and natural circulation flow rate in the PSSs. Therefore, the assessment of the prediction capability on the pressure drop and the natural circulation flow rate in the PSS is highly advisable. As part of this effort, in the present study, an evaluation regarding the capability of MARS-KS (version 1.5) for two-phase flow pressure drop is presented for the experimental data of Mendler et al.[1]

2. Description of Bettis Experiment Facility

Mendler et al. performed the natural-circulation tests with water at 800 to 2000 psia and obtained the two-phase pressure drop data using the Bettis natural circulation loop facility (see Fig. 1). The main loop was in the shape of a vertical rectangle 14.5ft high and 15ft long. Test section is located in the bottom of left vertical pipe and heated uniformly by heater. The coolant heated in the test section was cooled at the top of the loop right side.

The tests were performed in rectangular channels (0.1 inch × 1 inch; 0.2 inch × 1 inch; 0.25 inch × 1 inch) with 27 inch height. For the natural circulation flow experiments, the coolant was heated to the target temperature with forced circulation flow by a pump. After that, the pump was turned off and the steady state with natural circulation flow was established. The pressure drop was obtained as the pressure difference from the 5inch point at the bottom of the test section to the 27inch point. The tests were conducted under the conditions below.

- Pressure: 55.16, 82.74, 110.32 and 137.90 kPa
- Mass flux: 200 ~ 700 kg/m^2s
- Exit quality: 0.0 ~ 0.7 (Thermodynamic)
- Inlet subcooling: 10~60 ℃

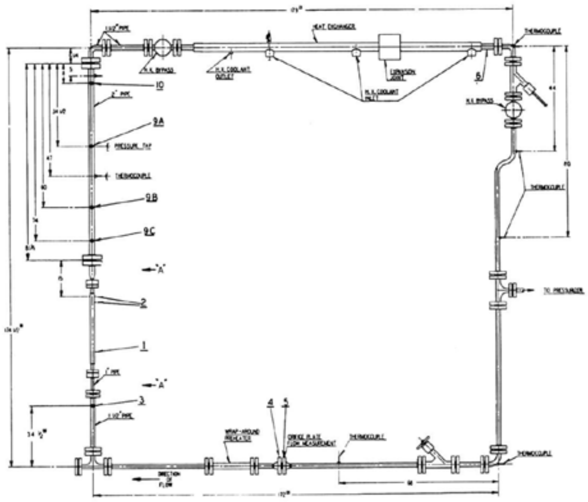

Fig. 1. Bettis natural circulation loop

3. MARS Analysis Results

In this study, 48 tests on rectangular channel (0.2 inch × 1 inch; 0.25 inch × 1 inch) with equivalent diameters of 8.5, 10.7mm are simulated by using MARS-KS. The experiments were conducted with natural circulation flow in the loop, but in this analysis, the flow boundary condition was used to obtain the pressure drop according to the exit quality at a constant flow rate. The MARS nodalization used in this analysis is given in Fig. 2.

MARS-KS calculation results are shown in Fig. 3 ~ 6. In Fig. 3 and Fig. 4, the x-axis shows the quality and the y-axis shows the pressure drop results. The increasing trend of the pressure drop as the quality increases in the exit area of the test section observed in the experiment is predicted by MARS-KS. However, the analysis results are under-predicted, and the greater the system pressure and heat flux, the greater the difference. In the Fig. 5 and Fig. 6, the difference between MARS-KS and experiment results of pressure drop and the exit quality are shown. As shown in the figures, most of the results are predicted within a 20% error range. In the case of low heat flux, the MARS-KS analysis results are predicted to be higher in quality than those of experiments, and the pressure drop results are predicted to be higher, also. In the case of high heat flux, on the contrary, MARS-KS predicts lower quality and higher pressure drop than the experiment. In a coming study, the reason for this trend will be analyzed and any improvement measures will be developed.

4. Conclusions

Mendler et al. experiment was analyzed using the MARS-KS version 1.5, and the calculation results were compared with the experimental data. It was discovered that most of the analysis results were predicted within 20% error bound. In addition, there was a certain tendency according to the heat flux, and the factors will be derived through various sensitivity analyses in the future.

In this analysis, the flow boundary condition was used to keep the steady state mass flow rate constant, but in the later analysis, the pressure drop and flow rate prediction performance of MARS -KS will be evaluated by simulating the loop as in the experiment. And the PSS prediction capability of MARS-KS 1.5 will be evaluated through the analysis of more diverse experimental devices.

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REFERENCES

[1] O. J. Mendler et al., Natural-Circulation Tests with Water at 800 to 2000 Psia Under Nonboiling, Local Boiling, and Bulk Boiling Conditions., Journal of Heat Transfer, 83(3), pp. 261-273, 1961.

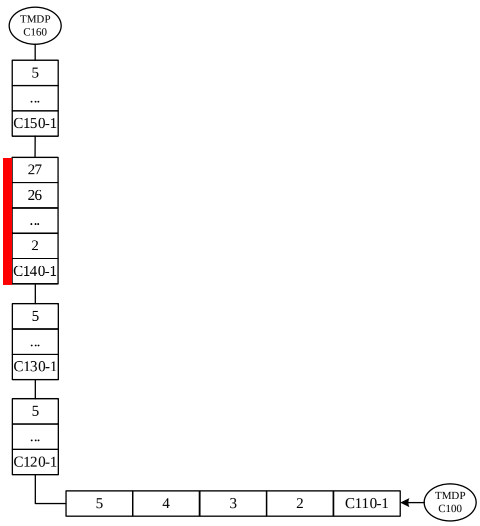
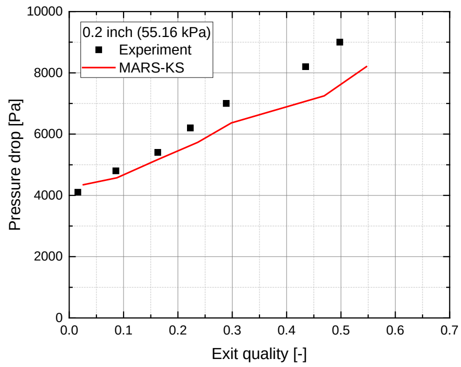
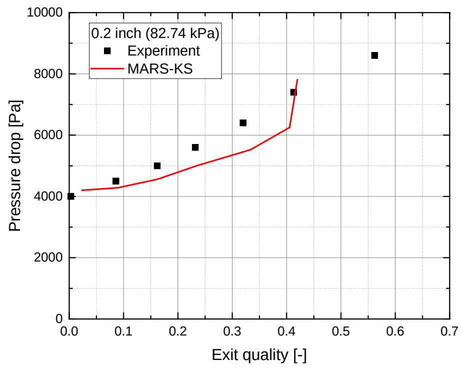


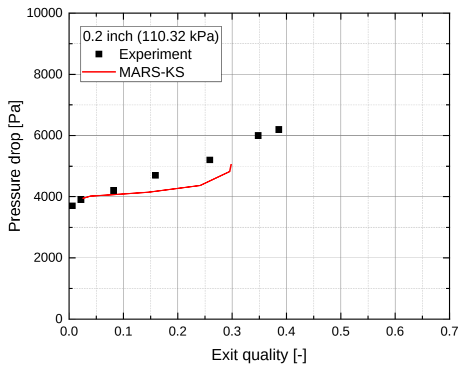
Fig. 2. MARS-KS Nodalization



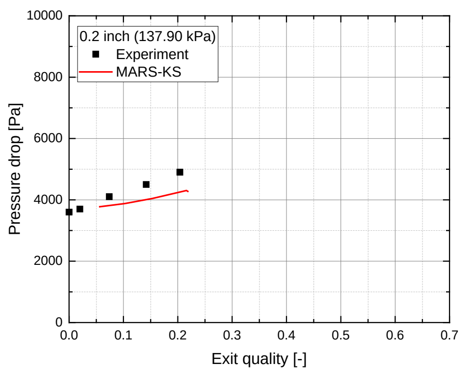
(a) System Pressure: 55.16 kPa



(b) System Pressure: 82.74 kPa

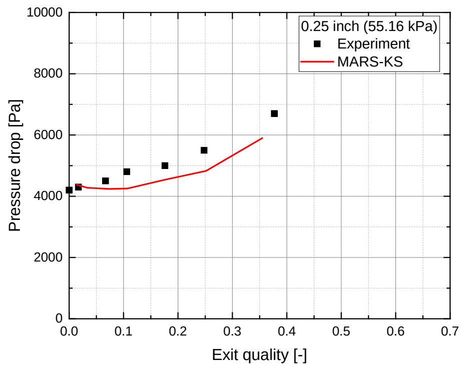


(c) System Pressure: 110.32 kPa

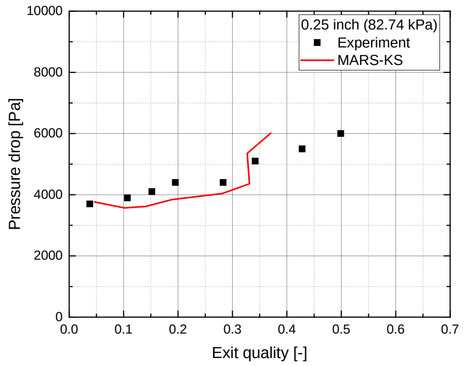


(d) System Pressure: 137.90 kPa

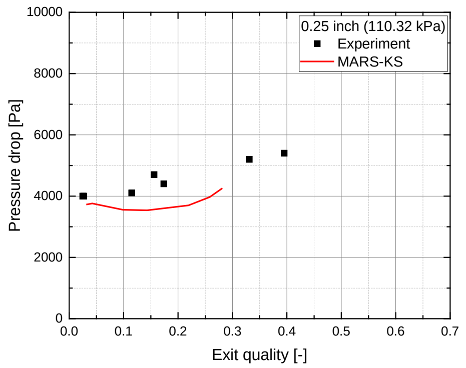
Fig. 3. MARS calculation results (0.2 inch × 1 inch)



(a) System Pressure: 55.16 kPa



(b) System Pressure: 55.16 kPa



(c) System Pressure: 55.16 kPa

Fig. 4. MARS calculation results (0.25 inch × 1 inch)

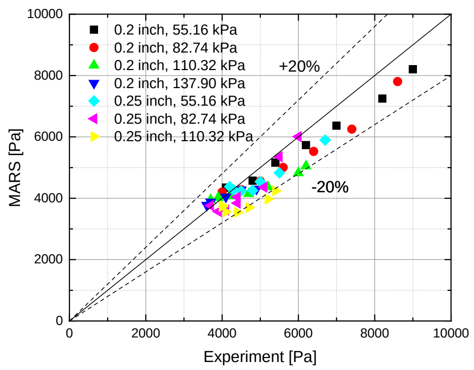


Fig. 5. Pressure drop difference between MARS and experiment results

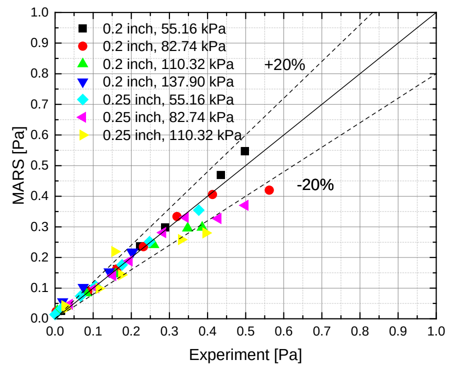


Fig. 6. Exit quality difference between MARS and experiment results