RELAP5/Mod3.3 and MARS3.0a Modeling of a Siphon Break Experiment

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1. Introduction

Pool water plays a very important role as a final heat sink for most pool-type research reactors following postulated events. Therefore, one of design criteria for the reactors is that the water level of reactor pool must not decrease below a predefined elevation even against the most severe accident due to ruptures of coolant boundary of connecting systems to the reactor pool. In order to accomplish the design criterion, all the connecting systems are usually arranged to be above the elevation of reactor core. However, some research reactors with a downward flow in the reactor core have a primary cooling system located below the elevation of reactor core because of meeting an available net positive suction head of pumps in the system. These reactors have a provision consisting of pipes penetrating a reactor pool wall at a higher elevation than that of reactor core and siphon break devices to meet the design criterion.

A series of experiments was carried out to figure out thermal hydraulic characteristics during siphon is blocked and establish design requirements for siphon breaker [1]. The experimental study provided a lot of data and observations to the process of siphon break, but it does not provide a sufficient theoretical analysis and present practical design requirements applicable to industry. The experimental range is not also sufficient to cover operating conditions of siphon breakers for research reactors.

A series of numerical simulations on the experimental data has been tried by using thermal hydraulic system analysis codes, RELAP5/Mod3.3 and MARS3.0a. This paper includes a part of the numerical simulations. First output from this study shows an importance of an adequate use of thermal hydraulic models in the codes and a big different prediction between the two codes especially in relation to the use of choked flow option. From this study, it seems that RELAP5/Mod3.3 has some problems on the control of a choked flow option-flag or the prediction of a choked flow criterion.

2. Modeling of the Experiment

The thermal hydraulic system analysis codes of MARS3.0a and RELAP5/Mod3.3 are used for this study. Figure 1 shows the node diagram to model the experimental facility.

As shown in Figure 1, the main components of the experimental facility are a 500-gallon upper tank (110), 4-inch siphon upcomer (140), apex (146, 150), and downcomer (160) pipes, a lower catch tank (200), and a return pump and associating return piping. A 3-inch PVC pipe (120, 130) connects the outlet from the bottom of the upper tank to the upcomer and contains a turbine flow meter. A 4-inch PVC (160, 170, 180) pipe connects the outlet of the downcomer to the catch tank. A 3/4-inch anti-siphon air line (510, 520, 530) is connected at the top center of the apex of 30-inch long. The air line contains a turbine flow meter. Orifices (515, 185) are equipped at the inlet of the air line and the outlet of the discharge line.

In the experimental study [1], siphon tests with various orifice sizes were carried out and water volume of the upper tank, water flow, air flow, and gauge pressures at the apex and the discharge pipe upstream of the outlet orifice were measured.

3. Results

3.1 Prediction of Single Phase Experiment

In order to compare the prediction of the codes with the result of a single phase experiment carried out with the ball valve (525) closed as shown in Figure 1, the water volume of the upper tank, the flow rate of water, and the gauge pressures at the apex and the discharge outlet orifice were calculated first of all, and the loss coefficient of the discharge outlet orifice were adjusted to correct a little bit difference between the prediction and the experiment. All the parameters predicted by both RELAP5/Mod3.3 and MARS3.0a show a good agreement with those measured. The adjusted loss coefficient of the orifice is used for all calculations to predict the siphon tests performed with the same discharge outlet orifice.

3.2 Effects of Choked Flow Option

Figure 2 is a comparison of water flow rates between the experiment and the prediction. The valve of 525 is open at zero second. At that time, air flows into the apex abruptly and the water flow decreases like a step. Both the codes predict the experimental data very well up to that time.

The level tracking model in the codes is not used for all the calculations. In case the choked flow option-flag in the codes is activated, RELAP5/Mod3.3 predicts a choked flow around from 60 to 90 seconds and a rapid siphon break at around 60 seconds as well. On the other hand, MARS3.0a does not predict a choked flow during the siphon and shows a large amount of flow oscillation after around 65 seconds. Researchers have tried to simulate the experimental data by using RELAP5/Mod3.3 without the choked flow option-flag activated. This calculation gives the exact same result of that calculated by MARS3.0a with the choked flow option-flag activated. It seems that RELAP5/Mod3.3 has some problems on the control of choked flow option-flag or the prediction of a choked flow criterion.

3.3 Effects of Level Tracking Option

Figure 3 shows the calculated and measured water flow rates. All the predictions were done with the choked flow option-flag activated. As the level tracking option is used, both RELAP5/Mod3.3 and MARS3.0a predict the water flow rates much better than those as compared with Figure 2. The great amount of the flow oscillation is also improved, and the siphon flow rate with time and the completion time of siphon break are reasonably calculated. On the other hand, it is found that RELAP5/Mod3.3 does not predict a choked flow although the choked flow option-flag is activated.

4. Conclusion

Authors model and predict the series of siphon experiments by using RELAP5/Mod3.3 and MARS3.0a. In case the level tracking option is taken into consideration for the calculations, both codes show a good agreement of the water flow rates with the siphon test investigated in this study. As the level tracking option is not used, the prediction of the water flow rates is not successful for both codes. RELAP5/Mod3.3 also predicts an unreasonable choked flow as the choked flow option-flag is activated.

REFERENCE

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[3] RELAP5/Mod3.3, Code Manual Volume V, User's Guideline, NUREG/CR-5535/Rev1, 2001

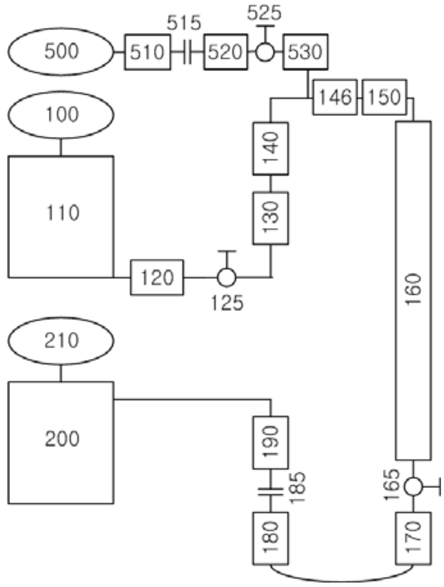

Fig.1. Modeling of the experimental facility.

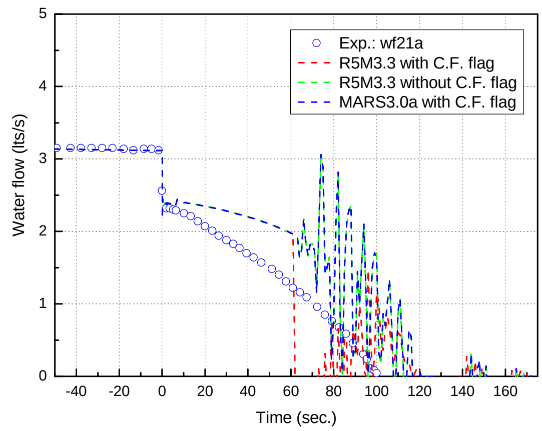

Fig.2. Prediction of water flow rates with the choked flow option.

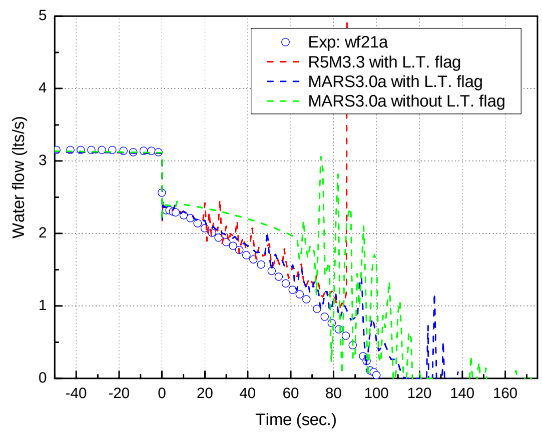

Fig.3. Prediction of water flow rates with the level tracking option.