Effects of a Heat Flux on the Prediction Accuracy of the MARS Reflood models

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1. Introduction

A 6x6 reflood test facility, ATHER (facility for Advanced Thermal Hydraulic Evaluation of Reflood phenomena) has been constructed and operated by KAERI. A series of bottom reflood tests were carried out[1,2]. Subsequently, counterpart reflood tests on the RBHT (Rod Bundle Heat Transfer) data in PSU (Penn. State University) were also conducted in order to investigate the effects of the heat flux on the peak cladding temperature and the quenching behavior.

The objective of the present paper is to evaluate the prediction accuracy of the best-estimate thermal hydraulic system code, MARS3.1[3] for the KAERI counterpart reflood data.

2. Modeling Method

The ATHER facility is modeled by 1-D pipe components of the MARS3.1 code. Four heat structures were modeled; heater rods, a guide tube, unheated rods, a cold wall of the test section. The 6x6 heater rod bundle has a chopped cosine profile. The internal detailed geometry of the heater rods was modeled.

Initially, the test section is filled with water up to the bottom of the heater rods. A heat-up process starts by introducing a measured electric power to the heater rods. During the test period, the system pressure is controlled at a predefined value. If any of the measured heater rod surface temperatures reaches a predefined temperature of about 716^{o}C, the reflood water is introduced into the test section.

3. Assessment Results

The PSU (Penn. State Univ.) constructed and has operated a RBHT (Rod Bundle Heat Transfer) facility in order to investigate reflooding phenomena in a rod bundle and to enhance an accuracy of the thermal hydraulic safety analysis code TRACE [4,5].

Among the RBHT data, counterpart tests to the RBHT-1383 were conducted with the ATHER facility. In the present paper, selected counterpart test data were used for assessment of the MARS3.1 code. The major parameters of the data used in the current assessment are summarized in Table 1. Most major parameters are maintained similar to each other. The effects of a linear heat flux are investigated.

Table 1. The KAERI counterpart data

	RBHT -1383	KAERI counterpart data (RBHT-*)		
		C1-R1	C2-R1	C3-R1
Init. wall T. (^{o}C)	760	718	715	719
System P. (MPa)	0.27	0.27	0.27	0.27
Reflooding V. (cm/s)	2.54	2.4	2.4	2.4
Water T. (^{o}C)	119	98	98	98
Linear Power (kW/m)	1.312	0.35	0.61	0.88

Figure 1 shows the calculated temperature profile which agrees well with data. The system pressure and reflooding time were also controlled to have the same boundary conditions as the test conditions.

Figure 2 shows the temperatures of the heater rods in the center region at three different elevations. At a low elevation of 0.39m, the agreement is acceptable. At a middle elevation of 1.85m, the predicted PCT and turnover time are similar to the measurements. After the turnover point, a different cooling slope is calculated in the code. At a high elevation of 2.945m, a slightly small PCT is predicted, but the quenching is much more delayed than in the measurement. As the elevation becomes high, the delayed quenching becomes severe. Vapor superheat is also plotted in Figure 2. It can be seen from the figure that the vapor superheating is decreasing linearly and it becomes zero when the heater rod is completely quenched.

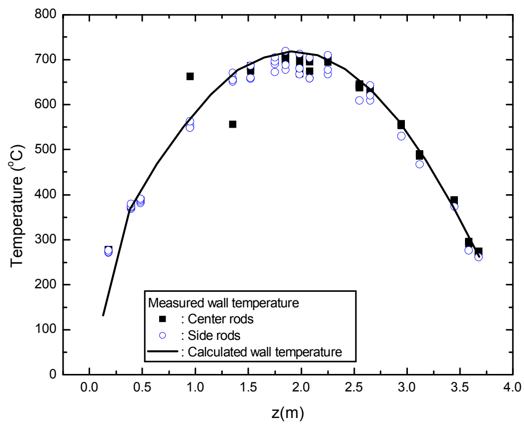

Figure 1. Initial wall temperature profile (RBHT-C3-R1)

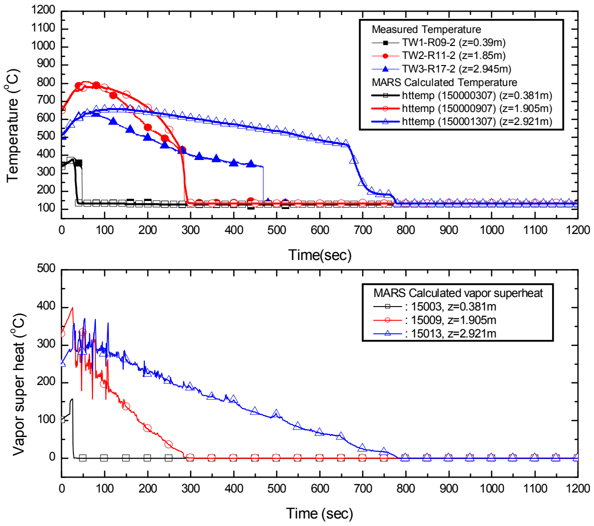

Figure 2. Trend of the heater wall temperature and vapor superheat (RBHT-C3-R1)

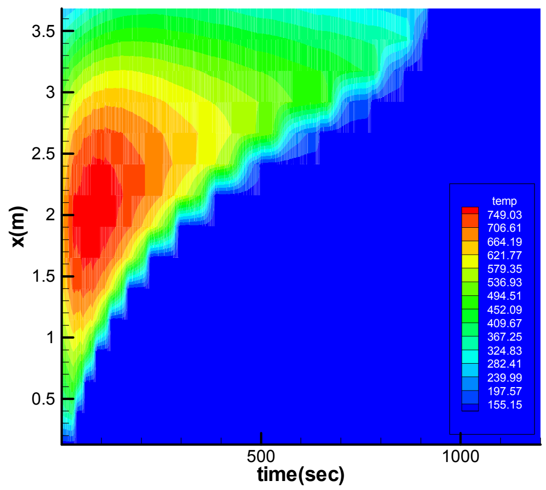

Figure 3. A heater wall temperature contour with respect to time (RBHT-C3-R1)

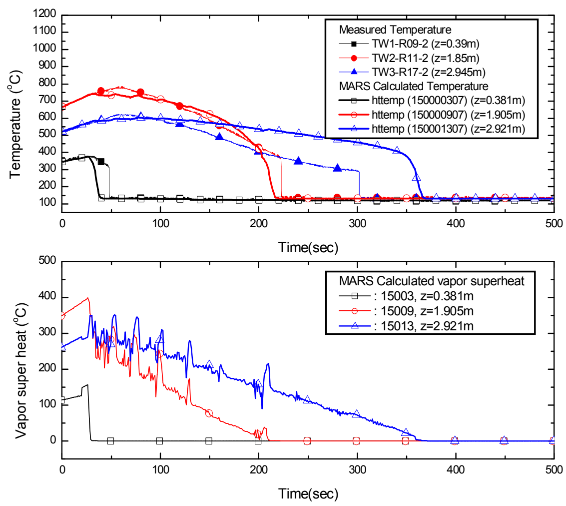

Figure 4. Trend of the heater wall temperature and vapor superheat (RBHT-C2-R1)

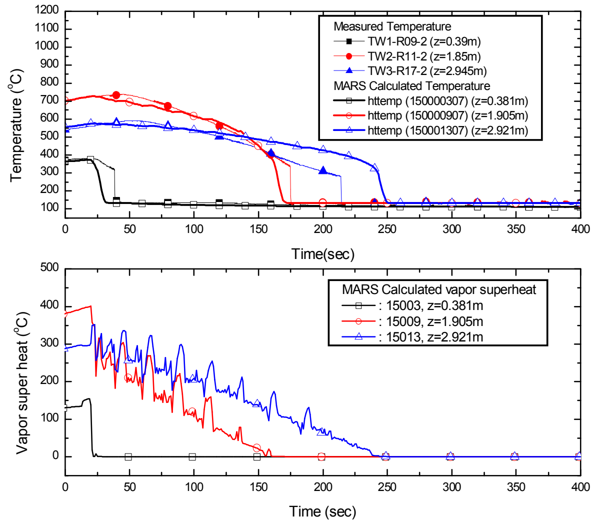

Figure 5. Trend of the heater wall temperature and vapor superheat (RBHT-C1-R1)

The heater wall temperature contour with respect to time is shown in Figure 3. Figures 4 and 5 show the trends of the heater wall temperatures for the other two cases; RBHT-C2-R1 and RBHT-C1-R1. It seems that the MARS3.1 code predicts the PCT with a reasonable accuracy for all the cases. However, a delayed quenching is mitigated as the heat flux becomes smaller.

4. Conclusion

It was found that when the heat flux is high, the prediction capability of the MARS3.1 code during the reflooding period is degraded more than expected. However, the predicted PCT is in good agreement with the data regardless of the heat fluxes considered in this study. Based on the present results, the detailed reflooding models in the MARS3.1 code need to be carefully investigated. Furthermore, a detailed separate effect test needs to be prepared in order to reduce the modeling uncertainties if necessary.

REFERENCES

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