Preliminary descriptions on the 6 x 6 reflood test of KAERI – Part II: System and vessel module analysis with MARS 3.0 and COBRA-TF

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1. Introduction

A 6x6 reflood test facility has been constructed by KAERI to quantify rewetting mechanism and evaluate the effect of dispersed flow cooling with respect to droplet behavior. The test section consists of a simulated 6x6 rod bundle, a flow housing, 4 pairs of borosilicate glasses for a visual observation and instrumentation. The detailed description on the test facility can be found in Part I of this paper. The objectives of the 6x6 reflood test facility are to enhance the understanding on thermal hydraulic behavior in the reactor core during the reflood phase, to evaluate the rewetting mechanism including the rewetting temperature behavior and rewetting velocity variation with respect to the experimental parameters, to investigate the effect of the spacer grid during the reflood period by quantifying the droplet behavior at the upstream and downstream sections of spacer grids.

During the last few years, there have been a lot of assessment and validation work on the reflood models of the thermal-hydraulic system codes, such as TRAC, COBRA-TF, RELAP5, and CATHARE[1-3]. In particular, it was reported that the RELAP5 code still has several deficiencies in the reflood model[3]. The MARS code, which was developed by integration of the one-dimensional RELAP5/MOD3 code and the multi-dimensional COBRA-TF code, has been improved to perform a subchannel analysis of light water reactors.

2. Analysis Methods and Results

In the present study, two different approaches were used with the latest version of MARS3.0 and their results were compared each other. One case of the reflood test matrix is simulated by the 1-D PIPE of RELAP5/MOD3 and 3-D VESSEL component of COBRA-TF in the MARS code for assessment on the prediction capability of each component. Both approaches share the same initial and boundary conditions for calculation.

2.1 PIPE module nodalization

Figure 1 shows a nodalization scheme in the 1-D PIPE model. The test section is simulated by a pipe component 150 with 17 axial nodes. The time-dependent volume 120 simulates the steam supplier, which provides initial steam flow in order to maintain the system at the predefined system pressure, removing the heat from the heater surface. The generated steam is injected to the test section component 150 of which a separator is on the top. The separated droplet is drained to the time-dependent volume 190. System pressure is maintained at a predefined value by controlling opening the valve component 175.

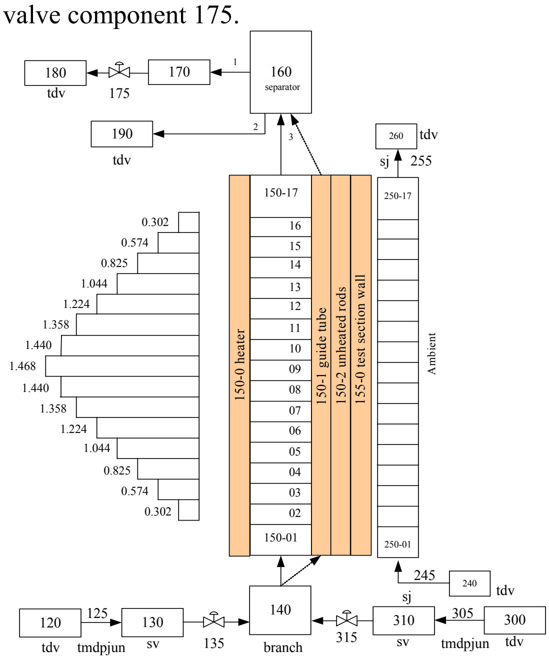

Figure 1. PIPE module nodalization for the 6x6 reflood test section

Four heat structures were modeled; heater rods, a guide tube, unheated rods, a cold wall of the test section. The heater has a chopped cosine profile as shown in Figure 1. The internal detailed geometry of the heater rods was modeled. A guide tube which is installed in the center of the test section was modeled. Two unheated rods in the corner of the test section were also modeled. Finally, outer rectangular cold walls were modeled with a free-convective boundary condition.

Table 1 Initial and boundary conditions

Parameters	Value
System pressure	4 bar
Initial steam mass flow rate	0.2kg/s
Initial wall temp.	500 ^{o}C at 13th node
Inlet coolant temp.	50^{o}C
Flooding velocity	2,5,8 cm/s

Initially, the flooding water isolation valve 315 is closed and the steam of 0.2kg/s is injected into the test section. The power of heater rods are controlled until the heater surface temperature at 13th node from the bottom is heated up to 500°C. During the heat-up process, the system pressure, which is defined the pressure at the component 170, is controlled to maintain 4 bar. After the system reaches a steady state condition, the valve 135 is closed, concurrently with opening of the valve 315 to initiate a transient calculation. Figures 2 through 4 show axial wall temperature profiles, depending on the flooding velocity. As the flooding velocity increases, the rewetting occurs more rapidly.

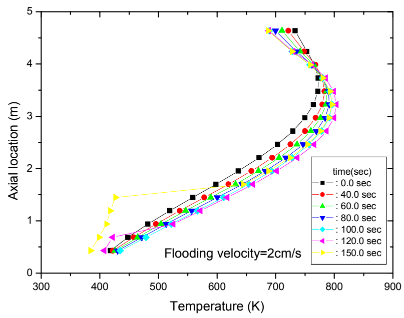

Figure 2. Wall temperature profile for flooding velocity 2cm/sec

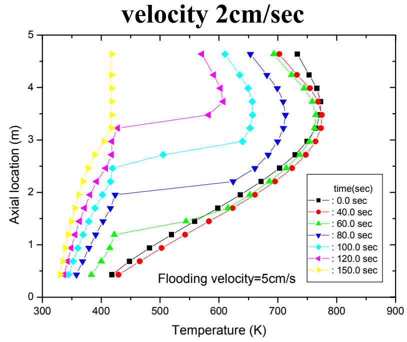

Figure 3 Wall temperature profile for flooding velocity of 5cm/sec

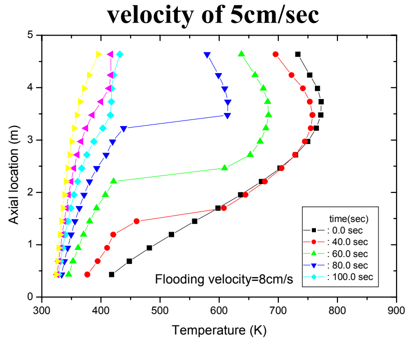

Figure 4 Wall temperature profile for flooding velocity of 8cm/sec

2.2 VESSEL module nodalization

MARS vessel module nodalization is also used to simulate the reflood test. The test section is modeled as a single channel without any lateral velocity components. Because the test section has 1/4 symmetry, the single channel includes 7.5 heating rods, 1/2 corner unheated rods, and 1/4 center guide tubes. These heating and non-heating rods are modeled as vessel heat structure. The outer shroud, otherwise, is modeled as cylindrical 1-D heat structure. As the steady state has reached, the initial and boundary conditions are the same to that of 1-D modeling. Figure 5 shows the predicted wall temperature at the node 13 and compares it with the PIPE modeling results. The VESSEL modeling shows an initial heat-up, which is not predicted by the PIPE modeling. Also, relatively late quenching time is calculated in the VESSEL modeling. It seems to be due to the different reflood models in each module.

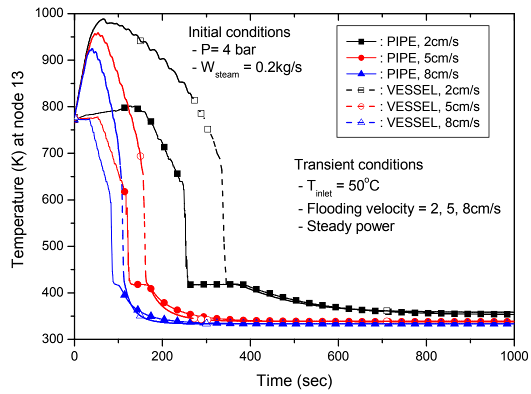

Figure 5. Comparison of wall temperature between the PIPE and the VESSEL modeling

3. Conclusion

A pre-test analysis has been carried out for a reference 6x6 reflood test case by using the latest version of MARS3.0. It is found that there are a little difference in the peak temperature and quenching time between the PIPE of RELAP5/MOD3 and VESSEL component of COBRA-TF. When the 6x6 reflood tests are available in the near future, more detailed assessment on the models in the code and comparison between the two models will be carried out.

Acknowledgements

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