Validation Calculation of Reflooding Tests Using TRACE code

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1. Introduction

The reflood phase of a postulated loss-of-coolant accident (LOCA) is characterized by a sequence of heat-transfer and two-phase-flow regimes advancing rapidly along the fuel rod assembly in the reactor pressure vessel. During the reflood phase, the fuel rods experience an initial gradual or rapid rise in temperature, followed by a temperature turn-around time when the peak cladding temperature (PCT) reaches and a quenching time when the rod temperature drops in a very steep manner. This sudden drop in temperature is a consequence of an increase in heat removal rate due to the transition from dispersed droplet flow film boiling to nucleate boiling [1].

The most recent research effort focused on the reflooding phenomena is the Rod Bundle Heat Transfer (RBHT) test facility, in which various types of reflooding and two-phase heat transfer experiments have been performed. This large-scale separate effect test facility, also designed to facilitate code development and validation, is still under operation for various experimental and benchmark tasks.

The objective of this study is to validate the TRACE code in reflood conditions with various inlet and boundary conditions using the RBHT test experimental data.

2. Methods and Results

The RBHT test facility has been designed to conduct various thermal-hydraulic experiments in the rod bundle geometry, reproducing the core behavior of a post-LOCA during the reflood phase [2,3].

Figure 1 shows an analytical model of the RBHT test facility using the TRACE5.0. The test section was modelled using a VESSEL component of 34 nodes, which was divided only in the axial direction. The upper and lower plenum were simulated as single control volumes using PIPE components which were connected to a BREAK and a FILL component, respectively. The rod bundle power of the bilinear profile with the peak power at L*=0.75 was applied to the test section using a POWER component. Three HTSTR components of the TRACE code simulated heated rods, unheated rods, and a flow housing. No heat loss through the wall of the flow housing was assumed conservatively. The system pressure was given at the top of the upper plenum as the outlet boundary. The water mass flow rate and temperature were set at the bottom of the lower plenum as the inlet boundary.

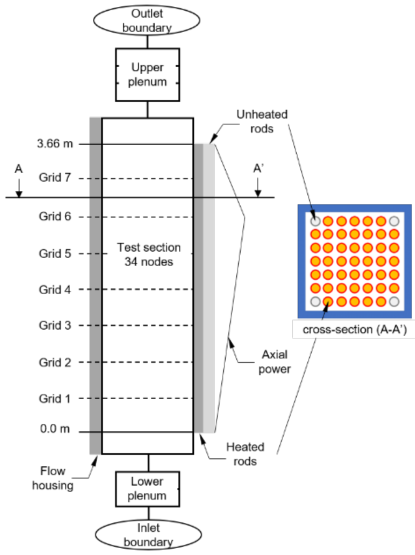


Fig. 1 Nodalization of the RBHT test section with the TRACE code.

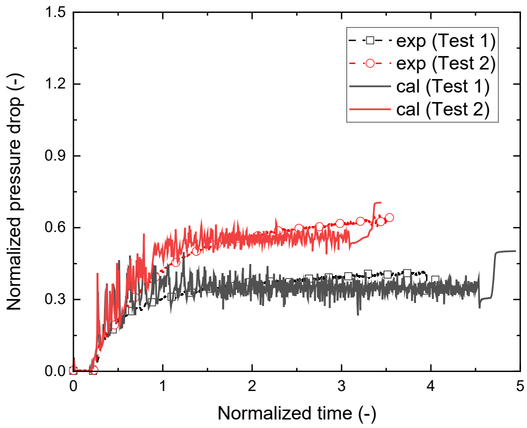
Among the reflooding experiments performed in the frame of the RBHT benchmark, recently organized by OECD/NEA, Table 1 shows a subset of the tests selected for the present study.

Table 1. Selected RBHT experiments for validation calculation

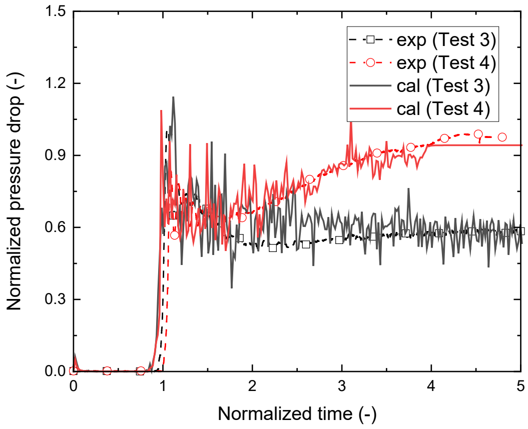
	Bundle Power [kw/m]	Inlet velocity [m/s]	Water subcooling [K]	Reflood temperature [K]
Test 1	1.31	0.025	10	1,000
Test 2	1.31	0.025	80	1,000
Test 3	2.30	0.150	10	1,144
Test 4	2.30	0.150	80	1,144

3. Results and Discussion

Figure 2 shows the behaviors of the pressure drop along the rod bundle, which consists of water head differences and wall friction losses, which are significantly affected by the interfacial and wall shears, respectively. The pressure drop and transient time are normalized based on the initial system pressure and PCT occurrence time measured at each experiment, respectively. The pressure drop predicted by the TRACE code was in reasonable agreement with the experimental results, although the magnitude of the pressure drop oscillations was larger than the measured results.



(a) Low inlet flow rate (Test 1 and 2)



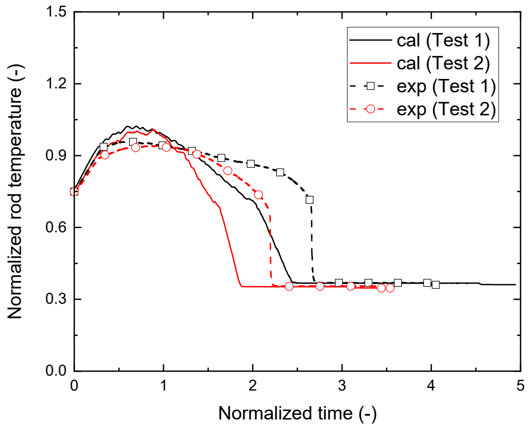
(b) High inlet flow rate (Test 3 and 4)

Fig. 2 Pressure drop along the bundle.

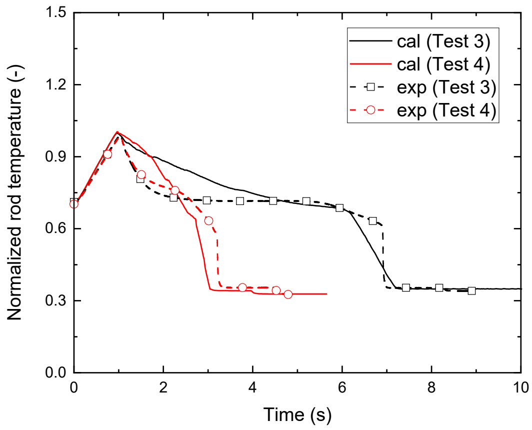
The calculations also presented a good agreement with the experimental data for the rod surface temperature and the quenching time at L*=0.74 near the peak power location where the PCT was measured, as shown in Fig. 3. The temperature is normalized based on the measured PCT of each experiment. However, after the maximum temperature, the predicted rod surface temperature dropped faster than the measured one, causing the rod surface to be rewetted earlier, which was more pronounced in the low flow rate conditions (Test 1 and Test 2) and similar to the previous reflood simulations of the TRACE code [4].

4. Conclusions

This study aimed at the validation of the TRACE code in reflood conditions with various inlet and boundary conditions using RBHT test experimental data. A series of calculations were performed, and the adequacy of the TRACE analytical model was confirmed through the comparison of the thermal-hydraulic variables with experimental results.



(a) Low inlet flow rate (Test 1 and 2)



(b) High inlet flow rate (Test 3 and 4)

Fig. 3 Rod surface temperature.

Acknowledgments

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