Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Influential Input Parameters for Reflood Model of MARS Code

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1. Introduction

Best-Estimate (BE) calculation has been more broadly used in nuclear industries and regulations to reduce the significant conservatism for evaluating Loss-of-Coolant-Accident (LOCA). Reflood model has been identified as one of the problems in BE calculation. The objective of the Post-BEMUSE Reflood Model Input Uncertainty Methods (PREMIUM) program of OECD/NEA is to make progress the issue of the quantification of the uncertainty of the physical models in system thermal-hydraulic codes, by considering an experimental result especially for reflood. It is important to establish a methodology to identify and select the parameters influential to the response of reflood phenomena following Large Break LOCA. For this aspect, a reference calculation and sensitivity analysis to select the dominant influential parameters for FEBA experiment are performed.

2. PIRT and FEBA Experiment

2.1 PIRT of RBHT Experiment

Through the Rod Bundle Heat Transfer (RBHT) program focusing the reflood phenomena, a Phenomena Identification Ranking Table (PIRT) was obtained [1]. Based on highly-ranked parameters in the PIRT, twenty-one input parameters in Table I are initially considered. The selected input parameters are classified into three groups (global parameter, basic parameter, and coefficient parameter) in accordance with specifications of PREMIUM Phase II [2].

2.2 FEBA Experiment

For the 'evaluation step' of the PREMIUM program, the FEBA experiments have been selected. The purpose of the FEBA program was one of the reflood heat transfer experiment during reflood phase [3]. The test section consists of a full-length (3900 mm) 5 x 5 rod bundle having a typical PWR fuel rod dimension, utilizing electrically heated rods with a cosine power profile in axial direction. The test, FEBA-216, was selected for both reference calculation and sensitivity calculation to identify the influential parameters. The initial system pressure and inlet velocity of the test were 4.1 bar and 3.8 cm/s, respectively.

3. Analysis for Influential Parameters

3.1 Reflood Models and Base Calculation

The special version of MARS code (MARS-KS-003) [4] is used, which has the different reflood model compared to the previous version. The model proposed by Bajorek and Young is incorporated for the dispersed flow film boiling (DFFB) wall heat transfer. Also, both space grid model and droplet enhancement model are included in this model [4].

Table I Initial Input Parameters

No.	Input Global Parameter
1	Chen nucleate boiling heat transfer coefficient
2	AECL CHF lookup table
3	Pool boiling CHF(Zuber)
4	Modified Weismann correlation
5	Bromley void weighted QF heat transfer
6	Forslund-Rohsenow equation
8	Droplet enhancement factor
9	Interfacial drag for bubbly flow
10	Ishii-Mishama entrainment
12	Interfacial HT of subcooled liquid
16	Interfacial HT of drop-steam
	Input Coefficient Parameter
7	Convection to superheated vapor(Turbulent, laminar, natural convection)
11	Weber number
13	Interfacial area of Inverted annular (roughness)
14	Dry/wet wall criteria
15	Transition criteria for void fraction
	Input Basic Parameter
17	ANS decay model
18	Heater(MgO) thermal conductivity
19	Heater(MgO) heat capacity
20	Cladding(Ni Cr) thermal conductivity
21	Cladding(Ni Cr) heat capacity

Figure 2 shows the MARS nodalization for FEBA test facility. The heated part is modeled by the pipe component with 39 subvolumes and 8 radial mesh points for bundle. Figure 3 shows the initial axial temperature distribution of the rod surface and the housing, where they are compared to the experimental data.

The calculation was conducted up to 500 sec. From the calculation result, it was found that the maximum temperature of rod surface at each measured location was well matched with the experiment data as shown in Figure 4. But the rewet time was calculated too fast and then the quench front elevation was higher than the experimental data.

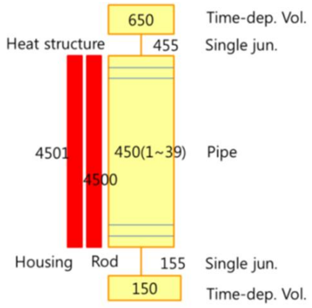

Figure 2 Nodalization for FEBA experiment

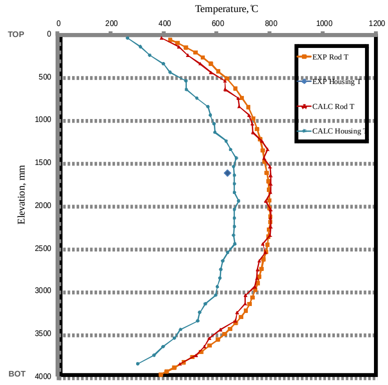

Figure 3 Initial axial temperature distributions of the rod surface and housing

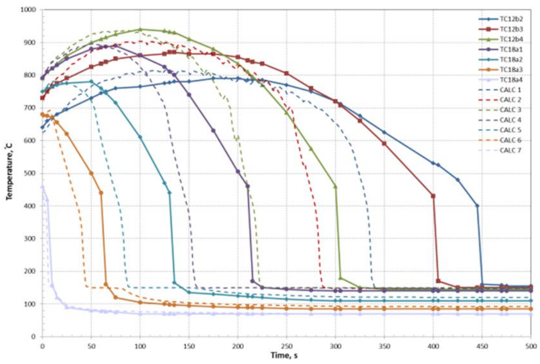

Figure 4 Rod surface temperatures along the test rod bundle

3.2 Selection Criteria for Influential Parameters

Criterion to select the influential parameters was determined such that an influential input parameter should satisfy that either of two reflood response (rod surface temperature or quenching time) shows the following large change at its extreme value in the range of input variation:

- the absolute value of variation in rod surface temperature is ΔT_{ref}= 30K, or
- the variation in quenching time is Δt_{quench}= 7%

3.3 Sensitivity Analysis

Sensitivity analysis for the influential parameters was performed by changing the associated parameters from the base input deck of FEBA-216 experiment. The maximum rod surface temperature and quenching time at 1425 mm height were calculated for each case. Following the selection criteria, figures 5 and 6 showed the most influential parameters with respect to the variation of rod surface temperature and quenching time, respectively. Finally, the following four parameters are selected: convection to superheated vapor, interfacial heat transfer of drop-steam, dry/wet wall criteria, Weber number. However, modified Weismann correlation was excluded because quenching behavior is somewhat different.

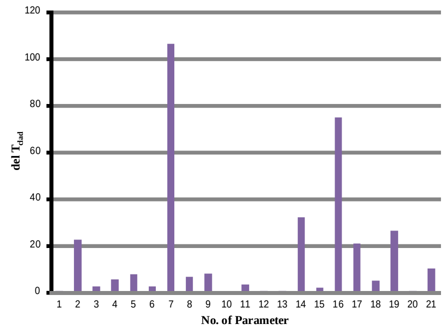

Figure 5 Rod surface temperature deviation for influential parameters

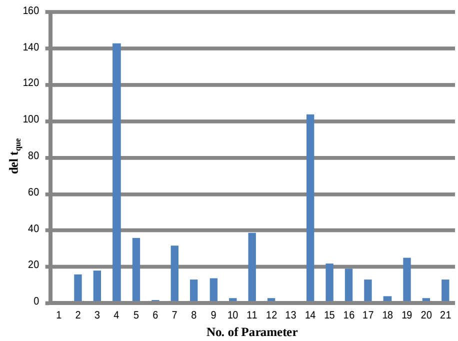

Figure 6 Quenching time deviation for influential parameters

4. Conclusions & Further Studies

Twenty-one input parameters are considered as potentially influential for reflood phenomena, from the highly ranked parameters based on RBHT PIRT. Sensitivity analysis for FEBA experiment showed that four influential parameters are dominant during reflood.

In the frame of the PREMIUM, the quantification and validation of the uncertainties will be performed for the physical models in the reflooding using FEBA and PERICLES experiments.

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