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Sensitivity Study of Reflood Model for MARS-KS1.3 3D Vessel Module using FEBA test data

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1. Introduction

The backbones of MARS-KS 3D Vessel module is COBRA-TF [1] which has an Eulerian three-field (gas, continuous liquid, and droplets) model for the two-phase flow calculations on a sub-channel basis. The addition of a droplet field gives a significant advantage over standard two-fluid models, (e.g. TRACE and RELAP5) since the effects of liquid entrainment can be directly modeled.

OECD-PREMIUM (Post-BEMUSE REflood Models Input Uncertainty Methods) project has been started for the development of advanced methodology of input parameter uncertainty of reflood model based on the experimental data. The main method is "inverse method" to eliminate the subjective decision of PDF of input parameter. Important parameters should be selected according to the selection criteria based on sensitivity analysis. FEBA (Flooding Experiment with Blocked Arrays) test [2] was chosen for sensitivity study of reflood model of MARS 3D Vessel module (i.e. COBRA-TF).

2. Model Description

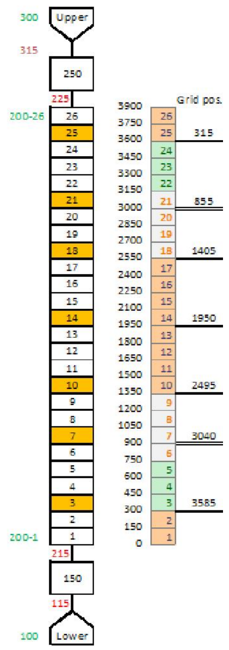

Fig1. Modeling for FEBA test

The FEBA test, which consists of 5x5 rod bundle of PWR dimensions with an electronic heater power, was conducted under different reflood conditions (coolant pressure, temperature and flooding rate) in order to study grid spacers and blocked effects in the emergency core cooling case. This part includes the modeling for FEBA test and the initial and boundary condition.

Firstly, in the model of FEBA facility in MARS-KS1.3 3D vessel (Fig. 1), the test was divided axially into 26 nodes of 3.9 meter in heated length based on the electrical power profile [2]. As shown in the Fig.1, these are 7 gird spacers located at corresponding nodes (3, 7, 10, 14, 18, 21 and 25). In the bundle cross section, due to the asymmetric geometry of FEBA test, only 1/8th rod bundle with one equivalent heater rod and a single channel was modeled (Fig.2). This single channel model is to have the simplest and fastest system behavior due to some difficulties with multi-channel model (long running time with a small time step and complicated behavior with a very small area of sub-channel). Since thermal inertia effect of housing wall is significant during reflood, the wall has also modeled as an insulated heat structure.

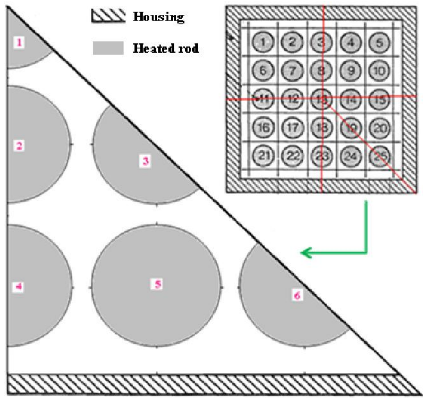

Fig.2. Cross section model of FEBA test

Secondly, the chosen FEBA test 216 was performed at the specific conditions as listed in table 1.

Table 1: Boundary conditions for FEBA test 216

Parameter	System pressure (bar)	Flooding flow rate (kg/s)	Feedwater (^{0}C)	Heat losses (W)
Value	4.1	0.0184	~ 37	0.0

In this table, after reaching at certain constant cladding temperature as in the experiment process [3], feedwater was injected into the low part of the system with initial fluid temperature of 48 degree Celsius, and gradually decreased in 30 second down to 37 degree Celsius. That temperature was kept constant until the end of the test. The heat loss through the wall was not modeled.

In MARS-KS 1.3 model, after pre-heating period at low power (790s), the system reached to the initial cladding temperatures of heater rod, those obtained temperatures, which matches well with experimental data (Fig.3), were kept almost constant in 80 second. So that the time system needed to reach the initial condition is 870 second.

3. Results

After investigating for reference case, the sensitivity analysis has then performed in order to select important parameters for next PREMIUM project step.

3.1 Reference case

Except the highest elevation, the calculated quenching time at each elevation is compatible with those in experimental data for reference case (Fig.4). The elevation of 2.475 meter (from the bottom of heated part), at which the peaking cladding temperature (PCT) occurred, was chosen for reference one. And based on the proposed list of criteria [4], two criteria that are PCT and quenching time have been selected for the sensitivity analysis.

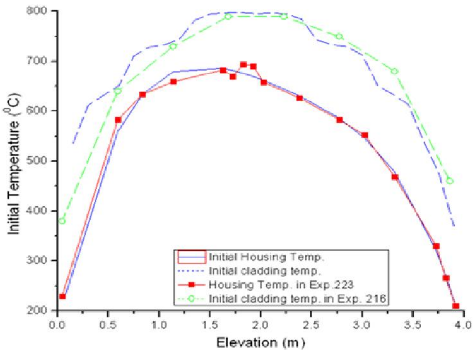

Fig.3. Comparing initial temperature for reference case

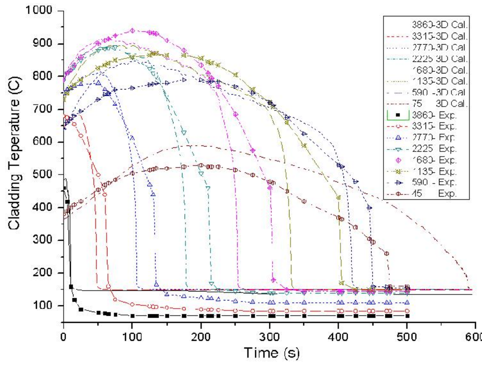

Fig.4. Comparing cladding temperature for reference case

3.2 Selected parameters

The sensitivity calculations have been performed with 29 cases in corresponding to the considered parameters. Because of the variation of each parameter in a range from minimum to maximum value, there are total 58 cases for sensitivity analysis calculation.

According to the criterion of the absolute variation of rod surface temperature of 10 degree Celsius and of quenching time of 10 second, and also to the uncertainty range of input parameter, ten final parameters with the high variations have been selected as listed in the table 2.

Table 2: The selected parameters for uncertainty analysis

Parameter	ID	T_{clad} variation [°C]	t_{rew} variation [sec]
Drop evaporation efficiency of transition boiling HT[1]	IP5	+24.1/-2.8	+89.0/-36.0
Modified Bromley correlations	IP7	+0.6/-2.3	+13.0/-6.0
Grid HT enhancement	IP8	+16/-26	+13.0/-20.0
Vapor Turbulent HT correlation	IP9	+2.3/-6.5	+2.0/-24.0
Droplet friction factor	IP13	+22.3/-27.6	+6.0/-8.0
Interfacial HT model of droplet	IP22	+36.5/-34.5	+9.0/-11.0
Flooding velocity	IP23	+19.2/-18.8	+26.0/-23.0
Heat capacity (MgO)	IP27	+1.7/-19.7	+4/-4
Heater Power	IP28	-12.0/+7.9	-5.0/5.3
Grid spacer blockage ratio	IP29	5.6/-14.2	6.0/-19.0

4. Conclusion

The important parameters have been selected based on sensitivity results of FEBA using a-priori PDF of input parameter. Since main objective of this study is to develop the methodology of eliminating the subjective decision of PDF. A posteriori PDF of input parameter will be determined using FEBA experiment data. CEA Circe [5] method will be used to determine the PDF; however another method suggested by KIT [6] will also be used for comparison.

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[1] HT: Heat transfer