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An Application of a Monte-Carlo Method to Assess the Code Uncertainty of MARS Code on the Clad Temperature of FLECHT-SEASET 31504

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1. Introduction

Use of a Best-Estimate Methodology (BEM) in accident analysis requires the quantification of code uncertainty. In KREM(KEPRI Realistic Evaluation Method) and CSAU[1], systematic methods have been developed to quantify the code uncertainty. However, the CSAU is conceptually difficult to implement, and KREM does not explicitly quantify code uncertainty.

The Monte-Carlo method is expected to provide the true code uncertainty, but it requires large computing resources. A modified form of Monte-Carlo method in which the important parameters are divided into "global" and "local" sets to reduce the number of calculations is developed. The variation of the "local" set of parameters is carried out within a single code run. This reduces the number of code runs while maintaining the method to be simple in concept and implementation. The method can also easily accommodate parameter additions.

The validity of the developed method was demonstrated by applying the method on the system module of the MARS[2] code to assess the uncertainty in clad temperature of FLECHT-SEASET 31504.

2. Methods and Results

2.1 FLECHT-SEASET 31504

The Full-Length Emergency Core Heat Transfer-Separate Effects and System Effects Tests (FLECHT-SEASET)[3] were carried out primarily to produce the reflood heat transfer data for the large break Loss-of-Coolant Accident (LOCA). The test number 31504 is carried out in 161-rod unblocked bundle configuration which is representative of Westinghouse 15x15 fuel assembly. The fuel rod is simulated by electric heater rods. The 31504 was carried out with the low flooding rate of 24.6 mm/s and uniform radial power distribution.

2.2 Important Parameter Selection, Classification and Ranging

Important parameters for consideration in the code simulation were selected. The selected parameters were then divided into two parameter sets, "global" and "local" according to their effects on clad temperature. The global parameters represent those that have effects on the whole system and the local parameters represent those that have primarily localized effects. The results of the selection are shown in Table 1.

For the important global parameters, the single phase heat transfer coefficient, nucleate boiling heat transfer coefficient, CHF (Critical Heat Flux), transition boiling heat transfer coefficient, film boiling heat transfer coefficient, flooding rate, and heater power were selected. For the local parameters, the thermal conductivity and the specific heat capacity of the heater rod are selected.

For each parameter, the uncertainty range was determined from available literature.

Compo-nent	Phenomena/ Parameter	Physical Model	MARS Code Parameter	Distribution Type	Nominal	Uncertainty Range (1σ)
Heater Rod	Single phase HT	Dittus-Boelter	Dittus-Boelter	Normal	1	0.1275
	Nucleate boiling	N.B. HTC	Chen	Normal	1	0.2
	CHF	Low Flow	AECL Look-up	Normal	1	0.37
	Transition boiling	Chen	Chen	Normal	1	0.2
	Film boliling	Film Boiling HTC	Bromley	Normal	1	0.18
	Stored Energy	Conductivity	Table input	Normal	1	0.1
		Specific Heat Cap.	Table input	Normal	1	0.058
Operation	Flooding Rate	Flooding velocity	Input for tmdpjun	Normal	1	0.02
	Electric Power	Power	Heater Rod Power	Normal	1	0.01

Table 1. Important Parameters and their Ranging

2.3 Code Modeling and Nodalization

The nodalisation used for the MARS simulation of FLECHT-SEASET is shown in Figure 1. For the current simulation, only the system module of the MARS code is used. The heating section is 144 inches high and it is nodalised into 20 volumes. A total of 159 rods was divided into 25 rod groups. For each group of rods, the rod thermal conductivity, k, and the specific heat capacity, cp, were varied. The variations in k and cp were implemented by input changes for the individual rod-groups.

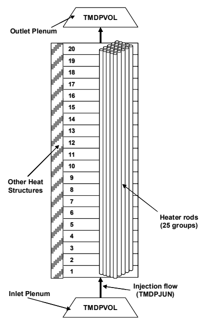

Figure 1. Nodalisation of FLECHT-SEASET 31504 for MARS Simulation

MARS code was modified to allow uncertainties to be incorporated in heat transfer coefficients. The variations in the heat transfer coefficients are implemented globally, and as such, same variations were applied for all heater rods.

2.4 Input Generation and Calculations

100 Monte-Carlo run cases were designed with 25 rod-group variations within each MARS run. For each run, all parameters were varied randomly according to the distribution and the range of the parameter uncertainty.

A series of computer programs was devised to run in sequence to automatically generate the 100 input decks.

100 runs produced a total of 2500 data points for 100 Monte-Carlo runs. Assuming local parameter selection has been judicious, approximately 10 times the calculation throughput was achieved. As each calculation run is completely independent, the calculations were run simultaneously on a number of computers to reduce the overall run time.

2.5 Results and Discussion

The Figure 2 and 3 show the calculated and experimental heater rod surface temperature at 72 and 78 inch locations, respectively. The Figure 4 shows the peak cladding temperature.

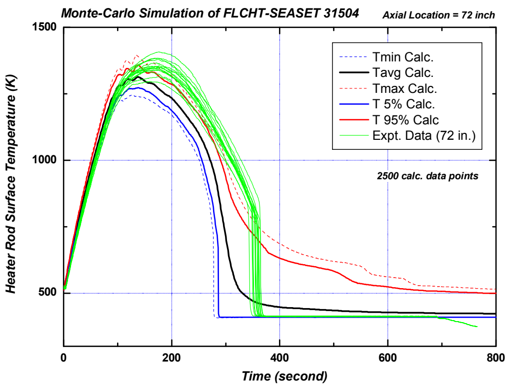

Figure 2. Comparison of calculated and experimental results for Rod Surface Temperatures at 72 inch location.

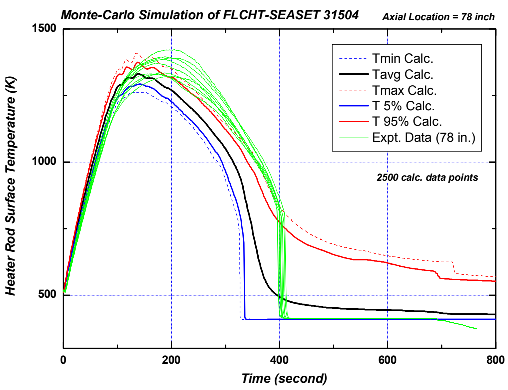

Figure 3. Comparison of calculated and experimental results for Rod Surface Temperatures at 78 inch location.

As can be seen in the Figures 2 and 3, the results shows that the overall prediction of MARS closely follow the experimental data but the calculated temperature range fails to bound the experimental data range. As can be seen in Figure 4, the same is true for the 78 inch results. The discrepancy becomes greater for the PCT. However, the calculated uncertainty band between 5% and 95% closely matches the experimental data spread for the 72 and 78 inch cases.

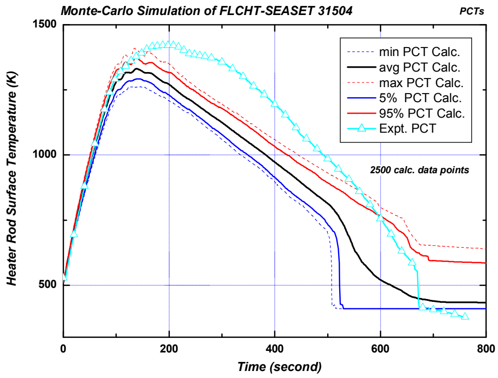

Figure 4. Comparison of calculated and experimental overall PCT.

This indicates that there is code deficiency for MARS with regards to the low flow reflooding phenomena. The system module of MARS code is largely identical to the RELAP5/Mod3.3 code, and the code deficiencies reported in the RELAP5 code apply[4] to MARS code. The calculated uncertainty band is expected to widen if the variation in the Weber number (droplet size) is included as a parameter.

3. Conclusion

A modified Monte-Carlo method has been proposed and successfully applied to assess the uncertainty of the system module of the MARS code on cladding temperature during reflood using FLECHT-SEASET 31504 experiment. Although the calculated temperature range fails to bound the experimental data due to code deficiencies, the proposed method can be used to find the 95% upper limit PCT based on distribution function.

REFERENCES

[1] “Compendium of ECCS Research for Realistic LOCA Analysis”, NUREG-1230, U.S. Nuclear Regulatory Commission, 1989.

[2] “MARS 3.0 Code Manual”, Korea Atomic Energy Research Institute, KAERI/TR-2811/2004.

[3] “FLECHT-SEASET Program : Final Report”, Westinghouse Electric Corporation, EPRI-NP-4112, Sept. 1986.

[4] “RELAP5/MOD3.3 Code Manual Volume III : Dvelop-mental Assessment Problems”, Idaho National Laboratoty, NUREG/CR-5535, 2001.