A Comparison on Application of MARS and RELAP5 to KINS Realistic Evaluation Methodology

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1. Introduction

The best estimate method with the uncertainty evaluation has been broadly used worldwide in licensing NPP. The KINS (Korea Institute of Nuclear Safety) has also conducted the regulatory audit calculation by using the KINS Realistic Evaluation Methodology (KINS-REM) [1]. The RELAP5/MOD3.3 code has been used in KINS-REM.

Currently, KINS has evaluated the applicability of the MARS code [2] for KINS-REM, which is the major part of the development and application of reactor transient analysis system for regulatory audit (RETAS). Since the dialing method of MARS was different from that of RELAP5/MOD3.3 in considering the uncertainty parameters, the effect for the code change should be evaluated. The accident scenario is selected as the LBLOCA of APR1400.

The objective of this study is to compare the results for MARS and RELAP5 that were obtained from the regulatory audit calculation. Also, the causes of the difference between results of two codes are identified.

2. Comparison on the Results of Two Codes

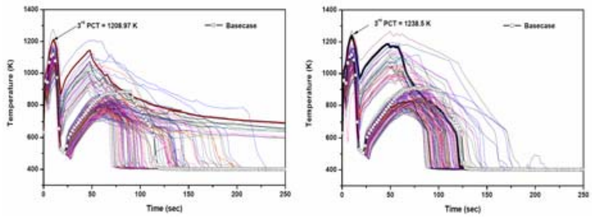
In KINS-REM, the final peak cladding temperature (PCT_{final}) is obtained as below;

$$PCT_{final} = PCT_{95/95} + B_{SCALE} + B_{IET} + B_{SET} + B_{PLANT} \quad (1)$$

where $PCT_{95/95}$ are the PCT with 95% confidence and 95% probability level. B_{SCALE}, B_{IET}, B_{SET} and B_{PLANT} are the bias due to the scale, the accuracy of code/model for the integral/separate effect tests and the system parameters which is not considered in determination of $PCT_{95/95}$, respectively.

In audit calculation for the LBLOCA of APR1400, the sampling sets used in reference [1] were consistently used in this study. The input data for RELAP5 were modified to be suited for MARS in considering the uncertainty parameters.

From 124 code runs, the fuel cladding temperature for two codes was obtained as shown in Fig. 1 and three high-ranking PCTs were also shown in Table I. In Fig. 1, the third high-ranking PCT (3^{th} PCT) means the $PCT_{95/95}$. according to 3^{th} order Wilks' formula [1].



(a) MARS (b) RELAP5

Fig. 1. Fuel cladding temperature

Table I: Three High-ranking PCTs for 124 runs

	Rank	No. Case	Node	Blowdown		Reflood	
				Time (s)	PCT (K)	Time (s)	Cladd.Temp (K)
MARS	1	25	14	10.	1276.28	52.	1207.77
	2	16	14	10.	1221.64	46.	1053.48
	3	92	14	10.	1208.97	48.	1144.44
RELAP5	1	25	14	10.	1271.4	52.	1196.1
	2	92	14	10.	1251.7	50.	1264.8
	3	11	14	10.	1238.5	48.	1041.2

2.1. Difference of Blowdown PCT

As shown in Table I, the blowdown PCT of MARS was higher than that of RELAP5 despite the calculation with same condition. In the case 92, the difference of the blowdown PCT was as much as 43 K. Generally, the initial stored energy in the steady state and the critical flow model could affect the blowdown PCT. There was no significant difference between the steady state results of two codes. Also, MARS used the same heat transfer models as RELAP5 including the critical heat transfer model. Therefore, the difference of the blowdown PCT was an unexpected result. From the detail assessment, we could identify that this difference resulted from the simple coding error in applying the CHF multiplier in the code dialing process.

From a previous study [3], it was found that RELAP5/MOD3.3 had a coding error in considering the fuel gap conductance. In this study, we could identify that MARS had the same coding error as RELAP5. Therefore, these coding errors were corrected in MARS. Fig 2 shows the fuel cladding temperature of the blowdown phase in the case 92. After the code correction, the behavior of the fuel cladding temperature between two codes was almost the same.

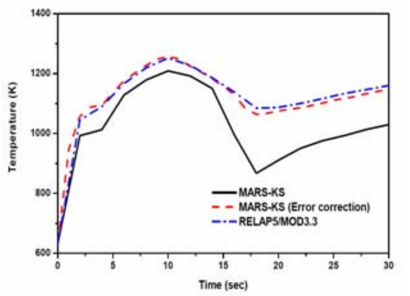


Fig. 2. Fuel cladding temperature for case 92

2.2 Difference of Reflood PCT

As shown in Fig. 1, the behavior of the cladding temperature between two cases was quite different, especially on the quenching behavior in the reflood phase. In MARS calculations, the fuel cladding for 11 code runs was not predicted to quench till 250 seconds. 11 cases were recalculated till 2000 seconds as shown in Fig. 3. In some code runs, the first quenching was not found even till 1000 seconds. The reheating after the quenching was found in other cases.

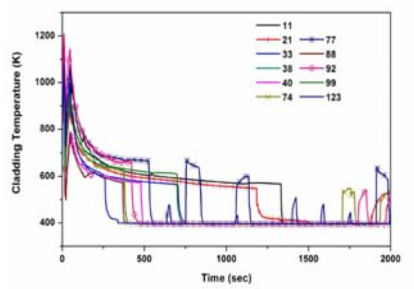


Fig. 3. Fuel cladding temperature for 11 code runs

In order to find the cause of the reheating after the quenching, the detail assessment was performed for the case 77. Fig. 4 shows the fuel temperature and the heat transfer mode in the case 77. In MARS, 47 and 48 in the heat transfer mode means the film boiling region. Therefore, the fuel temperature increased intermittently due to the film boiling. Also, in order to find the cause of the film boiling, the behaviors of the reactivity and the power were evaluated. As shown in Fig. 5, the instability of the fuel cladding temperature resulted from the thermal power growth due to the increment of reactivity.

From a previous study [4], we found that the uncertainty value for the CHF model was significant to the PCT behavior in reflood phase and the code runs with small uncertainty values for CHF model show non-quenching phenomena. Therefore, the abnormal behavior of the fuel temperature in the reflood phase resulted from the conservative uncertainty range for CHF model and the power mismatch. In RELAP5 calculations, the power may increase due to the reactivity change. However, since the uncertainty value for the CHF model was not considered in the reflood phase in RELAP5, the fuel cladding temperature didn't increase significantly.

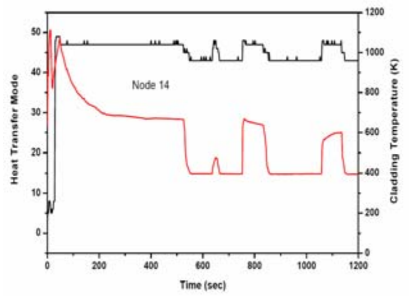


Fig. 4. Fuel cladding temperature and heat transfer mode for case 77

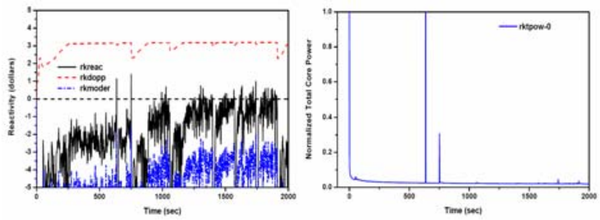


Fig. 5. Reactivity and power profile for case 77

3. Conclusion

In order to correct the abnormal behaviors of the fuel cladding temperature, MARS and KINS-REM would be improved to apply the uncertainty value to CHF models for the non-reflood and the reflood phase separately. Also, the further study should be needed to confirm the causes of the power mismatch.

REFERENCES

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