Effect of Reactor Upper Region Nodalization on APR-1400 LBLOCA BEPU Analysis

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1. Introduction

In the BE method with the uncertainty evaluation, the definition of system nodalization is important step influencing the prediction accuracy for specific thermal-hydraulic phenomena such as reflood, emergency core coolant bypass and blowdown quenching, etc. Recently, it was found that the temperature of upper region of APR-1400 reactor might be little lower than or similar to hot leg temperature due to the flow and convective heat transfer from the upper plenum through the review of detailed design data. In previous research [1], the sensitivity study of original and modified nodalization for LBLOCA was performed, and the effect of upper head nodalization and temperature was evaluated qualitatively. In this study, the effect of nodalization and temperature of reactor upper region on LBLOCA consequence was evaluated by BEPU calculation.

2. Modification of APR-1400 Nodalization

The reactor upper region consists of the upper guide structure assembly and the CEA shroud assembly. There are many holes in these assemblies to exchange the flow between the inner- and the outer-region. The conventional (original) upper region nodalization is shown in Fig. 1 (a). Figure 1 (b) shows modified nodalization reflecting design data. The upper region was separated into 2 axial volumes to simulate the actual circulation flow, and two axial volumes were connected each other with the cross flow junctions.

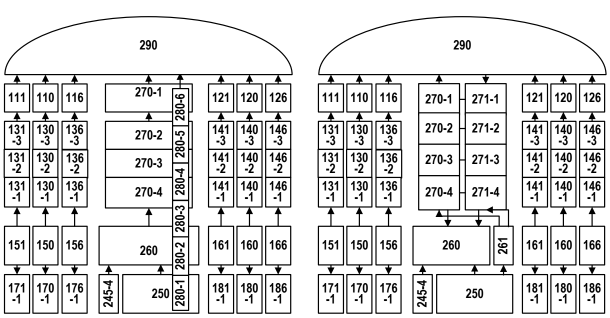


Fig. 1. Nodalization of Upper Region

Figure 2 shows the cladding temperature of the 14th node of hot rod in which PCT is occurred. As shown in this figure, in case of modified nodalization, the blowdown quenching was significantly deteriorated as compared to original case, and as a result, the cladding temperature in reflood phase became higher and the final quenching was also delayed.

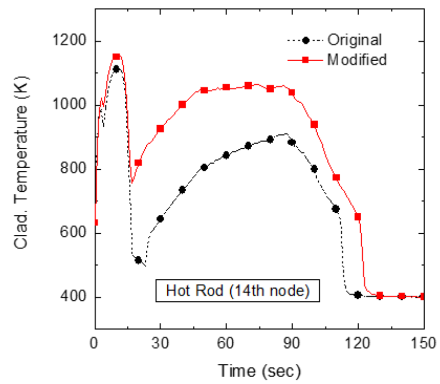


Fig. 2. Clad. Temperature of Hot Rod (14th node)

3. Results and Discussion

The sensitivity analysis was performed to evaluate the effect of the upper region temperature and nodalization on the BEPU analysis result; the accident was analyzed by applying the KINS-REM [2]. In the KINS-REM, the 95 percentile PCT following a LBLOCA is determined by simple random sampling for uncertainty parameters and 124 code runs based on the one-sided third order Wilks' formula. In this study, only important steps of this methodology required for the sensitivity analysis were introduced. In this analysis, 18 uncertainty parameters were considered; most of them were taken from the reference [3].

Figure 3 shows the PCTs of 124 cases and basecase for original version, and the $PCT_{95/95}$ was estimated to be 1255.3 K at 10 sec in the blowdown phase. As shown in this figure, most of PCTs were occurred in the blowdown phase and substantial blowdown quenching did in the most cases due to the lower temperature of the upper region in steady state. Figure 4 shows the PCTs for modified version, and the estimated $PCT_{95/95}$ was 1293.5 K at 46 sec in the reflood phase. In many cases, the blowdown quenching was reduced and the reflood PCTs were predicted to be relatively higher than original version. In particular, the

$PCT_{95/95}$ was increased by 38.2 K and the time that $PCT_{95/95}$ was occurred, was changed from blowdown to reflood phase due to the modification of upper region nodalization.

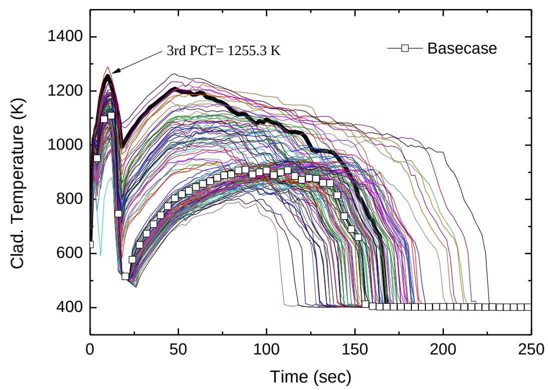


Fig. 3. PCTs of 124 cases and basecase (original)

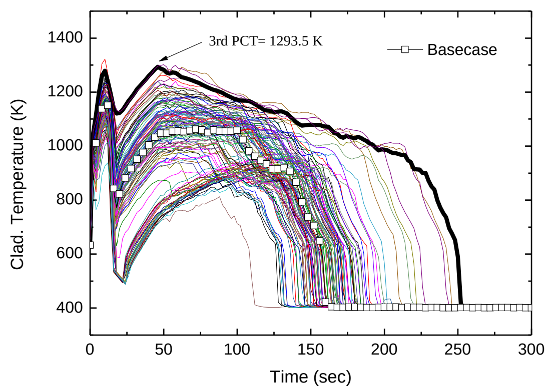
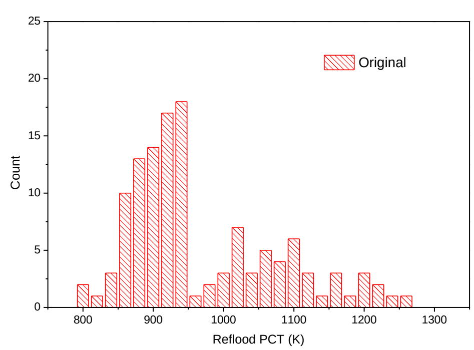
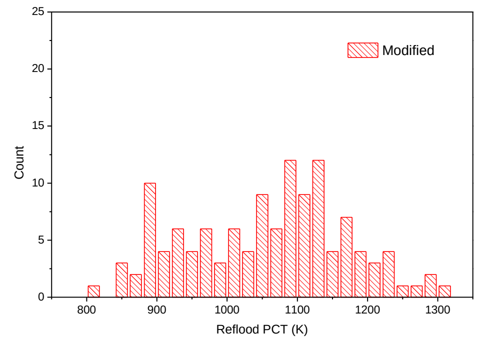


Fig. 4. PCTs of 124 cases and basecase (modified)

Figure 5 shows the comparison of reflood PCT distributions for original and modified version. For original version, two-thirds of reflood PCTs were distributed below 950 K, while those of modified version were widely distributed and 80 percent of PCTs were over 950 K.



(a)



(b)

Fig. 5. Comparison of reflood PCT distributions according to nodalization; (a) original (b) modified

4. Conclusion

In this study, the effect of nodalization and temperature of reactor upper region on LBLOCA consequence was evaluated by BEPU calculation. Due to the modification of reactor upper region, the core cooling and blowdown quenching was deteriorated, and as a result, the cladding temperature in the reflood phase became higher and the final quenching was also delayed. In BEPU analysis, the $PCT_{95/95}$ used in current regulatory practice was increased from 1255.3 K to 1293.5 K due to the modification of upper region nodalization, and it was occurred in the reflood phase unlike original case. Therefore, it was concluded that the modification of nodalization to reflect design characteristic of upper region temperature is an essential prerequisite to predict the PCT accurately in APR-1400 LBLOCA analysis.

REFERENCES

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