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Large Break LOCA Analysis with New downcomer Nodalizaion and Multi-Dimensional Model and Effect of Cross flow option in MARS code

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1. Introduction

The phenomena of LOCA have been investigated for long time. The most extensive research project for LOCA was the 2D/3D program experiments [1]. The results of the 2D/3D experiments show flow conditions in the downcomer during end-of-blowdown were *highly multi-dimensional at full-scale*. During reflood, the distribution of water in the core was one-dimensional. But flow in the core exhibited multi-dimensionality. One-dimensional manometer oscillation between the downcomer and core was observed. The water level was higher in front of the broken cold leg nozzle than at other azimuthal positions. Flow phenomena at the tie plate were uniform. With the background of 2D/3D study, Multi-dimensional codes such as TRAC [2], RELAP5-3D [3], CATHARE [4], SPACE [5], MARS [6, 7] and COBRA-TF [8, 9] were developed and applied LOCA application. In this paper, the authors modified the nodalization of MARS code LBLOCA input deck and performed LBLOCA analysis with new input deck.

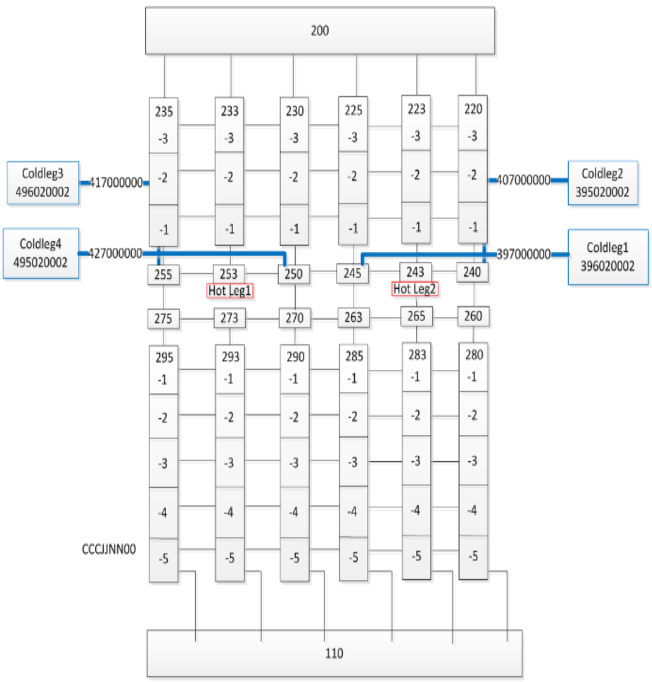

Fig.1. MARS Nodding scheme of Vessel in KREM

2. APR1400 LBLOCA Analysis

2.1. Code and Methodology

KEPRI Realistic Evaluation Methodology (KREM) with MARS-KS 1.4 Version [10, 11, 12, 13] is applied for system thermal hydraulics calculation. Analysis was processed under LBCOCA of 100% break size of cold leg case.

2.2. New Nodalization

As shown in Fig.1, the downcomer is divided into 6 azimuthal sectors to accommodate 4 cold legs and 2 hot legs. Four Direct Vessel Injection (DVI) lines are connected to the middle of upper downcomer. The authors divided azimuthal sectors from 6 to 12 and reassigned axial heights and volumes of each components with maintaining same total volumes. For example, the heights of components connected to cold leg are modified to internal diameter of cold leg nozzle. The middle points of axial locations of components connected to cold leg and DVI are modified to correspond with the middle point of cold leg and DVI.

Cold legs and DVI lines are reconnected to downcomer in horizontal direction as shown in Fig.2.

2.3. Multi-Dimensional Flow Model

For checking effects of multi-dimensional option, dimensional values like heights and volumes of down comer components remained the same as new input deck. For maintaining same pressure drop in downcomer with original input deck, the loss coefficients in junctions connecting each components were modified until mass velocity of cold leg became equal to mass velocity of cold leg of input deck used in APR1400 analyses during steady state.

3. Results and Discussion

3.1. Result of Existing & New Input deck

Even though the best way to check whether new input deck could describe more realistic coolant phenomena during LBLOCA is comparing results with LBLOCA experiment data. There were difficulties to get experiment data and perform comparative analysis. So instead, the authors compared coolant phenomena from new nodalizaion input deck and multi-dimensional model with LBLOCA analysis results from existing input deck. As shown in fig.3, PCT from new input deck decreased more speedily compared to that from existing input deck. The second PCT peak point from new input deck is lower than that from original input deck.

3.2. Effects of Cross flow option

MARS Code solves below Momentum Equation [10] to calculate coolant flow in hydro components

$$\rho\left(\frac{\partial\bar{v}}{\partial t}+\bar{v}\cdot\nabla\bar{v}\right)=-\nabla\mathrm{P}+\bar{\sigma}+\rho\bar{f} \qquad (1)$$

In existing input deck, momentum flux term ($\bar{v}\cdot\nabla\bar{v}$) is not applied to the cross flow junctions to calculate cross flow within each downcomer components. For more realistic safety analysis, the authors checked the effects of cross flow option in MARS for LBLOCA analysis. From existing and new input deck, the authors changed cross flow option to use momentum flux in both the to volume and the from volume. Then compared the results from input deck which applied cross flow option with results from original and new input deck which did not apply cross flow option.

In case of original input deck and new input deck, there was no critical change of PCT trend by using cross flow option as shown in Fig.4, Fig.5. But PCT trends of both cases show rapid drop at end of PCT drift curve and new input deck shows more rapid drop. The downcomer is divided into 6 at the original input deck and 12 at the new input deck. So, new input deck has double number of cross flow junctions applied the cross flow options. It can be inferred that cross flow option with new radial 12 divided nodalizaion has more effects on PCT trend.

3.3. Results of Multi-Dimensional Flow Model

In case of Multi-D downcomer model, PCT decreased more quickly than original input deck and PCT decreased more slowly than new input deck as shown in Fig.6. During high SIT flow period, PCT of Multi-D input deck show more similar trend with new input deck than original deck. This is because new input deck and Multi-D model share same dimensional values (volume, height) of downcomer. PCT drop is delayed by using Multi-D flow model.

4. Conclusions

An LBLOCA analysis for APR1400 with new downcomer input deck was conducted using KREM with MARS-KS 1.4 Version code. Analysis was processed under LBCOCA of 100% break size of cold leg case. The authors developed input deck with new downcomer nodalizaion and Multi-Dimensional downcomer model, then implemented LOCA analysis with new input decks and compared with existing analysis results. PCT from new input and multi-dimensional input deck shows similar PCT trend from original input deck. There occurred more rapid drop of PCT from new and multi-dimensional input deck than original input deck. We didn't implemented comparative analysis with experiment results. Therefore, we cannot assure that PCT from new and multi-dimensional input deck show more realistic results. However, PCT from new and multi-dimensional input deck are satisfied with PCT design limit [14]. It can be concluded that there occurs no acceptance criteria issue even though new and multi-dimensional input deck are applied to LBLOCA analysis. In future study, comparative analysis with experiment results will be implemented. Analysis of the effects of cross flow option in MARS for LBLOCA is conducted. Cross flow option has more effects on new radial 12

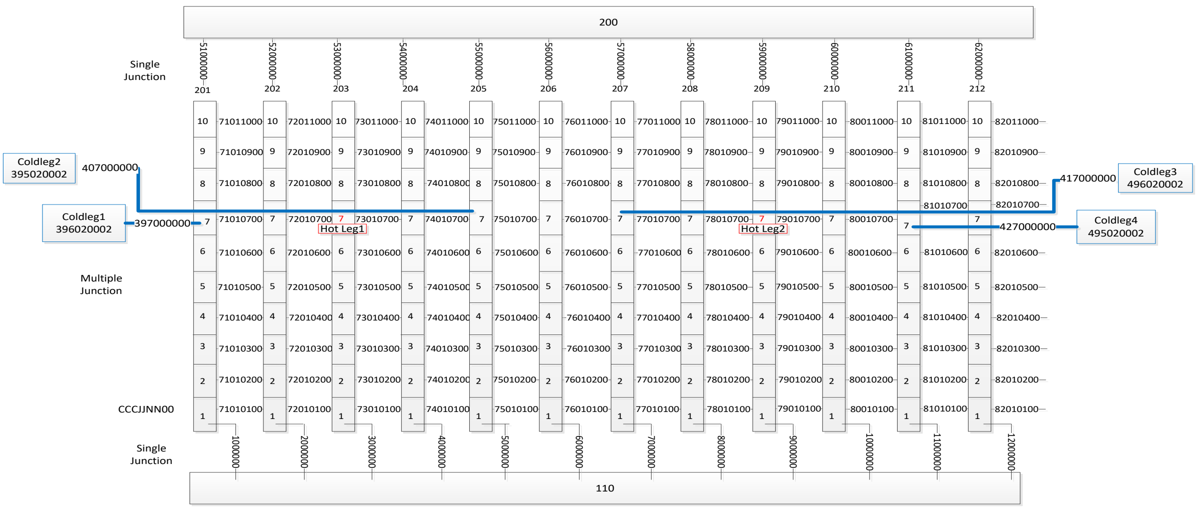

Fig.2. New Downcomer Nodalization of 12 Radial Components

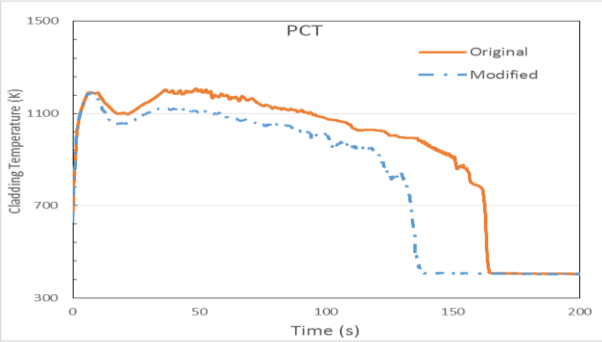

Fig.3. Results of Existing and New Input deck

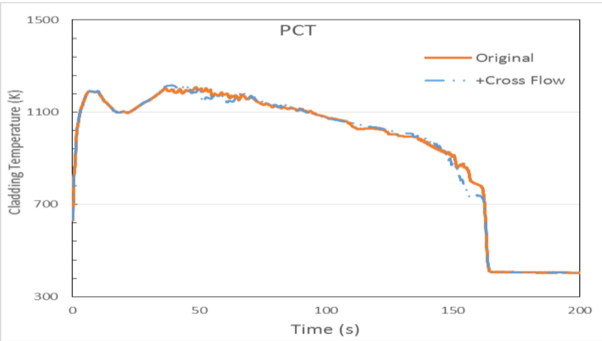

Fig.4. Results of Existing input deck and with cross flow option

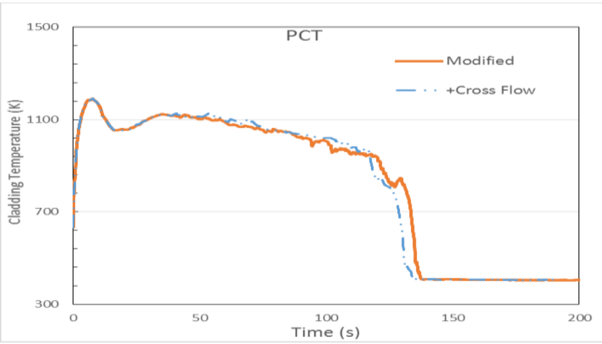

Fig.5. Results of New input deck and with cross flow option

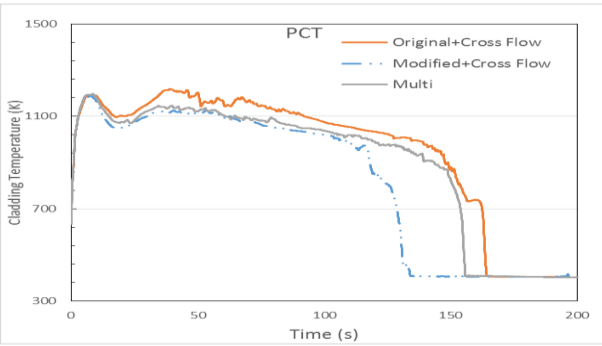

Fig.6. Results of Multi-D input deck

divided azimuthal sectors than 6 azimuthal sectors because 12 azimuthal sectors nodalizaion has double number of cross flow junctions which apply the cross flow options than that of 6 azimuthal sectors.

5. Acknowledgments

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