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Lessons learned from the 2nd Domestic Standard Problem Based on ATLAS Test

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1. Introduction

The 2nd Domestic Standard Problem exercise, DSP-02 with a 6-inch cold leg break LOCA test performed with ATLAS was successfully completed. Lessons learned from this DSP-02 exercise are summarized in this paper, focusing on the findings for code deficiencies and user guidelines.

2. Outline of the DSP-02

Since the first Domestic Standard Problem (DSP-01) exercise in 2010 [1], the 2nd DSP continued and was completed in 2011. In this DSP-02, it was suggested and executed that each participant was responsible for providing an additional analysis on at least one special topic to find out the code deficiencies. The 6-inch cold leg break SBLOCA data was used in view of a practical safety analysis. Twelve organizations participated in this program and the MARS-KS code was used. User effects and code deficiency were separately investigated. Quantitative comparison results rather than qualitative comparison will be highlighted in this paper.

3. Quantitative Comparison Results

3.1 Nodalization quantification (Q_A)

As the quality of transient code calculations is greatly dependent on how well the code model is initialized at a steady state condition, a “steady state” qualification based on measured data was performed, following the similar methodology as that proposed in the BEMUSE II program [2] in this DSP-02. The “steady state” qualification includes two different steps: one is related to the evaluation of the geometrical data and of the numerical values implemented in the nodalizations; the other is related to the quality of “steady state” calculation results. Nine parameters have been selected for nodalization qualification. A nodalization acceptability factor, Q_i of a given parameter can be defined as follows:

$$Q_{Ai} = \frac{E}{AE} \cdot W_i \,, \qquad (1)$$

where E, AE and W_i is the percent error, the acceptable error and weighting factor for a given parameter. Finally, the global acceptability factor, Q_A can be obtained by summing the whole single acceptability factors.

$$Q_A = \sum_i Q_{Ai} \,, \qquad (2)$$

The final nodalization quantification results are shown in Fig. 1. In the literature, Q_A<1.0 is required as an acceptable criterion. Around 50% of the calculations fulfilled the global acceptability in the present exercise. In the present quantification, two factors, AE and W_i, were determined by considering the relative importance of each inventory during a typical SBLOCA scenario. The effects of selected parameters on Q_{Ai} are also investigated. The secondary circuit volume (parameter 2) and maximum axial power distribution for the average rod (parameter 9) showed the greatest values in Q_{Ai} among the others. SNU showed the best result of 0.585, and SENTECH showed the greatest value of 2.14 among the participants.

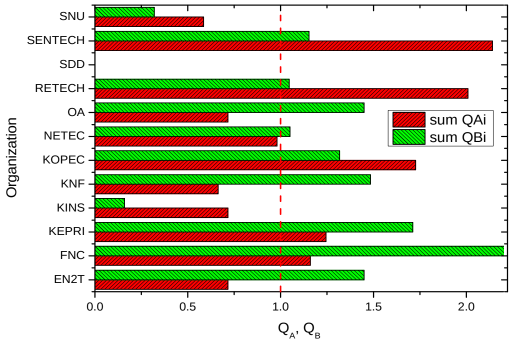

Fig.1 Nodalization and Steady state quantitifaction

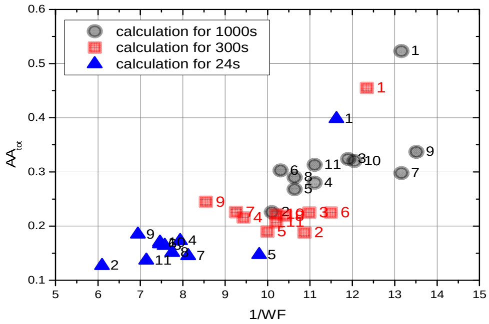

Fig. 2 Comparison of AA_{tot} for three time intervals

3.2 Steady state quantification (Q_B)

Steady state results can be quantified using a similar methodology used in the quantification of Q_A in the previous section. A total of 50 parameters were selected at a steady state condition, including the primary, secondary, and emergency core cooling systems. Taking into account the measurement uncertainties, different AEs from 0.25% to 30% were used depending on the parameters. As for the weighting factors, a value from 0.2 to 1.0 was used by considering the impact on the transient behavior. The final steady state quantification results are shown in Fig. 1. Two participants showed excellent steady state initialization results (Q_B<<1.0), but Q_B values by most other participants were either close to or a little higher than 1.0.

3.3 Transient quantification (AA_{tot})

The FFTBM method was used to quantifying the transient calculation accuracy [3]. Twenty two parameters were used and three time intervals were used based on PIRT results; 0-24s, 0-300s, and 0-1000 s. The final transient quantification results based on FFTBM is plotted in Fig 2.

3.4 Overall accuracy quantification (Q_{tot})

Overall quantification for the code prediction accuracy can be defined using the three quantification indices, Q_A, Q_B, and AA_{tot}. The first two indices and the last index are considered as factors to quantify the "user effects" and "code deficiency", respectively. Therefore, the three indices can be integrated by weighting factors to obtain a final figure of merit (FOM) for code accuracy quantification as follows:

$$Q_{tot} = W_A \tilde{Q}_A + W_B \tilde{Q}_B + W_C \tilde{A}\tilde{A}_{tot}, \qquad (3)$$

where W_i is the weighting factors. Q_A, Q_B, and AA_{tot} were normalized to have an equivalent influence on Q_{tot}. The final quantification result is shown in Fig. 3.

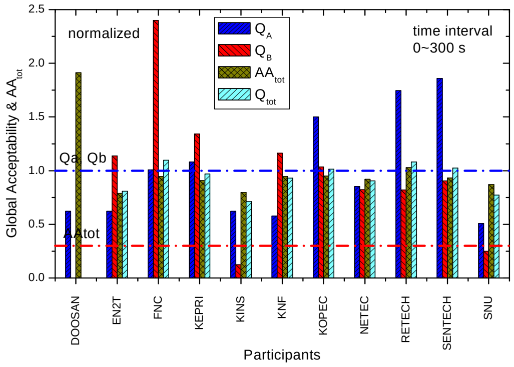

Fig. 3 Final accuracy quantification results for the second time interval (0~300 s)

4. Special Code Assessment Results

A brief summary of the outcomes from the special code assessment activities is described in this paper.

(1) Detailed modeling from the break nozzle to the break valve resulted in better agreement with the data. The discharge coefficient of Cd=1.0 is recommended.

(2) The loop seal clearing was greatly affected by a small model change. From a viewpoint of safety, where the loop seal clearing occurred and how many loop was cleared seem to be unimportant. However, the occurrence timing is very important.

(3) ECC bypass rate was estimated by injecting boron during the code calculation. Around a 30%-45% ECC bypass rate was obtained. But it needs experimental confirmation later.

(4) Over-predictions of the secondary pressure were due to a lack of heat loss modeling in the 2nd system.

(5) Momentum effects of ECC water were not a dominant factor affecting the transient calculations.

(6) 2D fluid mixing was not properly predicted by most calculations. A cross junction k-factor was not helpful to resolve insufficient mixing. The use of a turbulent mixing model of the MARS-3D code is recommended for better prediction.

(7) The ACC component needs to be improved to remove initial peak and minimize flow oscillation.

(8) Injection of cold water into the downcomer results in excessive condensation, causing an increase in the downcomer water level. It was found that utilizing the ECC mixer model mitigated the condensation. The condensation model needs improvement.

(9) RPV upper head temperature in most calculations was close to the hot leg temperature due to a reverse downcomer-upper head bypass flow. This caused early flashing and depression in the downcomer water level.

(10) The high core water level before the loop seal clearing was due to high reverse flow from steam generator to RPV the upper head. Appling the CCFL option to the RPV fuel assembly plate can mitigate this disagreement.

5. Conclusions

The 2nd ATLAS domestic standard problem was successfully completed. The overall figure of merit for code accuracy quantification was developed. Nodalization accuracy, steady state accuracy, and transient accuracy were integrated to produce a single quantification index. To determine code deficiencies of the MARS-KS code and to define a user guideline, special code assessment activities were carried out. The obtained outcomes will be used to improve the MARS-KS code model and to help code users perform a safety analysis.

Acknowledgements

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