Development of a System for a Linked Analysis of RELAP5 and MAAP4 and Its Application for an Analysis of LB-LOCA Case of APR1400

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1. Introduction

The RELAP5 (1995) and MAAP4 (1994) linked-analysis system was designed and illustrative calculation was performed. A large-break loss-of-coolant accident (LBLOCA) was taken as the reference case for the APR1400 (Advanced Power Reactor 1400MWe). For the early phase of this case, the calculational results of two codes have some deviations in water level depletion and hot assembly temperature. Ordinarily, it is considered that RELAP5 has enough accuracy in calculation of the thermal hydraulic behavior of typical PWR during design basis accidents. If the data set for the thermal hydraulic state of RELAP5 can be well-transferred to MAAP4 as an initial condition, the overall transients given by the linked analysis can get more reliability.
In this study, the linked analysis system of RELAP5 and MAAP4 doesn't mean the mechanically integrated code structure. The objective of this study is to formulate the linked analysis system of RELAP5 and MAAP4, which should precede construction of mechanically integrated analyzer. Thus, the main scope of this work covers development of the methodology for data linkage and decision of the transfer timing.

2. General Procedure for Linked Analysis

2.1 Main Procedure

The process of linkage may be described by the following steps. RELAP5 and MAAP4 are run from the initiating time for the same accident scenario. After some period of time, RELAP5 calculation is terminated when the peak cladding temperature approaches the value above the melting point of the cladding. RELAP5 generates major outputs that include all system variable data at user-defined time interval. On the other hand, MAAP4 continues calculation to the time of RPV failure. During the whole calculation time, MAAP4 generates restart files at regular intervals, each of which is composed of data set of all variables of MAAP4. The snapshot data of physical status of the system are recorded in the restart files and MAAP4 can be restarted from any point of time at which the restart file has been written.
The main idea of linkage is transfer of the data from RELAP5 to the restart file of MAAP4. After termination of RELAP5, the thermal hydraulic data to be transferred are assembled in a format adaptable to MAAP4. These data make up a snapshot of physical status and can be used as the initial condition for MAAP4. The overall procedure is shown in Figure 1.

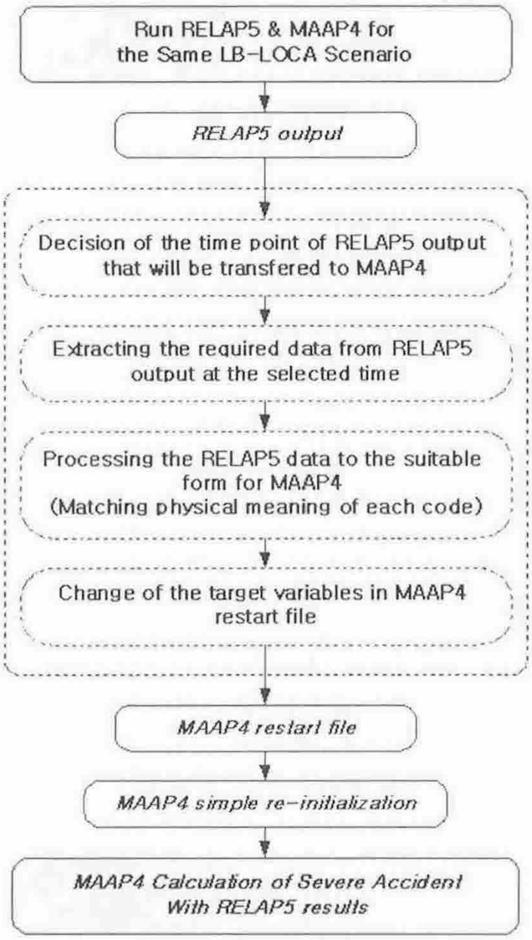

Figure1. Flowchart for RELAP5-MAAP4 linked analysis

2.2 Data Processing

The data of energy and mass of each water pool are calculated as follows.

- Coolant energy of each water pool

$$E_{f_M} = \sum_k [u_{f_k\_R}(1-\alpha_{k\_R})\rho_{f_k\_R}]V_{k\_R} \quad (1)$$

- Coolant mass of each water pool

$$M_{f_M} = \sum_k [(1-\alpha_{k\_R})\rho_{f_k\_R}]V_{k\_R} \quad (2)$$

The energy of fuel and cladding in core node is calculated from the heat structure temperature data of RELAP5. The values of volume-average temperature are used for calculation of the nodal energy of fuel and cladding.

$$Tm_{F_M} = \frac{\sum_i Vol_{i\_R} T_{i\_R}}{Vol_{fuel\_R}} = \frac{\sum_i A_{i\_R} T_{i\_R}}{A_{fuel\_R}} \quad (3)$$

$$Tm_{C_M} = \frac{\sum_j Vol_{j\_R} T_{j\_R}}{Vol_{cald\_R}} = \frac{\sum_j A_{j\_R} T_{j\_R}}{A_{clad\_R}} \quad (4)$$

- Calculation of core structure energy for fuel and cladding

$$u_{F_M} = \int_{T_{ref}}^{Tm_{F_M}} C_p(\tau) d\tau \quad (5)$$

$$u_{C_M} = \int_{T_{ref}}^{Tm_{C_M}} C_p(\tau) d\tau \quad (6)$$

3. Results

With analysis of the result of linked analysis, the process of data transfer from RELAP5 to MAAP4 can be considered as proper. At the linkage point, the system variables of MAAP4 show the same or nearly similar values with that of RELAP5. In addition, the last system behaviors of MAAP4 keep consistency with respect to the initial conditions given by RELAP5.

Then, a kind of sensitivity study is performed to investigate the effect of the linkage timing and to generalize the recommendable timing.

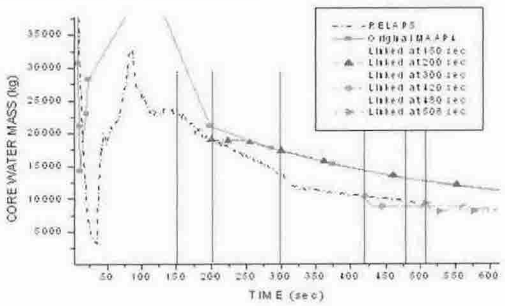

Figure 2 : Water Mass Inventory in Core

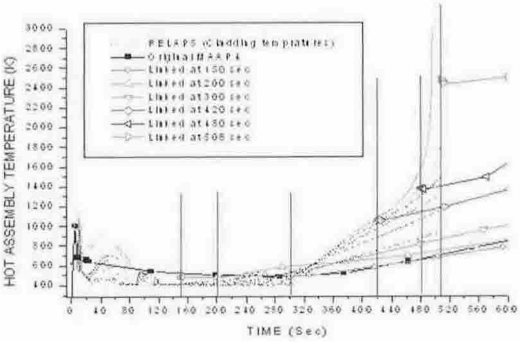

Figure 3 : Hot Assembly Temperature

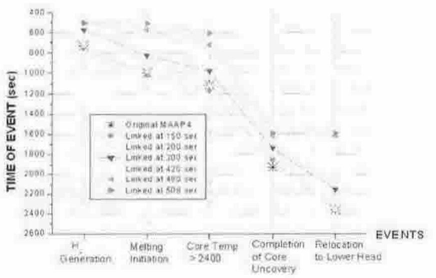

Figure 4 : The time spectrum of severe accident events for each linkage time

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The progression of severe accident gets to be faster if the data linkage time is at the latter. The results of ensuing severe accident calculation have a kind of consequential spectrum.

4. Conclusion

With this linked analysis, the weakness of MAAP4 can be rectified by utilizing the validated code, RELAP5, for the phase in which thermal hydraulic phenomena are dominant. According to various linkage times, each consequence makes a kind of spectrum for event time. This can give insight helpful to estimation of uncertainty in severe accident analysis performed by only MAAP4. And if this RELAP5-MAAP4 analysis system is more sophisticated by study on many accident scenarios and then this analysis system is validated, the result from this analysis system can be utilized in SAMG (Severe Accident Management Guide) or in PRA (Probablistic Risk Analysis).

Acknowledgement

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