Contribution ID: **21** Type: **ORAL**

Development of Integrated Severe Accident Analysis Code, SPECTRA for Sodium-cooled Fast Reactor

Thursday, April 21, 2022 1:52 PM (12 minutes)

Analytical evaluation of severe accidents (SAs) in sodium-cooled fast reactors (SFRs) becomes increasingly important. The progress of the SAs has been previously evaluated by transferring the analytical results between the multiple analysis codes with different roles. In this study, a new code named SPECTRA (Severe-accident PhEnomenological computational Code for TRansient Assessment) was developed for integrated analysis of the in- and ex-vessel phenomena. This paper provides the newly developed analytical models and the analysis of a loss of reactor level (LORL) event as one example of the SAs.
The SPECTRA code consists of the in- and ex-vessel modules which have a thermal hydraulics module as a base part. The in-vessel thermal hydraulics module computes complicated multi-dimensional behavior of liquid sodium and gas by using the multi-fluid model considering compressibility. Relocation of a molten core is computed by the dissipative particle dynamics method which has an advantage from the viewpoint of its wide applicability. A lumped mass model is employed for computation of the ex-vessel multi-component gas including aerosols. The fully implicit scheme is applied to the both thermal hydraulics modules in order to enable computation with a large time step width. The analytical models for sodium fire, sodium-concrete interaction, and debris-concrete interaction are integrated into the ex-vessel thermal hydraulics module. The in- and ex-vessel modules are coupled by exchanging the amount of leaked sodium and debris at every time step.
The LORL event is considered as one example of the SA scenarios. A sodium coolant leaks from a damaged pipe in a primary cooling loop and causes sodium fire. In case a molten core and sodium leak from a damaged lower head of a reactor vessel (RV), sodium-concrete interaction and debris-concrete interaction occur in the compartment under the RV. This event progress was computed in a simplified domain including the RV, the primary cooling loop, and the ex-vessel multi cells. The analytical result showed lowering of the liquid level due to sodium leak, boiling of the coolant around the core region, and molten core relocation in the in-vessel region. As for the ex-vessel region, the atmosphere temperature and pressure increased due to sodium fire, sodium-concrete interaction, and debris-concrete interaction. The basic capability to reproduce SA scenarios was demonstrated through this analysis.

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Session Classification: 6.4 Simulation Tools for Safety Analysis

Track Classification: Track 6. Modelling, Simulations, and Digitilization