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Development of Multi-level Simulation System for Core Thermal-hydraulics Coupled with Plant Dynamics Analysis - Prediction of Transient Temperature Distribution in a Subassembly under Inter-subassembly Heat Transfer Effect -

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In the design study of sodium-cooled fast reactor, various activities from sensitivity analysis on whole plant dynamics using simple model to detailed analysis on local phenomena of interest are being performed. In conventional way, the analyses on whole plant dynamics and local phenomena are performed individually and the mutual interaction between them are considered through the settings of boundary conditions for each individual analysis. The final result through the individual analyses may contain excessive conservativeness. Therefore, JAEA has developed the multi-level simulation system in which detailed analysis codes for local phenomena of interest are coupled with a plant dynamics analysis code in order to obtain evaluation results considering the mutual interaction with reasonable conservativeness by updating the boundary conditions successively in coupling process.

In this study, focusing on core thermal-hydraulics, the coupling analysis method using a plant dynamics analysis code named Super-COPD and a subchannel analysis code named ASFRE to evaluate temperature distribution in a subassembly during the transient from forced circulation to natural circulation has been developed as a part of multi-level simulation system. During the transient, the consideration of thermal interaction between whole core and in-subassembly is important because flow re-distribution is caused and temperature distribution in a subassembly is affected by that in adjacent subassembly due to inter-subassembly heat transfer effect in the core. In the coupled analysis using the sequential two-way method, Super-COPD runs first to update flow rate, inlet temperature and heat flux on the boundary wall of the subassembly for ASFRE calculation. Subsequently, ASFRE calculates thermal-hydraulics and pressure drop in the subassembly and turns to Super-COPD calculation in the next time step.

After confirmation of basic functions of the coupling method in a simple geometry, the numerical analyses on the test in EBR-II (SHRT-45R) were performed with two models of the specific subassembly of XX09 with thermo-couples; one was the subchannel model of ASFRE in the coupling method and another one was included in the core model of Super-COPD. Through the comparison of the temperature distributions among the results using only Super-COPD and the coupling method, and the measurement in XX09, it was shown that the coupled analysis could predict transient temperature distribution in a subassembly under inter-subassembly heat transfer effect and it was indicated that the multi-level simulation by changing the level of detail of the analysis model between the method with the plant dynamics code and the coupling method could be performed.

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