Development of a Base Model for a Performance Analysis Code of a SFR

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1. Introduction

We have been developing a sodium-cooled fast reactor (SFR) concept. The SFR has lots of different features compared to conventional pressurized water reactors (PWR). It uses sodium as a primary coolant and is a pool-type reactor to enhance the safety of a SFR. In addition, it adopts a passive concept for a safety system such as a passive decay removal system. Therefore, a new performance analysis code is required to complete and verify the design concepts. [1]

In this study, we developed a base model for the performance analysis code of a SFR. To develop the performance analysis, we adopted a modular modeling system (MMS) code as a base engine for the performance analysis code, which was developed by nHance Technology in USA. [2] These days, we have developed the base model of the primary loop model and the reactor model for a SFR.

The performance analysis code will be implemented after developing the intermediate loop and energy conversion system such as the steam generator and turbine. Also, the code will be used to develop a control and monitoring system. Finally, it will be an analysis engine for a simulator engine of a SFR.

2. Features of MMS code

The MMS code has lots of advantageous features when developing a performance analysis code for a SFR. It has a convenient user interface based on the Windows operating system and a capability to minimize the user input by an auto-parameterization. It has many basic component modules used in a plant such as pipe, pump, heat exchanger, turbine and control systems including electrical systems. This can enable a modular approach in developing a new analysis code and can analyze a plant in a real time due to the simplified modules. In addition, it has some experiences to develop a plant analyzer or a simulator for various industrial plants. [2][3] Therefore we adopted the MMS code for a base engine to develop a performance analysis for a SFR. Figure 1 shows a general procedure using the MMS code for developing a performance analysis code.

However, it doesn¡t have sodium property necessarily required for developing a sodium loop of a SFR because the MMS code has been developed for the conventional plants using water or various gaseous. This means that an additional user library or program is needed to apply the MMS code to the performance analysis code of a SFR. So, we developed a user program of the sodium properties for a sodium coolant loop and attached the program to the MMS code as external routines through modifying the user macro function in the MMS code. [2] The shadowed area in Fig. 1 shows the modified features to attach the sodium properties to the MMS code.

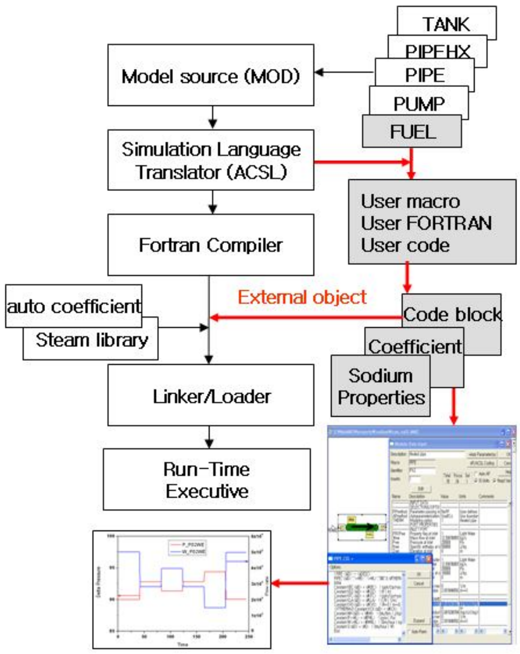

Fig.1 procedures for developing a MMS code

3. Analysis for PHTS Loop of the SFR

This chapter describes the primary heat transfer system (PHTS) loop model based on the base modules in the MMS code and the analysis results for the steady state of the PHTS loop of a SFR

3.1 PHTS Loop Model

Following the development procedures of the MMS code, we developed the base models for the PHTS and core of a SFR. The PHTS loop consists of 2 pumps, 4 IHXs, core and sodium pool. [4] The MMS code has some basic component modules such as pipe, pump and heat exchanger, which can analyze a coolant loop. However, the module should be changed to be adequate for the PHTS of a SFR including the sodium properties. So, we developed an IHX model and pump model of the PHTS loop of a SFR, based on the MMS basic component modules. Figure 2 shows the developed

PHTS model using the MMS code. As shown in Fig. 2, the PHTS loop model was composed of the hot and cold pool models divided into 2 nodes, respectively, 2 IHX models and 2 pump models. Since the whole model including the secondary systems was not developed, the boundary modules were used to assign the operating conditions of the secondary systems. The 4 IHX was collapsed into 2 IHX models to simplify the PHTS model. It was possible because the 4 IHXs were identical.

Also, the core model was developed. The basic core module in the MMS code can represent a conventional PWR core including the reactivity model, point kinetics equation and other core parameters like the fraction of a decay heat generation. The core of a SFR has some different characteristics compared to those of a conventional PWR core. The core of a SFR uses metal fuel assemblies and has some different reactivity coefficients in the reactivity model compared with those of PWR cores. The reactivity coefficient of poison materials like xenon, iodine and samarium is nearly zero because the energy of the neutron flux is very high (fast). The reactivity coefficient of the moderator temperature should be changed to the coefficient of the change of the sodium density as well as the fraction of the decay heat generation rate in the core is high due to the change of characteristics of the neutron flux. So, we changed the internal basic coefficients in the reactivity model of the basic core module of the MMS code in order to represent the characteristics of the SFR. Then, we developed a base model for a performance analysis code using the developed PHTS model.

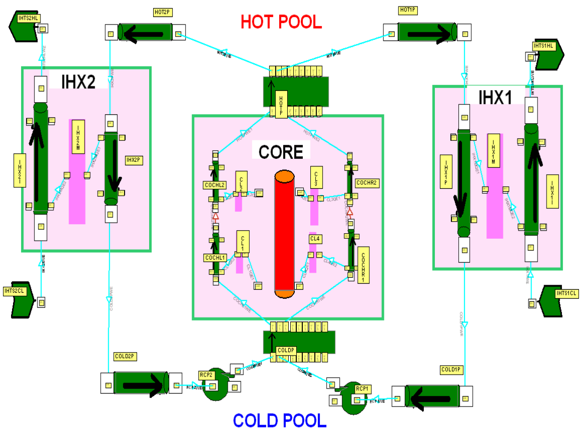

Fig. 2 MMS models for PHTS loop

3.2 Analysis Results

Using the developed base model for the PHTS loop of a SFR, we analyzed the initial state of the PHTS loop. Figure 3 shows the analysis results of the base model for the PHTS model. The core power and the flow rate of the hot pool are shown in the Fig. 3. The coefficients related to the core power and the flow rates need to be fine-tuned. This can be easily overcome by tuning the coefficients in the reactivity model and the pipe modules mentioned in section 3.1.

3. Conclusions

We developed a base model for the performance analysis code of the PHTS loop of a SFR, based on the MMS code. It could analyze the initial state of the PHTS loop. We will develop the secondary system models including the turbine and intermediate heat transfer system. After integrating two models, a performance analysis code will be developed for a SFR.

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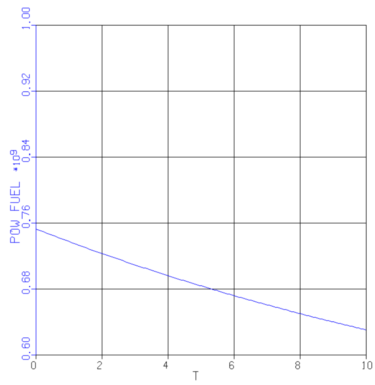
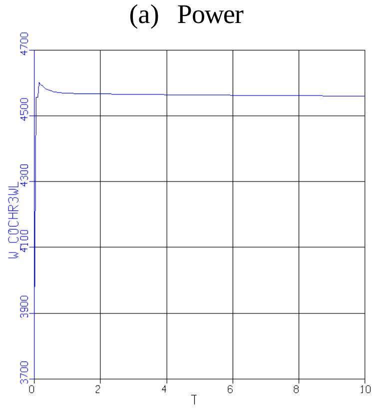


(a) Power



(b) Flow rate

Fig. 3 Analysis results of the PHTS loop model