Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-26, 2013

Structure of Fuel Performance Audit Code for SFR Metal Fuel

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1. Introduction

A Sodium-Cooled Fast Reactor (SFR) is a promising option to solve the spent fuel problems, but, there are still much technical issues to commercialize a SFR. One of issues is a development of advanced fuel which can solve the safety and the economic issues at the same time.

Since a nuclear fuel is the first barrier to protect radioactive isotope release, the fuel's integrity must be secured. In Korea Institute of Nuclear Safety (KINS), the new project has been started to develop the regulatory technology for SFR system including a fuel area. To evaluate the fuel integrity and safety during an irradiation, the fuel performance code must be used for audit calculation.

To develop the new code system, the code structure design and its requirements need to be studied. Various performance models and code systems are reviewed and their characteristics are analyzed in this paper.

Based on this study, the fundamental performance models are deduced and basic code requirements and structure are established.

2. Code structure

In the nuclear industry or research, a fuel performance code is used in two respects. The design and evaluation of nuclear fuel is the major concern, and then the support of fuel information for the other code systems such as thermal hydraulics and neutronics is another important role of fuel performance code. Therefore, in a structure design of fuel performance code, the above-mentioned two usages must be considered. To approach the first concern of fuel performance code, proper performance models and iteration loops must be developed to simulate the fuel behavior and their interdependency.

2.1 Fundamental performance models

The fuel performance code must have a prediction capability of a nuclear fuel rod during reactor operation conditions and this requirement means that the code should have proper and sufficient performance models which applicable to evaluate in-reactor behaviors such as a dimensional change, material property degradation, temperature, and stress-strain variation.

In case of LWR fuel performance modeling, various and advanced models have been proposed and validated based on sufficient in-reactor test results. However, due to the lack of experience of SFR operation, the current understanding of SFR fuel behavior is limited.

In spite of this limitation, our continuous efforts make us to find out several phenomena which will affect to the in-reactor behavior of SFR fuel. For example, the constituent redistribution is the key phenomenon which can be occurred in a mixed metal fuel system. In case of U-Zr fuel, re-distribution of Zr changes the thermal and mechanical property of fuel slug [1]. The Cladding wastage due to Fuel Clad Chemical Interaction(FCCI) and the anisotropic deformation of fuel slug are important phenomena of SFR fuel as well[2].

In addition to SFR fuel specific phenomena, a general fuel performance model such as temperature evaluation, stress-strain analysis, fission gas release and swelling are must be implemented in a SFR fuel performance code system[3].

Table 1. Fundamental models and their functions

Model	Function
Fission Gas release/Swelling	Rod internal pressure (hydrostatic pressure of fuel internal)
Constituent redistribution	Zr(for U-Zr) redistribution and its effect on material property change
Temperature calculation	1D or higher heat conduction including thermal hydraulic model of sodium coolant
FCCI	Cladding wastage or coating layer effect
FCMI	Mechanical interaction between fuel slug and cladding (elastic, thermal, plastic, creep, growth). 1D or higher order finite element model

Especially, Fuel Clad Mechanical Interaction(FCMI) must be evaluated because of the large deformation of SFR fuel slug. In case of LWR fuel performance modeling, the Finite Element(FE) modeling technique is under development to solve the complex interaction between the fuel and the cladding. However, FE model causes long solving time and some non-linear material behavior model must be newly developed [4]. Therefore, the simplified 1D model for FCMI analysis is presumed to be valuable and its modeling will be considered.

Based on the method discussed above, the fundamental performance models which must be implemented in the code system and their functions are summarized in Table 1.

2.2 Basic code requirements and structure

The fuel performance code must have interface with other code systems to support integral evaluation of reactor environments. Especially, the code for transient conditions has close relation with thermal-hydraulic and/or neutronic code systems.

In general, the dominant phenomena and their mechanism of fuel rod during steady-state and transient conditions are different, and thus to describe them requires different approaches. Therefore, in case of LWR fuel, there are two independent code (steady-state and transient/ accident) systems but some special modules are designed to share the results in the steady-state [5, 6].

At the current stage, we will focus on the development of the steady-state code system because transient fuel behavior requires sufficient understanding of steady-state behaviors. However, the interface between two fuel performance codes and the other codes must be considered before the development of fuel code design.

Figure 1 shows the overall structure of the new code system. For ~~the~~ extension and maintenance of the code system, each performance model will be classified in some modules. As mentioned in the previous chapter, save(?) and intermediate input/output decks will be designed to link with the other code systems.

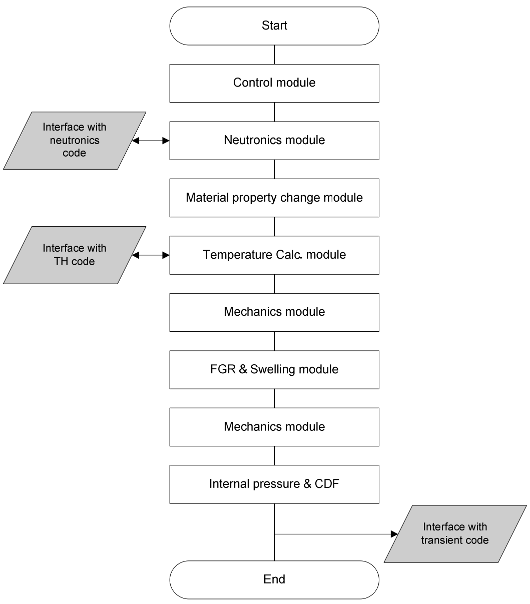

Fig. 1. Overall structure of SFR fuel performance code

3. Conclusions

The project for the new fuel performance code development has started to evaluate the integrity and safety of SFR fuel in a regulation aspects.

The fundamental performance models, which are indispensable for evaluation of in-reactor behavior of SFR fuel's safety and integrity, were selected. Also the basic code structure and the iteration loops were decided to simulate the interdependency between performance models and link with the other code systems for neutronics and thermal hydraulics.

Based on the current approach, the full-scale study will be continued to develop the SFR fuel's performance code system.

4. Acknowledgement

This work has been carried out under the Nuclear R&D Program support by the Ministry of Education, Science and Technology of the Republic of Korea with Korea Institute of Nuclear Safety collaboration.

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