Design of Integrated Analysis Tool for Degradation Evaluation of Spent Nuclear Fuel in Dry Storage System

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1. Introduction

The spent nuclear fuel must be safely managed until appropriately disposed. At present, the spent fuel used in the pressurized water reactor in Korea is safely stored in wet storage pool of the reactor. The dry storage of spent nuclear fuel is a practical alternative until it is appropriately disposed. During storage, spent nuclear fuel undergo material property changes, so called degradation, as a function of time. The degradation of the spent fuel during the dry storage depends on the temperature. Thus the detailed temperature profile is suggested as the first item on the gap analysis report [1]. The UNF-ST&DARDS in the USA is being developed to streamline computational analysis capabilities for characterizing input for the overall waste management system [2]. This study is focused on a platform design for integrated evaluation of temperature change and degradation characteristics of the spent nuclear fuel.

2. Design of Integrated Analysis

In order to evaluate the integrity of the spent fuel in dry storage cask, the temperature distribution of the fuel and the degradation of the cladding should be evaluated accordingly. The degradation of the cladding depends on the temperature, and the temperature changed depending on the fuel geometry. The creep, which is one of the key degradation mechanism of the cladding, can cause a diameter change of the fuel cladding and the rod internal pressure. Therefore, an integrated analysis platform was designed to evaluate the two closely related phenomena.

2.1 Thermal hydraulics

Based on the COBRA-SFS [3] developed for thermal hydraulics analysis of dry storage system, an integrated analysis platform has been modified. The flow chart and the modified structures of COBRA-SFS are illustrated in the Fig. 1.

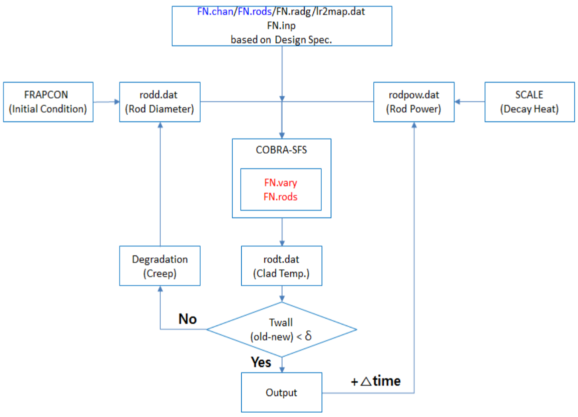

Fig. 1. The flow chart of thermal hydraulics for integrated analysis.

In COBRA-SFS, the inputs related to the fuel geometry are prepared for the initial design of the fresh fuel. The spent fuel geometries for initial conditions of dry storage are produced by the fuel performance code, and these results are read during COBRA-SFS calculation process. At a certain time step, the temperature and geometry changes are iterated until the convergence condition is reached.

2.2 Degradation

In the current version, the integrated platform allowed to evaluate the degradation of creep and DHC (Delayed hydride cracking). For the creep evaluation, the modified EPRI model was modularized. The threshold stress intensity factor, KIH is calculated by Shi & Puls Model and the applied stress intensity factor, KI is calculated by ductile fracture handbook of EPRI [4].

3. Integrated Analysis

The initial conditions of spent fuel at the dry storage beginning are produced with fuel performance code, such as FRAPCON, to reflect power history during irradiation. The decay heat, which is the heat source of spent fuel, is designed to be calculated from a specific code such as SCALE. Variables delivered from FRAPCON are cladding diameter, rod internal pressure, nodal burnup, hydrogen content, total/plastic strain, stress and fast fluence. The calculation flow diagram of the integrated analysis is shown in Fig. 2 and the calculation process can be summarized as follows.

(1) Calculation of initial condition with FRAPCON.
(2) Calculation of decay heat with SCALE.
(3) Generation of input file for storage cask, boundary conditions, calculation conditions.
(4) Generation of geometry input files for COBRA-SFS based on design specification.
(5) Run the integral analysis tool
(6) Update changed geometry
(7) Calculation of temperature distribution.
(8) Calculation of geometry change and rod internal pressure by degradation.
(9) Iteration from (6) to (8)
(10) Estimation of DHC
(11) Go to next time step

The cumulative strain rate obtained from the preliminary calculation is shown in Fig. 3.

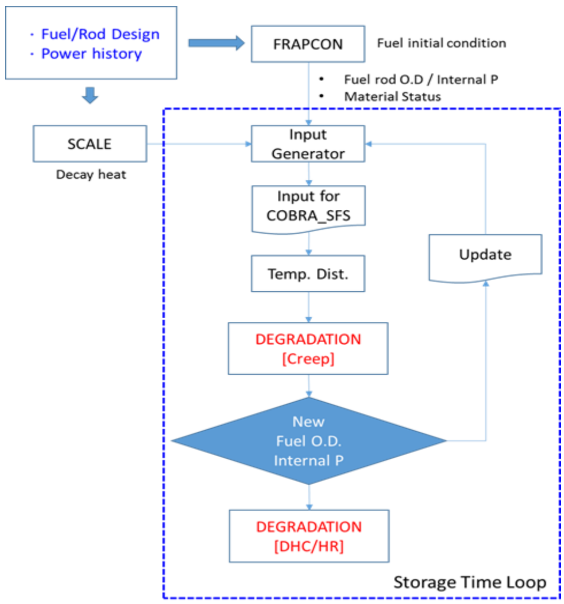

Fig. 2. Flow diagram of the integrated platform.

4. Conclusions

The integrated analysis tool for evaluation of spent fuel cladding integrity during dry storage is designed. This integrated analysis platform has been developed to evaluate the detailed fuel temperature and fuel degradation, simultaneously. The input structure of COBRA-SFS has been modified in order to conveniently apply the geometry change of spent fuel due to creep deformation. The developed degradation models within the integrated analysis tool have been verified.

As a future work, the module to calculate the decay heat for each rod and the database system to manage the fuel information and the analysis results should be linked or integrated.

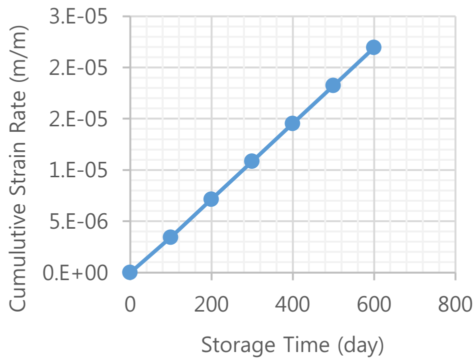

Fig. 3. Cumulative strain rate of integrated analysis tool.

ACKNOWLEDGEMENT

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