Development of Spent Fuel Cladding Degradation Model in Integrated Platform

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1. Introduction

During dry storage, the spent fuel claddings could degrade through degradation mechanisms such as creep, hydride reorientation, and delayed hydride cracking (DHC). Thermal analysis is crucial for a reliable degradation analysis, because the cladding temperature is a major factor of these degradation mechanisms. In this regards, the new analysis platform has been developed to evaluate the integrity of domestic spent fuel during dry storage. For the analysis, cladding degradation models such as creep and DHC were developed and implemented to this platform. Each model are developed based on well-developed existing model and updated based on our own experimental data. This data was mainly produced under QA (quality assurance) program. In this paper, the developed creep and DHC models are introduced.

2. Integrated Platform

The schematic diagram of integrated platform for spent fuel cladding integrity evaluation during dry storage is described in Fig. 1. According to fuel/rod design and power history, decay heatis calculated by decay code such a SCALE code and fuel initial condition before storage is calculated by FRAPCON code. FRAPCON gives information such as fuel rod outer diameter, rod internal pressure and material status (hydrogen content, oxide thickness, etc). Input for COBRA-SFS is generated from this information and used for temperature distribution analysis. When the cladding temperature distribution is calculated, updated fuel outer diameter and rod internal pressure are calculated by developed creep model and re-used for thermal analysis of next time-step. In addition, at each time-step, DHC occurrence is judged using calculated temperature, geometry and rod internal pressure. And these procedures are iterated as storage time goes by.

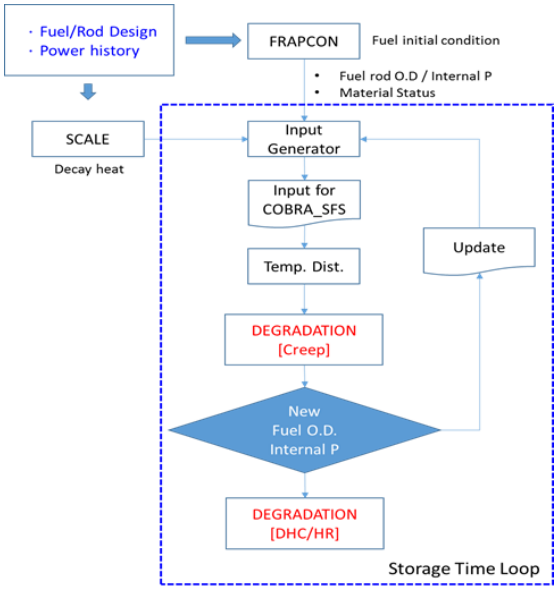

Fig. 1. Schematic diagram of the integrated platform for spent fuel cladding integrity evaluation [1].

More details of each degradation model, marked in red on Fig. 1, are described in the following section.

3. Cladding degradation model

3.1 Creep

To evaluate the behaviors of post-irradiation creep for PWR spent fuel cladding, the EPRI model which is modified for annealing and hydrogen effect based on EDF-CEA model-3 was used [2]. This model can apply to the stress and temperature range of interest in dry storage and easily modify reflecting the effect of each parameter using our experimental data. So, we improved with a model constant change based on our data produced using temperature, stress, and hydrogen content as a variable (Fig. 2). In addition,

the irradiation hardening effect will be reflected as soon as hot-cell test results.

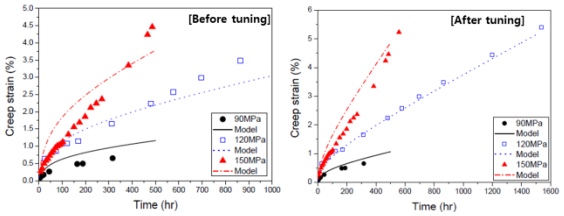

Fig. 2. Improvement with a model constant change based on unirradiated Zircaloy-4 creep experimental data.

3.2 Delayed hydride cracking (DHC)

The overall flow of developed DHC assessment model is shown in Fig. 3. For the assessment, the K_{IH} (threshold stress intensity factor) of Zircaloy-4 fuel cladding is key parameter and many tests and analysis had been performed to evaluate that. Among the prediction models, the Shi & Puls model [3] correspond with the behavior of existing experimental results. So, Shi & Puls model with modified relevant parameter values was used for K_{IH} prediction and would be improved by our experimental data under QA program.

A comparison with K_I (applied stress intensity factor) and K_{IH} was applied to determine whether the crack on the cladding grows. In the case where the K_I is larger than the K_{IH}, the initial crack grows at the rates calculated in the crack growth module. More details of DHC model was described in another papers [4,5].

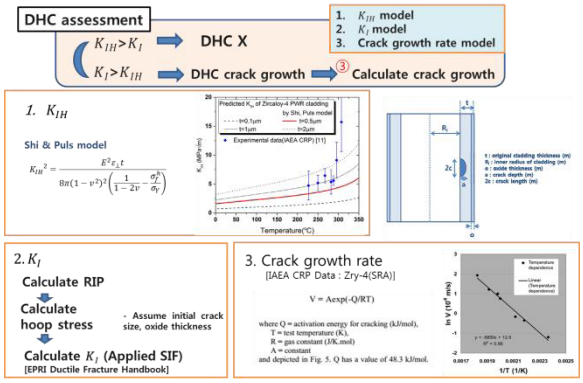

Fig. 3. Methodology of DHC assessment of spent fuel cladding. [3]

4. Conclusion

The platform integrated thermal analysis and cladding degradation model was developed to evaluate the integrity of domestic low burnup PWR spent fuel. For the analysis, cladding degradation models (creep and DHC) were developed and adopted to this platform. Each model are developed based on well-developed existing model and updated based on our own experimental data.

ACKNOWLEGMENT

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