Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

A Study of Integrity Evaluation System for Spent Fuel and Selection of the Representative Spent Fuel

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1. Introduction

Occurrence of spent fuel (SF) by nuclear power generation is inevitable, and SF management and disposal problem must be solved for sustainable development. SF storage capacity of each domestic nuclear power plant will reach a saturated state in the near future. Although there are several methods of SF disposal, interim storage is suggested as the most realistic and promising alternative.

SF integrity evaluation is a regulatory requirement that is described in 10 CFR 71(transportation) and 10 CFR 72(storage) of the U.S. NRC licensing requirement. NRC regulation states that retrievability of SF after storage should be ensured and SF integrity under the normal condition must be guaranteed during transportation and handling process that is entailed before/during/after the interim storage. And SF integrity evaluation under the hypothetical accident condition is a core technology element for an assessment of critical, shielding, and containment [1].

In this paper, SF integrity evaluation system which is suitable for domestic situation is suggested, and necessity of representative SF selection and its method is described.

2. SF Integrity Evaluation System

Domestic regulatory requirements and evaluation system for the SF integrity evaluation has not been fully established. Thus, it is needed to analyze the overseas regulatory requirements and evaluation system, and represent own SF integrity evaluation system.

2.1 Overseas SF Integrity Evaluation System

Overseas SF storage/transport system operators and national institutions have established their own integrity evaluation system, and use it for SF integrity evaluation and cask design. 10 CFR 71 and 72, the licensing requirements of the US are the basis for performing this evaluation. 10 CFR 71 states that structural integrity of SF should be maintained under a normal condition during transport, and 10 CFR 72 states that SF must remain retrievability after storage [1].

There is a representative overseas SF integrity evaluation system developed by EPRI. Here, the structural response characteristic evaluations are performed to select the weakest SF by considering that various types of SF in the cask are loaded. And interactive response characteristics are identified through the detailed modeling of the selected representative SF-cask system, and fuel cladding integrity is finally evaluated [2].

2.2 Establishment of the Domestic SF Integrity Evaluation System

According to nuclear fuel cycle shown in Fig. 1, nuclear fuel undergoes various environmental changes. At this moment, physical/material characteristic changes are occurred on nuclear fuel in each process. Especially, in the process of transportation/handling/storage of SF, mechanical response should be predicted by reflecting these histories.

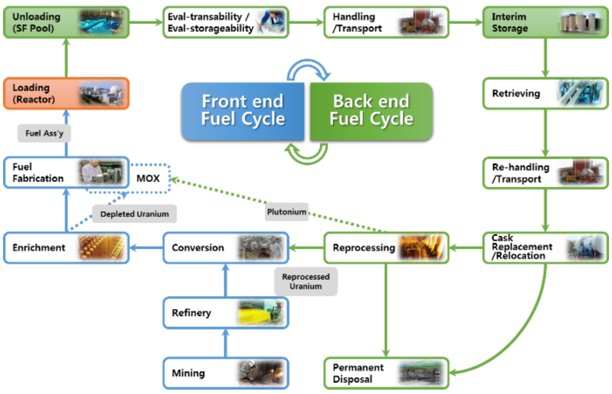


Fig. 1. Fuel Cycle

Referring the overseas system, overall SF integrity evaluation system is proposed for domestic SFs as shown in Fig. 2. First of all, the basic design/fabrication information about SF and status/characteristic analysis of SF based on incore performance data SF are needed. Because many kinds of SFs have been stored in spent fuel pool since the start of the nuclear power generation in Korea, it is needed the process to define the limiting SF among those as a representative. And then, response is determined through computer modeling and global analysis about SF-Cask system. As a result of this process, K_I(fracture toughness), ε_f(strain) and SED(strain energy density) are obtained by calculating the stress which is occurred on the cladding by applying load. Then, failure evaluation is performed by comparison between above results and K_{Ic}(critical fracture toughness), ε_f(failure strain) and CSED(critical strain energy density) which are defined by statistical processing & probabilistic model of analytic & experimental SF data.

At this time, integrity evaluation can be carried out restrictively to the side drop that is regarded as the worst drop mode. It is required consultation with licensing institutes.

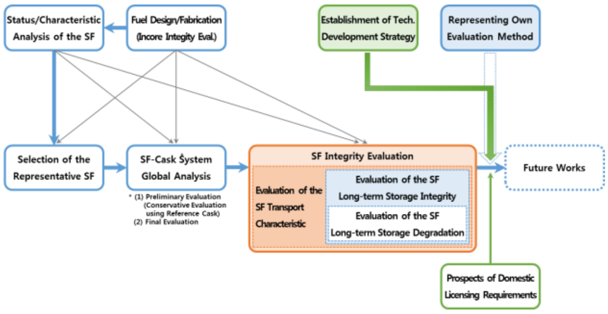


Fig. 2. SF Integrity Evaluation System

Considering domestic circumstances, mid-entry strategy should be acquired in order to construct own SF integrity evaluation methodology. In other words, EPRI methodology which is optimized to domestic infra-structure can be applied as overall integrity evaluation system, and then validation & verification of effectiveness need to be performed by domestic SF data. As a result, time and cost needed in own technology development can be saved and overcome a technological gap efficiently.

2.3 Necessity of representative SF selection and its method

In previously proposed domestic SF integrity evaluation system, the most urgent part is a selection of representative SF. Currently, there are many types of SF in Korea. Performing a separate integrity evaluation of all existing SF is not efficient in terms of time and cost, and it is impossible considering urgency of technology development. Therefore, it is needed to define the worst condition SF as a representative, and then to be carried out integrity evaluation.

EPRI used following methods in order to select representative SF; (1) structural, physical, and material characteristic analysis of candidate SF, (2) SF assembly computer modeling, (3) parametric analysis by drop mode. Fig. 3 shows drop orientation of dry storage cask and Fig. 4 shows axial and horizontal impact model for parametric analysis [2].

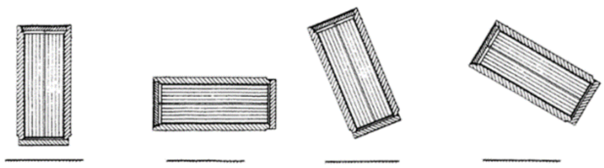
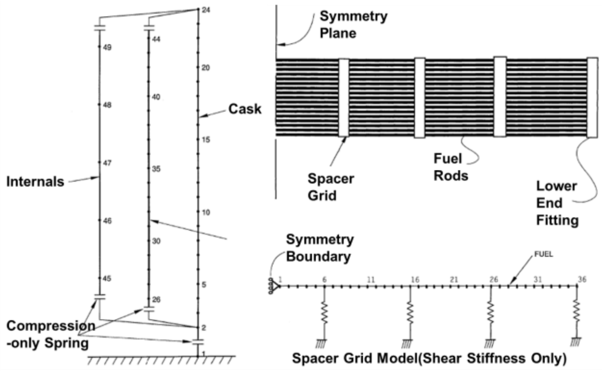


Fig. 3. Dry Storage Cask Drop Orientation



(a) Axial (b) Horizontal

Fig. 4 Impact Model for Parametric Analysis

3. Conclusions

The ultimate goal of the SF integrity evaluation is to evaluate a safety margin in case of transportation/ handling/storage of SFs. It means that retrievability of SF after storage should be assured and SF integrity must be guaranteed at normal condition in the process of transportation/handling accompanied before/during/after interim storage.

In Korea, SF integrity evaluation system is not established up to date. Especially, representative SF selection technology that is essential to SF integrity evaluation has not been fulfilled. To overcome this situation effectively, the methodology and technology of an overseas agency need to be benchmarked. In this paper, an overseas SF integrity evaluation system is analyzed, and an evaluation system suitable for domestic situation is suggested. Also, necessity of representative SF selection and its method is described.

REFERENCES

[1] NRC, 10CFR71/72, Packaging and Transportation of Radioactive Material/ Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor, 2013

[2] EPRI, Fuel-Assembly Behavior Under Dynamic Impact Loads Due to Dry-Storage Cask Mishandling, 1991