Study on Evaluation Scheme of Spent Fuel Structural Integrity Coupling of Cask System

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1. Introduction

Around ten thousand tons and various kinds of spent fuels (SF) as shown in Fig.1[1] have stored in the domestic plants, and the year of storage capability limit is coming soon so the issue of SF disposal has come to hot potato. Thus, it is necessary to develop urgently the common and basic technologies related to SF interim storage. Among these studies, the SF integrity evaluation is a sort of key technology for the related dry interim storage.

Although a series of research and development has been performed, regarding the SF structural integrity coupling with a cask system of SF transportation and/or storage, no activities has not been taken including even regulation field.

Thus, in this paper, what sorts of evaluations from the view point of SF structural integrity are necessary and bases, why this information is must-do item not may-do one, and how each system that is cask, fuel assembly and fuel rods and including the damaged fuels can be organically set to efficiently develop them, are to be studied by reviewing the existing technical practice. And also some executable scheme is to be suggested.

2. Structure Deformation Evaluation Practice

Through gathering and analyzing technical information from abroad leading institutes such as IAEA, EPRI, NRC, US National Labs etc., SF integrity evaluation methodologies are grasped and briefly introduced to suggest some indigenous system for its understanding.

In the evaluation methodology of ERPI, the first process is to choose the representative SF since a cask generally can accommodate several kinds of PWR SFs and even BWR ones. During this process, parametric analyses are used to determine one limiting SF to save time and cost for the detailed evaluation. The parametric analyses also demonstrated the importance of coupling of SF and the cask/cask internals under the normal and hypothetical events. In this evaluation, the defining of SF initial condition such as material prosperities, structural deformation conditions including SF and fuel rod bows and SF tilt, their failure/damage etc. is also reflected. After selecting the limiting SF, next step is to perform the detailed analysis coupling SF with cask. These analyses computed safe cask handling drop height limits, which value is over the normal regulation value 1 foot. Overall evaluation body is depicted in Fig. 2.

Another exhausted work was performed by Sandia Nat'l Lab. Since cladding failure behavior is a function of cask and assembly designs, transport-loading conditions, fuel irradiation histories and other initial conditions, and making cladding failures highly statistical events, the developed methodology characterized the dynamic environment of the cask and its contents (SF) and deterministically models the peak stresses that are induced in spent-fuel cladding by the mechanical and thermal dynamic environments. The peak stresses were evaluated in relation to probabilistic failure criteria for generated or preexisting ductile tearing and material fractures at cracks partially through the wall in fuel rods.

US NRC also performed a similar evaluation as shown in Fig.3[2]. Studies show that the capability of the fuel rod to withstand the expected loads encountered under normal and accident conditions may also be reduced, given degradation of the material properties under extended use, such as decrease in ductility. This evaluation includes SF fuel rods, spacer grids, and top/bottom nozzles to assess possible cladding failure/rupture under hypothetical impact accident loading too.

Besides this practice, other major institutes have also a similar evaluation system in a large view and sense.

3. Methodology Suggestion for SF Integrity Evaluation Coupling of Cask and Necessary SF Data

As results of analyzing the upper mentioned methodologies, SF integrity evaluation can be suggested as shown in Fig. 4 by reflecting Korean SF status and characteristics.

And also SF structural conditions shall be applied to the evaluation to get more conservative responses as aforementioned procedure since SF has experienced a lots of external loads and deformed in shape of bow, tilt etc. Fig.5 shows the schematic diagram of this SF structural deformation mechanism and deformation shape under various kinds of environment. The real measured data of SF bow is shown in Fig. 5. This kind of data can be employed in performing SF integrity analysis itself and in designing cask system too.

4. Conclusion

The technology of structural integrity for spent nuclear fuel is one of the most key technologies for cask design optimization and applicability criteria of next process (processes of recycling, reprocessing and disposal) through the evaluation of spent nuclear fuel integrity itself after long-term storage. The technology of structural integrity for spent nuclear fuel has been performed for simulations and related tests in normal and accident conditions in abroad. No research results and technologies in domestic, however, have been performed yet. So the SF integrity evaluation technologies as suggested in this paper and the related regulation shall be developed for the safety view point.

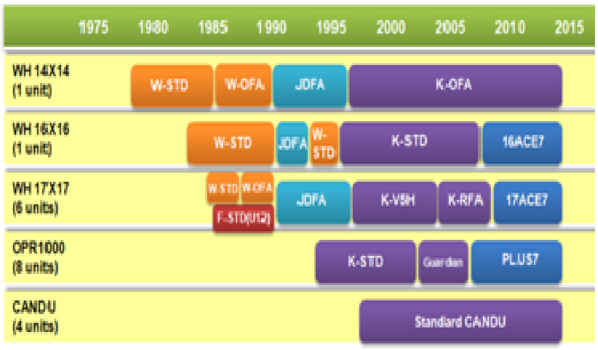

Fig. 1 Fuel Loading History in Korea Nuclear Plants

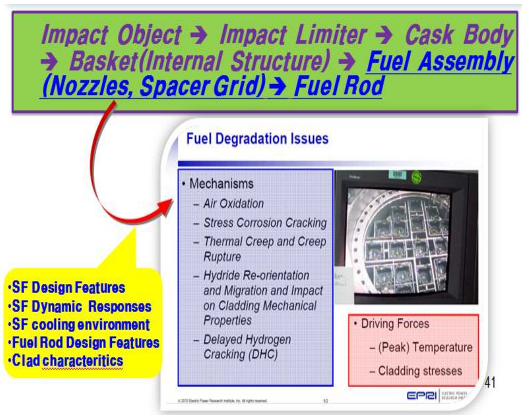

Fig. 2 Overall Scheme of SF Integrity Evaluation

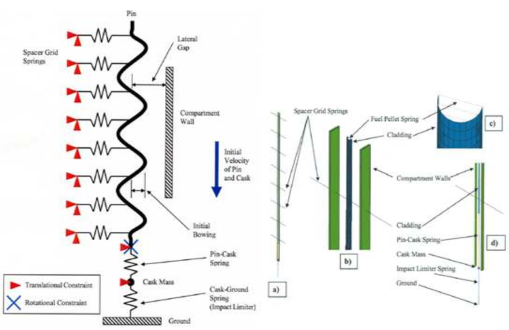

Fig. 3 SF Structural Integrity Simulation

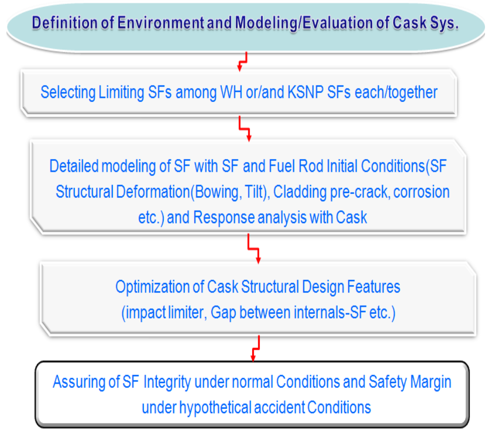

Fig. 4 Suggested SF Integrity Evaluation System

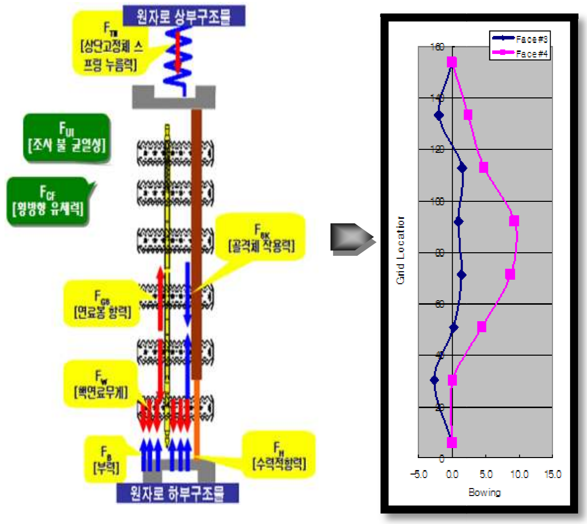

Fig. 5 SF Structural Deformation Contributors(Left) and Real Measured Data of SF Bow

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