Speculation on the Structural Integrity Evaluation Approach for Spent Fuel

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1. Introduction

A half century and a quarter century roughly have elapsed as of this year since introduction of nuclear into Korea and the commercial operation of Kori unit 1 respectively. Currently, Korea has 20 nuclear power plants in operation and 4 plants are under construction, ranked at the 6th position worldwide. Getting a glimpse of what is going on behind the veil of this outstanding achievement, the issue of spent fuel(SF) disposal has come to hot potato. As of last year, around ten thousand tons of SF has stored in each plant, and the year of storage capability limit is coming soon. Thus, even though the government is keeping "wait and see" policy, it is necessary to develop urgently the common and basic technology related to SF interim storage regardless whatever policy will be chosen in considering time press. One of these primary technologies is to study on the various characteristics of spent fuels which is supplied to develop some kinds of tools as a source technology information. Among these studies, the SF integrity analysis is a sort of basic technical information for the related dry interim storage research. In a large sense, there are two aspects on this study. One is to study on the SF rod behavior and the other is on the SF structural integrity under a series of events such as shipping, handling and long term dry storing of it. The former is mostly focused on the clad material degradation due to corrosion, pellet-clad interaction, other mechanical fracture etc. The latter mainly performs the fuel structural integrity under normal and accident conditions. Generally, the evaluation of SF integrity attaches more importance to fuel rod relatively than to fuel assembly since fuel rod clad is the direct medium surrounding the radioactive resource. However, the structural integrity of SF is also crucial to establish the related evaluation system since it is directly connected to the compatibility with various kinds of handling tools, storage facility etc. The evaluation of SF structural integrity except fuel rod is not well known what kind of activities there are compared to other related items. This evaluation could be used to set up the criteria of the damaged or undamaged fuel, and are supplied to its shipping, handling and storing system designs. Thus, what sorts of evaluation works from the view point of SF structural integrity are necessary, why this information is important, and how damaged or undamaged fuels are defined are to be studied by reviewing the existing technical information in this paper.

2. Spent Fuel Structural Integrity

PWR fuel assembly experiences many changes from the time it is manufactured, loaded in the reactor and repositioned in the core several times until finally removed from the reactor for the interim storage, reprocessing or final disposal etc. This history can alter fuel assembly characteristics such as its mechanical properties, geometrical shape etc. Any of these alterations which jeopardizes SF integrity could be considered to represent damage. In general, fuels are considered to be damaged if they cannot function as required for post-reactor conditions and operations, and can not guarantee its integrity. US federal regulations, for the storage and transport are given in 10 CFR Parts 71 and 72, and an applicant is free to define a damaged fuel in any manner, provided that the definition allows the regulations to be met. The related contents about the definition of damage, are described in Table 1 by NRC and ANSI respectively[1]. These definitions about SF structural integrity and damage are some comprehensive that it is need to examine a matter closely. Going into little more details, SFs in storage, possibly eventually have to be removed from the storage cask either to be placed into a transport cask or to be transferred to a disposal cask. In this case, for SF to be classified as undamaged, all relevant past and current experience should indicate that SF can be handled and moved using normal methods. If SF has been altered such that it may not be handled and moved by normal means then it does not fulfil its purpose and should be classified as damaged. Alterations to, or removal of, the fuel rods, grid spacers, grid straps, or other structural components or hardware may affect the way SF has to be handled. And also SF shall not assume a configuration, during either normal conditions or postulated accident conditions, such that criticality could occur[1]. In the structural analysis of the assemblies during an event it is usually assumed that specified components of the assembly such as grids, flow mixers, nozzles, etc. are in place and that the components have the properties associated with the given material, irradiation level and transport temperature. Should the structural integrity of SF be adversely affected under the design basis storage and/or transport conditions, then the assembly might not fulfil the requirement that it maintains its configuration and it should be considered damaged. The cask or canister designer has the freedom to design a system that mitigates the forces transmitted to SF and fuel rods. If the storage cask or transport package design prevents or mitigates forces transmitted to its contents such that structural integrity is not significantly compromised, SFs need not be classified as damaged, assuming other factors (temperature, inert atmosphere, etc.) have been adequately addressed. This example illustrates how the design of the system can change the requirements that define SF as either damaged or intact. For reasonable assurance of those above-mentioned damaged or undamaged protocol, various kinds of evaluations are necessary. One is to evaluate SF top nozzle integrity which makes it ensure compatibility with some handling tool and connectivity with SF body. Once Kori unit experienced the top nozzle was separate from the fuel body during a lifting operation[2]. Another is to analyze mechanical characteristics of structural components such as the mechanical properties of grid spring reflecting its irradiation effect, SF skeleton ect. which will be used to hypothetical accident evaluation like an aforementioned drop accident. The other is to evaluate SF structural deformation such as its bow, twist etc. Those items are related to compatibility with handling tools and canister, to retrievability of SF from a canister or storage, and to maintenance of the original fuel geometry, to avoid variations in fuel reactivity and to ensure that subcriticality is maintained etc. In fact, key data on SF must be available to make an informed decision in the planning and implementation of technical options for spent fuel management.

Table 1. Comparison of NRC and ANSI definitions of damaged fuel

NRC (ISG-1)	ANSI
● The fuel assembly ✓ Is damaged in such a manner as to impair its structural integrity; ✓ Has missing or displaced structural components such as grid spacers; ✓ Is missing fuel pins which have not been displaced by dummy rods which displace a volume equal to or greater than the original fuel rod; ✓ Cannot be handled using normal (i.e. crane and grapple) handling methods; ● The fuel assembly structural hardware or cladding material properties are in a degraded condition such that its ability to withstand the normal and design basis events of storage (for storage-only casks), or the normal and hypothetical accident	● Fuel assemblies that have structural damage such that they cannot be handled by normal methods.

3. Conclusion

Regarding SF integrity, the establishment of protocol is primarily important whether it is damaged or undamaged for a canister acceptability. This strongly depends on storage management activities. To make a final decision, various kinds of SF structural integrity evaluations are prerequisite such as top nozzle connectivity, SF structural configuration etc. And also some mechanical characteristics are necessary to analyze the hypothetical accidents for storage canister and fuel rod integrity analysis.

Acknowledgments

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