# Mechanical Characteristic Speculation of PWR Spent Nuclear Fuel Structure

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## 1. Introduction

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. Under a severe radiation and a thermo-mechanical conditions, this mechanism can alter fuel assembly characteristics such as its mechanical properties, geometrical shape, material characteristics etc. Any of these alterations which impact spent nuclear fuel(SNF) integrity should be considered to design a canister for its transportation or storage. Regarding the cask or canister design, there could be a freedom to design a system that mitigates the forces transmitted to SNF 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, the detailed SNF properties are necessary to make a decision of the elaborated design parameters, assuming other factors (temperature, inert atmosphere, etc.) have been adequately addressed. An approach to those work formations is to analyze mechanical characteristics of structural components which are the mechanical properties of grid spring reflecting its irradiation effect, SNF strength and SNF structural deformation such as its bow, twist etc. Those information is also used to evaluate hypothetical accident like an drop accident of SNF cask/canister and to select limiting fuel assembly for cask/canister to accommodate various kinds of SNFs. Since there have been many kinds of nuclear fuels that have been loaded into nuclear power station in Korea, to select a limiting case of SNF is very important to design a cask or canister for safety and integration. Especially, the fuel assembly structural properties are a sort of essential data. Thus, in this paper, some approaches to evaluate SNF mechanical characteristics are suggested through the existing technical information review, some test data and the analysis methodology, and also closely study the mechanical characteristics of some representative SNF for its general comprehension.

## 2. SNF Mechanical Characteristics Evaluation

As previously mentioned, PWR fuel assembly mechanical properties show quiet a complex behavior under/after irradiation. SNF beginning status is considered as end status of fresh fuel, and the mechanical status of SNF is mostly defined during its irradiation in the reactor. Thus based on the irradiation behavior, to grasp the mechanical parameters and properties of SNF is essential to supply the technical information to design a canister/cask. Within this framework, one of the most basic important item is the knowledge of the fuel assembly stiffness due to the characteristic change of fuel rod-to-grid system as fuel irradiation since fuel grid-to-rod interaction mainly dominates the fuel mechanical behavior of fuel and consequently allows to diagnosis the performance of irradiated structures in terms of fuel deformation, dynamic responses etc. Generally, fuel rod support is provided by a spring-dimple system fixed to the grid. During irradiation, the spring force decreases and a gap between the rod and the spring may occur. This phenomenon is due to the stress relaxation of grid spring and dimple, irradiation growth and fuel rod diameter reduction due to its creep down effect. Many methodologies have developed to predict these fuel assembly properties and status. One of the existing evaluation of SNF evolution thorough finite element model with fuel assembly test and irradiation information have shown that the axial and lateral fuel assembly stiffness decrease of around 50 - 60 % and the natural frequency of the first eigenmode decreases of about 50 % after irradiation[1]. More simple and similar approach to overcome the analysis obstacles com from the highly nonlinear mechanism has been performed to understand GRI effects and the related mechanical characteristics. To know the contribution degree of this GRI effect to the axial stiffness, the analysis is performed by comparing the results from the classical mechanical analysis for bare fuel assembly(skeleton) without considering the interaction between the fuel rod and grid cell with the stiffness from the axial strength test[2]. It is also confirmed that GRI gives the much contribution to fuel stiffness and these values are around 40~70 % depending on the FA features. It can be judged that the SNF axial stiffness decrease by around half of that of the initial fuel status. Even though those two fuels are different in the design features, general trend and characteristic results show similar. And also another analysis is performed to perceive dynamic response as irradiation through ANSYS finite element model by reflecting the mechanical characteristics as shown in Figure 1. In this model, two slide elements are applied to fuel rod-to-grid connection and two beam elements simulate the equivalent fuel rods and guide thimbles respectively. To simulate grid spring irradiation relaxation, grid cell stiffness values are applied to the model from 100 % of fresh fuel status to 10 %. As results of modal analysis, the first eigenvalues slightly decreased as grid cell stiffness get smaller as shown in Figure 1. The natural frequency difference between 100 % cell stiffness and 10 % is around 17 %. Considering fuel axial stiffness difference i.e 50 %, those value can be regarded as reasonable since a natural frequency is proportional to square root of the stiffness. From those facts, in spite of the material hardening effects, SNF structural stiffness is far lower than that of a fresh fuel. These approaches and analysis results can be used as input parameters and/or indirect technical information to design canister/container.

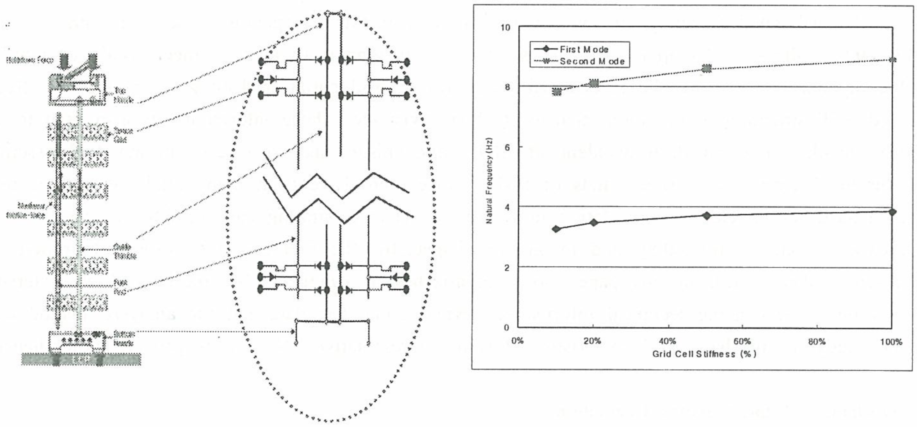


Fig. 1. Conceptional force FBD in FA(Left), FEM Model(Mid) and Modal Analysis Results(Right)

## 3. Conclusion

Some approaches to evaluate SNF mechanical characteristics are suggested through the existing technical information review, some mechanical data and the analysis methodology, and also closely study the mechanical characteristics of some representative SNF for its general comprehension. From this speculation, it can make sure what SNF structral properties are. These approaches and analysis results can be used as input parameters and/or indirect technical information to design canister/container from the view of the aforementioned faces.

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