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Structural Integrity Evaluation for Damaged Fuel Canister of a Research Reactor

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1. Introduction

The purpose of this document is to confirm the structural integrity of damaged fuel canister through the numerical simulation. The analysis results of canister including damaged fuel are evaluated with design limits of the ASME Sec. III NF Codes and Standards. The main function of canister is to store and protect the damaged fuel assembly generated from the operation of the research reactor. The canister is classified into safety class NNS (Non-nuclear Safety) and seismic category II [1].

2. Design

2.1 Structure

The canister is composed of the 'lid', 'basket' and 'support block'. The canister is employed for storing and protecting the damaged fuel. The canister should be designed with considering the geometric shape of the fuel assembly, storage capacity, and the size of rack. The shape of the canister is designed into commercialized circular tube due to economic benefit and easy manufacturing. The damaged fuel assembly is loaded in a dedicated canister by using special tool and supported by lower block in the canister. Then it is move into the damaged fuel storage rack under safeguards arrangements. The canister is securely supported at guide plate and base plate of rack.

In the view of the design of the damaged fuel canister, another important design factor is to decide the canister type. The canister is chosen as vented can type to release the pressure.

The canister is mainly made of stainless steel excepting the support block which has a contact with a damaged fuel assembly. Since the canister is stored in the pool, the support block is made using aluminum 6061 T6 material to minimize the galvanic corrosion.

The canister is suitably designed to store one damaged fuel assembly. The lid of canister plays part in preventing external object from flowing into the canister as well as in helping operator easily handle the canister. The canister is securely locked with bolting structure to prevent the fission product from being released to the pool.

3. Structural Integrity Evaluation

3.1 Analysis

To evaluate the structural integrity of the damaged fuel canister, the response spectrum analysis has been performed under the seismic load of SSE(Safe Shutdown Earthquake) by using ANSYS software. The elements used in the analysis model are shell, solid, and mass 21 element. The lid, basket, and support block of canister are modeled as the solid 186, shell 181, and mass 21 elements, respectively. The total number of elements is 58,255 and the total number of nodes is 86,844. The fixed boundary condition in the 3-axis direction is imposed on the bottom of the canister and the horizontal degree of freedom of canister is restricted at the contact position between the canister and guide plate of damaged fuel storage rack.

The canister is designed to withstand the seismic load after SSE event. The structural integrity of the canister is evaluated in accordance with ASME Sec. III Subsection NF [2]. Computer code used for this analysis is ANSYS version 16.0.0. Dead load and seismic load are considered in load condition and the hydrodynamic load is applied using the added mass method in the analysis.

The response spectrum analysis is performed for seismic analysis of the canister. It is performed with each directional floor response spectrum. The number of modes considered in mode combination is 250ea. The mass participation factors are 65.71%, 56.68%, and 67.71%, respectively. Other modes beyond the 250th mode are considered by using the missing mass method. Fig. 1 shows the finite element model of canister.

Fig. 1. Finite element model for damaged fuel canister

3.2 Evaluation

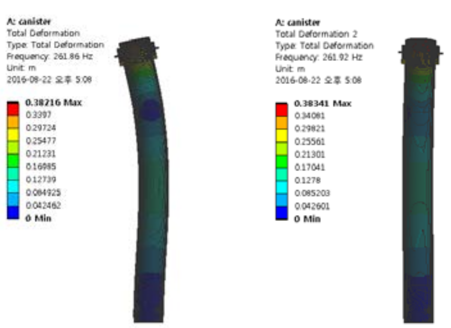
The numerical results were conservatively evaluated because the buoyant effect is neglected in the static and response spectrum analysis. Fig. 2 shows four mode shapes in the structural models of the canister. Table I represents the first to fourth natural frequencies. The bending mode is happened to the first frequency. When the level A and D service loading combination are applied, the maximum membrane stress intensities of canister are about 0.3 MPa and 0.9 MPa, the maximum stress intensities of membrane plus bending are about 0.4 MPa and 1.1 MPa, respectively. All the response spectrum results according to load combinations are tabulated in Table II. The maximum stress intensities of the canister occur on the bottom of canister. The stress intensity of canister under the level D service loading are shown in Fig. 3. These analysis results show that maximum membrane stress and bending stress under service loading conditions are within the ASME III NF code limits [2].

Table I. Natural frequencies of canister

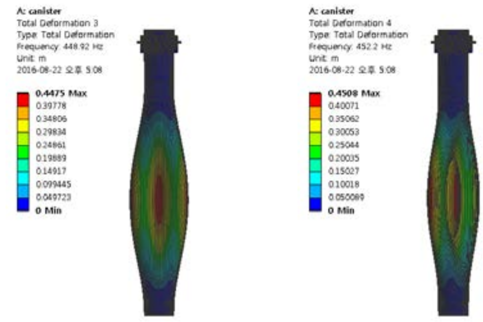
1st frequency	261.86 Hz
2nd frequency	261.92 Hz
3rd Frequency	448.92 Hz
4th Frequency	452.2 Hz

Table II. Response spectrum analysis results of canister according to Load Combinations

Load Combination	**Stress Type**	**Stress** [MPa]	**Service limit D** [MPa]
Level A	Pm	0.3	115
	Pm+Pb	0.4	206
Level D	Pm	0.9	173
	Pm+Pb	1.1	309



(a) 1st mode shape (b) 2nd mode shape



(c) 3rd mode shape (d) 4th mode shape

Fig. 2. Mode shapes of damaged fuel canister

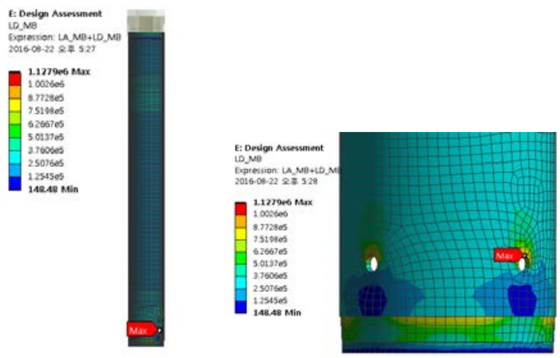


Fig. 3. Stress intensity of canister under level D service loading

4. Summary

The structural integrity evaluation for the canister is performed by using response spectrum analysis. The analysis results show that the stress intensity of the canister under the seismic loads is within the ASME Code limits [2]. Thus, the validity of the present design of the canister has been demonstrated.

Acknowledgements

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REFERENCES

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[2] ASME Boiler and Pressure Vessel Code, Section Ⅲ, Rules for Construction of Nuclear Facility Components, Subsection NF, American Society of Mechanical Engineers, 2004.