Evaluation of the Structural Integrity of the Thermal Column Extension

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1. Introduction

The thermal column (TC) is an irradiation facility of research reactors that provides well thermalized neutrons [1-3]. It usually consists of a boral-lined aluminum or stainless steel port filled with graphite blocks, a lead shield to reduce the gamma flux from the core, and a shielding door. Irradiation samples are put in some space between the graphite blocks.

The TC extension dealt with in the present work is a TC part in the pool to obtain highly thermalized neutron flux. It is located between the heavy water vessel and the TC liner which is a reinforced part of pool liner in front of the TC. The TC extension is fixed to the support structure, which is made of stainless steel, on the pool bottom. Because it is a flow path of neutrons from the reflector to the TC port, it is a pile of graphite blocks in the aluminum can. In order to increase the available thermal neutron flux in the TC, the water gaps between the TC extension and the heavy water vessel, and between TC extension and the pool liner should be minimized as possible, but there exists a minimum limit, considering the manufacturing and installation tolerance and the seismic deformation of the TC extension in the pool.

To evaluate the structural integrity of the TC extension, finite element analysis has been performed for a given loading condition. The numerical results are presented, and the integrity of the TC extension is discussed.

2. Methods and Results

2.1 Water gap

The water gaps among the TC extension, the pool liner, and the heavy water vessel in the present work are assumed to be 5mm. The actual gaps, however, can be smaller than this value because of the manufacturing and installation tolerance. Assuming that the tolerance is 1mm, the minimum gap becomes 4mm. Therefore, the maximum allowable deformation of the TC extension in the pool along the heavy water vessel or the pool liner (*i.e*., *x*-direction in Fig. 1) should not exceed 4mm.

2.1 Seismic loads

For given floor response spectra (FRS) at the pool bottom under the safety shutdown earthquake (SSE), seismic analysis has been performed, and the inertia force at the mass center of the TC part in the pool, as shown in Fig. 1, has been obtained. It should be noted that all the load directions can be reversed.

2.3 Finite element analysis

A three-dimensional finite element analysis has been performed using a commercial finite element code, ABAQUS. It consists of three-dimensional 8-node linear brick and 4-node linear tetrahedron elements. The total number of elements is about 30,400. The boundary conditions on the bottom boundary are taken to be fully fixed. The tie constraints are imposed on the boundaries between the TC extension and the support structure. Materials, which are aluminum 6061-T651, stainless steel 304L, and graphite IG-110, assumed to be isotropic and elastic.

The inertia force is imposed on the mass center of the whole assembly as shown in Fig. 1. Several load combinations can be assumed with respect to the loading direction, but critical two cases are chosen for the finite element analysis. The *x*, *y*, and *z* directional components of the forces are then (-27200N, 7910N, 7910N) and (27200N, 7910N, 7910N). It has been confirmed that other cases give almost the same results as or less critical than these two cases.

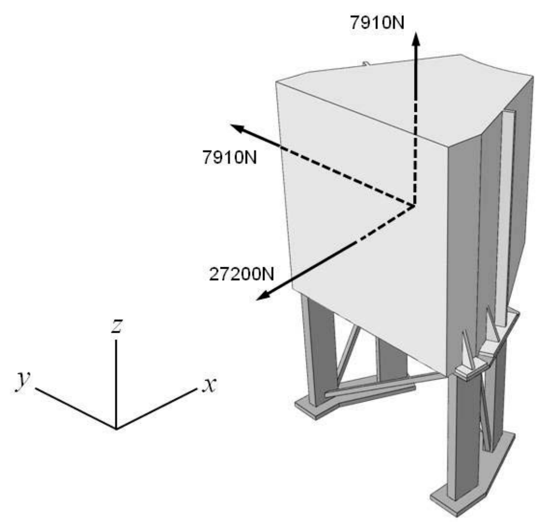
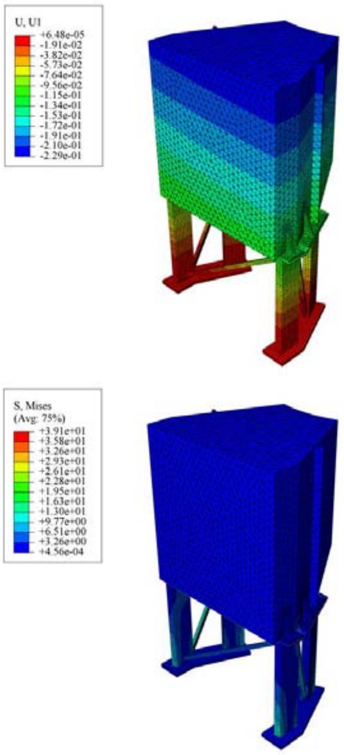


Fig. 1. Schematic of the TC part in the pool which is consists of a TC extension and a support structure. The inertia force on its mass center generated from the seismic loads is also presented.

For these two cases, the maximum *x*-directional displacements and the Mises stresses are given in Table I, and the contours of Mises stress and displacement along the x-direction are shown in Figs. 2-3. The maximum *x*-directional absolute displacements of the two cases are about 0.23mm, and occur on the top of the TC extension. The maximum Mises stresses are below 40MPa in the support structure and 6MPa in the TC extension can, respectively.

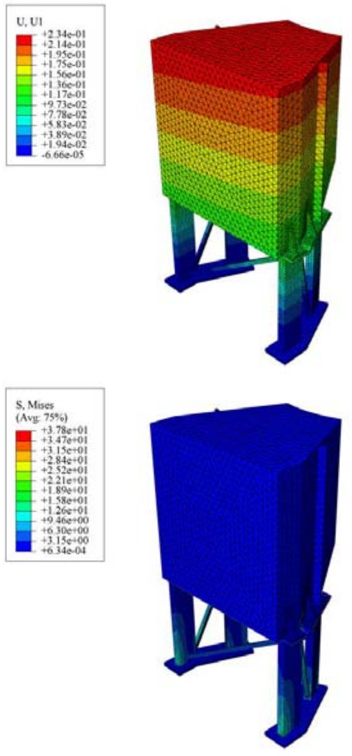
Table I: The maximum *x*-directional displacements and the maximum Mises stresses for the given loading conditions

	Toward the TC liner	Toward the heavy water vessel
Max. Mises stress (MPa) of the support structure	39	38
Max. Mises stress (MPa), of the TC extension can	5.5	5.7
Max. displacement (mm)	0.23	0.23



(a)
(b)

Fig. 2. Distributions of (a) *x*-directional displacement and (b) Mises stress for the 3-directional inertia force on the TC extension and the support structure. The *x*-directional component of the inertia force is toward the TC liner.



(a)
(b)

Fig. 3. Distributions of (a) x-directional displacement and (b) Mises stress for the 3-directional inertia force on the TC extension and the support structure. The *x*-directional component of the inertia force is toward the heavy water vessel.

3. Discussion and Conclusions

The maximum deformation of the TC extension evaluated is below 0.25mm, which is substantially smaller than 5mm, the assumed nominal water gaps among the TC extension, the pool liner, and the heavy water vessel. Even though the manufacturing and installation tolerance, 1mm, is additionally considered, we can conclude that the water gaps are sufficient for the given seismic loads. The Mises stresses are below 40MPa in the support structure made of stainless steel 304L and 6MPa in the aluminum 6061-T651 can, respectively. These stress levels are below the maximum allowable stresses of the given materials. From this analysis, the structural integrity of the TC extension is verified.

REFERENCES

[1] Technical reports series no. 455, Utilization Related Design Features of Research Reactors: A Compendium, IAEA, 2007.
[2] G. H. Jeong, S.-H. Yun, D.-G. Lee, C.-H. Jung, and K. W. Lee, A Study on the Wigner Energy Release Characteristics of Irradiated Graphite of KRR-2, Journal of Korean Radioactive Waste Society, Vol. 4, pp. 209-216, 2006.
[3] S.-K. Kim and O. Song, A MAUT Approach for Selecting a Dismantling Scenario for the Thermal Column in KRR-1, Annals of Nuclear Energy, Vol. 36, pp. 145-150, 2009.