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A STUDY ON THE SEISMIC ANALYSIS FOR HANARO CAPSULES AND CAPSULE SUPPORTING SYSTEMS

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ABSTRACT

The three instrumented capsules are used for material irradiation tests in research reactor, HANARO(Hi-Flux Advanced Neutron Application Reactor) of KOREA. This paper presents the results of the seismic analysis to evaluate the structural integrity of instrumented capsules(ICs) and capsule supporting systems(CSSs) in HANARO. The natural frequencies and mode shapes for ICs and CSSs are determined with the free vibration analysis. The response spectrum analysis is performed using the given operating basis earthquake(OBE) and safe shutdown earthquake(SSE) floor response spectrum. In this study, the structural integrity of structures under seismic loads is evaluated on the basis of ASME B&PV Code, and the seismic analysis results confirm the structural criteria of the ASME Code.

KEYWORDS

HANARO, Instrumented Capsule, Capsule Supporting System, Test Hole, Clamp Arm, OBE, SSE, Response Spectrum Analysis, Structural Integrity

1. INTRODUCTION

The development of advanced nuclear materials includes a program for the evaluation of irradiated materials exposed the irradiation environments. These experiments can be performed by using suitable capsules in case of non-integral test. The capsules are inserted to the test holes of IR1, CT and IR2 in HANARO, and these capsules are supported by CSSs such as H-beams, base plate and clamp arms et al.. The ICs and CSSs are designed by Korea Atomic Energy Research Institute(KAERI) and should not the interfere with other installed structures. Seismic analysis for ICs and CSSs is performed to evaluate the structural integrity of these structures. The seismic analysis model includes ICs, H-beams, the channel bracket, the base plate, clamp arms and hexagonal test holes.

The structural integrity of structures under the seismic loads is evaluated on the basis of ASME Boiler and Pressure Vessel Code, Sec.III, Div. 1, Part NF(ASME Code, 1989) with the parameters such as displacement, reaction force and stress through the response spectrum analysis.

2. DESCRIPTION OF STRUCTURES

Capsule Supporting Systems(CSSs)

The CSSs consist of H-beams, the channel bracket, the base plate and clamp arms etc., and these are located at the first platform(EL. 78.73m) in HANARO. All structures are immerged in reactor pool. The base plate is designed by stairs type with height difference of 85mm so that three clamp arms can be installed. The clamp arms are placed on the base plate with the use of H-beams and the channel bracket. One edge in clamp arms of the cantilever type is bolted with the base plate and the finger of the free edge grasps the upper protection tube of the capsule. The clamp arms are connected with the control unit systems of the second platform(EL. 85.58m) and are operated manually at the control unit system. The length of the clamp arm is 900mm for IR1 hole, 780mm for CT hole and 650mm for IR2 hole, respectively.

Internal Test Holes

The test holes for inserting the IC are made of Zircaloy-4 and are the same hexagonal type as the nuclear fuel assembly flow tubes. The major and minor diagonal of hexagonal test holes are 74.4mm and 80.4mm, respectively, and the length is 910mm.

Instrumented Capsules(ICs)

The IC consists of a mainbody and a protection tube made of SA-240 Type 304 stainless steel. Table 1 shows the material properties of ICs and hexagonal test holes. The mainbody part with the test specimen to be placed in the in-core region of HANARO is the cylindrical shell with 2mm in thickness, 60mm in external diameter and 870mm in length. The protection tube part connected with the capsule mainbody is 34mm in diameter, 1.65mm in thickness and 5,120mm in length.

Table 1. Material properties of SA-240 type 304 stainless steel and Zircaloy-4

Material	Type 304	Zircaloy-4
Modulus of Elasticity (GPa)	193.	94.3
Mass Density (Kg/m^3)	7913	6500
Poisson's Ratio	0.27	0.35
Ultimate Strength (MPa)	515.	415.
Yield Strength, S_y (MPa)	205.	240.
Allowable Stress, F_t (MPa)*	123.	144.

* Allowable Stress (ASME Code Sec.III, NF-3322.1) : $F_t = 0.60S_y$

3. LOADS AND BOUNDARY CONDITIONS

For the seismic analysis of ICs and CSSs, the loads considered are the dead load, the seismic OBE and SSE floor response spectrum data. Table 2 shows the load combinations and acceptance limits based on the ASME Code.

The seismic loads of this study are transferred through both the grid plate structure of the reactor bottom region(EL. 73.36m) and H-beams fixed at the reactor pool wall of the first platform (EL. 78.73m). For the conservative analysis, the predominant accelerations in the three orthogonal directions are considered for the applied input motions. Figure 1 shows a typical seismic acceleration response spectrum of the applied input motion in the vertical direction at the bottom region of the capsule mainbody and the test hole. Also the floor response spectrum in the horizontal directions at H-beams of the first platform is shown in Fig. 2. The damping values used for the response spectrum analysis are 2% for OBE condition and 4% for SSE condition (USAEC, 1973).

As the boundary conditions, H-beams and the bottom of test holes are fixed at the reactor pool wall and the grid plate structure, respectively and the bottom of the capsule mainbody is considered as a simple support to the capsule mounting spider.

Table 2. The load combinations and acceptance limits

Load Combinations	Acceptance Limits
1. Dead Load	Service Level A
2. Dead + OBE	Service Level B
3. Dead + SSE	Service Level D

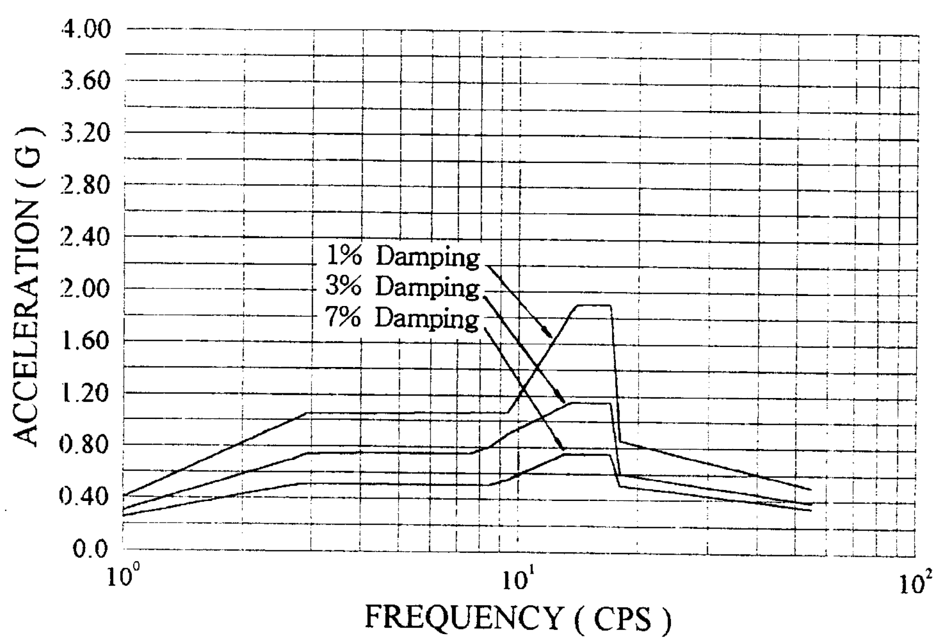

Fig. 1. Vertical floor response spectrum of 0.2G SSE condition(EL. 73.36m)

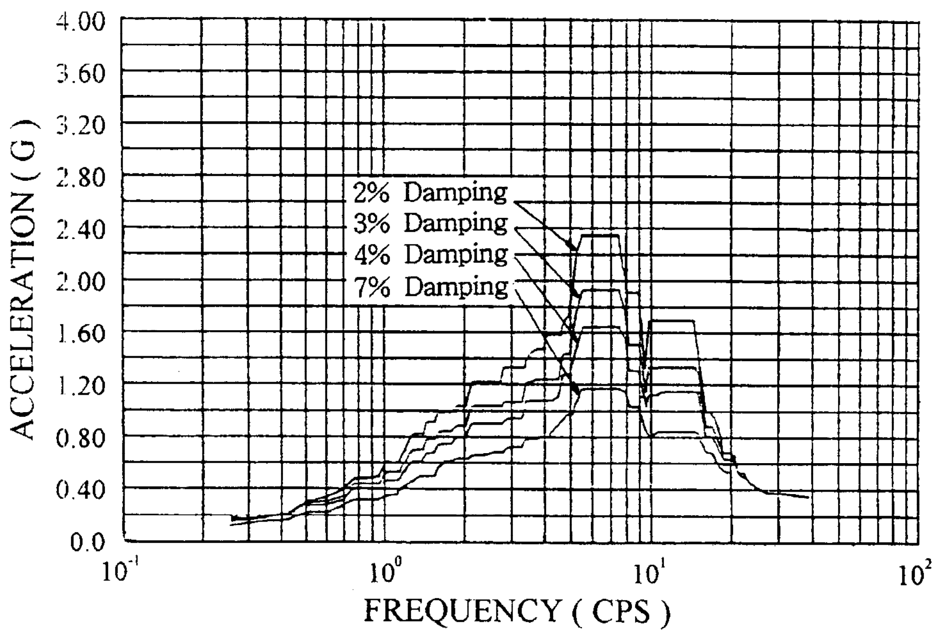

Fig. 2. Horizontal floor response spectrum of 0.2G SSE condition (EL. 81.35m)

4. ANALYSIS MODEL

The finite element model for the seismic analysis consists of H-beams, the channel bracket, hexagonal test holes, the base plate, clamp arms and instrumented capsules. Figure 3 shows the analysis model of ICs and CSSs.

The base plate, the channel bracket, H-beams and test holes are modeled using 387 shell elements, and the total mass of these is 182 kg. The clamp arms are modeled by 27 elements of 3D beam, and the mainbody and the protection tube of ICs are used with 3D pipe elements. The irradiation test specimens in the internal of the capsule mainbody are considered as an added mass, and the total mass of the capsule including the added masses is 52 kg.

The role of springs installed at the top position of the capsule mainbody is to guide the capsule during loading of the capsule in the test hole and to support the capsule during irradiation testing. The spring-damper elements are used for these springs, and the assumed spring constant is 15 N/mm and the damping coefficient is neglected. Since the ICs and CSSs are immerged in water, the hydrodynamic masses(Blevins, 1979) due to the dynamic behavior of structures are added to each nodal point using mass elements. The numbers of used mass element are 287, and the total added mass is 34.2 kg.

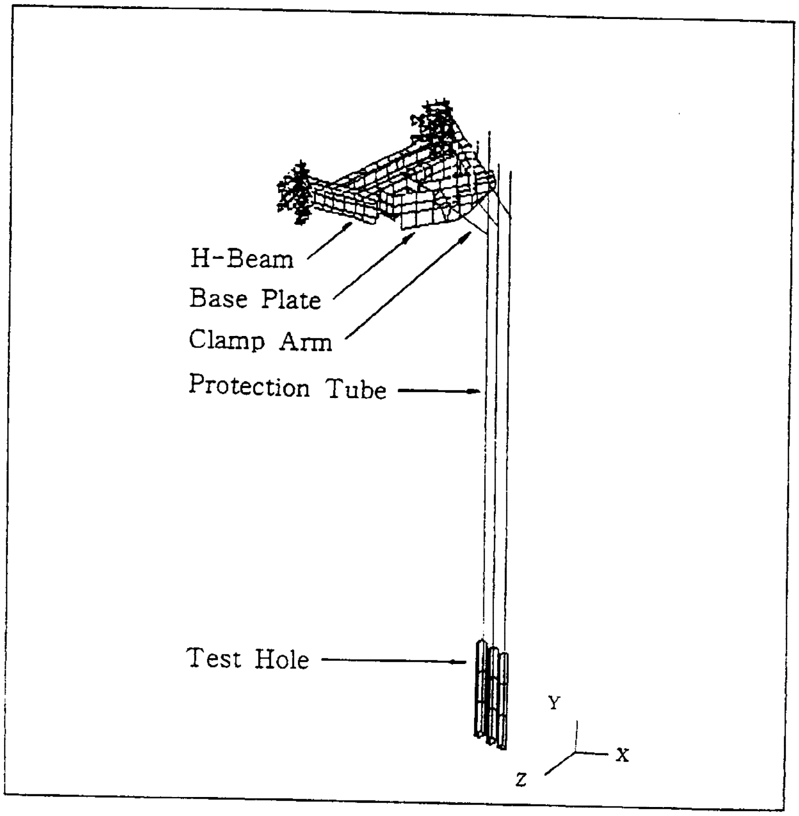

Fig. 3. Finite element model of instrumented capsules and capsule supporting systems

5. STRUCTURAL ANALYSIS AND RESULTS

The seismic analysis in this study is carried out by the response spectrum analysis method using the finite element program, ANSYS(Desalvo *et al.* 1989).

Response Spectrum Analysis

The natural frequencies and mode shapes are determined with the free vibration analysis. The fundamental natural frequency is 8.1 Hz and the mode shape of this frequency is the bending mode of the capsule as shown in Fig. 4.

The individual mode in the response spectrum analysis can be combined by the standard methods of the modal combination as described in Regulatory Guide 1.92(USNRC, 1976) The responses of individual mode are determined considering the correlation of closely spaced modes with ten percent method and then combined by the SRSS(square root of the sum of the square) method for the three seismic directions. All important modes over 90% of effective masses are considered in the X,Y,Z each directions.

Table 3 shows the calculated displacements of the principal position for each service levels. The maximum displacement by the seismic load occurred at the middle position of the capsule protection tube in the IR1 test hole. The maximum displacements in the vertical and horizontal direction are 0.033mm and 8.44mm in case of Service Level D, respectively. But, ICs are not interfered with other structures since these are located in the chimney. Also, ICs and CSSs have not any effect on the neighbour structures since the maximum displacement of all positions are smaller than allowable values.

Table 4 shows the reaction forces for capsule mounting spiders in the bottom of the capsule mainbody. For the Service Level D, the reaction forces of the IR2 test hole are 177.6 N and 22.6 N in the vertical and horizontal directions, respectively. The allowable reaction force of capsule mounting spiders is about 843.7 N in the vertical direction, then analysis results will satisfy the allowable value of capsule mounting spiders.

Table 5 shows the calculated stresses of the principal positions. The allowable values of ASME Code according to the service level are listed together. The maximum stress occurred at the connecting part of the clamp arm and the base plate, and the maximum value is 40.59 MPa. Also, the stress of the test hole of Zircaloy-4 material is 5.20 MPa and is lower than the allowable stress value.

Table 3. The calculated displacements and the allowable values for instrumented capsules and supporting systems

(unit : mm)

Service Level	Element No. (Node No.)	Displacement		Horizontal Allowable
		Horizontal	Vertical	
Service Level A (Dead Load)	301(306)[1]	0.002	-0.064	N/A
	361(376)[2]	0.076	-0.012	N/A
Service Level B (Dead + OBE)	400(416)[3]	7.44	0.029	N/A
	405(409)[4]	2.35	0.002	7.2
	424(700)[5]	0.43	0.022	0.5
Service Level D (Dead + SSE)	400(416)	8.44	0.033	N/A
	405(409)	2.66	0.003	7.2
	424(700)	0.49	0.025	0.5

1) right edge of the base plate
2) top position of the capsule protection tube in IR2 test hole
3) middle position of the capsule protection tube in IR1 test hole
4) connecting part of the capsule mainbody and the protection tube in IR1 test hole
5) top position of IR2 test hole

Table 4. The reaction forces for capsule mounting spiders

(unit : N)

Position \ Reaction Force	Horizontal	Vertical	Allowable
IR1 Test Hole	29.5	169.8	843.7
CT Test Hole	27.3	174.8	843.7
IR2 Test Hole	22.6	177.6	843.7

Table 5. The calculated stresses and the allowable values for instrumented capsules and supporting systems

(unit : MPa)

Element (Node) \ Service Level	Service Level A (Dead Load)	Service Level B (Dead + OBE)	Service Level D (Dead + SSE)
271(296)[1]	0.81	35.91	40.59
394(363)[2]	0.62	26.35	29.80
423(432)[3]	0.37	21.47	24.37
405(409)[4]	0.76	13.91	15.66
490(925)[5]	0.048	4.59	5.20
Allowable Stress	123.0	184.5	246.0

1) connecting part of the base plate and the clamp arm in CT test hole
2) grasping part of the top protection tube
3) bottom end of the capsule mainbody
4) connecting part of the capsule mainbody and the protection tube in IR1 test hole
5) bottom end of IR1 test hole

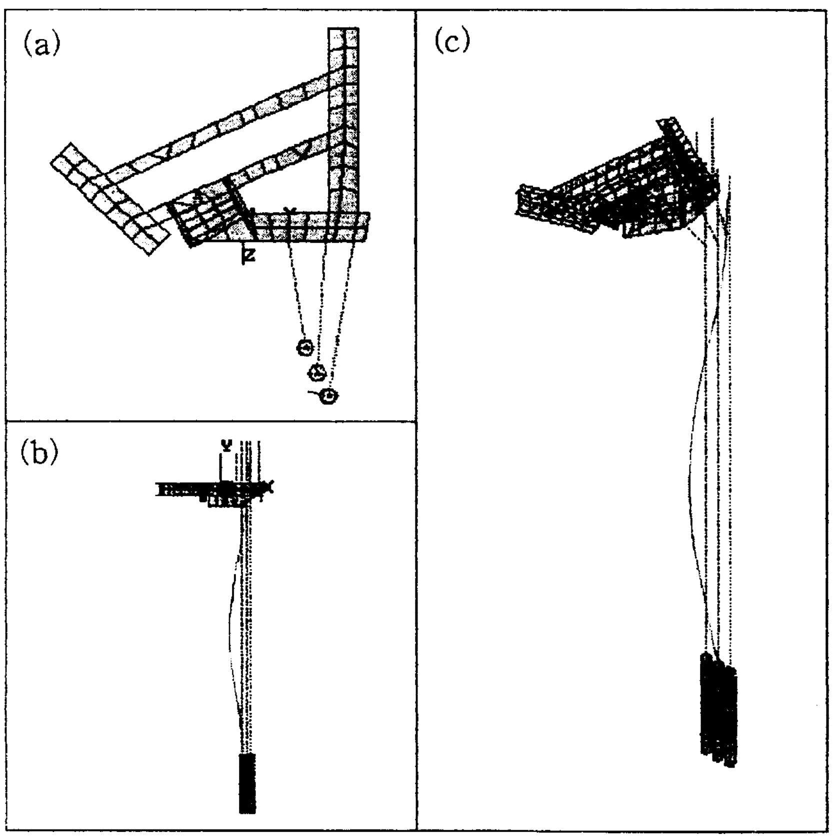

Fig. 4. The first mode shape of instrumented capsules and supporting systems
(a) At top view (b) At side view (c) At global side view

6. CONCLUSIONS

The seismic analysis is performed by using a finite element program, ANSYS to evaluate the structural integrity of ICs and CSSs in HANARO under the various loads such as the dead, OBE and SSE loads. Analysis results show that the structures under seismic loads are not interfered with other near structures. The reaction forces at the bottom end of the capsule mainbody are lower than the allowable force of capsule mounting spiders in HANARO. The maximum stress level is 40.59 MPa at the connecting part of the clamp arm and the base plate. The stress values for ICs and CSSs fully satisfy the acceptance limit of the ASME Code under the dead and the seismic load conditions.

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