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Drop analysis for structural integrity evaluation of KJRR fuel transport container

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1. Introduction

A fuel transport container for KiJang Reserch Reactor(KJRR) has been developed to transport fresh fuel assemblies and fission molly targets which are used for a research reactor built in Kijang.

The KJRR fuel transport container is a type-A(F) container, which is defined in domestic and foreign regulations of a radioactive substance container. According to Nuclear Safety and Security Commission's notification, the container should meet the accident conditions defined in IAEA safety Standard Series, US NRC and etc [1-3].

In this study, a structural integrity of the KJRR fuel transport container is evaluated by conducting computational analyses of 9-meter free drop and 1 meter puncture.

2. The evaluation of structural integrity

The KJRR fuel transport container is shown as in Fig. 1. ABAQUS [4] is utilized to evaluate the structural integrity of the container. According to the transportation accident condition, the 9-meter free drop accident was analyzed in various drop directions such as bottom vertical, lid vertical, horizontal, and CoG (center of gravity). The 1-meter puncture analysis was also evaluated in vertical and horizontal directions.

SA240 Type304 is used for KJRR fuel transport container and its design stress strength (S_m) is 138MPa. The primary membrane stress of stainless steel should be less than the largest value, among $0.7S_u$ and S_y=1/3(S_u-S_y). And its maximum local stress is $0.9S_u$

A limited axial stress SA193 B7, material used in fastening bolt, is $0.7S_u$ and its limited shear stress is $0.42S_u$ [5].

Figure 1 shows the finite element model of KJRR fuel transport container. The model can be divided into external over pack that consists of balsa wood which can reduce impacts, and internal canister that contains the fuel.

The energy curve and stress distribution of the bottom vertical drop analysis, and stress contours of the lid and canister in transportation accident condition are shown in Fig. 2 - 5.

The energy curve shown in Fig. 2 indicates that the first impact is included in the analysis duration and the peak internal energy occurs at 1.35 ms. Figure 3 and 4 show the stress contours of the canister's lid and body at 1.35 ms.

The maximum tresca stresses of the lid and body were measured as 232.7 MPa and 321.1 MPa, respectively. It means that those do not exceed the limited stress, 463.5MPa.

In Fig. 5, the bolts which can clamp the canister body and the lid are shown. Pre-bolt analysis has been conducted that analyzes the initially applied force when the bolts are connected. And the analysis of 9m drop was then conducted after the pre-bolt analysis. The stress contour of the bolt is shown in Fig. 5.

The average axial stress of the bolts was measured as 264.3MPa, and the average shear stress was 136.2MPa. It means those results does not 602MPa of limited axial stress and 361.2MPa of limited shear stress.

Table I shows the stress values calculated from the drop and puncture analyses. The stress exceeding the limited value is calculated from the CoG drop analysis. However, it would not lead to a meaningful damage to the container because the stress is shown only in an external vertex point of the canister lid and overpack as the concentrated stress. The other result values are less than the limited stress value in all transportation accident analyses. Therefore, we confirmed that structural integrity of the KJRR fuel transport container can be maintained in every transportation accident condition.

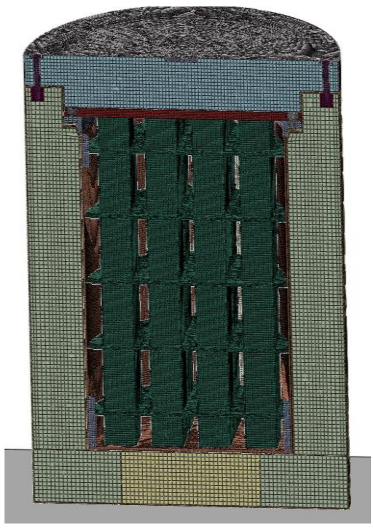

Fig.1. KJRR fuel transport container FEM Model

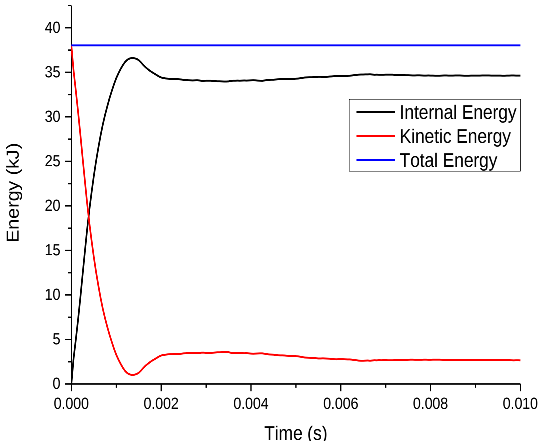

Fig. 2. Energy curve in the bottom vertical drop

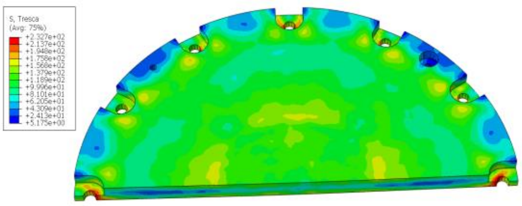

Fig. 3. Stress contour of lid in the bottom vertical drop

Table I: Analysis results in transportation accident condition

Transport accident condition		Analysis result [MPa]		
		Limited Stress	Canister Body	Canister Lid
Bottom Vertical Drop	P_m	360.5	121.5	197.3
	Max. Stress Intensity	463.5	321.1	232.7
Lid Vertical Drop	P_m	360.5	9.6	154.8
	Max. Stress Intensity	463.5	275.7	281.6
Horizontal Drop	P_m	360.5	136.1	168.9
	Max. Stress Intensity	463.5	235.5	214.5
Center of Gravity Drop	P_m	360.5	12.9	100.1
	Max. Stress Intensity	463.5	233.4	499.2
Vertical Puncture	P_m	360.5	98.9	152
	Max. Stress Intensity	463.5	219.5	236.6
Horizontal Puncture	P_m	360.5	93.3	25.9
	Max. Stress Intensity	463.5	222.6	45.7

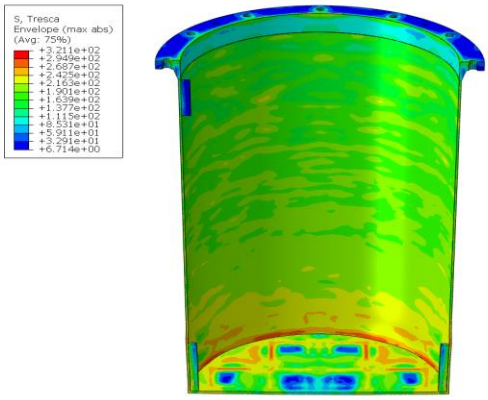

Fig. 4. Stress contour of canister in the bottom vertical drop

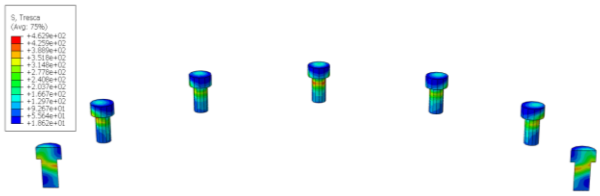

Fig. 5. Stress contour of bolts in the bottom vertical drop

3. Conclusions

The drop and puncture analyses of KJRR fuel transport container in transportation accident condition are performed in this study.

According the analysis results, it is confirmed that structural integrity of the KJRR fuel transport container can be maintained in the transportation accident condition. Hereafter, when the test model is produced, a safety test will be conducted and its result will be compared with the result of drop and puncture analyses.

REFERENCES

[1] Nuclear Safety and Security Commission's notification 2014-50, "Regulation for Packaging and Transportation of Radioactive Material", 2014
[2] IAEA safety standards No. SSG-26, "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material", 2014.
[3] US NRC Code of Federal Regulation, US NRC 10 CFR Part 71, "Packaging and Transportation of Radioactive Material", 2014
[4] ABAQUS User's Manual for Rivision 6.14-1, Hibbit, Karlson & Sorenson Inc., 2014.
[5] ASME Boiler & Pressure Vessel Code Section Ⅲ Div. 1, Appendices F, "Rules for Evaluation of Service Loadings With Level D Service", ASME, 2015.