Preliminary Thermal Stress Analysis for a Fuel Transfer Cask of PGSFR

Kang Soo Kim [a*], Sung Kyun Kim [a], Keun Bae Park [a]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon*
[*]*Corresponding author: kskim5@kaeri.re.kr*

1. Introduction

The Ex-Vessel Transfer Machine (EVTM) for the Prototype Gen IV Sodium Fast Reactor (PGSFR) is a self contained shielded system used to move new and spent core assemblies (fuel, reflector and control rod assemblies) used in the reactor core. EVTM contains the fuel transfer cask holding the new and spent core assemblies. In this paper, the shape and the dimension of the fuel transfer cask were built up, the thermal stress of the cask was performed in case that the fuel transfer cask holds a spent fuel assembly with the decay heat. The analysis results were compared with the criteria of ASME NB code and the structural integrity of the fuel transfer cask to the thermal stress was confirmed.

2. Methods and Results

2.1 FEM Model

The fuel transfer cask consists of the SS316 stainless steel, the lead and air cooling space. An analysis model using the ANSYS Code [1] is shown in Fig. 1. The element SOLID 70 and element SOLID 185 are used for modeling. The dimensions of the cask are as follows.

- Fuel Cylinder Diameter : 0.36 m
- Air Cooling Space Diameter : 0.72 m
- Lead Shielding Space Diameter :1.42 m
- Height of Cask : 5.28 m

6 DOF fixed boundary condition was applied at the area contacting with the EVTM. This area is from radius 0.48 m to radius 0.71 m at the cask bottom plate.

2.2 Material Properties

The material properties are presented in Table 1 [2].

Table 1 Material Properties of Cask

Material Properties	SS316	Lead	Air
Thermal Conductivity (W/m°C)	15.40	35.30	0.023
Thermal Expansion (m/m °C)	16.4E-6	27.6E-6	
Modulus of Elasticity(N/m^2)	189E9	166.6E9	
Poisson's Ratio	0.3	0.45	
Density(kg/m^3)	8000	11360	

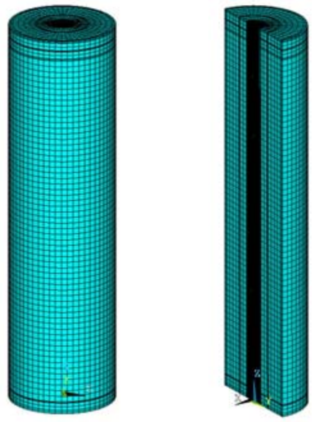

Fig. 1 ANSYS model of Cask

2.3 Design Requirements of Code

The fuel transfer cask is designed in accordance with ASME NB [3].

The results of the stress analysis shall satisfy the requirements of Table 2.

Table 2 Stress Limits for Design Condition, Level A and B

	Stress Limits
Design Condition	$P_m < S_m$, $P_L+P_b < 1.5S_m$
Level A and B	$P_m + P_L + P_e + Q < 3\ S_m$

2.4. Analysis Results

2.4.1 Dead Weight Analysis

The analysis results by the dead weight are shown in Fig. 2 .

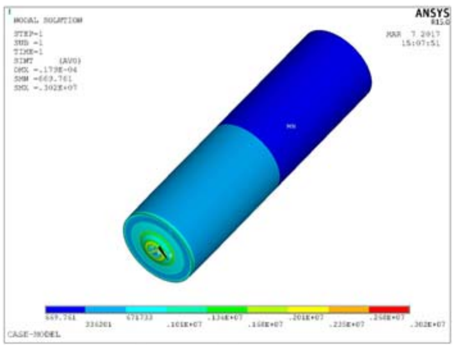

Fig. 2 Stress Distribution for Dead Weight Analysis

The linearized stresses at the bottom plate of the cask (node number 1867-1897) are shown in Table 3.

Table 3 Linearized stresses for dead weight analysis

P_m	0.624 MPa
P_m+P_b	2.215 MPa

2.4.2 Heat Transfer Analysis

In case that the fuel transfer cask holds a spent fuel assembly, the decay heat is as follows.

Q= 2000W/VOLUME = 2000 / 0.32 = 6250 (W/m^3)

20 ºC of the room temperature at the surface of the cask is applied to and the air cooling space is always maintained as 20 ºC. The results of the heat transfer analysis are shown in Fig. 3.

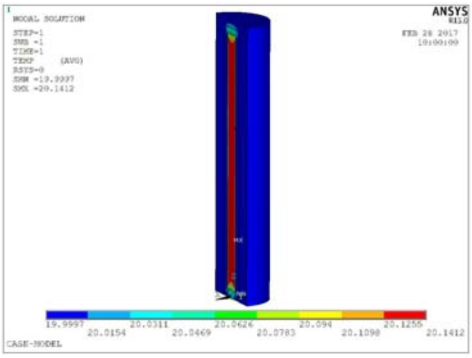

Fig. 3 Temperature Distribution for Heat Transfer Analysis

2.4.3 Thermal Stress Analysis

The results of the thermal stress analysis are shown in Fig. 4.

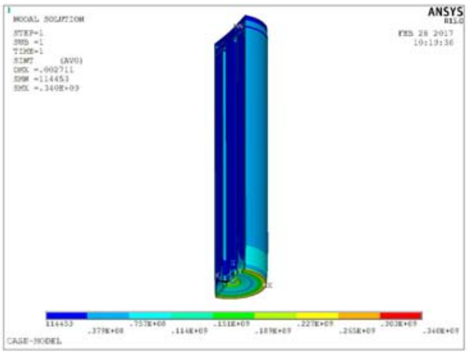

Fig. 4 Stress Distribution for Thermal Stress Analysis

The linearized stresses at the bottom plate of the cask (node number 3532-3562) are shown in Table 4.

Table 4 Linearized stresses for thermal stress analysis

$P_m +P_L +P_e +Q$	340.4 MPa

The stress intensity value of the SS316 at the room temperature is 137.9 MPa(S_m) [4]. Also, 1.5 S_m and 3 S_m of the SS316 are 206.85 MPa and 413.7 MPa respectively. The result values of the dead weight analysis and the thermal stress analysis are lower than the stress limits for Design Condition, Level A and B. Therefore, the structural integrity for the given dimension of the cask is confirmed.

3. Conclusions

The fuel transfer cask by the given dimension was designed and was modeled by ANSYS code. And then the dead weight analysis and the thermal stress analysis were performed. The result values of the analysis satisfied the stress limits for Design Condition, Level A and B of ASME NB. Therefore, the structural integrity for the given cask was confirmed.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science, ICT and Future Planning).

REFERENCES

[1] ANSYS Users manual, Release 15.0, ANSYS Inc.

[2] SFR-840-DM-306-001, Rev.0, Cask Thermal Design and Thermal Analysis Model, 2016

[3] ASME B&PV Sec. III, Division 1, Subsection NB.

[4] ASME Materials, Part D, Table 2A.