Thermal Stress Analysis for the Plate Type Fuel Assembly

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1. Introduction

The plate type fuel assembly is the most popular type of fuel assembly for research reactors. It is necessary to check the structural integrity of the fuel assemblies under pressure and temperature conditions in the reactor core.

The typical plate type fuel assembly was modeled using a 3-D solid element by IDEAS code and this modeling was transferred into the ANSYS INPUT. Also, the temperature and the pressure distribution of the plate type fuel assembly, which were obtained from the thermal hydraulic analysis, were added in the ANSYS INPUT. And then the thermal stress analyses were performed for estimating the structural integrity. The analysis results showed that the plate type fuel assembly of Aluminum Alloy 6061-T6 material meets the limits of stress intensity for Level A and Level B service of ASME Code, Section III, Subsection NB[1]. Also, the thermal stress analyses according to changing the boundary conditions for the nozzle were performed. That is, the thermal stress analyses according to the attachment methods of the nozzles were performed and the structural integrities of the plate type fuel assembly were estimated.

2. Methods and Results

2.1 FEM Model

The FEM model of the plate type fuel assembly is shown in Fig. 1. This model was made by the IDEAS Code and the only 1/4 of the plate type fuel assembly considering symmetric shape was modeled. The dimension of rectangular section was 85x76.2 (mm) and the height of the plate type fuel assembly was 1025 mm. The height of the nozzle was 185 mm. The modeling made by IDEAS Code was transferred into the ANSYS INPUT.

The temperature and pressure distribution in axial direction obtained in hydraulic analysis were added in ANSYS INPUT and the thermal stress analysis were performed. The Solid 92 element (10 Node Tetrahedral Structural Solid) was used for the stress analysis. The total nodes and elements of this model were 47,842 and 23,500 respectively.

2.2 Material Properties

The material of the plate type fuel assembly was Aluminum Alloy 6061-T6 and the mechanical properties were as follows.

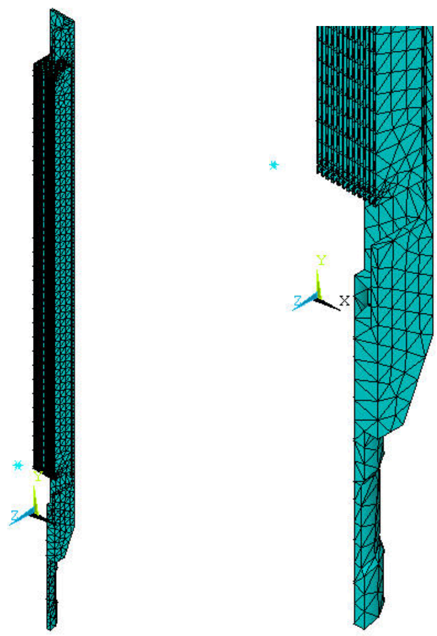

Fig. 1 FEM Model of the plate type fuel assembly

Ultimate Tensile Strength (MPa)	289.7
Yield Strength (MPa)	241.4
Modulus of Elasticity (MPa)	69000
Poisson's Ratio	0.33
Strength Intensity=S_m	96.5

2.3 Design Requirements of ASME Code

The plate type fuel assembly in the research reactor is generally classified as class 2 and should meet ASME Code, Sec. III, NC-3216 and Appendix XIII-1140[2]. But, the stress category of class 2 components is almost equal to that of class 1. Thus, the plate type fuel assembly is to be applied to the stress category of class 1 components. Stress Intensity of the plate type fuel assembly in Level A and Level B service should meet as follows.

$$P_L + P_b + Q < 3\,S_m$$

Where, P_L : Local Membrane Stress, P_b : Bending Stress, Q : Secondary Stress, S_m : Stress Intensity.

2.4 Analysis Results

The thermal stress analyses according to changing the boundary conditions between the nozzle and the plate which nozzle was inserted in were performed. That is, the thermal stress analyses according to the attachment methods between the nozzles and the plate were performed.

2.4.1 Fix for Upper and Bottom Part of Nozzle

In case of fixing the upper and bottom part of the nozzle (the displacements in x, y and z direction were fixed), the weak point (the point which the maximum stress is generated) was presented at the end of the nozzle (98.1 MPa) and the maximum displacement in the x direction was presented at the middle part of the fuel assembly (0.0649 mm) as shown in Fig. 2 and Fig.3.

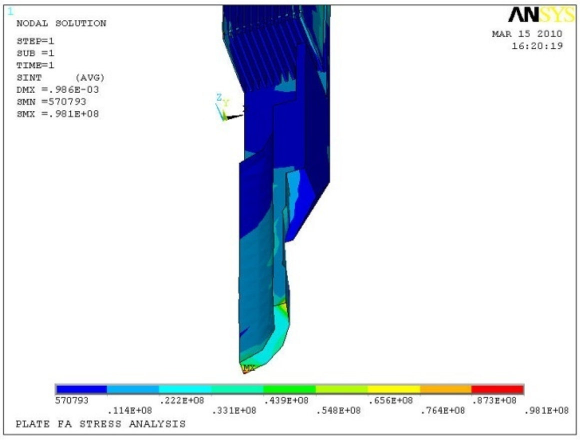

Fig. 2 Stress Contour

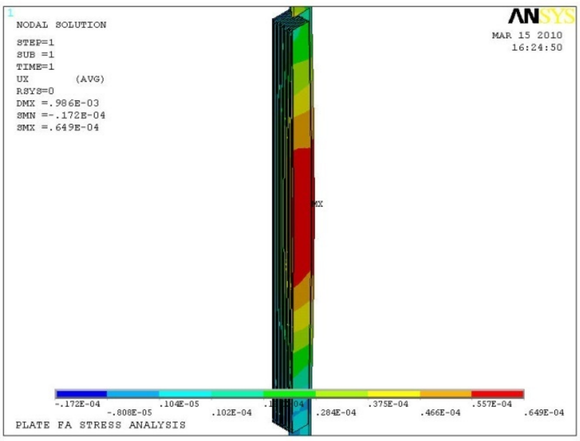

Fig. 3 Displacement Contour in the x direction

2.4.2 Fix for Bottom part of Nozzle

In case of fixing the bottom part of the nozzle, the weak point (the point which the maximum stress is generated) was presented at the end of the nozzle (91.4 MPa) and the maximum displacement in the x direction was presented at the middle part of the fuel assembly (0.0649 mm).

2.4.3 Fix for Bottom part of Fuel Assembly

In case of fixing the bottom part of the fuel assembly (F/A), the weak point (the point which the maximum stress is generated) was presented at the upper of the fuel assembly (53.2 MPa) and the maximum displacement in the x direction at the middle part of the fuel assembly (0.0649 mm).

The stresses of the analysis results were linearized again. The summary of these are as follows and these values are below 3 S_m (289.5 MPa). Therefore, the plate type fuel assembly of Aluminum Alloy 6061-T6 material meets the limits of stress intensity for Level A and Level B service of ASME Code, Section III, Subsection NB.

	Fix for upper and bottom part of nozzle	Fix for bottom part of nozzle	Fix for bottom part of F/A
Weak Point(MPa)	98.10	91.94	53.20
F/A Top Part(MPa)	16.71	16.71	16.71
Middle Part(MPa)	26.23	26.23	26.24
Bottom Part(MPa)	20.68	20.79	21.51
Nozzle Part(MPa)	21.44	2.66	0.4236
z- Displacement(mm)	0.00163	0.00119	0.000331

3. Conclusions

The typical plate type fuel assembly was modeled and analyzed by IDEAS code and ANSYS Code. The thermal stress analyses according to changing the boundary conditions between the nozzle and the plate were performed.

In case of the various fix methods, the results of thermal stresses were much lower than 3 S_m (289.5 MPa). Therefore, the structural integrity of the given plate type fuel assembly was checked for Level A and Level B service of the Nuclear Power Plant. Also, we can know that the design for the attachment between the fuel assembly nozzle and the plate is very flexible.

Acknowledgements

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REFERENCES

[1] ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, Division 1, Subsection NB, Class 1 Components, 1998.

[2] ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, Division 1, Subsection NC, Class 2 Components, 1998.