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Thermomechanical Analysis of Reactor Vessel Upper Head Vent Nozzles

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1. Introduction

Thermal and structural analyses are done for a reactor pressure vessel (RPV) upper head suffering from the primary water stress corrosion cracking (PWSCC) in Alloy 600 base metal nozzles resulting from the high welding residual stress. Circumferential cracks were also found in the control rod drive mechanism (CRDM) nozzles in U.S. nuclear power plants [1].

In this study analysis is done using ANSYS to look into thermal stress of RPV upper head vent nozzles except the weld zone.

2. ANSYS Analysis

2.1 Modeling and Meshing

The RPV upper head and nozzles were modeled to check on the thermomechanical behavior of a particular nozzle out of eighty four nozzles.

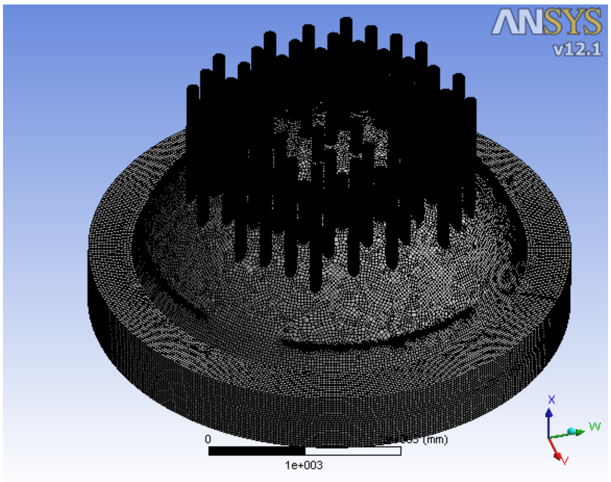

Fig. 1 RPV upper head and nozzles of the assembly.

Figure 1 shows the shape of the modeling assembly and illustrates how the grids of each part are made. The girds of two parts are generated with different meshing techniques. The RPV upper head is meshed in hexahedrons, whereas the nozzles are meshed in tetrahedrons. The number of nodes is 12,568,299.

2.2 Material Properties

Table I: Material properties [2]

Part	Material
RPV upper head	SA508
RPV top head vent nozzles	Alloy600

Table II: Material Properties Used in Analysis.

Materials	Elastic modulus [GPa]	Thermal expansion [/℃]	Yield strength [MPa]
SA508	192	1.15e-5	479.4
Alloy 600	214	1.22e-5	273.7

Materials	Density [ton/mm^3]	Specific heat [mm^2/s^2·℃]	Conductivity [kg·mm/s^3·℃]
SA508	7.83e-9	4e+8	40.7
Alloy 600	8.47e-9	4.42e+8	14.9

Table III: Boundary Conditions

Parameter	Operation
Operating load temperature [℃]	318.8
Out side temperature [℃]	48.9
Inside pressure [MPa]	15.51

Values in Tables I through III were supplied to ANSYS for thermal stress analysis of the RPV upper head nozzles. Temperature and convection were first set for a steady-state thermal analysis in ANSYS. Then the thermal distribution was determined. The static structural analysis was performed to find the von Mises stress. This completed the thermal stress analysis.

3. Methods and Results

Both the temperature distribution and the associated thermal stress were obtained by the use of ANSYS.

Figure 2 presents the steady-state temperatures in the range of 287.98℃ to 318.84℃.

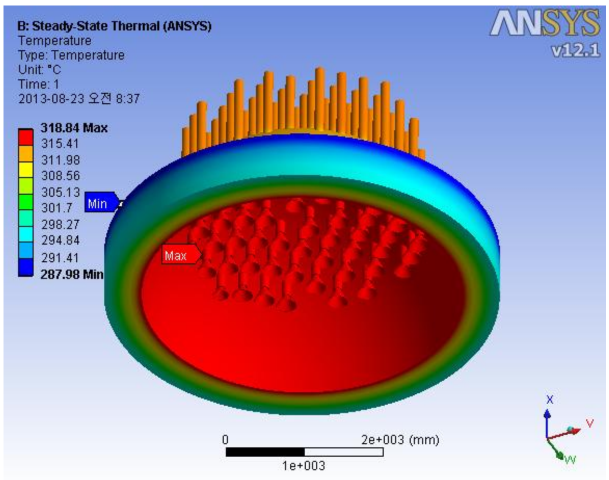

Fig. 2. Thermal analysis.

Figure 3 shows thermal stress applied to the nozzles. The residual stress grows from the outside toward the center in an asymmetric pattern.

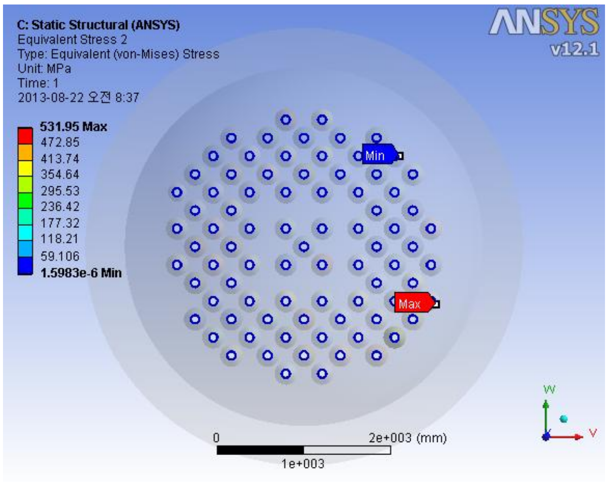

Fig. 3. Thermal stress analysis.

Figure 4 shows the maximum and minimum thermal stresses.

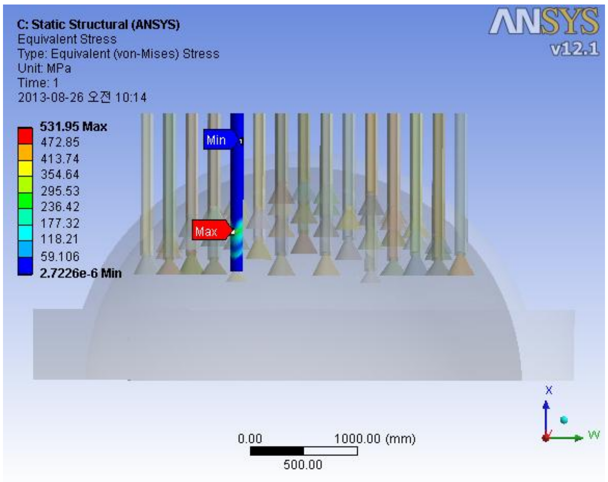

Fig. 3 Thermal stress of a RPV top head vent nozzle.

4. Conclusions

This study has observed the thermal stresses applied to twenty two nozzles of the eighty four nozzles. However, relatively small stress distribution is shown, because we did not consider the effect of residual stress for welding. Further study is in progress to account for the residual stress in the boundary conditions for weld.

REFERENCES

[1] H.Y. Bae, et al. "Sensitivity Analysis of Nozzle Geometry Variables for Estimating Residual Stress in RPV CRDM Penetration Nozzle" *Trans. Korean Soc. Mech. Eng. A*, Vol. 37, No. 3, pp. 387~395, 2013.

[2] YGN 3&4 Final Safety Analysis Report, Korea Hydro & Nuclear Power Co. Ltd., 1995.