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Structural Analysis of the Pantograph Type IVTM in PGSFR

S. H. Kim [a*], G. H. Koo [a]
[a]*Korea Atomic Energy Research Institute, Daejeon 305-600, The Republic of Korea*

[*]*Corresponding author: shkim5@kaeri.re.kr*

1. Introduction

The pantograph type IVTM (In–Vessel Transfer Machine) in PGSFR handle fuel assemblies inside the reactor core, which has six kinds of movements and transfers the new and spent core assemblies between the fuel transfer port and the reactor core. The main components of the IVTM are composed of the upper driving part, the main tube and the pantograph arm including the gripper. The upper part which is driven by the motor is excluded from the analysis model. In the IVTM, the main tube supports the pantograph arm and the slot in which the movement of the pantograph arm is possible. The gripper mechanism is mounted to the gripper guide structure and the vertical movement of the gripper is possible by using the screw driver shaft [1].

In this study, we performed the primary stress analysis by considering the IVTM 3D configuration. Also, the thermal stress analysis was carried out and the mode characteristics of the structure by the natural frequency analysis were analyzed. The material of the IVTM is the 316 stainless steel and the ANSYS 14.5 is used for the finite element analysis. The analysis is performed on the basis of the configuration presented in the Fig. 1.

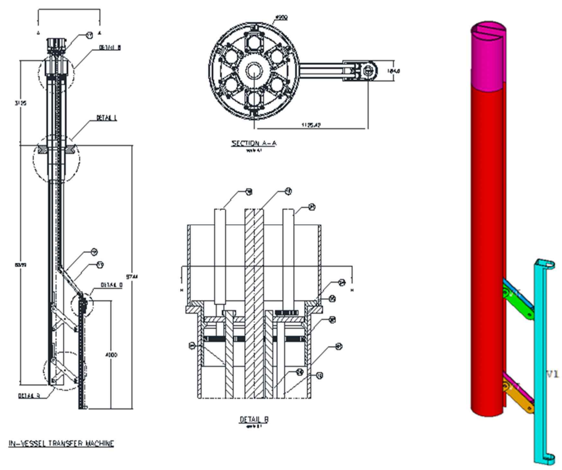


Fig.1 IVTM configuration and analysis model

2. Structural Analysis for the Pantograph Type IVTM

2.1 Primary Stress Analysis for Design Loads

The IVTM is supported by the rotating plug, which has the maximum arm length of 1.125 m. When the fuel assemblies are inserted and withdrawn from the reactor core, the refueling design load of 24.5 kN is considered at the gripper. The primary stress analysis is carried out by considering the above design load and a dead weight. Fig. 2 shows the stress intensity distribution due to the refueling design load and the dead weight. As shown in this figure, the maximum stress intensity is 40.6 MPa. Also, from the Fig. 3, we can see that the maximum stress occurs at the rotation pin joint of the pantograph arm link. The maximum displacement is 4mm, which occurs at the lowest end of the pantograph arm.

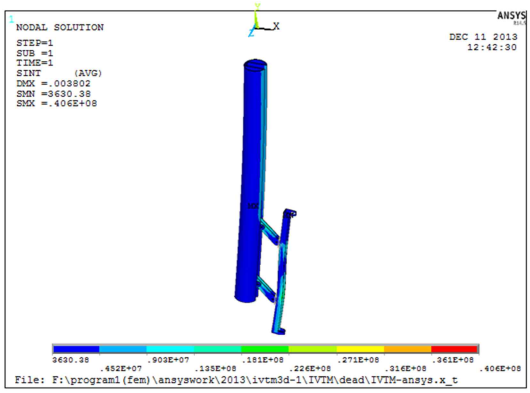


Fig.2 Stress intensity distribution for the primary design load

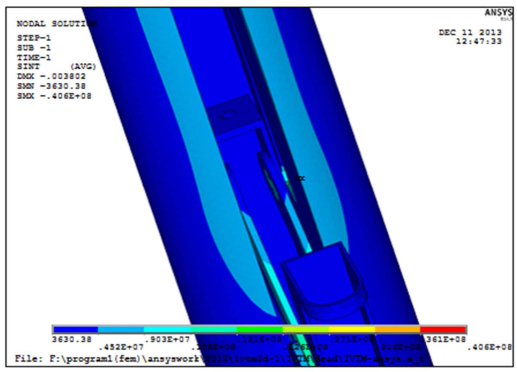


Fig.3 Maximum stress intensity location for the primary design load

2.2. Thermal Stress Analysis

In the thermal stress analysis, the temperature distribution of the coolant around the IVTM is assumed conservatively as a bulk temperature by the reactor level. As a boundary condition, the top surface of the IVTM is simply supported in an axial direction and a node is fully constrained to prevent the stress concentration. The maximum coolant temperature around the IVTM is 545 °C and the used heat transfer coefficient in the reactor cover gas region is 2.2783 W/ °C-m^2. As a result of the analysis, the temperature distribution of the IVTM by the thermal load is calculated as shown in Fig. 4. Fig. 5 shows the stress intensity distribution for the thermal load. As shown in this figure, the maximum stress intensity is 41.3 MPa, which is generated at the welded joint of the top surface. The maximum displacement as shown in Fig. 6 is calculated as 4.8 mm.

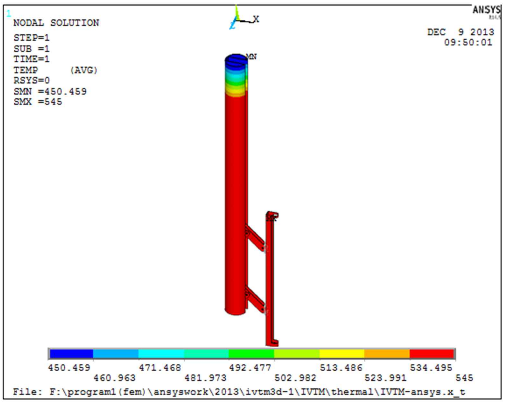


Fig. 4 Temperature distribution for the thermal load

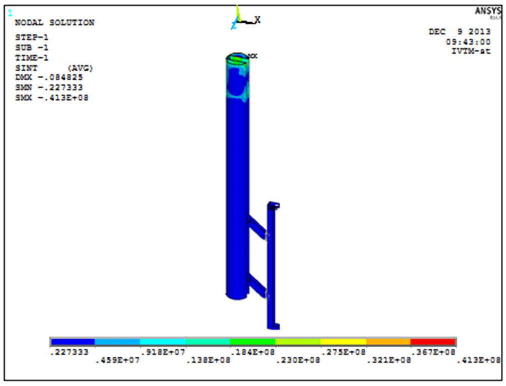


Fig. 5 Stress intensity distribution for the thermal load

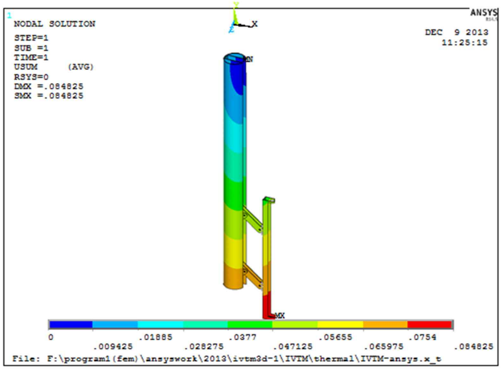
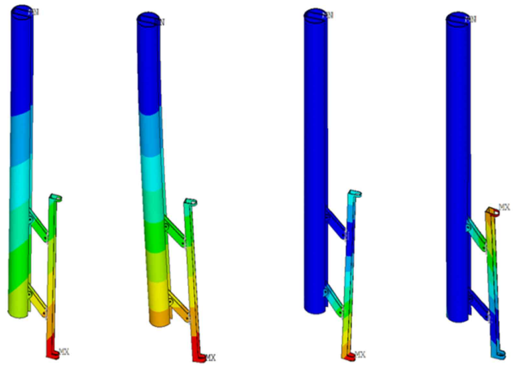


Fig. 6 Displacement distribution for the thermal load

2.3 Natural Frequency Analysis

The natural frequency analysis is performed to understand characteristics of the vibration mode of the IVTM. As a result of the analysis, the dominant natural frequencies of the IVTM are evaluated as shown in Fig. 7. Fig. 8 represents the first mode shape of the natural frequency analysis. In this figure, we can see that the main tube bending is dominant mode and the natural frequency is 6.87 Hz.



(6.87 Hz) (7.69 Hz) (20.09 Hz) (20.64 Hz)

Fig. 7 Mode shapes for the natural frequency analysis

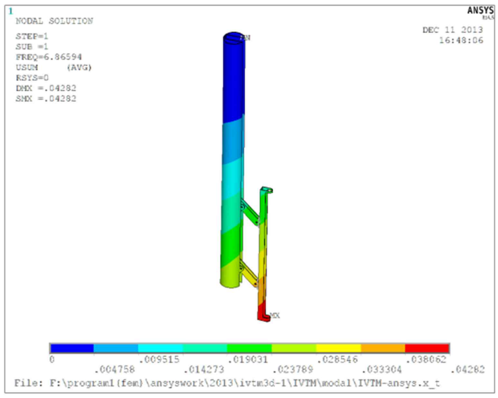


Fig. 8 First mode of the natural frequency analysis

3. Conclusion

The structural analyses are carried out to evaluate the structural integrity of the IVTM. The primary stress analysis for the refueling design load, the thermal stress analysis and the natural frequency analysis are performed, and the stresses and displacements are evaluated.

Acknowledgements

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REFERENCES

[1] ANL, Advanced Burner Test Reactor Preconceptual Design Report, ANL-ABR-1, 2006.