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Structural Integrity Evaluation for the IVTM Gripper in PGSFR

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1. Introduction

The IVTM (In-Vessel Transfer Machine) is the instrument for transferring the core assembly inside the reactor vessel. The IVTM use the gripper finger for the connection and disconnection with the core assembly, which is designed to be possible for the rotation and vertical movement of the gripper. Fig. 1 shows the 2D design drawing of the IVTM. In this figure, we can see that the IVTM gripper is supported by the gripper guide structure. In the gripper movement, the gripper is lowered to pick up the core assembly with its fingers closed. On contact with the end of the core assembly, the gripper fingers are opened, and then connected with the core assembly. The gripper is then raised with the core assembly. This is the gripper mechanism to handle the core assembly.

The purpose of this study is to analyze the gripper stresses and displacements for the design loads applied to the gripper, and also to evaluate the structural integrity of the gripper design for 60 year lifetime. The materials of the gripper used for the analysis are the 316 SS in the gripper body parts and the Inconel 718 alloy in the gripper finger parts, respectively [1].

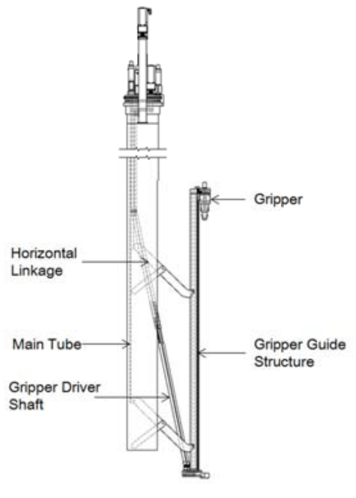


Fig. 1 Design configuration of the IVTM in PGSFR

2. Modeling of a gripper

Fig. 2 represents the 3D configuration and half-symmetric model for the structural analysis of the IVTM gripper using the ANSYS code [2]. The analysis model contains the gripper post, the gripper head and gripper finger parts. The total length of the gripper is 510 mm. In addition, the length and width of the gripper finger which can connect and disconnect the core assembly are 195.4 mm and 150.1 mm, respectively.

As shown in Fig. 2, the gripper fingers are fixed by the pin, and activated by the gripper actuator shaft. Fig. 3 shows the boundary condition for the gripper. The dead weight and the maximum refueling load of 27 kN which can be considered in the malfunction of the gripper are applied to the lower part of the gripper finger. In the constraint condition, the end part of the gripper head is fixed, and the contact condition of no separation is applied on the contact surfaces for the rotation of the gripper fingers. The thermal stress analysis is not considered because the analysis structure is local, and has the identical temperature distribution in entire position.

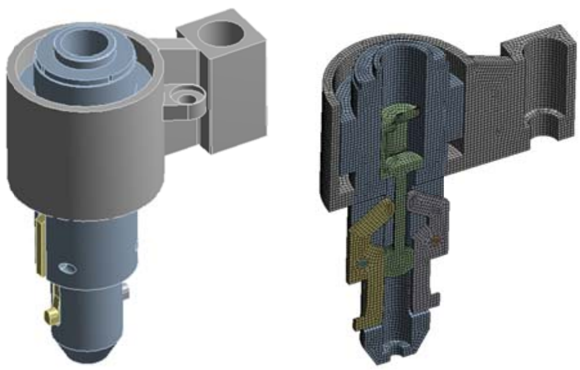


Fig. 2 3D configuration and half-symmetric model of the gripper

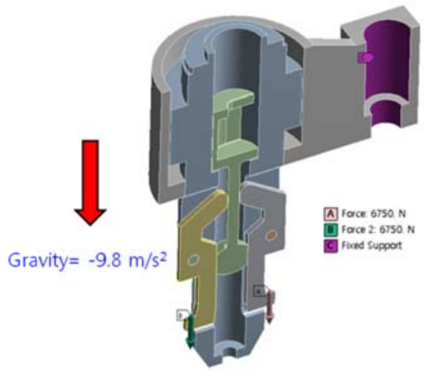


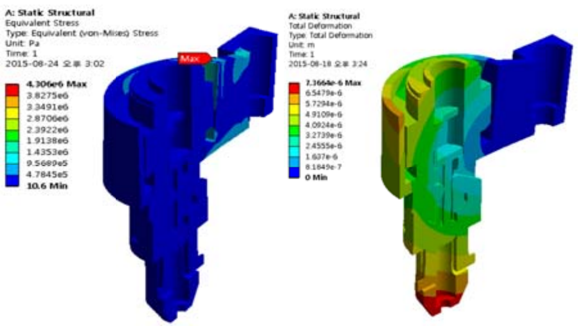
Fig. 3 Boundary condition for the stress analysis

3. Results and discussions

Fig. 4 (a) shows the primary stress analysis result for the dead weight. The maximum stress of 4.6 MPa occurs at the geometrical discontinuity of the upper part of the gripper head. From this figure, one can see that the stress level for the dead weight is very small. Fig. 4 (b) indicates the maximum displacements due to the dead weight. As shown in this figure, the maximum displacement of 0.007 mm occurs in the lowest part of the gripper.

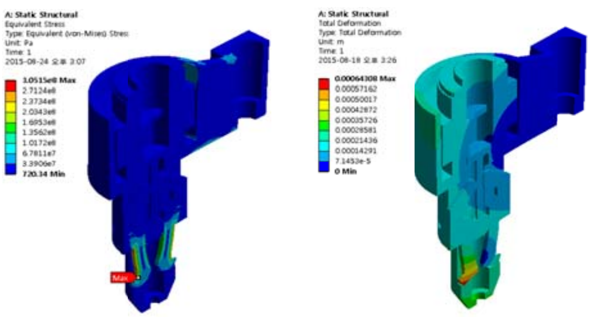
Fig. 5 (a) and Fig. 5 (b) show the gripper analysis result for the refueling load. The maximum stress of 310.6 MPa occurs at the geometrical discontinuity of the gripper finger as shown in Fig. 5 (a). As this location is the part that supports the refueling load applied to the gripper finger, which generates high stresses at the gripper finger. Fig. 5 (b) shows the maximum displacement for the refueling load. As shown in this figure, the maximum displacement of 0.6 mm is generated at the lowest part of the gripper finger. For the evaluation according to the ASME design rule on the stress analysis results [3], the stress evaluation sections should be chosen on high stress generation positions, and then the stress linearization should be performed. Fig. 6 shows the evaluation cross sections of the gripper. In this figure, we can see the high stress regions at the gripper finger.

From this result, six evaluation sections are chosen for the left sided gripper finger because the stress distribution between two fingers has the symmetry. For the evaluation according to the ASME design rule, the structural integrity evaluation is performed on the evaluation sections. Table 1 shows the structural integrity check results of the IVTM gripper for the design condition. As shown in this table, the maximum membrane stress of 271.5 MPa occurs in the outer surface of the evaluation section E.



(a) Stress intensity (b) Displacement

Fig. 4 Gripper analysis result for the dead weight



(a) Stress intensity (b) Displacement

Fig. 5 Gripper analysis result for the refueling load

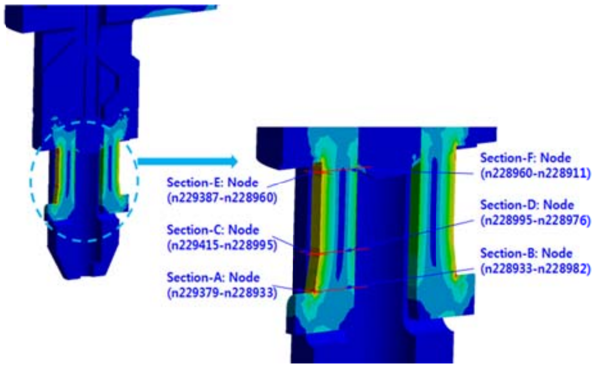


Fig. 6 Evaluation cross sections of the gripper

In addition, it is confirmed that the primary stress evaluation for the design condition satisfies the design rule.

Table 1 Structural integrity check results

Sections	Nodes	Linearized Stress	Calculated Stress (MPa)	Allowable Stress (MPa)	Results	Temperature (°C)	C&S
Section-A	Inner (229379)	Pm	228.3	Sm = 318	0.393	200	ASME Sec III Div1-NB
		PL+Pb	206.0	1.5Sm = 477	1.316		
	Outer (228933)	Pm	228.3	Sm = 318	0.393	200	ASME Sec III Div1-NB
		PL+Pb	324.3	1.5Sm = 477	0.471		
Section-B	Inner (228933)	Pm	35.1	Sm = 318	8.060	200	ASME Sec III Div1-NB
		PL+Pb	180.9	1.5Sm = 477	1.637		
	Outer (228982)	Pm	35.1	Sm = 318	8.060	200	ASME Sec III Div1-NB
		PL+Pb	120.4	1.5Sm = 477	2.962		
Section-C	Inner (229415)	Pm	259.7	Sm = 318	0.224	200	ASME Sec III Div1-NB
		PL+Pb	259.4	1.5Sm = 477	0.839		
	Outer (228995)	Pm	259.7	Sm = 318	0.224	200	ASME Sec III Div1-NB
		PL+Pb	260.8	1.5Sm = 477	0.829		
Section-D	Inner (228995)	Pm	35.7	Sm = 318	7.908	200	ASME Sec III Div1-NB
		PL+Pb	226.1	1.5Sm = 477	1.110		
	Outer (228976)	Pm	35.7	Sm = 318	7.908	200	ASME Sec III Div1-NB
		PL+Pb	157.0	1.5Sm = 477	2.038		
Section-E	Inner (229387)	Pm	271.5	Sm = 318	0.171	200	ASME Sec III Div1-NB
		PL+Pb	257.9	1.5Sm = 477	0.850		
	Outer (228960)	Pm	271.5	Sm = 318	0.171	200	ASME Sec III Div1-NB
		PL+Pb	285.0	1.5Sm = 477	0.674		
Section-F	Inner (228960)	Pm	43.0	Sm = 318	6.395	200	ASME Sec III Div1-NB
		PL+Pb	230.6	1.5Sm = 477	1.069		
	Outer (228911)	Pm	43.0	Sm = 318	6.395	200	ASME Sec III Div1-NB
		PL+Pb	157.0	1.5Sm = 477	2.038		

4. Conclusions

For six sections of the IVTM gripper, the structural integrity according to ASME-NB design rule is checked for the dead weight and refueling load because it is under the low temperature during the refueling operation. As a result of the evaluation, it is reviewed the IVTM gripper design has the structural adequacy.

Acknowledgements

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REFERENCES

[1] ASME Boiler and Pressure Vessel Section II, Part A, Part D, ASME, 2013.
[2] ANSYS User's Manual for Revision 15.0, ANSYS Inc.
[3] ASME Boiler and Pressure Vessel Code Section III, Subsection NB, ASME, 2013.