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Analysis of Hold Down Force for IVTM in PGSFR

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1. Introduction

The PGSFR (Prototype Generation IV Sodium Cooled Fast Reactor) is a new design for a compact sodium-cooled fast nuclear reactor. The main components of the IVTM (In-Vessel Transfer Machine) for PGSFR are composed of the upper driving part, the main tube and the pantograph arm including the gripper. As shown in Figure 1, the bottom of the pantograph arm has a tapered feature machined into it at the interface where it contacts the surrounding core assemblies when the hold down is engaged. A tapered feature on the core hold down assembly engages features in the top of the core assemblies and may help to reduce the deflections at the bottom of the main structural support tube while under refueling loads. Hold down force is one of the most important parameter for design IVTM.

2. FE Analyses

2.1 FE Model

Preliminary finite element analyses were performed to simulate the effects of using the tapered core spreader features on the bottom of the pantograph arm and on the tops of the core handling sockets of the surrounding core assemblies. The goal was to determine the hold down force, stresses and deflections in the IVTM components and in a set of six surrounding core assemblies which are located inside the reactor core. Frictionless separation constraints were defined between the contacting surfaces of the IVTM hold down and the top contacting surfaces of the modified core handling sockets on the surrounding core assemblies. Fixed boundary conditions were applied to the outer cylindrical surfaces on the bottom of the core assembly.

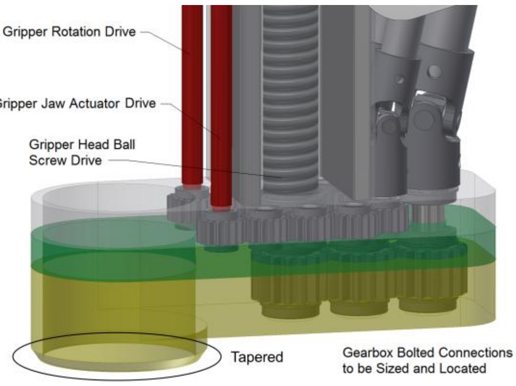

Fig. 1. The bottom of the pantograph arm

2.2 FE Analysis

Elastic numerical simulations were performed using the finite element software package ABAQUS v.6.14 [1]. Figure 2 illustrate a typical FE mesh for analysis with fuel assemblies. Eight-node linear brick elements (C3D8) were used and the small strain assumption was employed in the elastic analyses. Top Load Pad (TLP) surfaces are shown in Figure 2 with red lines.

3. Results

3.1 Reaction Force and Displacement

Elastic numerical simulations were performed using the finite element software. The analysis is performed with two steps. In first step, Design loads, 500N are applied for each TLP surfaces. All fuel assemblies are contact with other fuel assemblies as shown in figure 3.

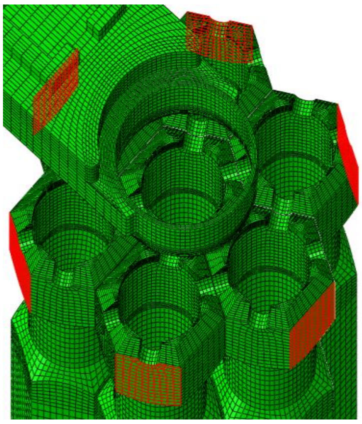

Fig. 2. Typical FE mesh for FE analyses with TLP surfaces

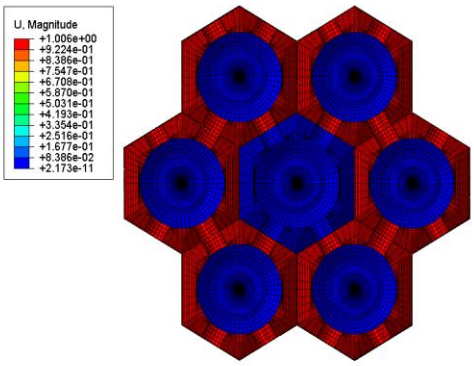

Fig. 3. Contour plot for displacement at the end of first step

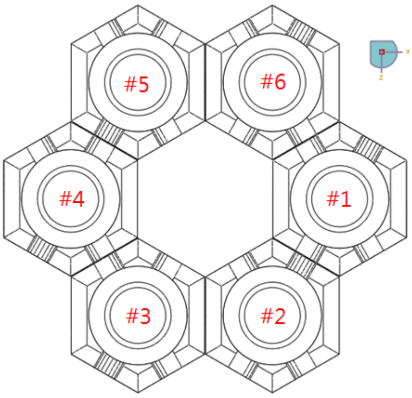

Fig. 4. Fuel assembly number for each fuel assembly

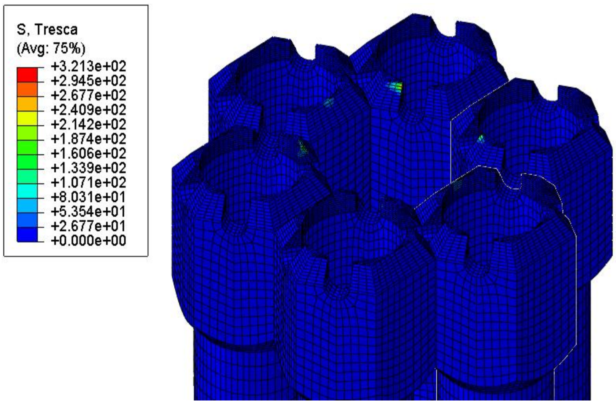

Fig. 5. Stress distribution of fuel assemblies

In second step, apply displacement to hold down plate. The hold down displacement and reaction forces of fuel assemblies when all fuel assemblies are detached are summarized in table 1. The hold down force and displacement are 3626.8 N and -2.27 mm, respectively. The maximum reaction force of fuel assembly is 641.05 N.

3.1 Stress and Deformation

Figure 5 shows the contour plot of stress distribution. The maximum stress is 321 MPa at contact surface with hold down plate. Figure 6 shows the contour plot of deformation of hold down plate. The deflection of hold down plate is 0.044 mm.

3. Conclusions

Elastic FE analysis was performed to calculate hold down force and displacement. The design load for top load pad is 500 N. The hold down force and displacement are 3626.8 N and -2.27 mm, respectively. The calculated values will be used to design IVTM for PGSFR. The maximum reaction force of fuel assembly is 641.05 N. The calculated values will be used to design receptacle and lower grid plate for PGSFR.

Table 1. Hold down force, displacement and Reaction forces of fuel assemblies

Hold Down		Reaction Forces of Fuel Assemblies (N)					
Force (N)	Disp. (mm)	#1	#2	#3	#4	#5	#6
3623.83	-2.27	641.05	582.828	588.905	639.316	588.852	582.88

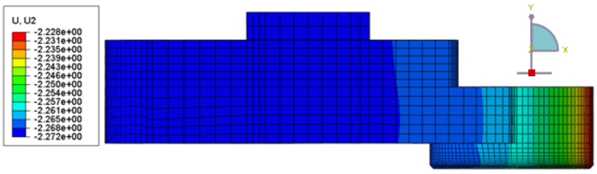

Fig. 6. Deflection of Hold down plate

REFERENCES

[1] ABAQUS Ver. 6.14 User's manual, Dassault Systemes, 2014.