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Comparison Study on Finite Element Model for Structural Analysis of Lower CTS Cylinder Lifting Adaptor in ITER Assembly Tool

Jinho Bae [a]*, Kyoungo Nam [a], Hyunki Park [a], Dongjin Kim [a], Heejae Ahn [a], Yongsu Yoo [b], Emma Watson [c], Robert Shaw [c]
[a] *ITER Korea National Fusion Research Institute, Gwahangno 305-806, Yuseong, Daejeon, Korea 169-148*
[a] *SFA Engineering Corp., 166 Sinhang-ri, Dunpo-myeon, Asan-si, Chungcheongnam-do, 336-873, Korea*
[c] *ITER Organization, CS 90 046, 13067 St Paul lez Durance Cedex, France*
**Corresponding author: jhbae@nfri.re.kr*

1. Introduction

The ITER tokamak assembly tools are purpose-built and specially designed to complete the ITER tokamak machine which includes; Vacuum Vessel (VV), VV Thermal Shield (VVTS) and Cryostat Thermal Shield (CTS), Toroidal Field Coil (TFC) and Poloidal Field (PF) coils, and other components contained in the cryostat. Based on the engineering design and design description documents prepared by the ITER organization (IO)[1, 2]. In this paper, FE models to verify the structural integrity of the Lower Cryostat Thermal Shield (LCTS) Lifting Adaptor are prepared and compared with their structure analysis result.

2. Description of the LCTS Assembly Tools

The LCTS (Figure 1) consist of the LCTS cylinder and the LCTS floor and it is supported by mounting it off the cryostat floor. The primary function of the CTS is to shield the superconducting magnets from heat radiating from the inner wall of the cryostat [3]. The LCTS cylinder is envisaged to be transferred from the Assembly hall to the Tokamak Pit, for its final installation on the cryostat base. The same lifting frame is used to lift and install the lower/upper CC feeder rings, CC feeder ring lift tool is used; only the lifting adaptor for LCTS cylinder are counted in here. This tool is envisaged to have interfaces with LCTS cylinder and its segments and CC feeder ring lift tool [4]. Figure 2 shows the 3D model of the LCTS Lifting adaptor.

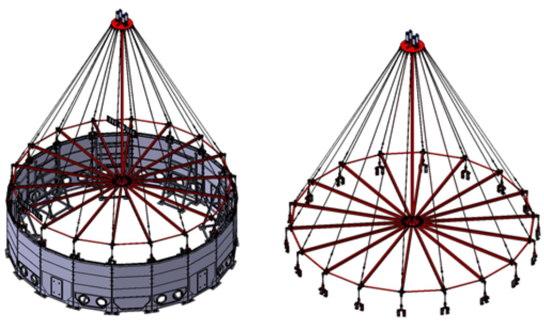


Fig. 1. Configuration of CC Feeder ring lift tool installed with LCTS Cylinders assembled and CC Feeder ring lift tool disassembled

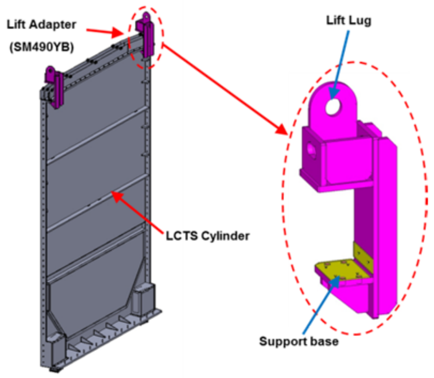


Fig. 2. Configuration of Lower Cryostat Thermal Shield Cylinder and Lift Adaptor

3. FE Analysis

3.1 FE Models and Material property

The ANSYS Workbench that is a common FEM program is used in this numerical analysis to calculate deflection and stress of LCTS lifting adaptor in the ITER assembly tool. Its material used in this analysis is SM490YB, and material properties are specified in the following table 1. The Yield and allowable stress are 355 and 234 MPa respectively

Table. 1 Material Property of SM490YB

Material	SM490YB
Young's Modulus [MPa]	2.06E+05
Poisson's ratio	0.3
Density [kg/mm³]	7.85E-06

3.2 Boundary and Load condition

The analysis is applied with design factors in ITER Load Specification Document [5]. According to Appendix A of the document, LCTS lifting adaptor is identified as Lifting Accessories. Its design factor is shown in the table 2. The weights for one panel and adaptor are 2.5 tones and 60 kg respectively in 3D model. According to table, the weights are applied Dynamic amplification factor 2.0 and tool factor 1.35. So, the vertical load that was calculated by load factors is about 25,320N. The force is applied to Lug of adaptor in this analysis.

Table. 2 Minimum design factors of Lifting Accessories

Stress (based on yield stress)	Fy/1.1
Safety factor	Not applied
Dynamic amplification factor	2.0

Fy = Material yield stress

In the ANSYS, there are three types of Boundary Condition (BC) that are 'fixed support', 'displacement' and 'remote displacement'. All of conditions can be apply on vertices, edges. They are able to prevent nodes from moving X-, Y-, and Z-directions rotations for beam/shell elements [6]. Each BC's characters seem similar but they are some different. Especially, 'remote displacement' is able to select the two behaviors that are 'Rigid' and 'Deformable' at the chosen area. If use 'Rigid' behavior in analysis, that result should be approximately equal to other analysis with 'fixed support' and 'displacement' applied. But, if use 'Deformable' behavior in analysis, that all of results are changed, because 'Deformable' option allows that the selected geometry is free to deform as shown in figure 3.

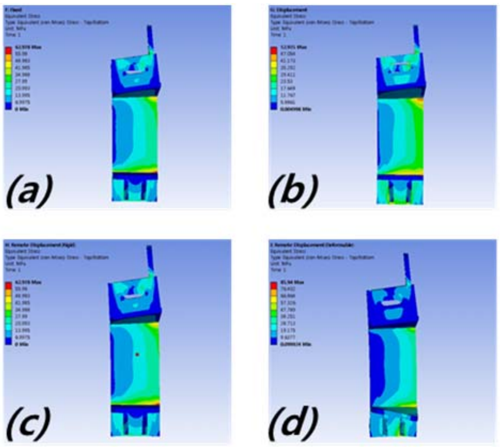
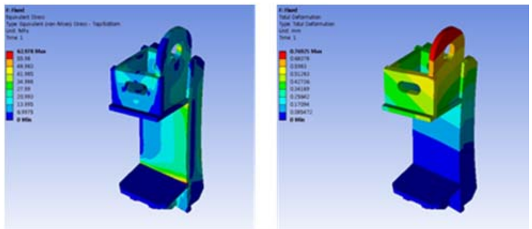


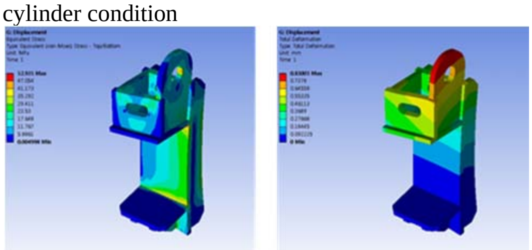
Fig. 3. Equivalent stress results of BC cases; (a) Fixed Support (b) Displacement (all of values are zero) (c) Remote Displacement (all of values are zero, and Rigid applied) (d) Remote Displacement (all of values are zero, and Deformable applied)

4. Structure Analysis Results

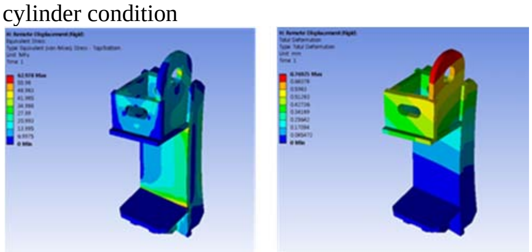
In case of 'fixed support' applied, the maximum displacement is 1 mm at end of lug as shown in (a-1) and The maximum equivalent stress is 50 MPa at support base as shown in (a-2). In case of 'displacement' applied, the maximum displacement and equivalent stress are 1 mm and 50 MPa respectively as shown in (b). In case of 'remote displacement' applied, the maximum displacement and equivalent stress are 10 mm and 80 MPa respectively as shown in (c). In this case, equivalent stress is higher than the others. The result is caused by deformation at selected geometry. In all of analysis, stress value is below than the allowable stress 234 MPa.



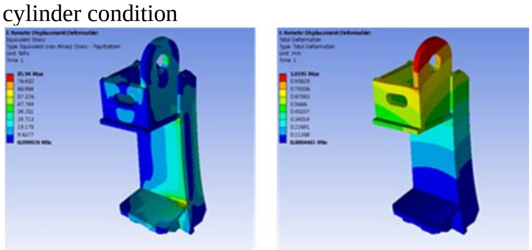
(a) 62.9 MPa and 0.77 mm respectively in lifting one cylinder condition



(b) 52.9 MPa and 0.83 mm respectively in lifting one cylinder condition



(c) 62.9 MPa and 0.77 mm respectively in lifting one cylinder condition



(c) 85.9 MPa and 1.02 mm respectively in lifting one cylinder condition

Fig. 4. Equivalent stress and displacement results

5. Conclusion

In the paper, each analysis result with difference BC applied was compared with the equivalent stress and the results of analysis were evaluated according to SM490YB's allowable stress. And the conclusions of this paper are summarized as following.

- The structural stabilities of the LCTS lift adaptor have been studied using ANSYS codes for verifying structural strength for this tool. The results of the analysis show that; for the structural stability of the sector lifting tool considering Dynamic amplification factor 2.0, tool factor 1.35 and BCs, all equivalent stress are less than allowable stress.

- This analysis with deformable behavior applied at support area is suitable to ensure more conservative for design of lift adaptor.

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