Calculation No:<u>NSTXU-CALC-11-29-00</u> **Revision No:<u>0</u>**

Title:* *OBD12 Hold Down Submodel

Purpose of Calculation: (Define why the calculation is being performed.)

High local contact stresses between the hold down rods and the OBD12 tiles, in the preliminary design review, resulted from contact between the rods and graphite at the boundary of holes for threaded fasteners. Reducing the rod diameter at this area can significantly reduce these contact stresses by moving the contact point away from the hole boundary. A local model was used to analyze this effect.

Codes and versions: (List all codes, if any, used)

ANSYS version 19

References (List any source of design information including computer program titles and revision levels.)

Drawing E-ED1408, Row 1 and 2 Outboard Divertor Tiles Assembly and Details

Assumptions (Identify all ssumptions made as part of this calculation.)

Assume 230 pound preload per fastener – a conservative value. Sigrafine R6510 and 316 Stainless Steel are the tile and rod materials. Nonlinear contact elements are used in the model.

Calculation (Calculation is either documented here or attached)

Using symmetry, ¼ of the block/rod model was analyzed. The details of the calculations are contained on the following pages.

Conclusion (Specify whether or not the purpose of the calculation was accomplished.)

The maximum principal stress is 5.25 MPa, significantly below the allowable value of 19.0 MPa. The stress contour plots clearly show that the contact point has moved away from the sharp edge of the hole.

Cognizant Individual (or designee) printed name, signature, and date

Robert Ellis Digitally signed by Robert Ellis Date: 2018.09.24 12:16:40 -04'00'

Preparer's printed name, signature and date

Robert Ellis Digitally signed by Robert Ellis Date: 2018.09.24 12:16:57 -04'00'

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Checker's printed name, signature, and date Jiarong Fang Digitally signed by Jiarong Fang Date: 2018.09.27 16:53:49 -04'00'

Analysis of Simplified Model of OBD12 Tile Hold Down Rod

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1.0 INTRODUCTION

The simplified model of the ODB12 tile hold down rod has been completed. The model consists of a SGL R6510 graphite block with a 316 stainless steel rod as shown in Figure 1. The block is shown in magenta and the rod is shown in cyan.

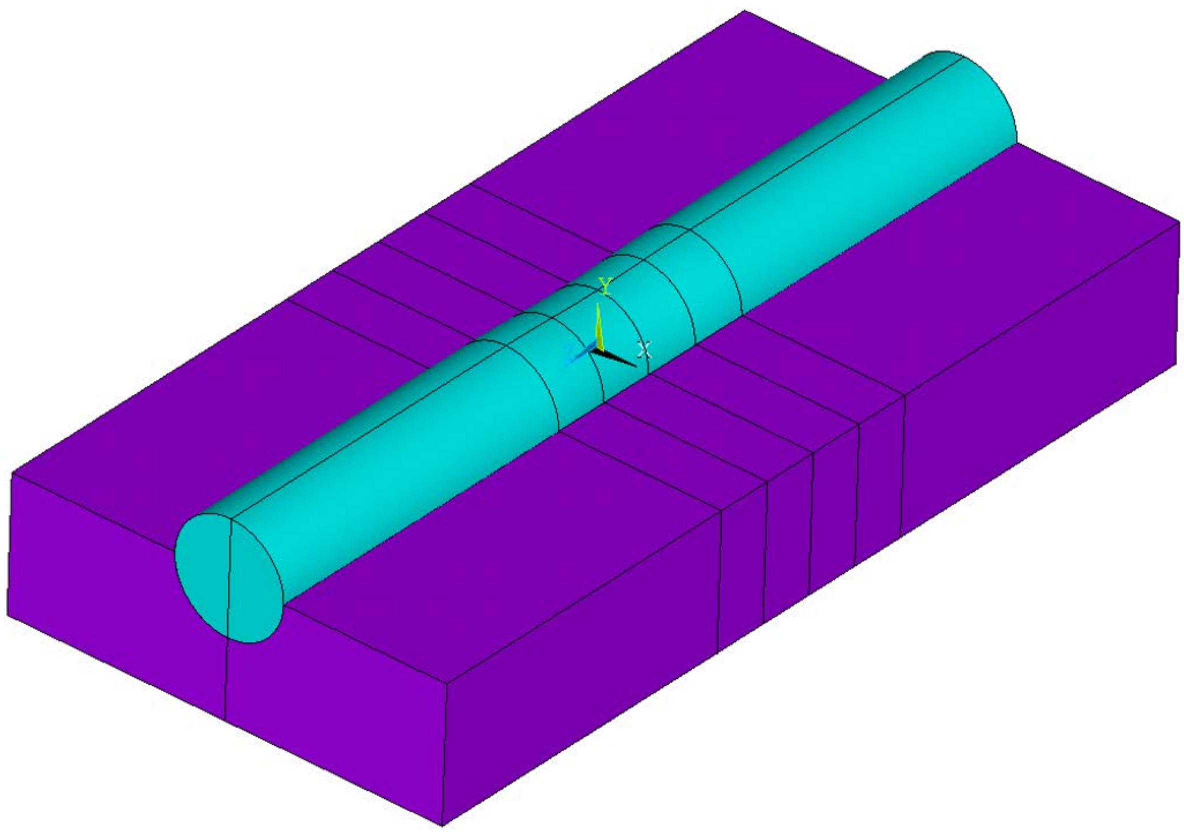

Figure 1. SGL R6510 Block and 316 Stainless Steel Rod

2.0 ELEMENT INFORMATION

Due to symmetry it is only necessary to model ¼ of the model as shown in Figure 2. The model includes standard contact elements with a friction coefficient of 0.3 between the block and rod. The rod is tapered from the center 9.525 mm, for a total of 19.05 mm. The mesh is shown in Figure 3. The figure shows that the mesh is refined in the region of the initial contact, at the end of the taper. The mesh is predominately hex elements. The rod is all hex elements. The small section around the hole is the only region that is not hex elements, as shown in the right side of Figure 3. This is away from the initial contact and is not in a high stress region. The model contains 75,606 Solid186 elements, 2387 Targe170 elements and 2729 Conta174 elements for a total of 80,722 elements. The model has 312,661 nodes. The element mesh on the rod was specified as 0.0005 m. The refined mesh on the graphite block around the contact region was specified as 0.0002 m.

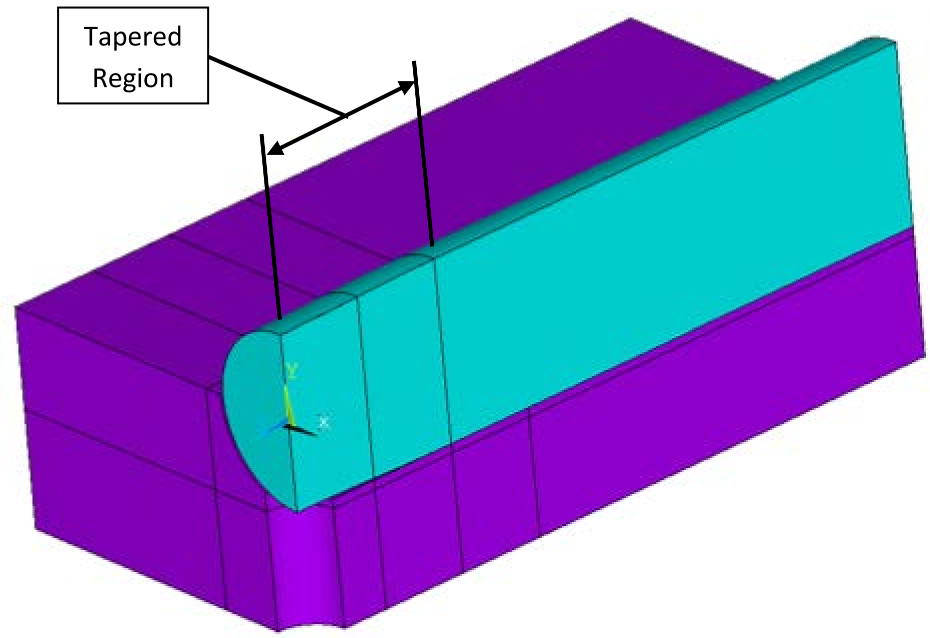

Figure 2. Quarter Model of the Block and Rod

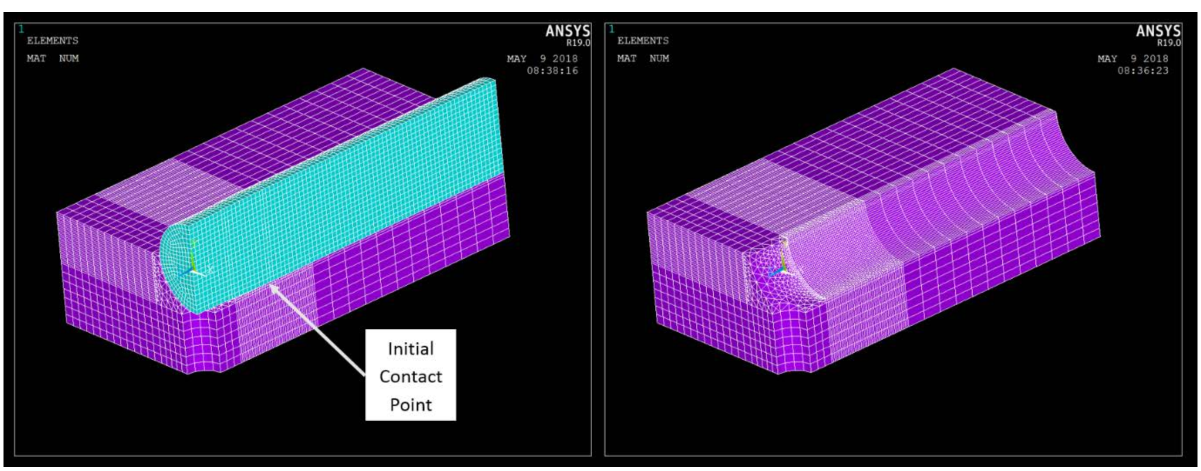

Figure 3. Quarter Model Mesh

3.0 Materials

The materials in the model consists of SGL R6510 for the graphite block and 316 stainless steel for the rod. The SGL R6510 material is from the PPPL workbench material file and the properties for the stainless steel are from the ITER Material Handbook (ITER Material Properties Handbook for 316 Stainless). The properties used in the analysis are shown in Table 1.

Table 1. Material Properties

Material	Modulus of Elasticity	Poisson's Ration	Ultimate Tensile Strength	Ultimate Compressive Strength
SST 316	198.8 GPa	0.29	577 MPa	
SGL R6510	11.5 GPa	0.3	38 MPa	130 MPa

4.0 Loads and Boundary Conditions

The load applied to the model is equivalent to a force of 1023 N (230 lbf). Due to symmetry an actual force of 1023/4 or 255.75 N was applied to the top of the rod as shown in Figure 4. Symmetry boundary conditions were applied to the red faces shown in the figure to account for the quarter symmetry. The back face is fixed in the direction normal to the plane (Z-direction). This is actually another symmetry plane, due to the block and rod extending to another bolted location. The bottom faces of the block are fixed in the vertical direction (Y-direction).

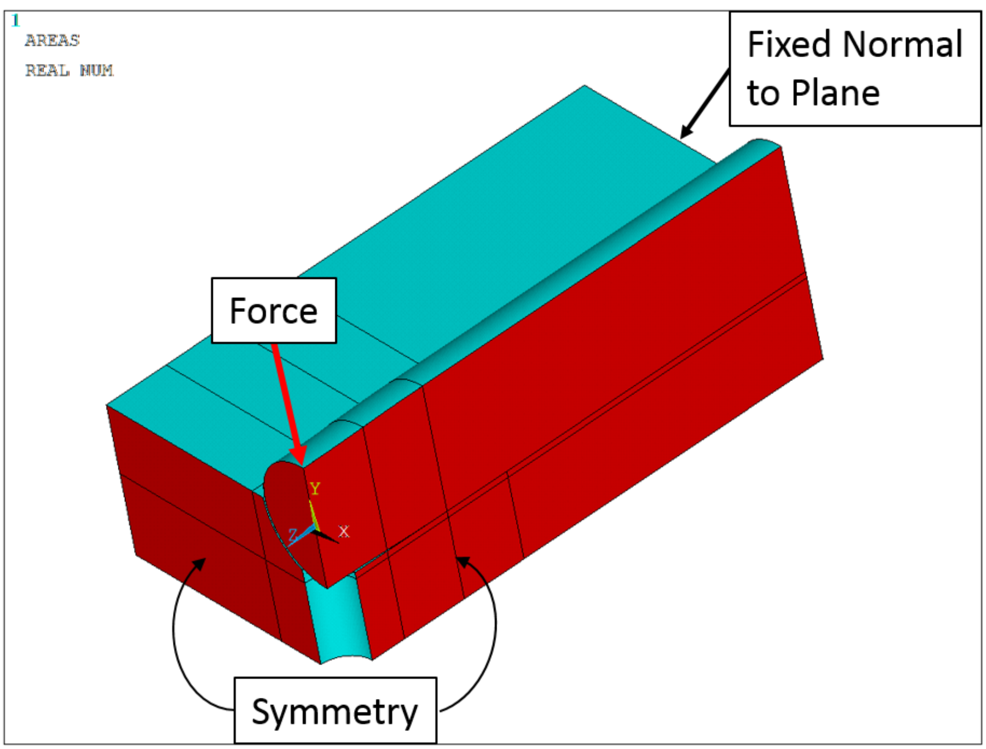

Figure 4. Loads and Boundary Conditions

5.0 Results

The maximum and minimum principal stresses are shown in Figure 5. The contour legend values are shown in Pa. The maximum principal stress is 5.25 MPa, which is 7.2 times less than the ultimate tensile strength of 38 MPa. The minimum principal stress is -18.4 MPa, which is 7.1 times less than the ultimate compressive strength of 130 MPa. The contours show some irregularities around the boundaries between the yellow to orange to red. This occurs where the refined mesh transitions to the larger mesh, but the stress values are low in this area. The values are less than a compressive stress of 5 MPa, which is 26 times less than the ultimate compressive strength of 130 MPa.

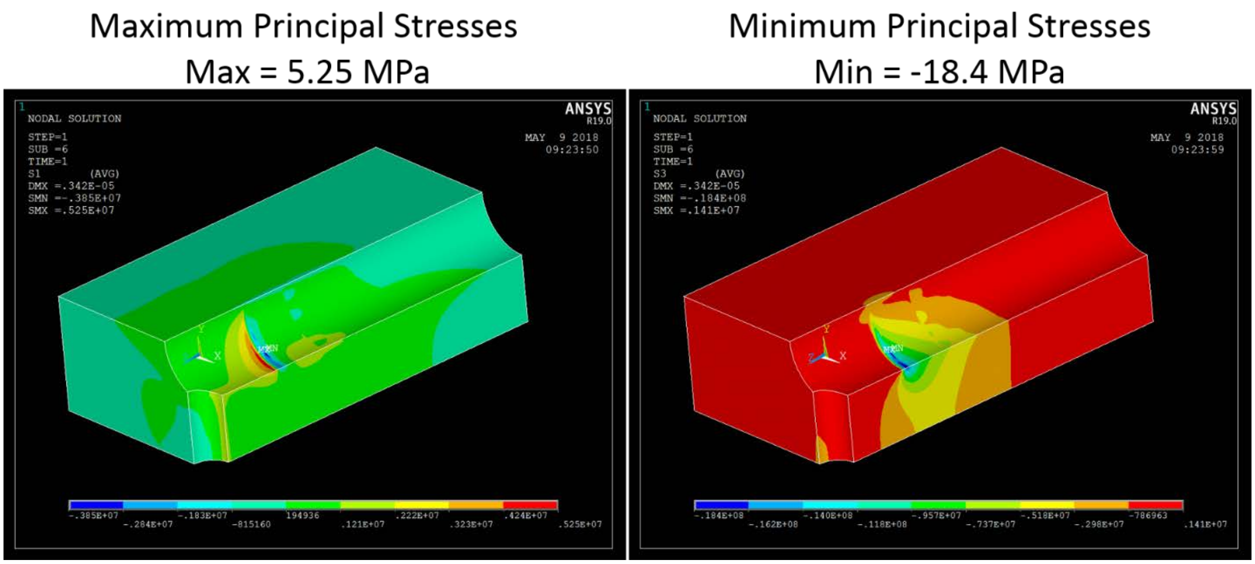

Figure 5. Graphite Block Principal Stresses

The force applied to the stainless steel rod causes a vertical displacement to the rod and the graphite. The vertical displacement of the graphite along the axis where the rod contacts the graphite is shown in Figure 6. The maximum vertical displacement of the graphite of 3.4 μm occurs near the initial contact point, 9.8 mm from the center.

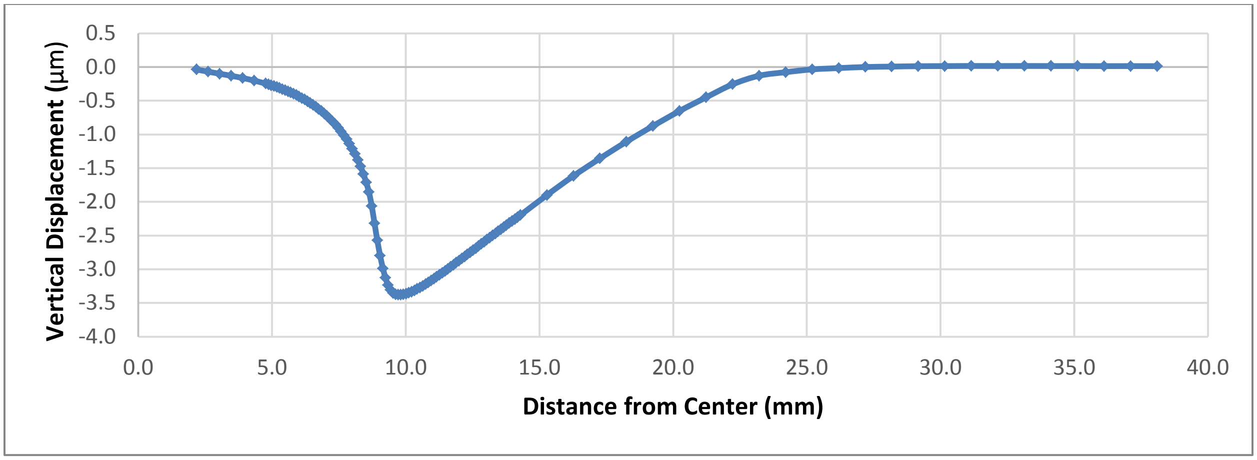

Figure 6. Vertical Displacement of Graphite