NCSX Vacuum Vessel assembly tooling study

Objective: To determine the relative displacements of the NCSX single field period vessel segment under gravity loading conditions and various orientations during assembly.

Method: A single field period FEA model (without ports) was created which included the proposed trunnion supports at the ends of the vertical port-12. Various orientations and support locations were considered.

Results: The results of the study are shown in the following figures of the displacement contours on the shell field period. The ranges of the various plots have been adjusted to provide maximum resolution (maximum number of contours) in the shell region. In general, the least relative shell displacement results when the shell is supported from the two parting flanges (figure 4), although this could be the most difficult and expensive support condition to accomplish, particularly if the shell is required to rotate during measuring and installation of the coil loops. Figures 1 & 3, with support off the trunnion and NB port flange may provide a more workable alternative for most orientations.

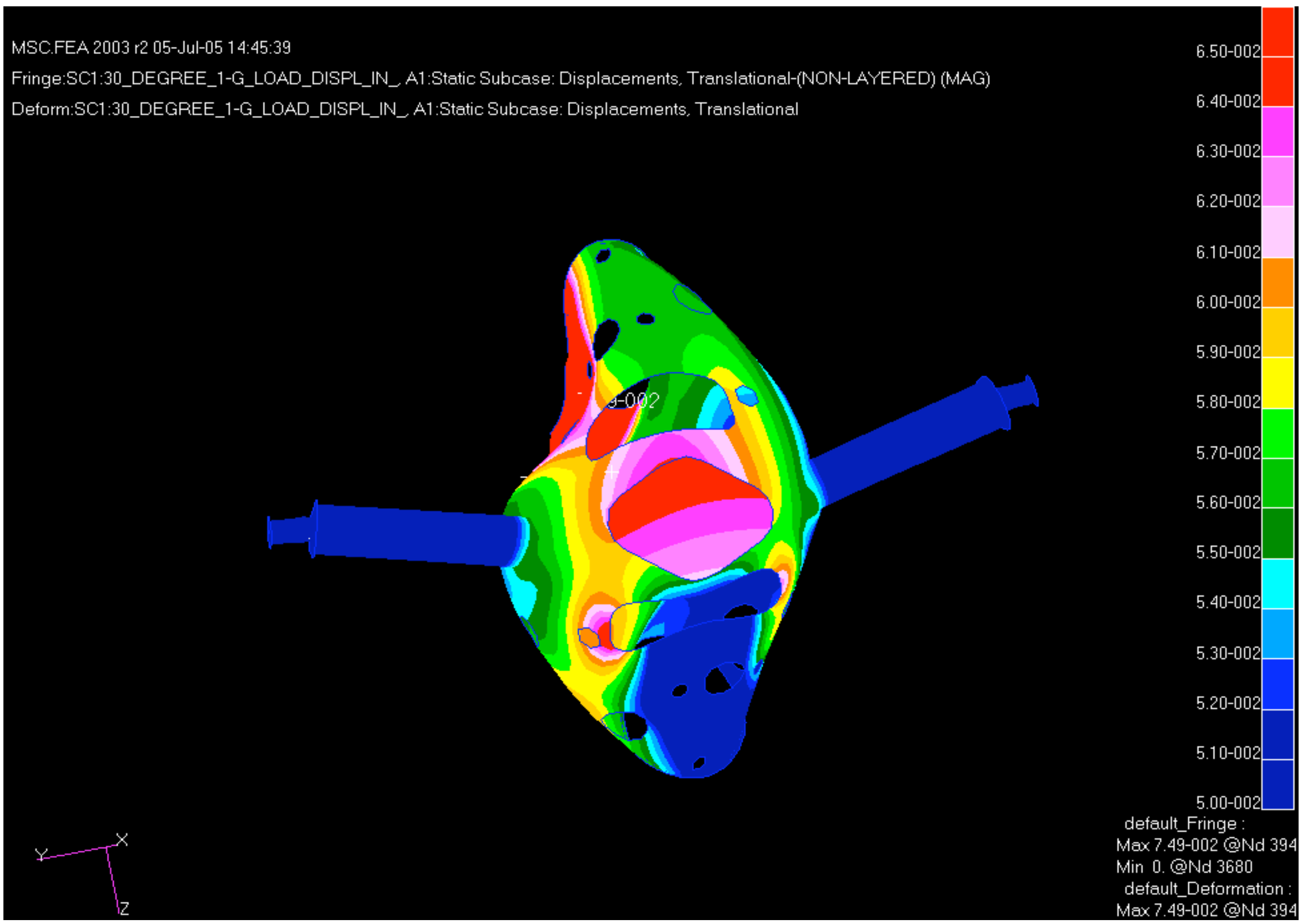

Figure 1. Vertically restrained at the trunnion supports – 30º orientation (model21bbexx2g001)

Figure 1 is a contour plot of the displacement magnitude on the shell field period rotated 30 degress, due to a 1-g gravity (30 degree-positive-downward Z) load with vertical Z-direction constraints applied at the trunnion supports. The magnitude of the displacements are calculated as the square root of the sum of the squares of displacements in the X, Y, & Z directions. The range of the displacements on the shell is 0.050” to 0.061” or about 0.011” relative displacement with the major contribution coming from the flexure of the shell due to bending moments at the port-shell interface. This range is fairly typical of the shell flexure at any rotational angle (slightly higher at 0 degrees and slightly lower at 90 degrees), when supported off the trunnions attached to the vertical ports (port-12).

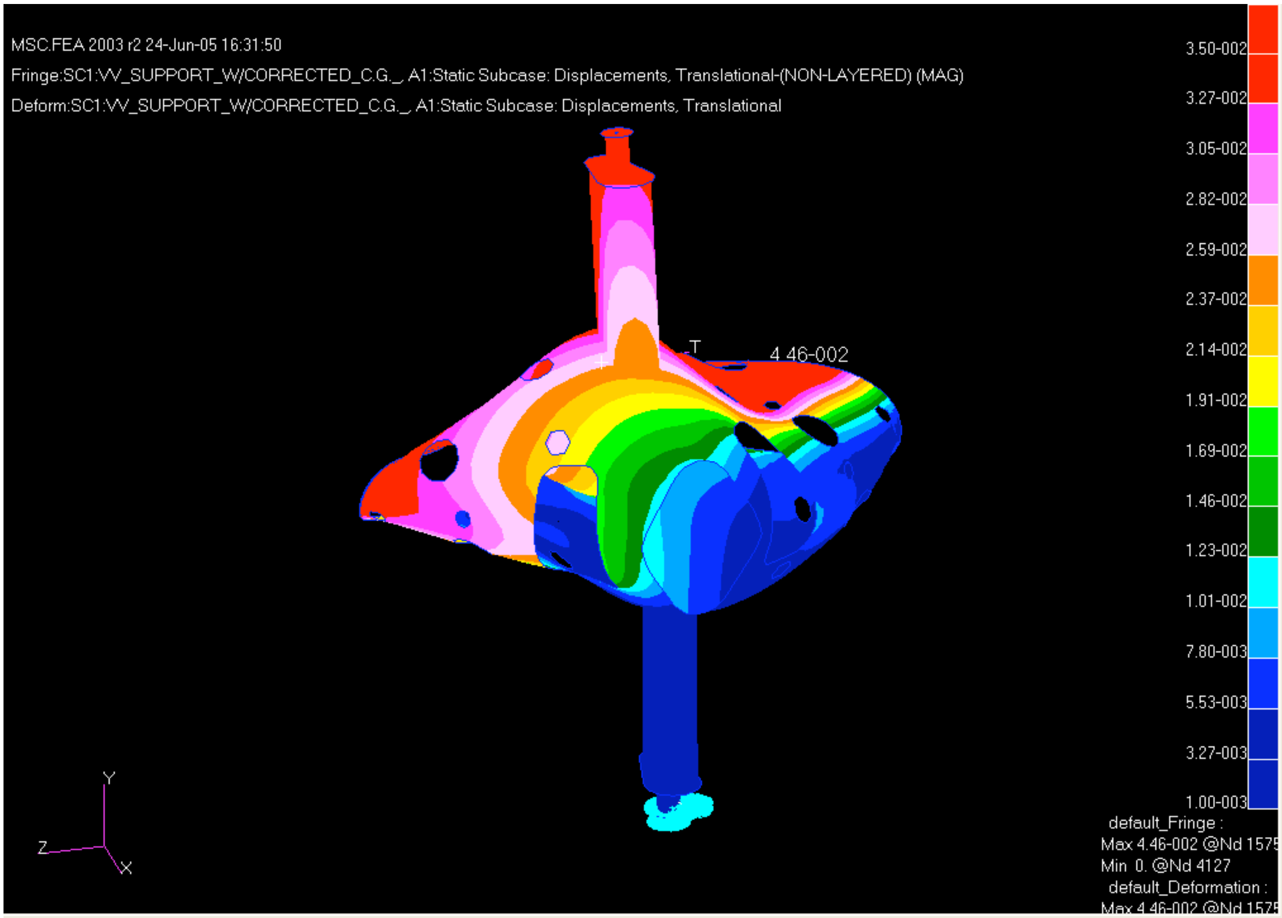

Figure 2. Vertically restrained at the vertical port flange (model21bbexx2h001)

The magnitude displacement contours shown in figure 2 are for a 1-g loading acting in the negative Y direction (ie. vertically downward in the figure). The vertical constraints are applied at the lower trunnion support (shown as blurred light cyan arrows at the lower trunnion in the figure). The range of displacements on the shell for this support configuration is 0.001" to 0.035" with the maximum shown as the red contour. It can be seen in the figure that the upper half of the shell and vertical port are deflecting the most, with the lower portion showing relatively smaller (0.001-0.027") displacements. While this is the worst relative shell displacement of any of the support configurations analyzed, a support at the upper flange could reduce the overall shell displacements substantially.

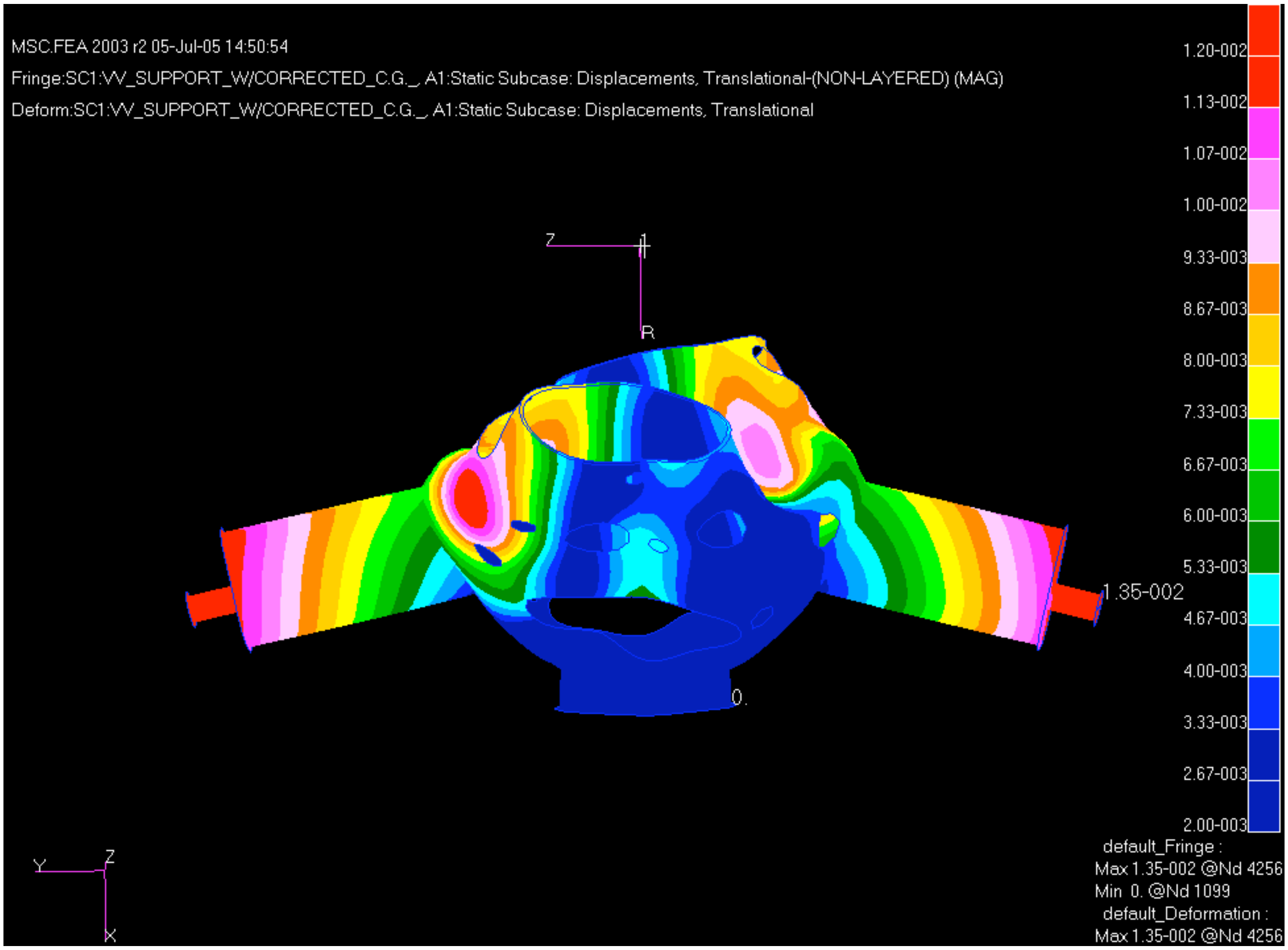

Figure 3. Vertically restrained at the N.B. flange (model21bbexx2i001)

Figure 3. shows the range of displacements for a 1-g loading condition (gravity acting in the positive X direction in this model), with verical constraints applied at the Neutral Beam parting flange. The displacement contours are again the magnitude, or square root of the sum of the squares of the displacements in the three orthoginal directions X, Y, &Z. The displacements range from of 0.002” at the NB flange to ~0.012” shown as the red spot on the left side of the shell in figure 3. This displacement pattern is stellerator-symmetric (dyhedral symmetry).

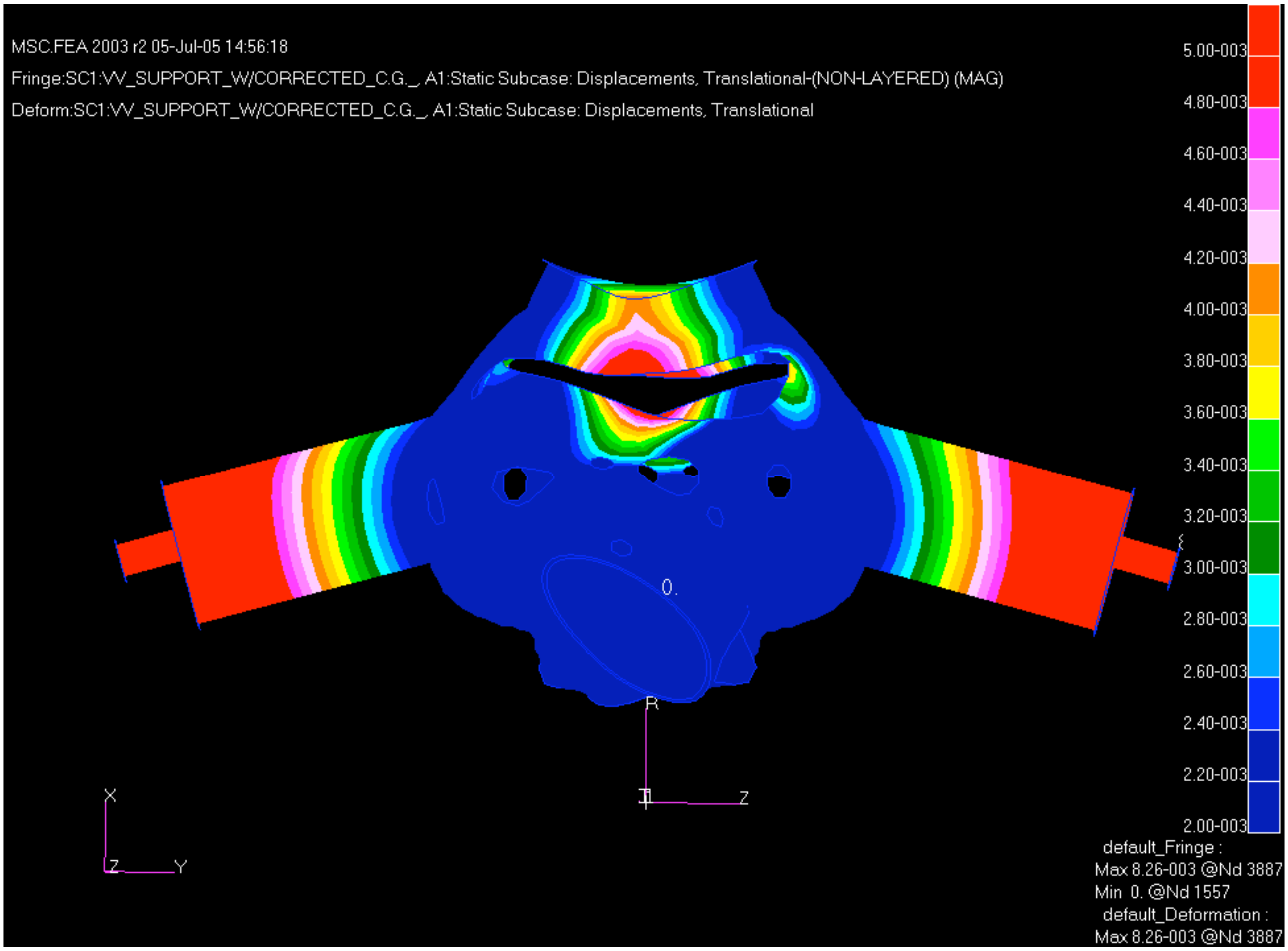

Figure 4. Vertically restrained at the parting flange (model21bbexx2j001)

Figure 4 shows the magnitude of displacements for a vertically (x-dir) restrained vessel field period with a 1-g applied load and the constraints applied at the parting flanges. The range of displacements on the shell are between 0.000" and 0.005" with the minimum deflection at the flanges and the maximum at the mid-plane of port 4.