**ZTF Cryostat Dewar Sidewall FEA Simulation**

**Andrew R. Lambert – 09/22/2014**

**Introduction**

This document describes finite element analysis of the dewar side wall and evaluation of its strength against atmospheric pressure. The side wall geometry is shown in Figure 1.

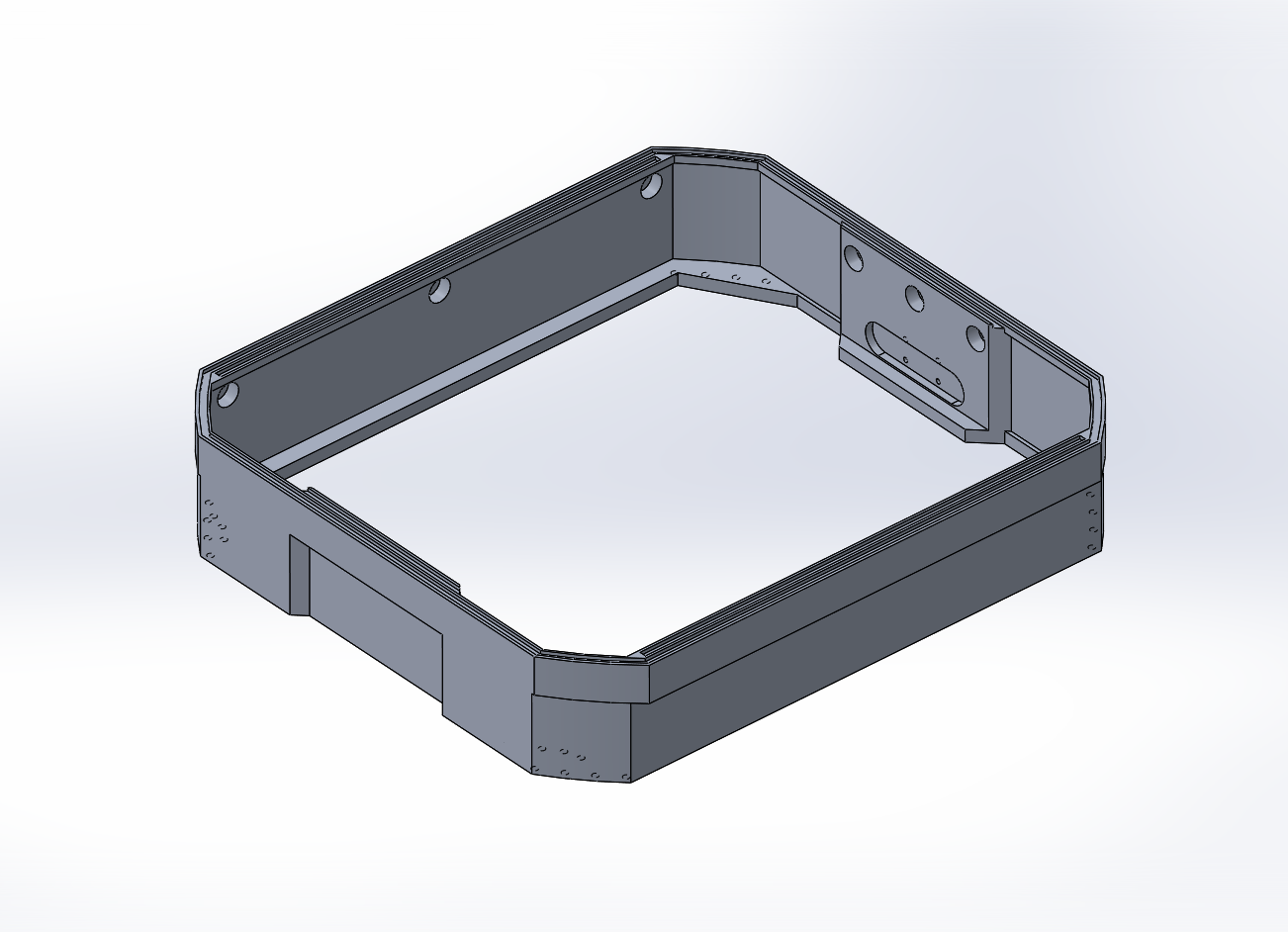


Figure 1: Dewar Side Wall

The dewar side wall supports the focal plate via the G10 flex struts, and also experiences atmospheric pressure loading due to interior vacuum. Currently, it is assumed that the dewar will be constructed from 6061-T6 Aluminum alloy, the material properties of which are shown in Table 1.

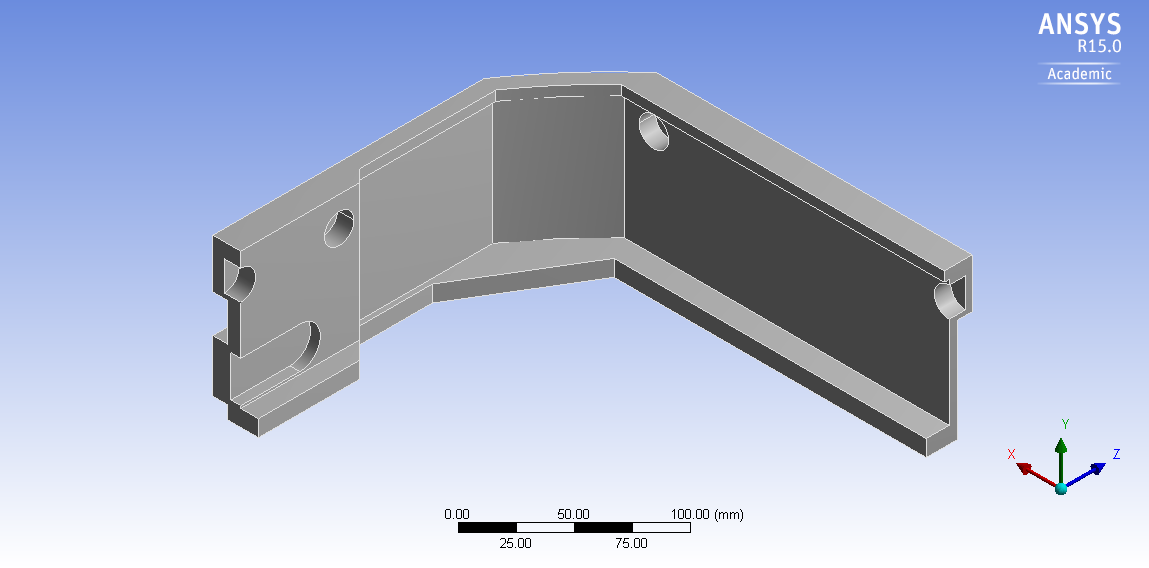
Table 1: Aluminum 6061-T6 material properties

|  |  |
| --- | --- |
| **Property** | **Value** |
| Density | 2700 |
| Young's Modulus [GPa] | 69 |
| Yield Strength [MPa] | 276 |
| Poisson's Ratio | 0.33 |
| Thermal Conductivity [W/m-K] | 180 |
| Coefficient of Thermal Expansion [oC-1] | 23.6 x 10-6 |

Of critical importance is that the dewar walls are thick enough to withstand the pressure load and not deform significantly such that the location of the focal plate is altered. For this analysis, the yield strength of aluminum is used at criteria for factor of safety (FOS) calculation and evaluation of whether or not the current dewar design is acceptable.

**FEA Modeling**

The geometry used for the finite element model is a simplified version of the dewar side wall shown in Figure 1, specifically, the dewar is altered to a one-quarter geometry to take advantage of symmetry. The dewar geometry is shown below in Figure 2.



Symmetry surfaces

Figure 2: Dewar side wall FEA geometry

The real dewar has a back-wall attached to it on the backside and a fused silica window on the frontside, both of which also experience vacuum and exert compressive forces normal to their mating surfaces on the dewar side wall. Atmospheric pressure is integrated over the projected areas of the backwall and window to approximate these compressive forces, ~ 5,340 N. The boundary conditions on the dewar are shown in Figure 3.

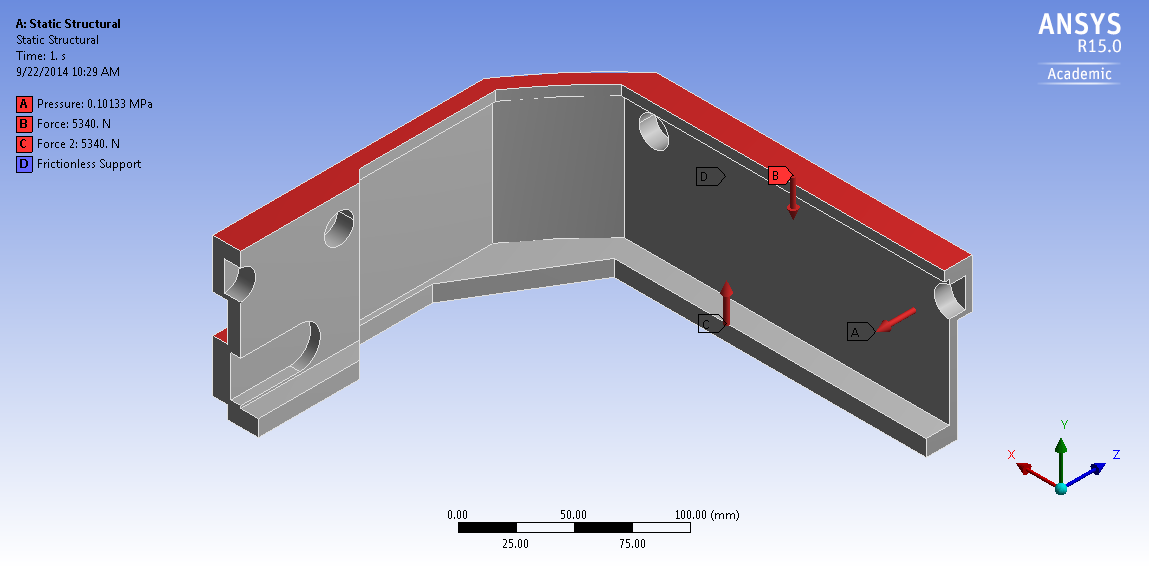


Figure 3: Dewar side-wall boundary conditions

In addition to the forces exerted on the side-wall by the back-wall and window, the back-wall adds some stiffness to the side-wall, which is not included in this model. This makes the analysis inherently conservative and serves as a type of worst-case stress scenario.

The model mesh uses 62,305 quadrilateral elements with a size of 2.0 mm. The meshed geometry is shown in Figure 4.

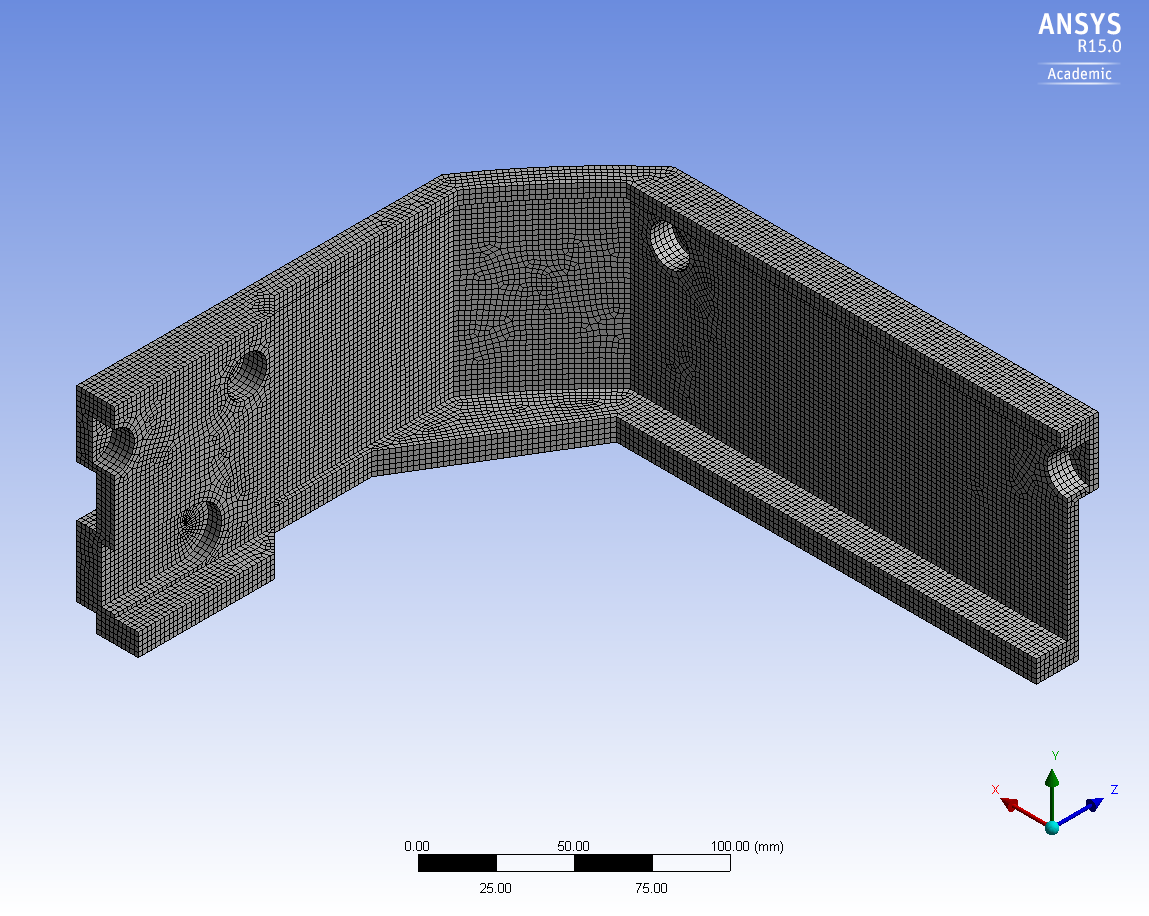


Figure 4: Model mesh

**Results**

In order to evaluate the dewar’s strength, the maximum equivalent stress is compared with the tensile yield of the material. Equivalent stress is shown in Figure 5.

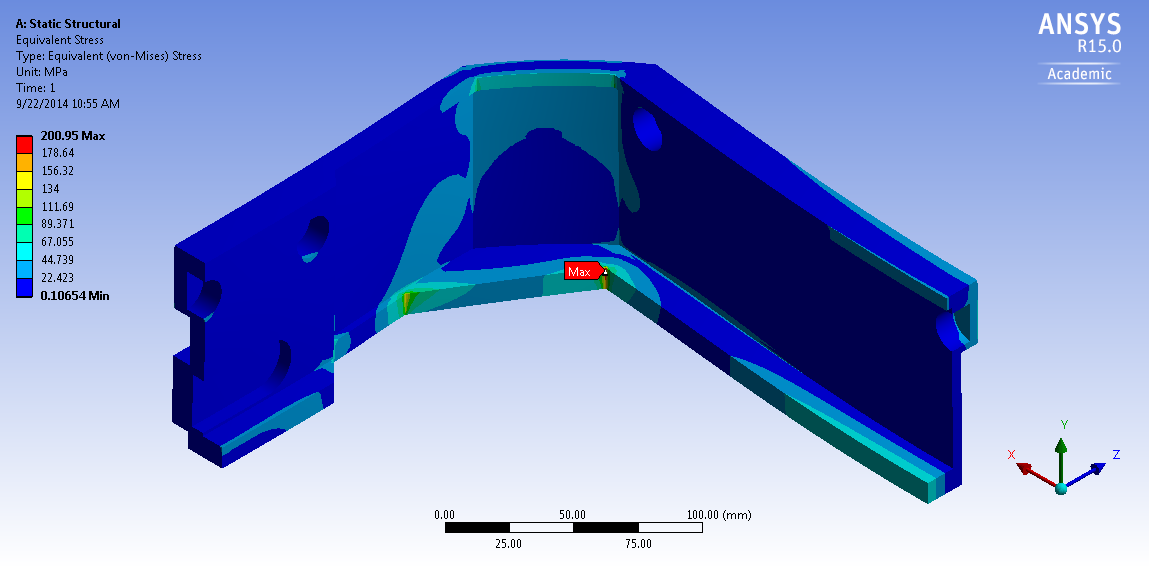


Figure 5: Equivalent stress [MPa]

The maximum stress is ~201 MPa and is located at the corner of the dewar side wall. This stress is due to flexing of the dewar walls under atmospheric pressure. This stress is primarily compressive, as plots of the maximum principle stress show low tensile stresses here; however the minimum principle stress is quite large here at -230 MPa. The factor of safety is shown in Figure 6.

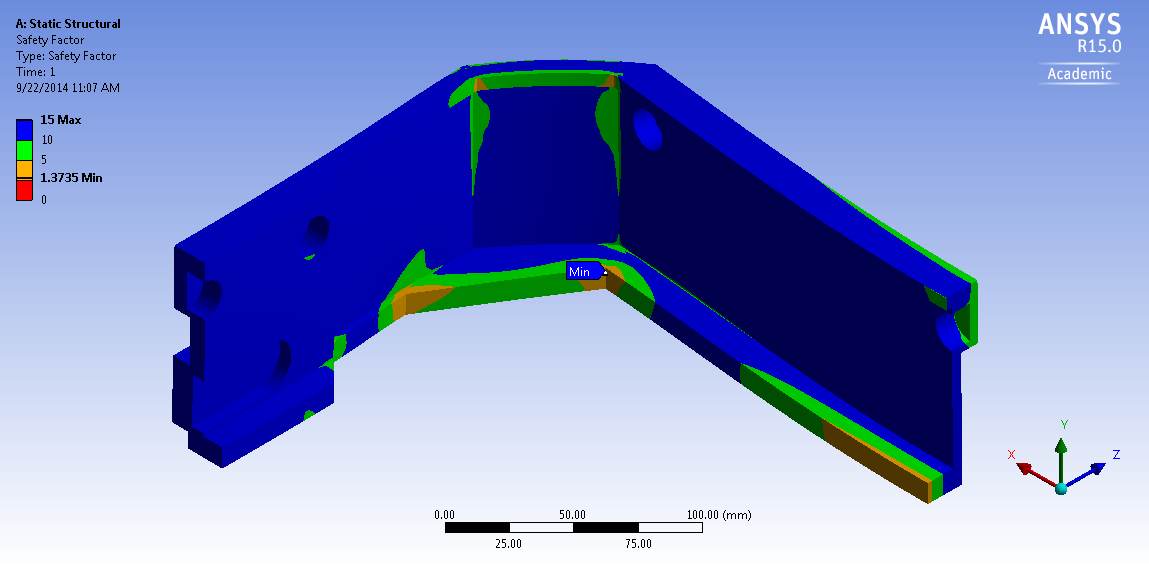


Figure 6: FOS of dewar side wall

As previously mentioned, this is a conservative analysis due to the absence of the dewar backwall. In order to approximate its effect, several simplified models were run to determine how backwall thickness affects maximum stress in the sidewall. The model with the backwall is shown in Figure 7.

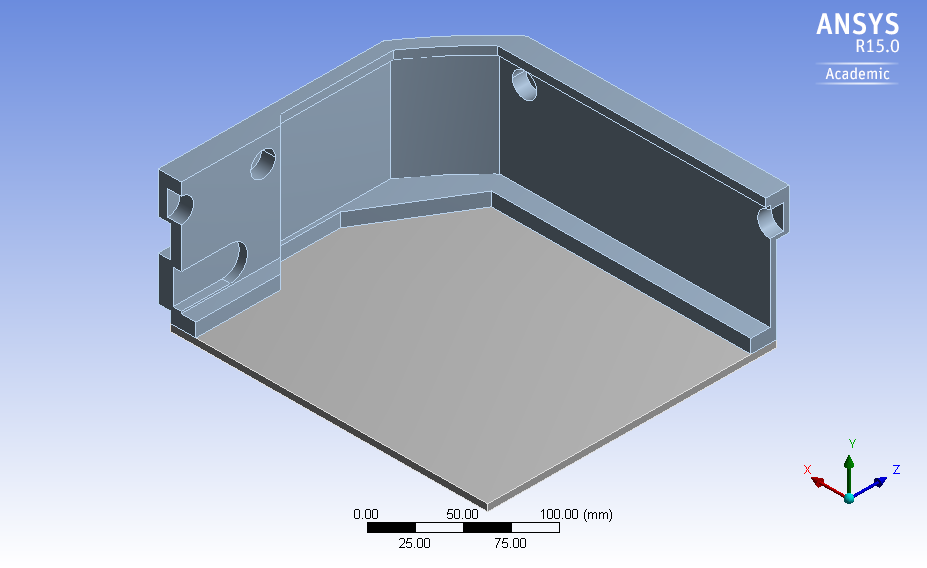


Figure 7: Dewar model with backwall

As Figure 7 shows, the backwall is approximated as a flat plate that is attached to the dewar sidewall back flange. Atmospheric pressure is also applied to the backwall, and the force boundary condition is removed. As mentioned, several different runs were completed to determine the effect of thickness on the stress in the dewar wall. It is assumed that the backwall material is also Aluminum 6061-T6. Table 2 shows values for the maximum equivalent stress in the dewar sidewall and the corresponding factor of safety.

Table 2: Maximum equivalent stress [MPa] and minimum FOS for varying backwall thickness

|  |  |  |
| --- | --- | --- |
| **Back-plate thickness [mm]** | **Max. Equivalent Stress in Side-wall [MPa]** | **FOS (minimum)** |
| None | 201 | 1.4 |
| 5 | 115 | 2.4 |
| 10 | 61 | 4.5 |
| 15 | 57 | 4.8 |
| 20 | 55 | 5.0 |

As Table 2 shows, there is minimal improvement in stress and factor of safety after backwall thickness exceeds 10mm. The location of the maximum stress for this thickness of backwall has changed as well. At 10mm, the backwall is sufficiently stiff to prevent flexing of the dewar walls as seen in Figure 5. The maximum stress now corresponds to thinner portions of the sidewall as illustrated in Figure 8, and is induced by the vacuum load and bending of the flange due to atmospheric pressure on the backwall.

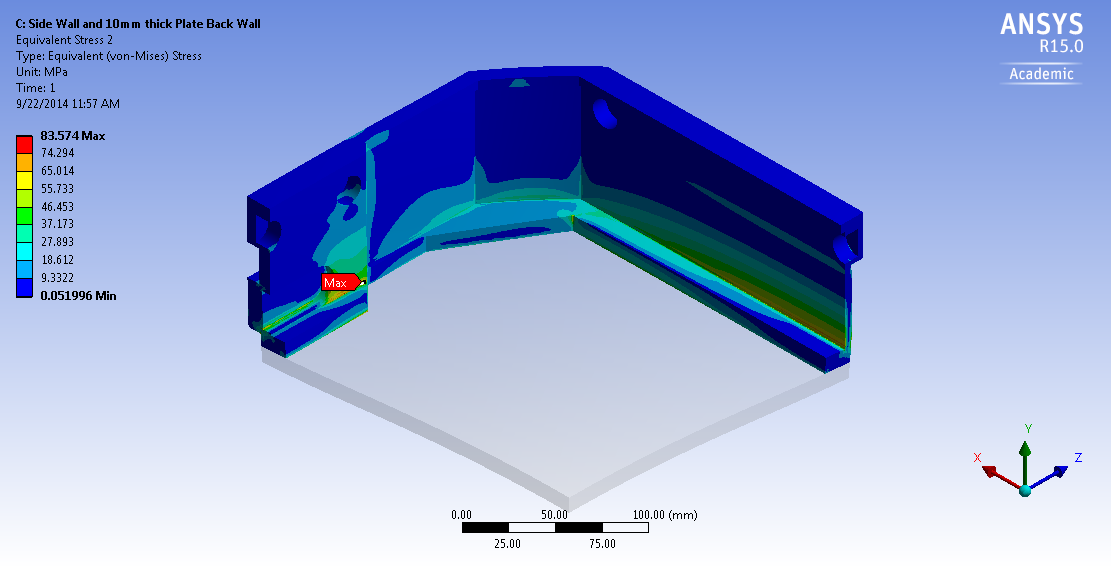


Figure 8: Equivalent stress in dewar sidewall with 10mm thick backwall

As Figure 8 shows, the maximum stress location is not in the corners of the sidewall as before. The backwall provides sufficient stiffness to keep the sidewall from bulk bending, but there is higher stress at the thin portions. The FOS for this thickness is about 4.5, which is quite good as the loading for the dewar sidewall is well-defined. These regions of the dewar may be thickened, and sharp edges should have a slight fillet and chamfer to remove any localized stress concentrations.

**Conclusion**

Overall, the current dewar design is quite robust and provides enough strength against atmospheric pressure. High stress areas depicted in Figure 8 may be thickened to reduce stress, but no large design changes are necessary for acceptable dewar performance. It is recommended that the backwall have an effective stiffness that is equivalent to a 10mm thick flat plate.