FINAL REPORT ON TASK 3

Stresses developed in structural epoxies due to thermal expansion in metal-carbon fiber tube couplings

Introduction -

The study is based on metal and carbon fiber couplings and their interactions with structural epoxies used to bind them together.

We will be analyzing thermal expansion with two models with one a normal metal coupler and another inspired by the dragon plate design.

Then we will be analyzing 3 assemblies :- the normal ,dragon plate, and dragon plate without ridges.

The assemblies would contain one coupler, a carbon fiber tube and a model of the epoxy of 0.5mm thickness.

We will be checking the stresses developed in the epoxy in each assembly caused by a temperature change from 60*C to 0*C.

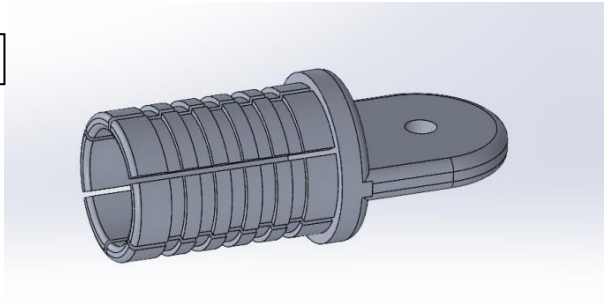
Objective -

One of the primary concerns when bonding metal fittings into carbon fiber tubes is the fact that the metal component, when subjected to reductions in temperature, will shrink much more than the carbon fiber tube. This is due to a mismatch in the thermal expansion coefficients (CTE) of the two materials, with the metal component having a CTE of over ten times that of the carbon fiber tube. As a result, delamination can occur between the aluminum insert and the carbon fiber. We shall analyse various design and check the effectiveness of different design choices to contain this problem.

Description and images of models used -

1) Dragon plate inspired coupler – a coupler with a slotted and ridged design.Material used: aluminum alloy 1060
2) Normal coupler – a coupler with no slots or ridges.Material used: aluminum alloy 1060
3) Structural Epoxy models – 0.5mm thickness models with standard structural epoxy properties.
4) Carbon fiber tube - 2mm thickness tube with 14.5 mm inner diameter.

1



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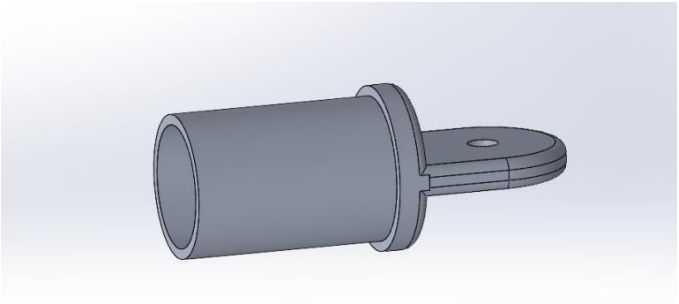

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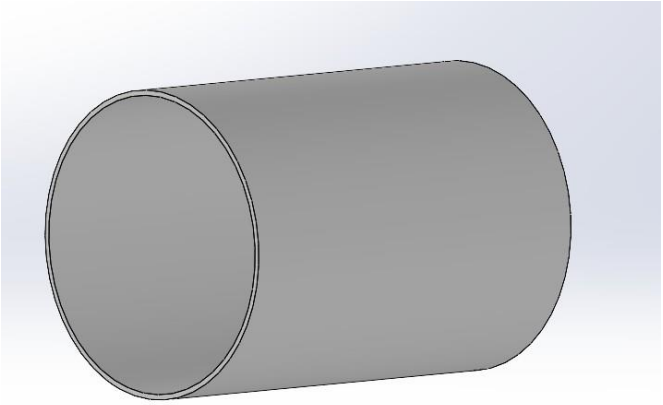

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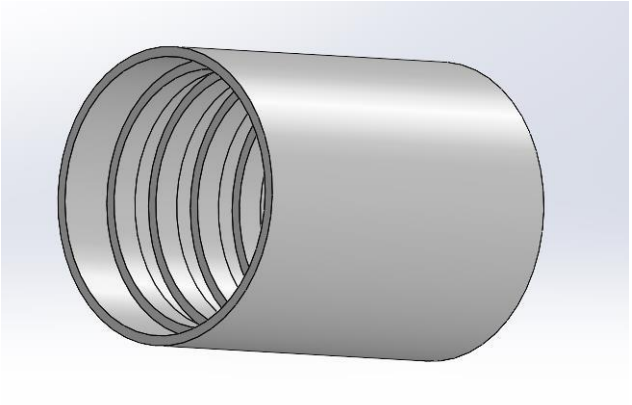

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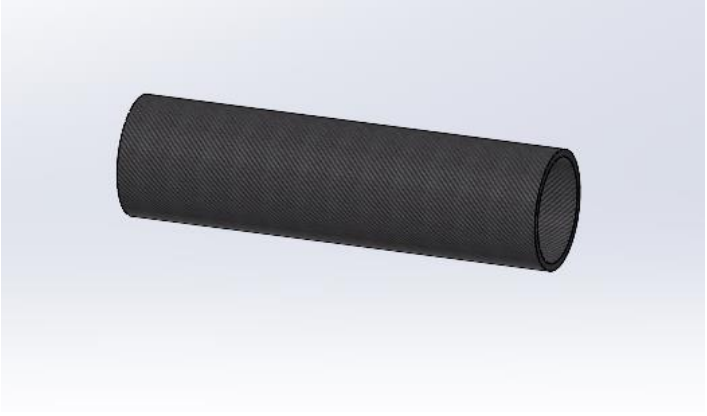
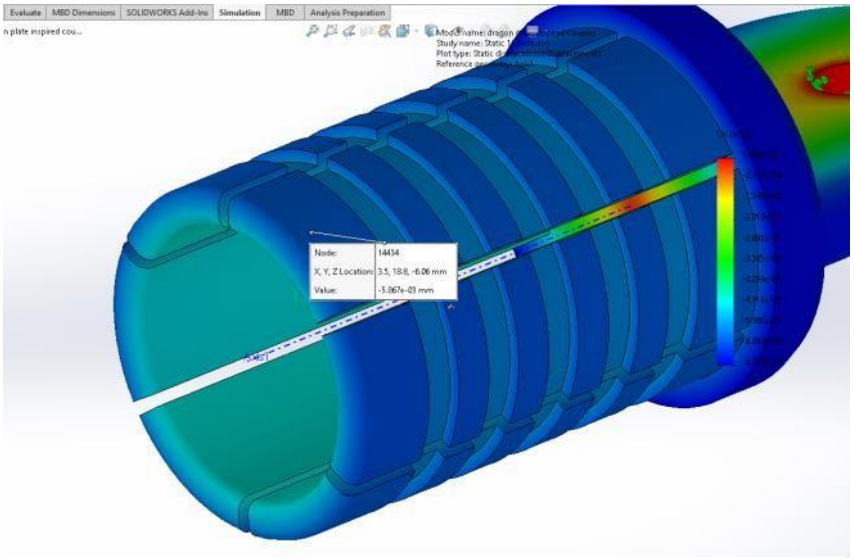


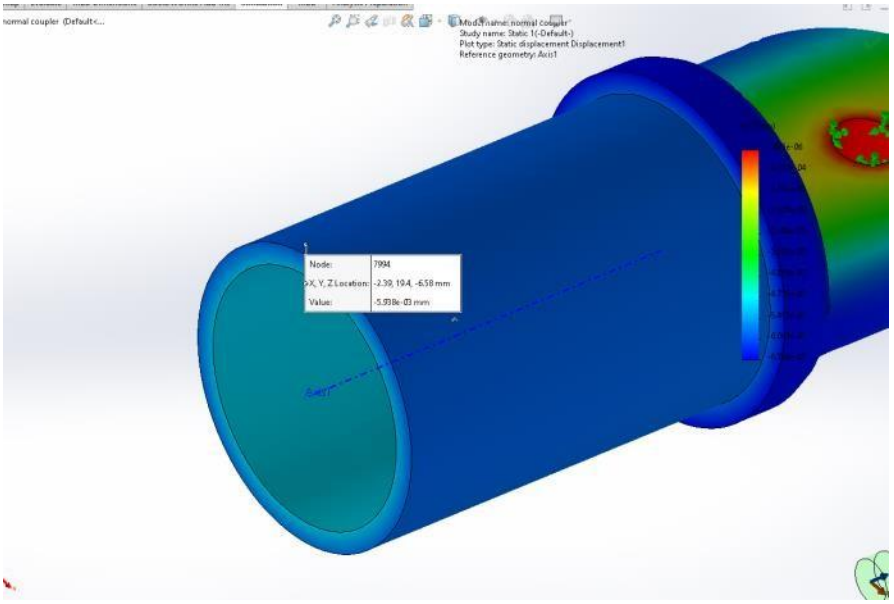
Methodology -

Thermal expansion -

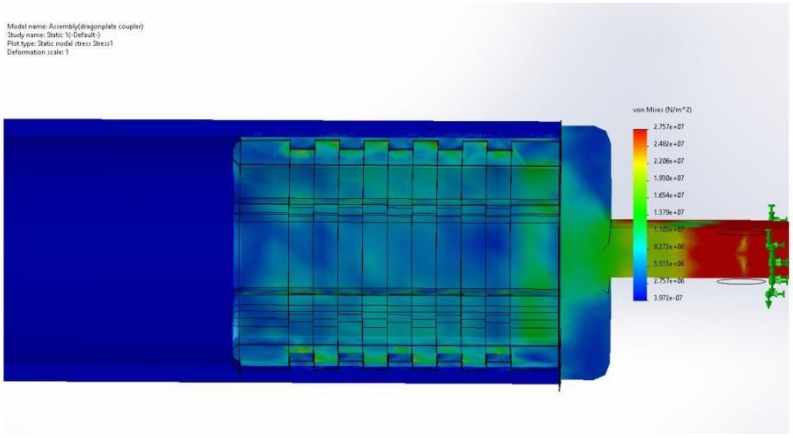
The main reason for peel stress on the epoxy is due to change in diameter of the metal coupling. We shall make a slotted design to make the thermal expansion less radial and more circumferential . This analysis of thermal expansion/contraction will showthe displacement in radial direction of the different designs.

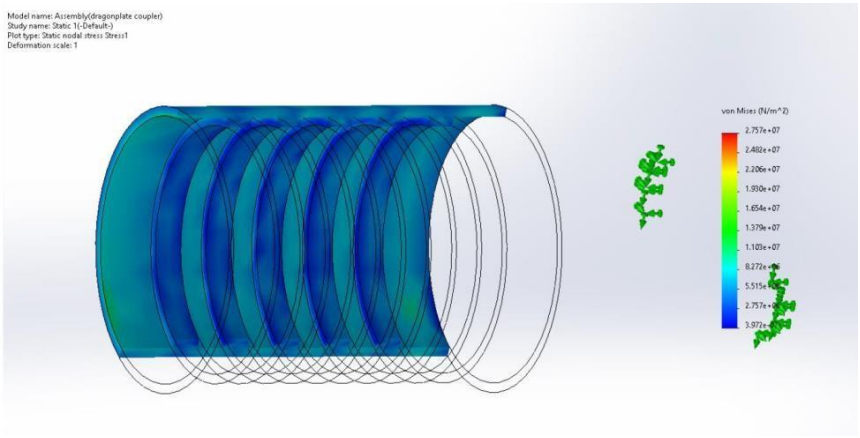
As shown in the screenshots attached the dragon plate inspired coupler presentedlower radial displacements(-5.876 e-03) compared to normal coupler(-5.938 e-03)difference of 1.044%.

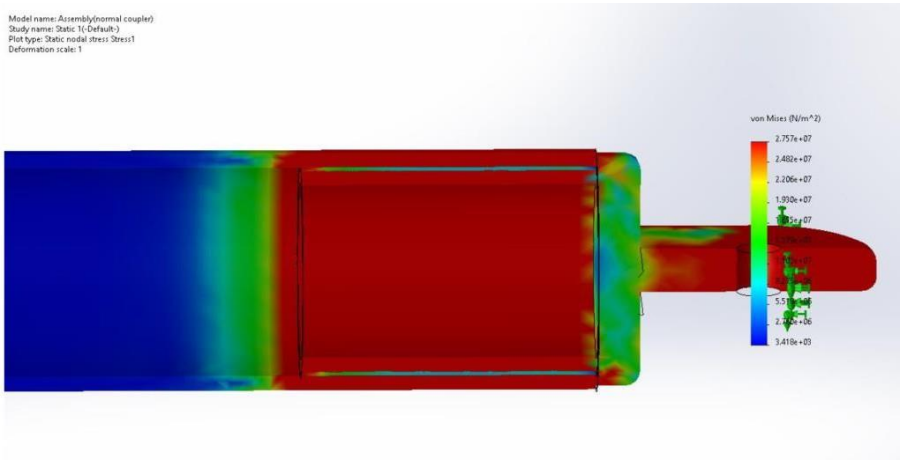


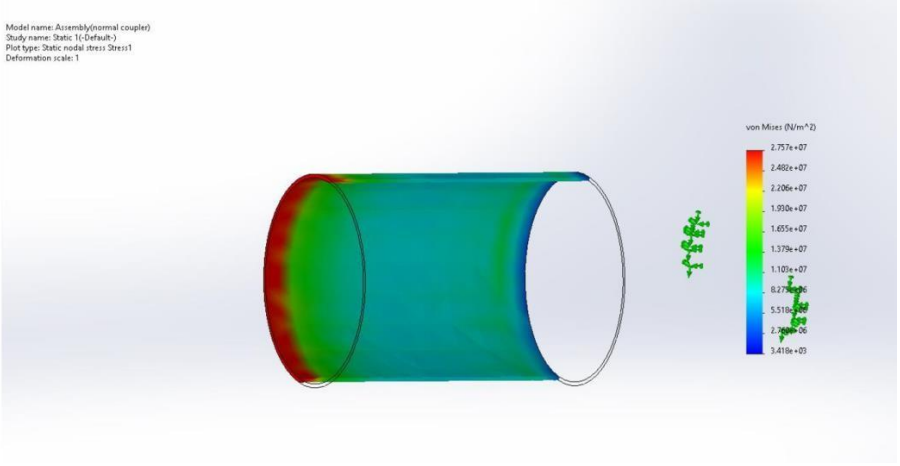


Stresses developed due to thermal expansion in the above designs -





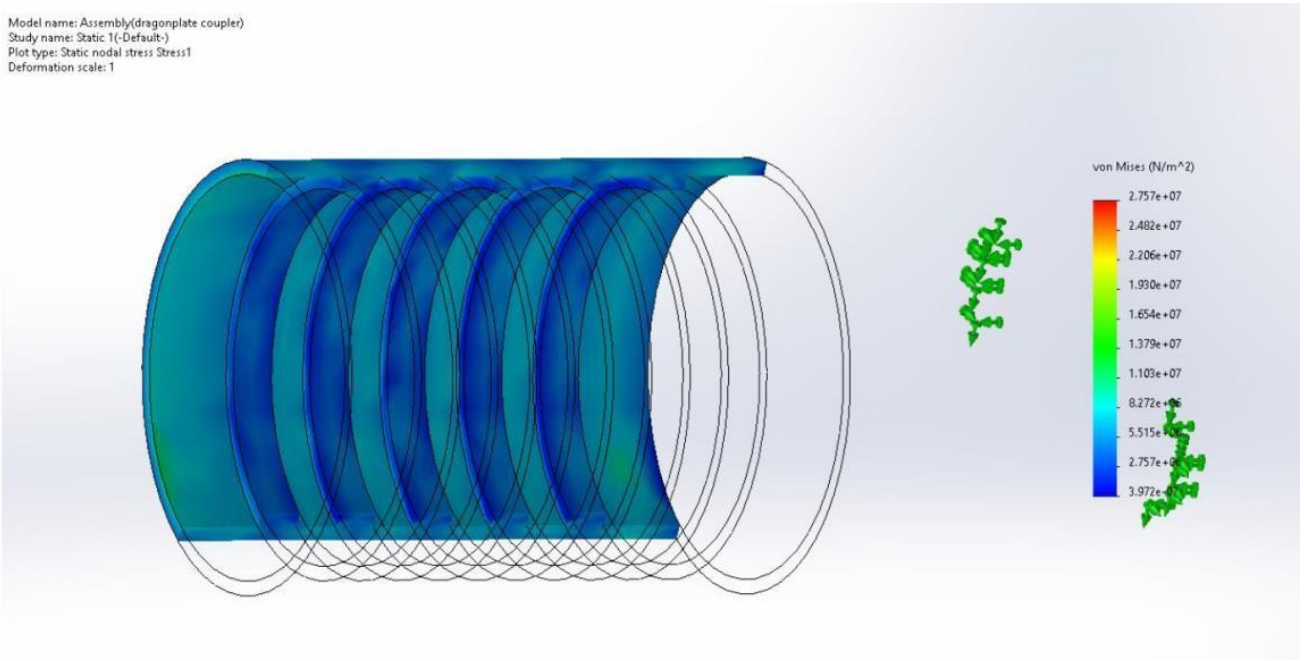


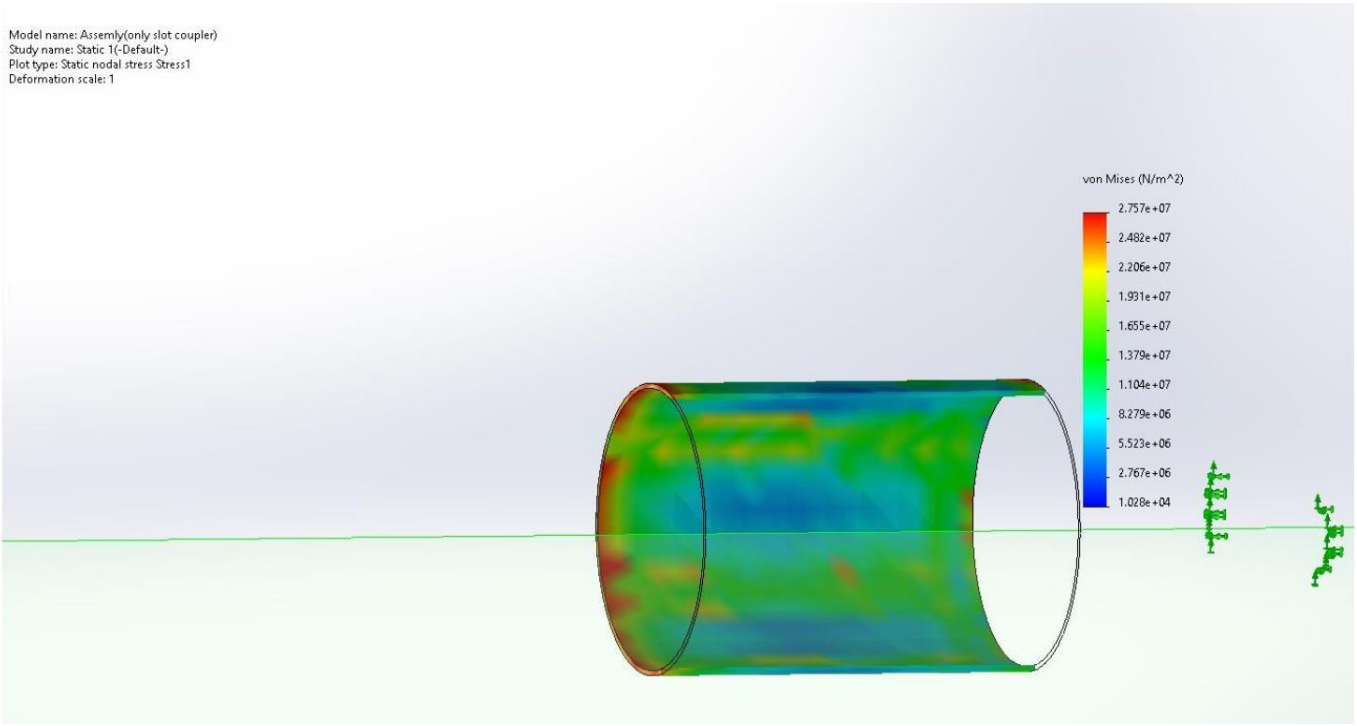


We can see the stresses developed in the dragon plate design are lesser then those of the normal design.

<u>Checking stresses in an only slotted design vs ridged and slotted design</u> -

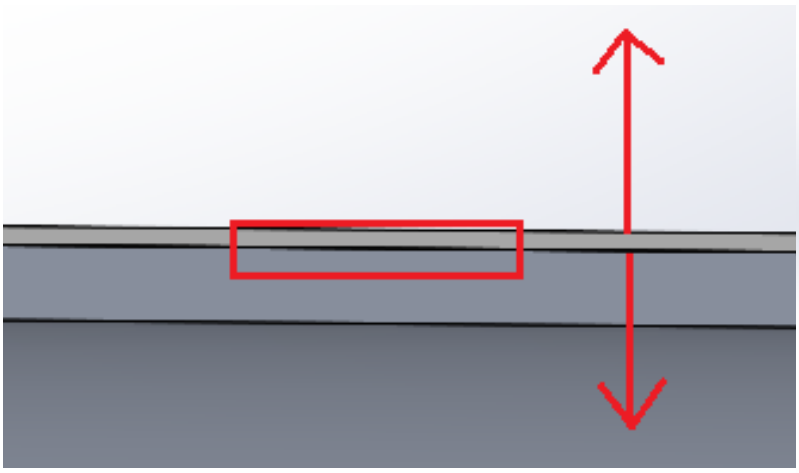
To check the effectiveness of ridges we shall be checking the stresses in the layer of epoxy in the dragon plate design vs only slotted design.

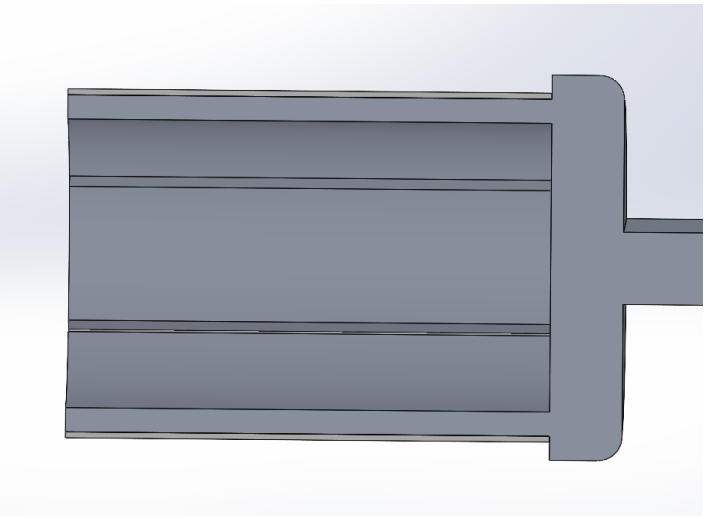




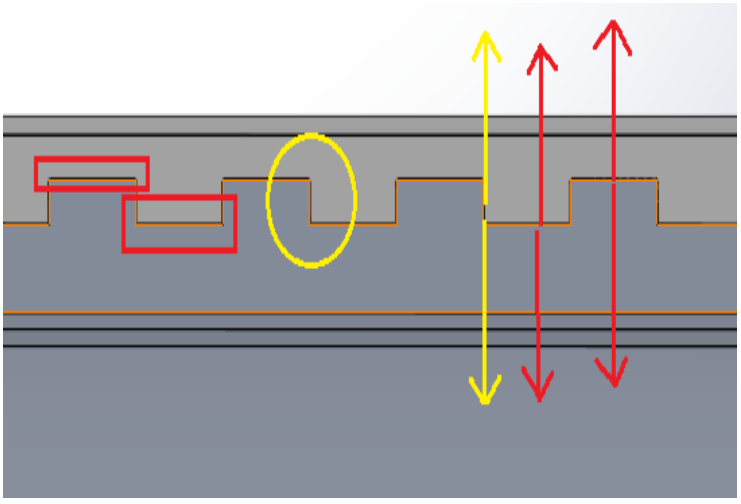
<u>Studying how ridges help lower peel stress and apply shear stress</u> –

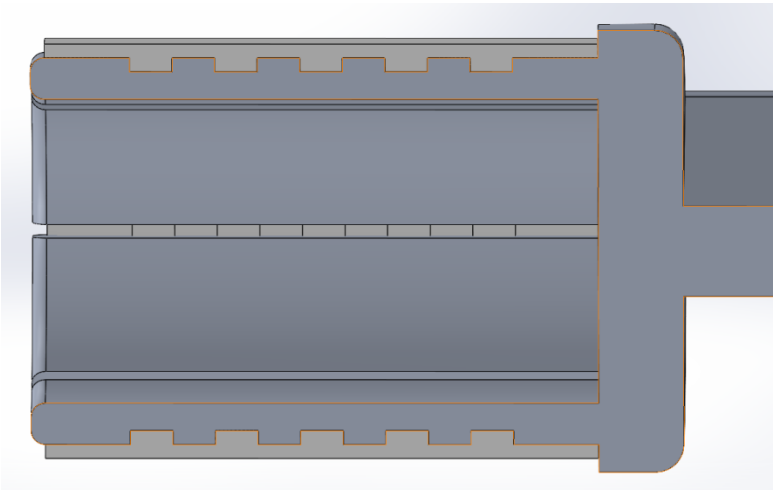
In the design without ridges the stresses are developed normal to the curved surfaces as shown by the red rectangle. These stresses pull the epoxy perpendicular to the surface which causes peel stress. The figure below shows the contact surface and the direction of the peel stress acting in red color.





In the design with ridges the stresses developed normal to the curved surfaces are shown in red and tangential to the flat surface or the ridges are marked in yellow. The red marks show the direction of the peel stress and the surface they act on. The yellow marks show the direction on the shear stress and the surfaces they act on.

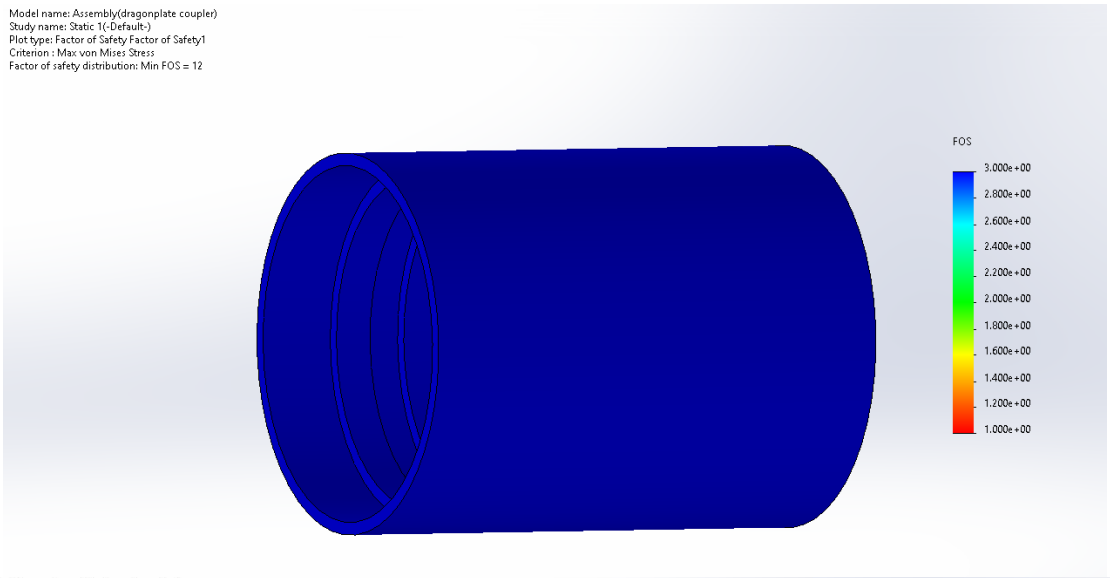


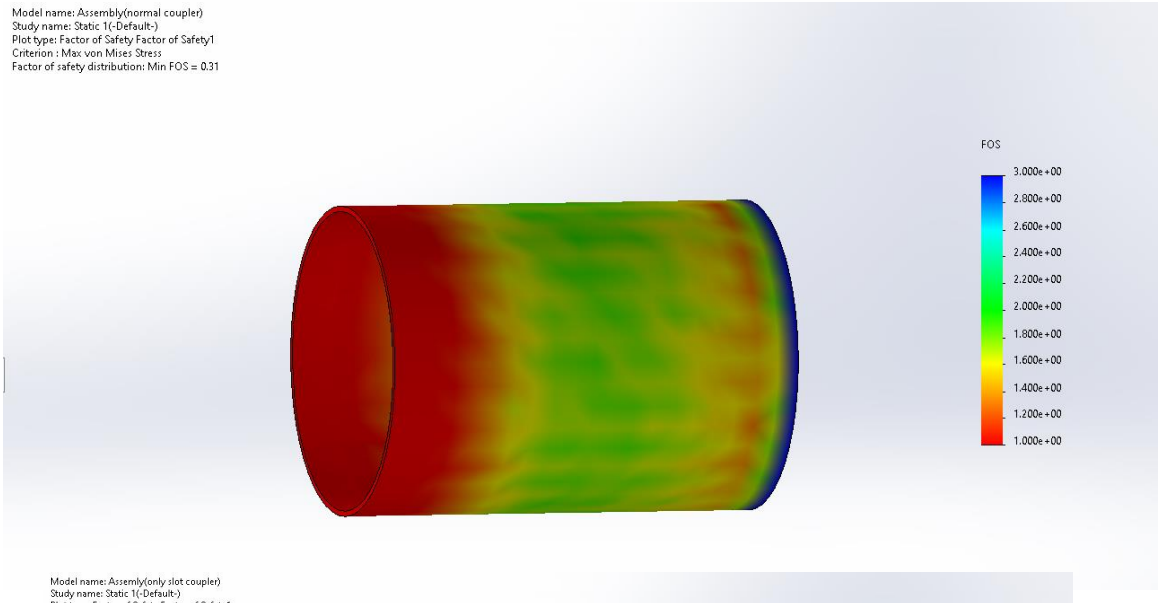


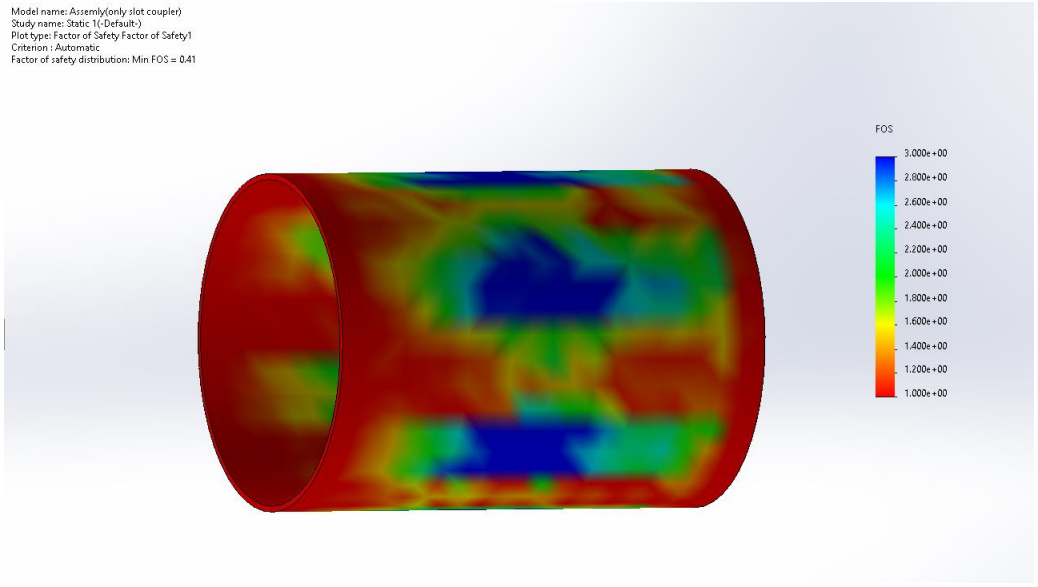
As we can see in the above diagrams there is only one cylindrical contact surface for the normal design on which the peel stress acts normal to it. In the ridged design the peel stress acts on the cylindrical surface shown in red but there is also a shear stress that acts on the flat surfaces of the ridges marked in yellow. These numerous surface take most of the shear stress and in turn reduce the peel stress on the cylindrical surface.

Results –

For the results we shall check the factor of safety(**FOS**) plots for the epoxy in each of the designs. The maximum and minimum values in the **FOS** heat map are 3 and 1 i.e the areas marked in blue have a factor of safety of 3 and areas marked in red have a factor of safety of 1 or less and that is where the part will fail.







The images show us that the epoxy in the dragon plate design (1)has a factor of safety of over 3
While the other epoxy in the other design(2,3) will fail as it has larges areas in red indicating a factor of safety of 1 or less where it will fail.

Conclusion –

The simulations show that the slotted design helps in reducing the radial contraction of the aluminum coupler and the ridged design helps reducing the peel stresses. Overall the dragon plate design which incorporates both performs better in all the simulations.