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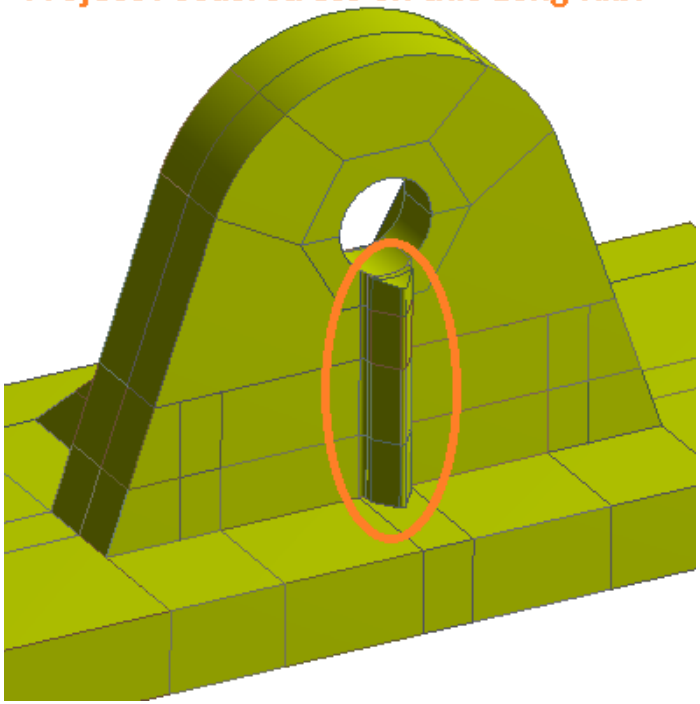
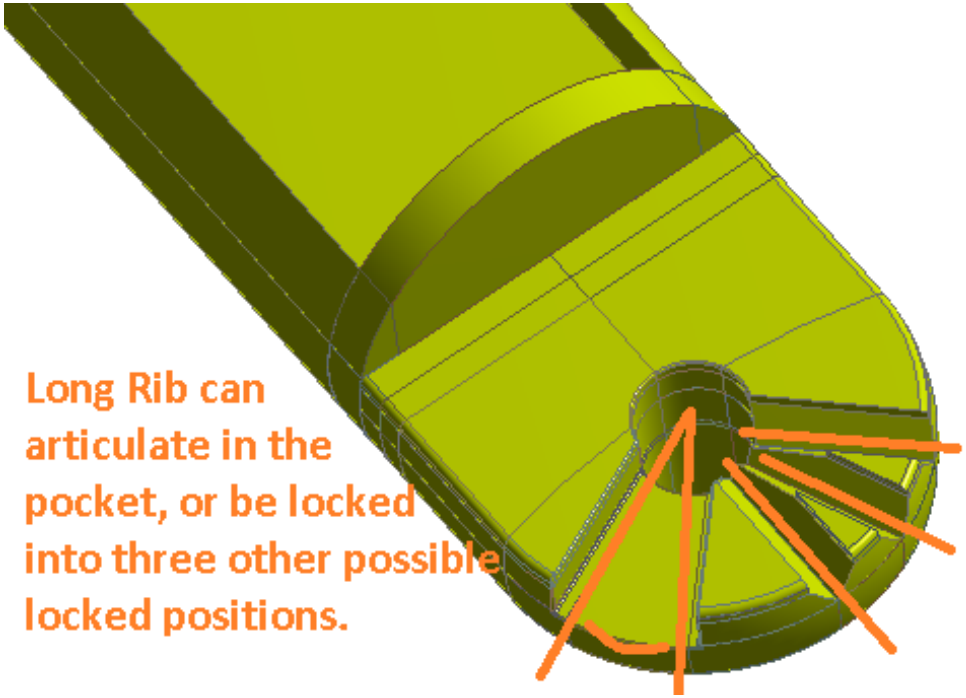
FE Static Stress Report:

Articulating Pole Scrubber Head Stress due to Long Rib Contacting the Pocket Side

Project Focus: stress on this Long Rib.





One Articulating Pocket and 3 Fixed locations....

Table of Contents

Note: This powerpoint report is not exhaustive. We are including complete AutoGenerated mht ANSYS Workbench reports for the interested reader. Refer to those for more information.
We are also including some animation files to provide additional insights.

1. Introduction

- Report consists of results for Structural FEA (finite element analysis) of Pool Scrubber Head.

- Due to dual-direction articulation, relative to both pocket sides, either side of pocket wall impingement should be equally suitable for stress prediction of the long rib as it hits (stops) against the pocket side.

- We impose a displacement on the bottom leading-edge of the Scrubber plate, and that displacement pushes on and rotates the Scrubber Pad Plate causing Rib impingement. Especially for non-linear (contacts/gaps) we prefer “displacmenet” driven loads because they are more numerically stable.

- As the Scrubber rotates it closes the remaining gap between its long rib and the nearby Side of the Pocket in the Arm. We track reaction forces and correlate that to the predicted rib stress - - thus, “Push lbs vs. Stress”.

2. Objective

Leverage FEA to predict the relationship between stress induced on the long Rib vs. the reactive force on the loaded edge, as the articulation is restricted to its specific angular range.

3. Assumptions. Spec's of FEA.

Linear Generic Nylon Material Properties.

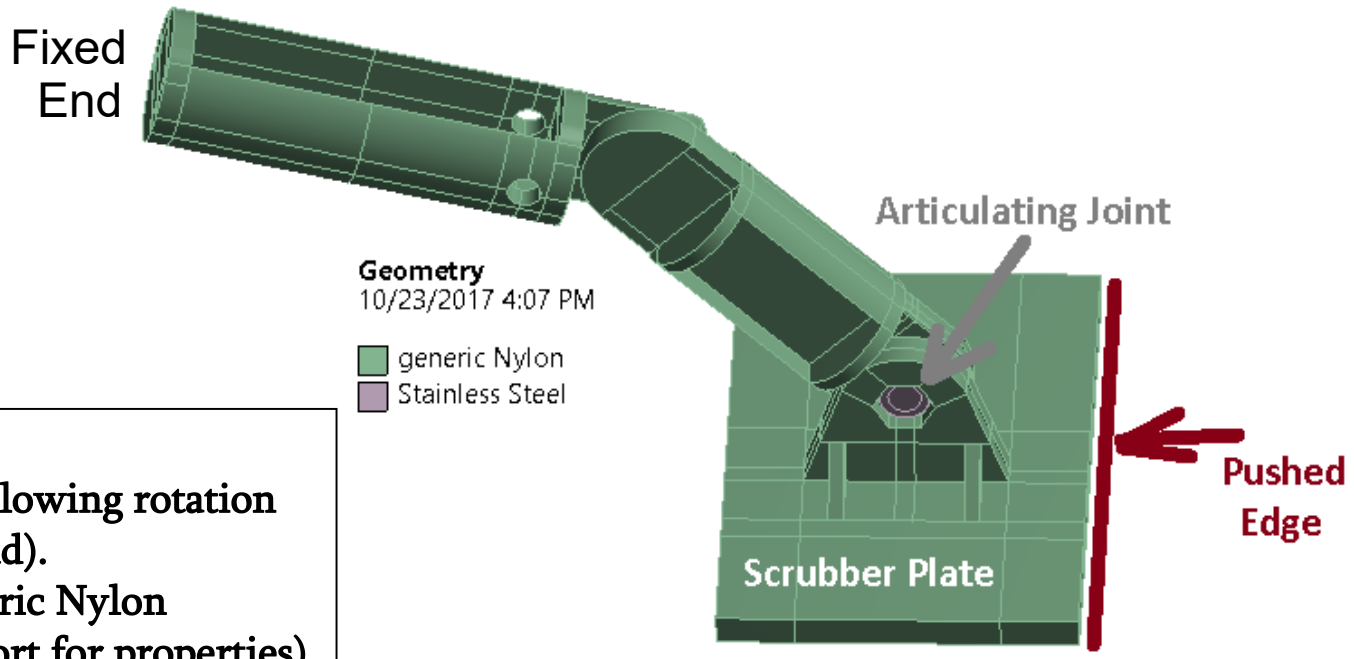
Finer Mesh near pivot & Rib.

Static Analysis having non-linear contact elements and NL Large Geom.

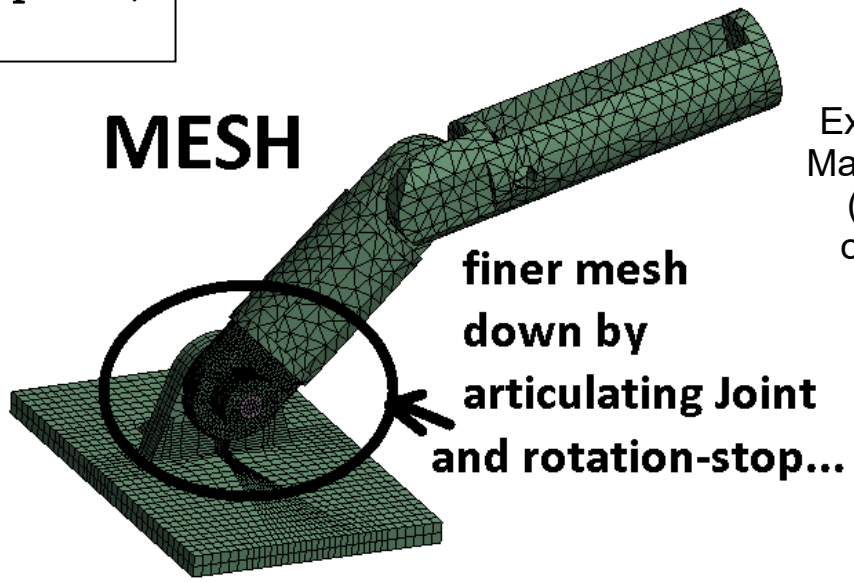
Frictionless contact- - thus all rotating load goes to rib-stops, which is worst case, therefore conservative.

SST shaft is relative stiff and provides negligible axial preload from bolt/knob. When Rib hits pocket side, it halts rotation, while SST shaft & other mating faces restrain motion in all other directions.

4. 3D Model: Model considered for FEA. Mesh (below)



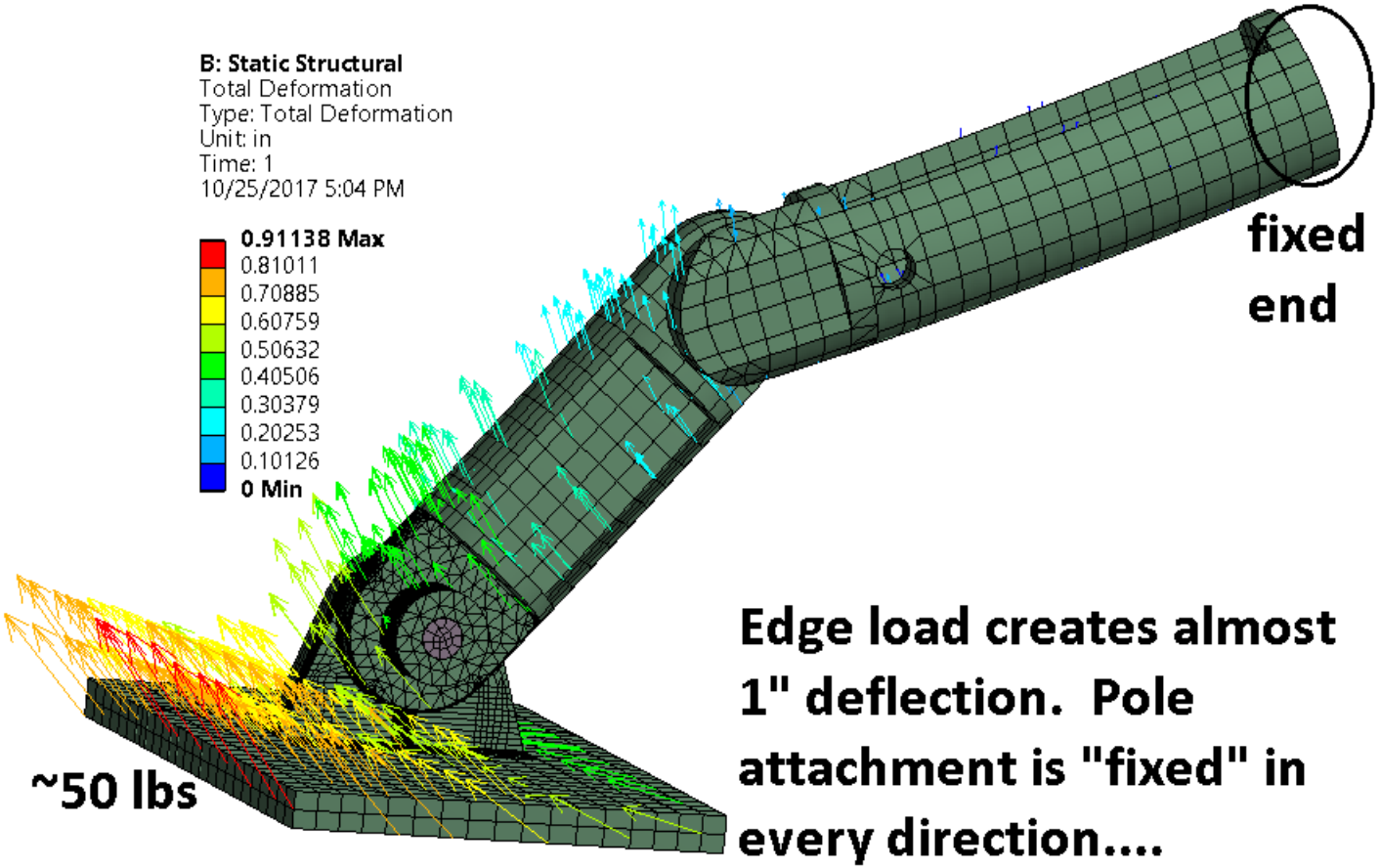
Steel Axle bolt (Gray) allowing rotation (frictionless & no preload).
The rest (green) is Generic Nylon
(see detailed mht report for properties)



Example mesh shown. May not be "final" mesh. (For final mesh see other plots here and mht report)

Mesh plots can be found on Figures 1,2,3,4 of the provided mht report

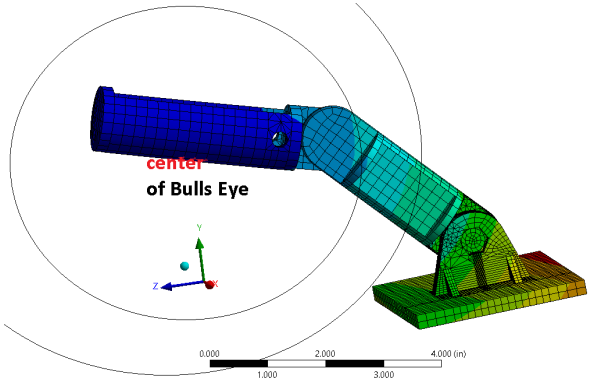
5. Deflection Plots of Entire Mesh. ~1” per #50



Edge load creates almost 1" deflection. Pole attachment is "fixed" in every direction....

Even though we are doing “stress” analysis, it is useful to look at deflection plots to insure motion under load is as expected....
We can see that the Rib will rotate and impinge one side of pocket. Either pocket wall is suitable for FEA. We picked one.

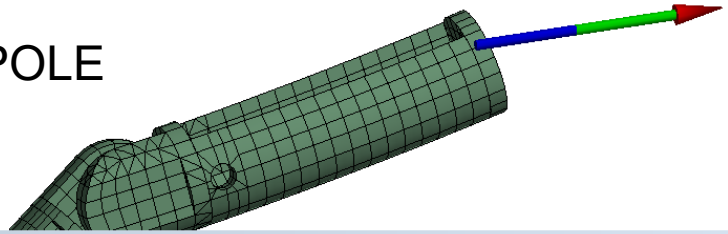
Deflection plots can be found on Figures 10,11,12 of the provided mht report



In FEA, the “USUM (total net displacement) Bulls eye” is an indication of rotation, and the eye-center is the CENTER of rotation

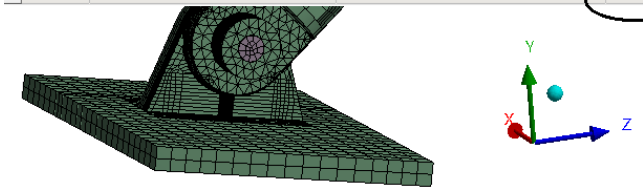
6. Reaction Force, Equal & Opposite

Force from POLE

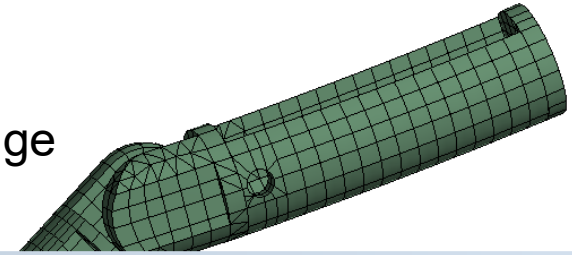


Tabular Data

	Time [s]	Rfrc Pole Attachement (X) [lbf]	Rfrc Pole Attachement (Y) [lbf]	Rfrc Pole Attachement (Z) [lbf]	Rfrc Pole Attachement (Total
6	0.65	-7.819e-007	-1.4908e-005	25.488	25.488
7	0.775	-4.3506e-007	-8.1845e-006	33.232	33.232
8	0.9	-3.0397e-006	-9.3764e-006	41.756	41.756
9	1.	-2.1127e-005	-1.2366e-004	49.18	49.18

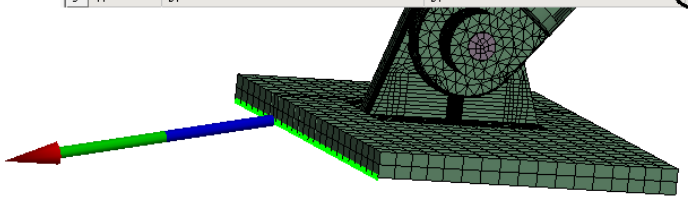


Opposite Force, on Edge due to being pushed.



Tabular Data

	Time [s]	Rfrc Edge of Scrubber (X) [lbf]	Rfrc Edge of Scrubber (Y) [lbf]	Rfrc Edge of Scrubber (Z) [lbf]	Rfrc Edge of Scrubber (Total)
6	0.65	0.	0.	-25.488	25.488
7	0.775	0.	0.	-33.233	33.233
8	0.9	0.	0.	-41.757	41.757
9	1.	0.	0.	-49.183	49.183



The Load scenario here is that someone might be pushing on the far end of a Pole, and the scrubber Pad hits and stops on a edge, wall, etc... We are producing about #50 lbs. Which is a reaction force for the imposed edge displacement.

Here we check the reaction forces, which should be equal and opposite at 49.2 lbs

These plots can be found on Figures 55,56 of the provided mht report

7. Stress Plots at Rotation Stops 31ksi Rib. 39Ksi Pocket

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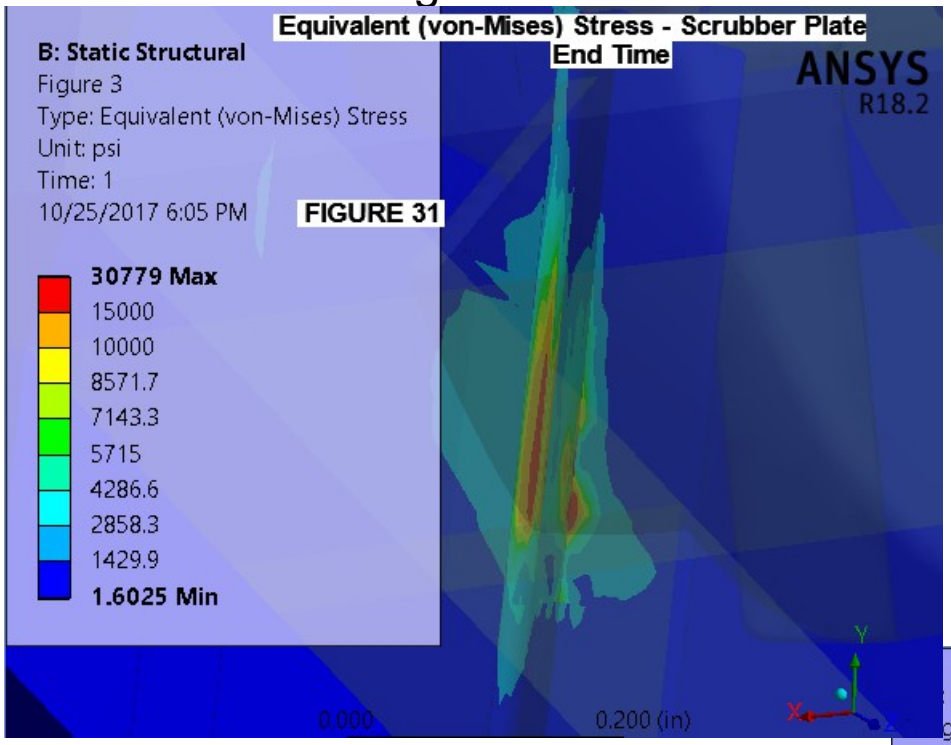
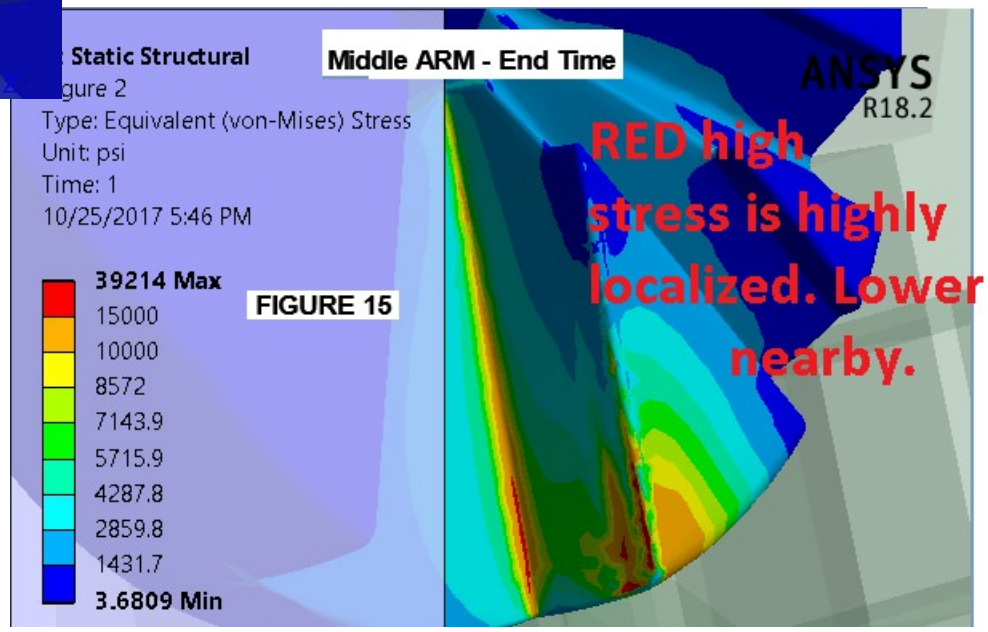
Long Rib Side



FEA of Long rib hitting one Pocket wall. Due to Rotational Symm, either wall impingement could be equally simulated and studied.
Larger Fillets would likely reduce Stress at the fillets.
Actual surface contact stresses would probably not change...

Pocket Side Wall



These plots can be found starting at Figures 15, 31, etc of the provided mht report

8. Stress Interpretation: Contact & Sub-Surface

With FEA we typically predict "Normal Stress" and "Bending Stress", and compare these to the material strength.

For "generic Nylon" we find typical (web) values: (note WIDE range of values for this material)

Tensile Strength at Break	ASTM D638	Dry as molded (about 0.2% moisture content)	13,700 psi
Tensile Yield Strength (psi)	ASTM D638	Dry as molded (about 0.2% moisture content)	8000 to 12,000 psi
		Conditioned with 50% relative humidity	6500 to 8500 psi
Compressive Strength (psi)	ASTM D695	Dry as molded (~ 0.2% moisture content)	12,500 to 15,000 psi (Yld)
Flexural Strength (psi)	Rupture or Yield ASTM D790	Dry as molded (about 0.2% moisture content)	17,900 psi
		Conditioned with 50% relative humidity	6100 psi

Note: High humidy (50%) degrades Nylon strength significantly (~ 20% to 50% strength reduction)

In this case, the "contact stress" seems to dominate, but stress at rib & wall fillets are high too but localized, and for a "#50 edge load, we are predicting stresses higher than seemingly allowed above. However, contact stress is not as "directly damaging" as bending & normal stress - - Contact stress does not directly "tear" 3D geometry apart. Repetitive contact stress leads to accumulation of surface damage, which may propagate later. A discussion of contact stress is found:

https://wp.optics.arizona.edu/optomech/wp-content/uploads/sites/53/2016/10/Tutorial_LeCainNicholas.pdf

"Any time there is a radius in contact with another radius or flat, contact stresses will occur. In the case of two spheres contacting each other, the entire force will be imparted into a theoretical point. Due to elastic properties of the materials this point will deform to a contact area. The deformation that occurs will produce high tensile and compressive stresses in the materials. Even if a singular loading does not produce a failure, it can lead to future fatigue or surface damage. "

In this case we see high contract stresses as well as lower nearby stresses and stresses we can invision below the surface. The lower stresses nearby and under the surface are a safeguard against initial catastrophic failure.

9. Observations and Conclusion:

- FEA predicted Contact (surface) Stress is high, but shallow. For ~#50 applied load, rib stress ~ 31ksi psi. However nearby and sub-surface stress is more like: ~ 8 to 10 kpsi.
  - We've predicted stresses and believe immediate Rib failure will NOT occur on the first load, but it may accumulate damage over time and eventually fail (especially in high humidity (pools) where Nylon is weaker!). Due to moment arm, the #50 edge load probably induces #100 at Rib.
  - According to the reference OPTI 521 tutorial document: "Stresses due to contact of spherical or cylindrical components can have extremely large magnitudes. The depth of the stress fields tends to be very shallow though. The low depth of the stresses tends to lead to purely surface damage. Cai and Burge have shown that even in the case of glass that fails from the propagation of defects, total structural failure is improbable. Surface damage or surface deformation can be of concern...."

- **Conclusion**: Surface Stress is very high, Immediate Failure is not expected since subsurface stress is significantly lower and within typical Nylon limits. Stresses in the 3 "locked configurations" may be lower since the long rib is more fully entrapped so additional surface area is available to press against the rib and stabilize it.

- **Recommendations**:
  - To maximize long term Rib survival, we recommend that a second set of pockets & ribs be considered & probably designed (approx 180 degrees apart from these). A 2nd rib set should reduce stresses in half. (FEA could be used to confirm this).