FEA Report on Tube Dryer
KD-2008 FEA Rev 4

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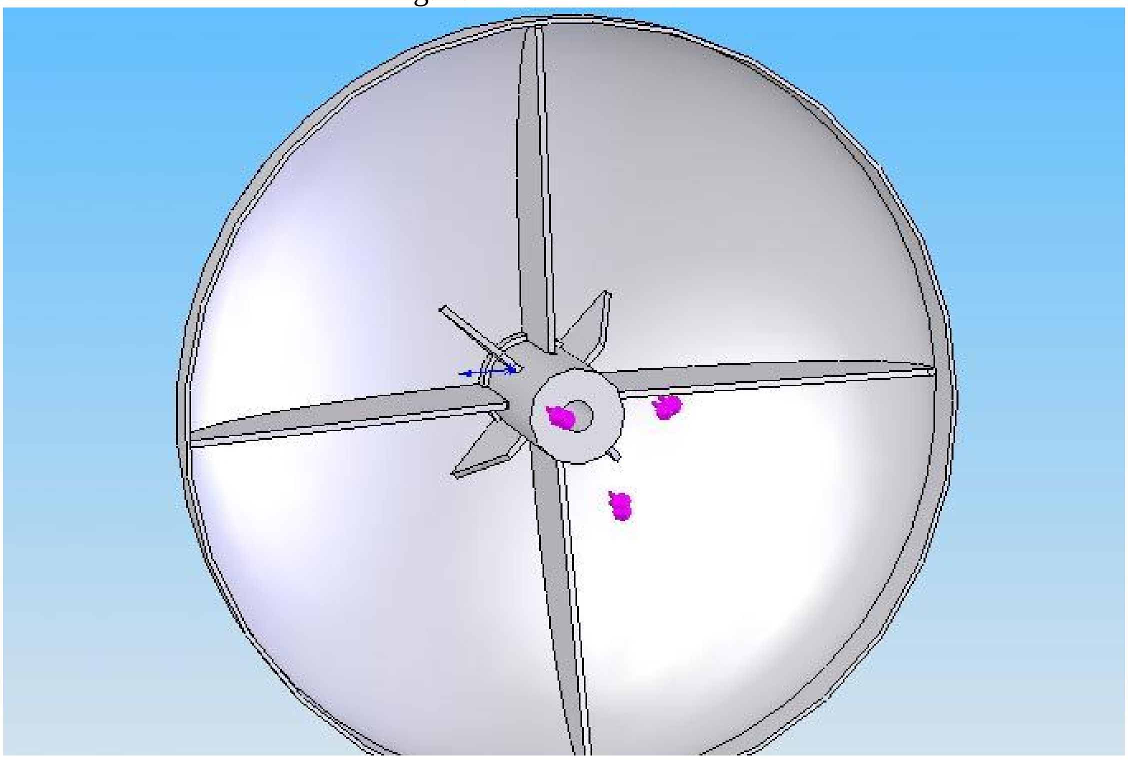
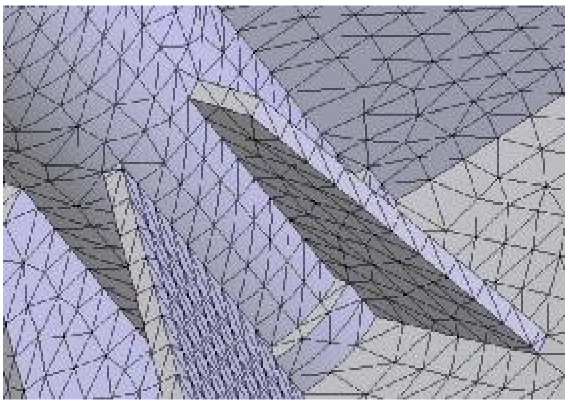
Introduction
The tube dryer is designed to ASME Section VIII Div 1 2007 Edition. Pressure boundary has been verified by PVElite. FEA is used to check effect of central stay/stiffeners on stresses in tubesheet and head. A model is created in SolidWorks and run in Cosmos. Loads considered include internal pressure, weight and torque from shovels, which is detailed later.

Model
Head assembly is modeled and analyzed. The model includes central support, head/stiffeners and tubesheet. Nozzles on head have been verified by code rules and are not included in this model.

A full model is created for application of bearing loads. Half of the model is shown to see the inside of the model.

Fig. 0: model to show inside





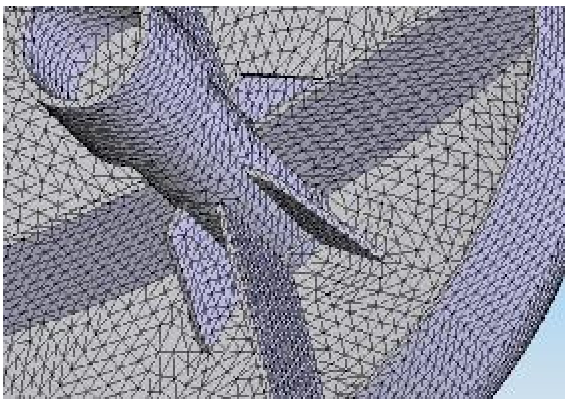
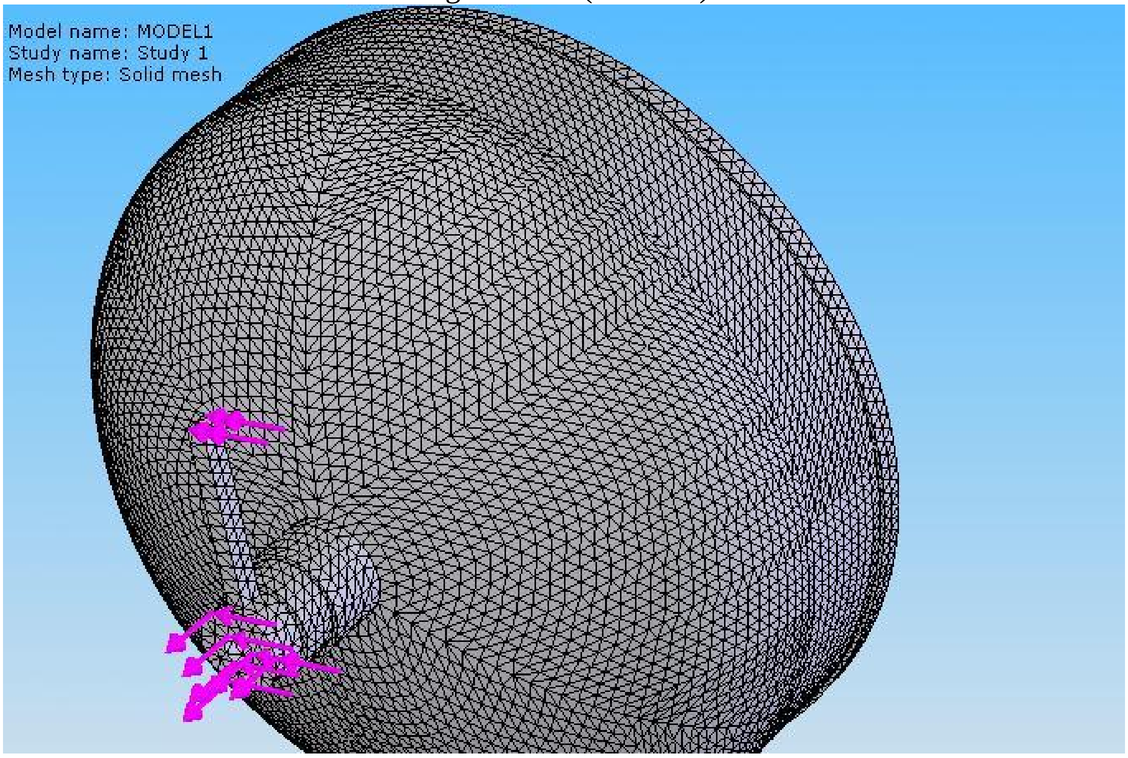
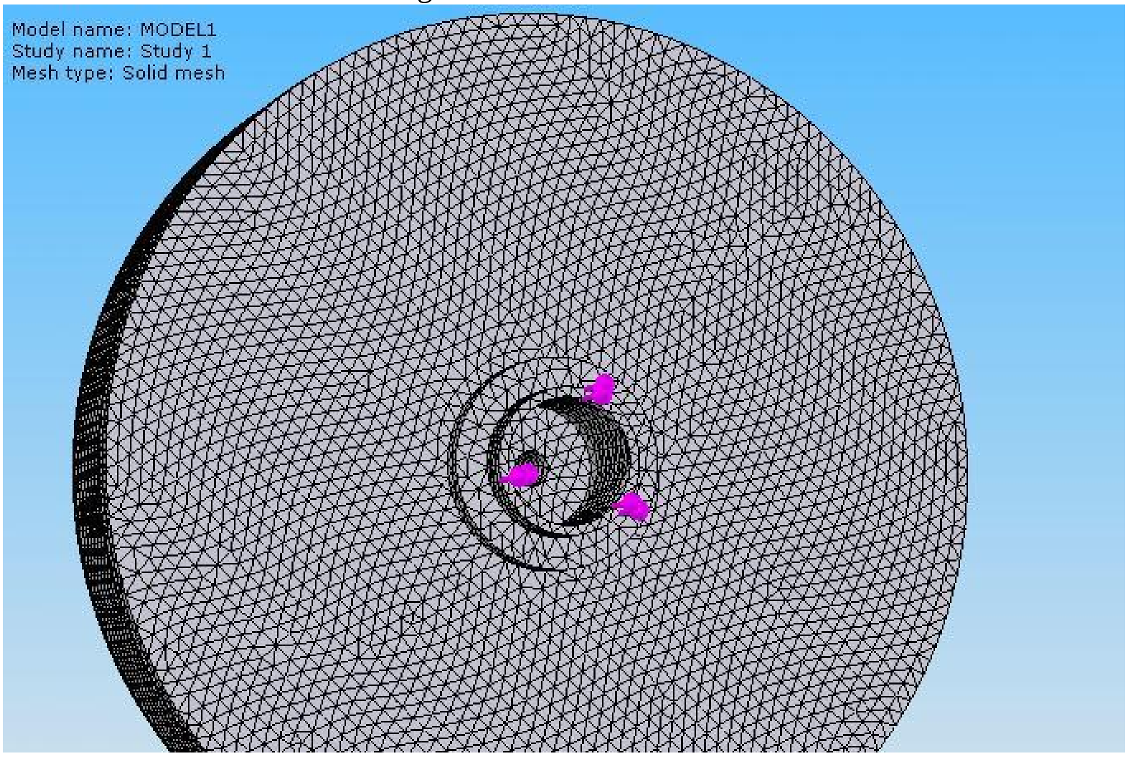


Fig. 1: mesh (3D solid)



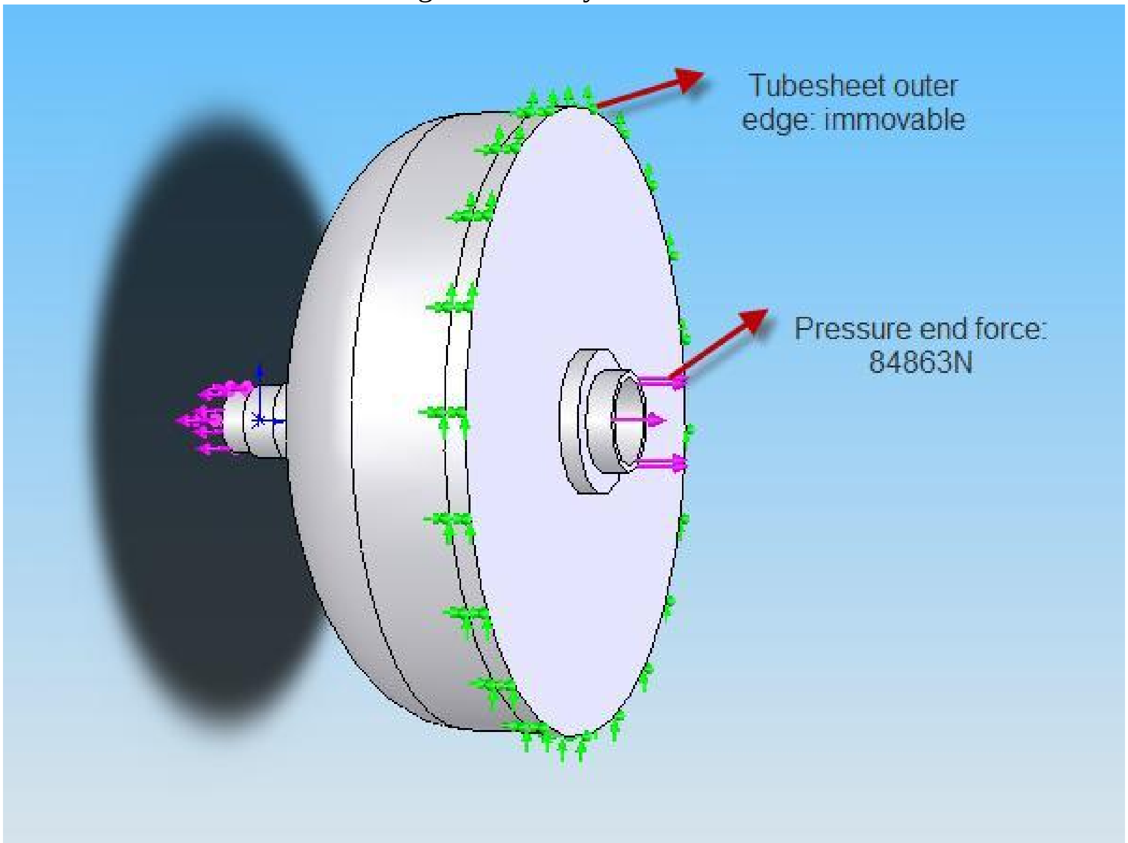
Mesh size: 40mm

Fig. 2: meshes on tubesheet



Boundary conditions
To apply loads to model properly, tubesheet outer surface is anchored.

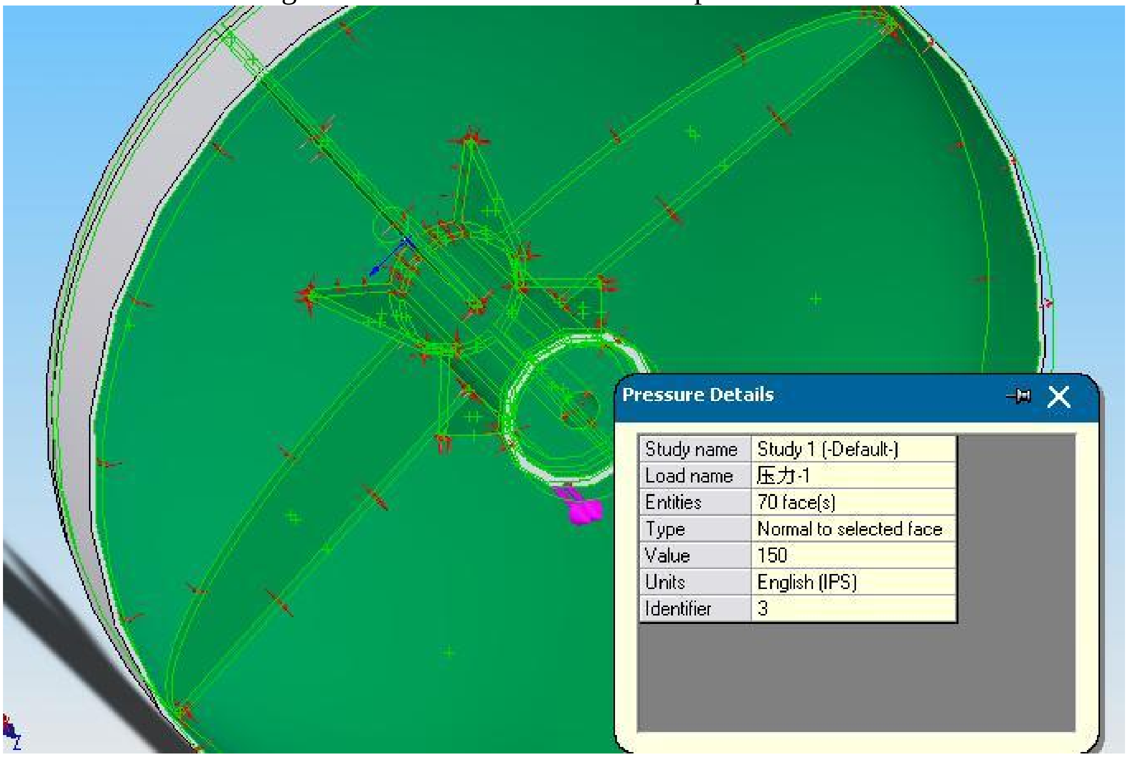
Fig. 3: boundary conditions



Loads

150psi pressure load is applied to inside surfaces.

Fig. 4: half model to show internal pressure loads



Pressure end load added to central tube cut-off: 84863N (See Fig. 3)

Central tube inside diameter d = 323mm(corroded) = 12.7165”

Pressure P = 150 psi

Load = P x 0.785 x d^2 = 150 x 0.785 x 12.7165^2 = 19051 lbs = 84863N

Pressure load added on transmission shaft end: 6875N (See Fig. 5)

Transmission shaft inside diameter d = 92mm(corroded) = 3.622”

Pressure P = 150 psi

Load = P x 0.785 x d^2 = 150 x 0.785 x 3.622^2 = 1545.5 lbs = 6885N

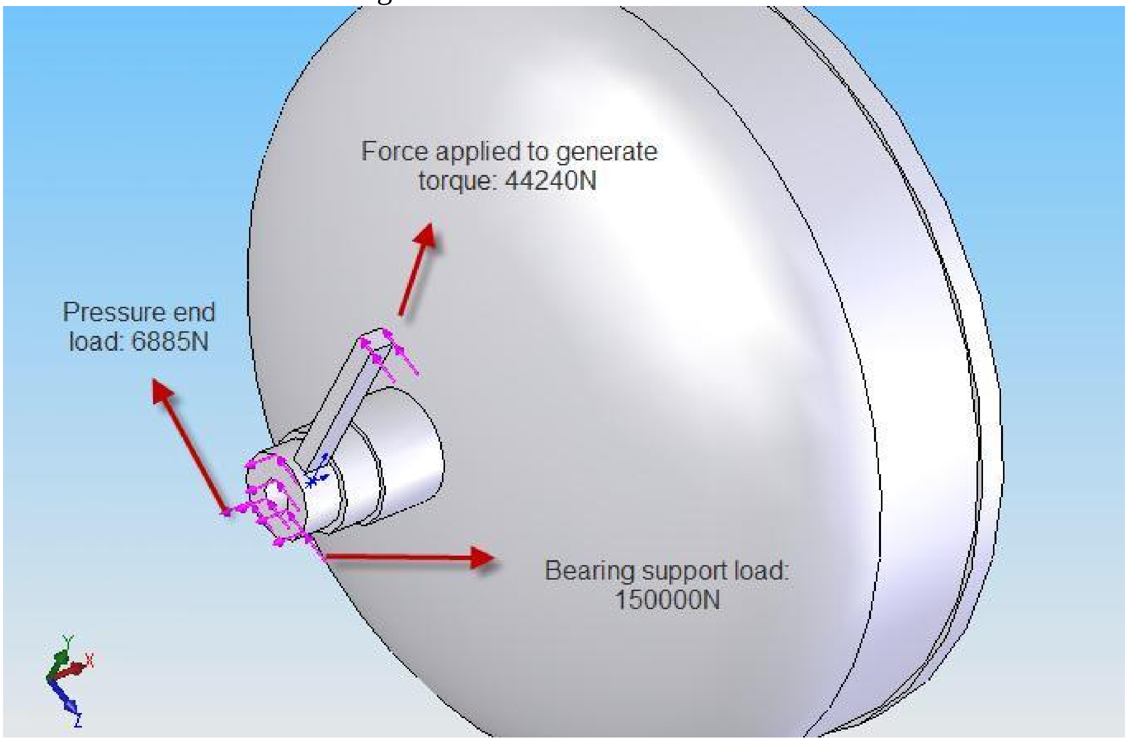
Force on the key to generate torque: 44240N (See Fig. 5)

Torque = 44240N x 24.55” = 27587N.m

Force on the bearing support from weight: 150000N (See Fig. 5)

Force = 30Ton / 2 = 150000N

Fig. 5: loads on transmission shaft



Materials:
Head and tubesheet: SA-516 70, allowable stress Sa = 20,000psi from ASME IID
Central tube: SA-106 B, allowable stress Sa = 17,100psi from ASME IID
Transmission shaft: SA-266 Gr. 1, Sa = 17100 psi from ASME IID
Ribs: SA-36, Sa = 16600 psi from ASME IID

Results
Stresses above 20,000psi are shown in red. Model stresses at general locations are below allowable = 20,000psi. Stresses in red on rib to head joints are secondary stresses (PL+Pb+Q) and are below 3 x Sa. Stress values in red areas are sown in Fig. 5.5 & 5.6.

Fig. 5.1: overall stresses in head – stress plot limited to 20,000psi

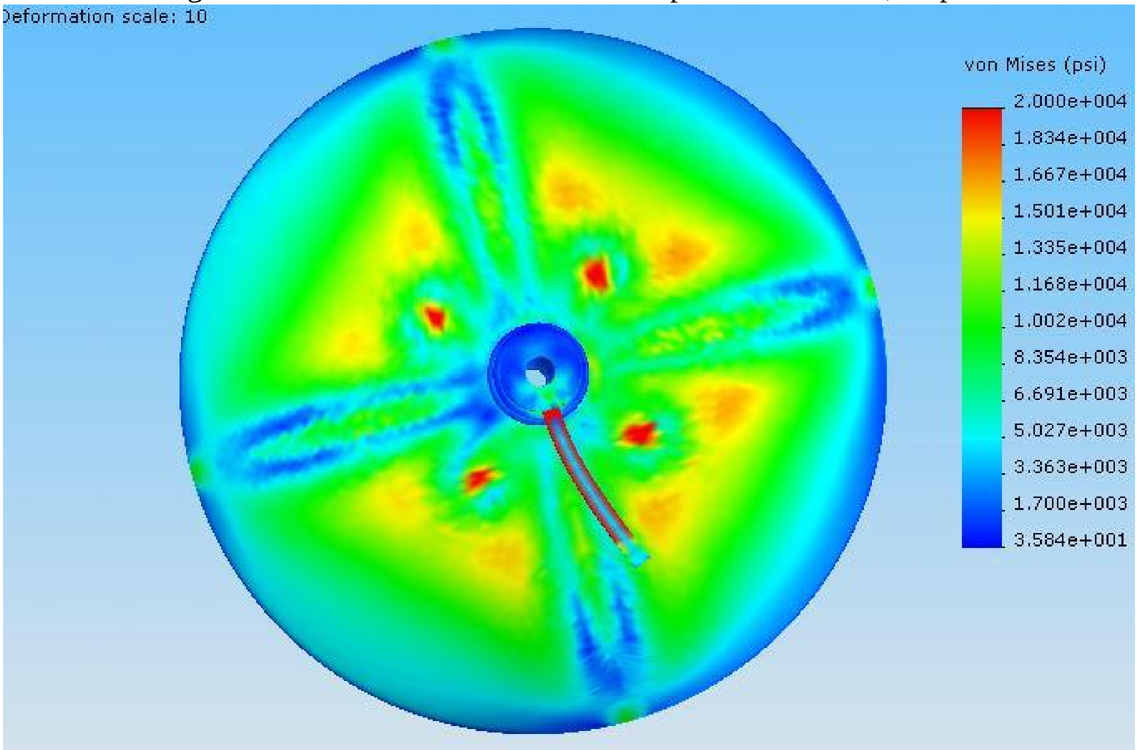


Fig. 5.2: stresses in tubesheet - stress plot limited to 20,000psi

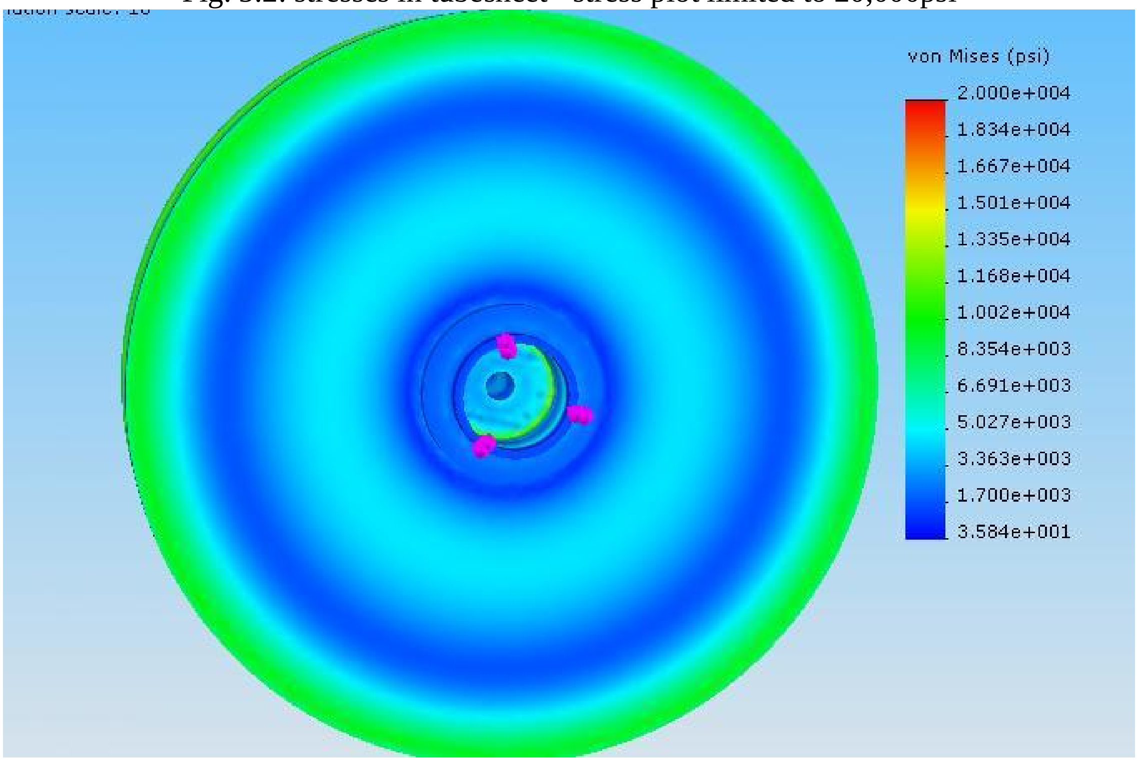


Fig. 5.3: stresses inside - stress plot limited to 20,000psi

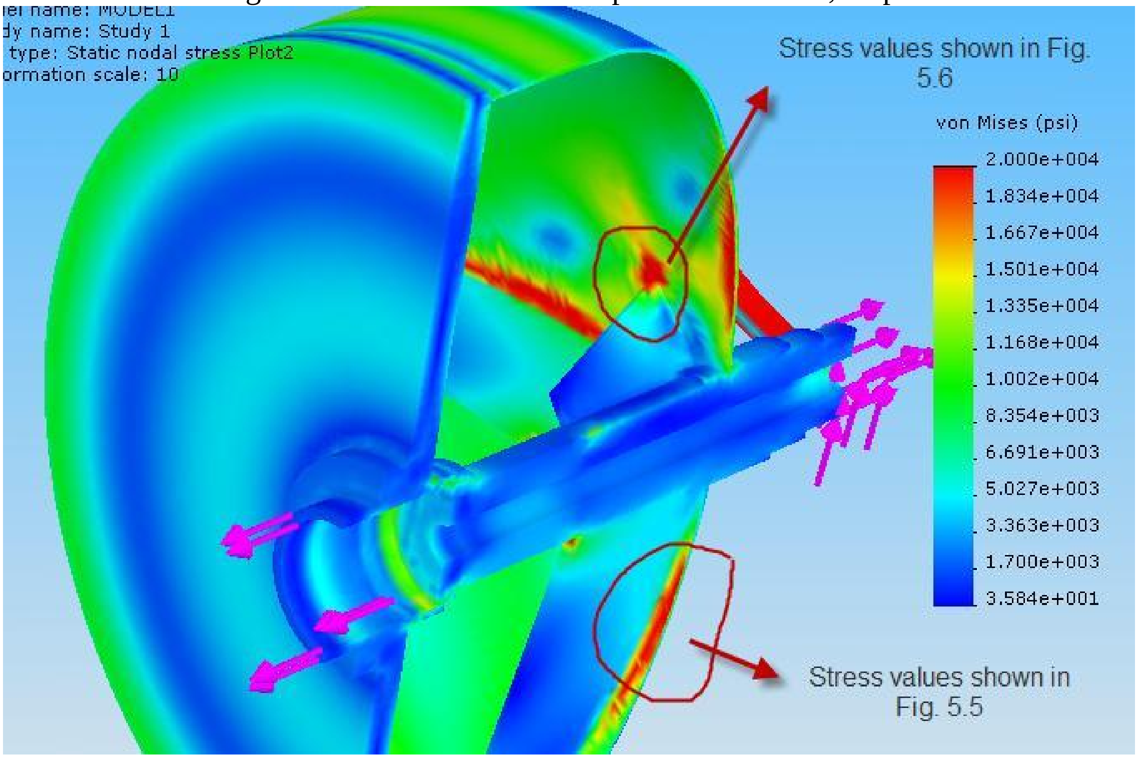


Fig. 5.4: inside tubesheet - stress plot limited to 20,000psi

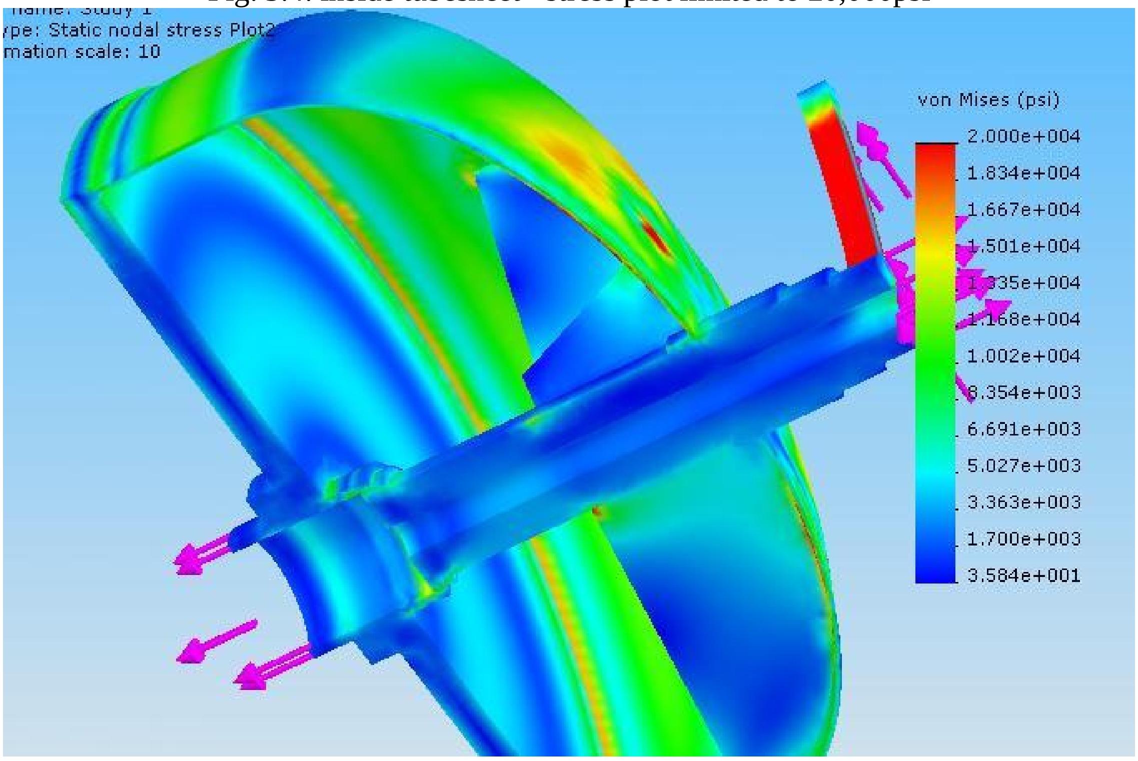


Fig. 5.5: peak stress in head

Peak stresses in head at rib joints are localized and are considered as discontinuity stresses generated by rib support. Per ASME Section VIII-2, the allowable stress limit is 3 x Sa(20000 for SA516 70) = 60000 psi. Stresses at corner are acceptable.

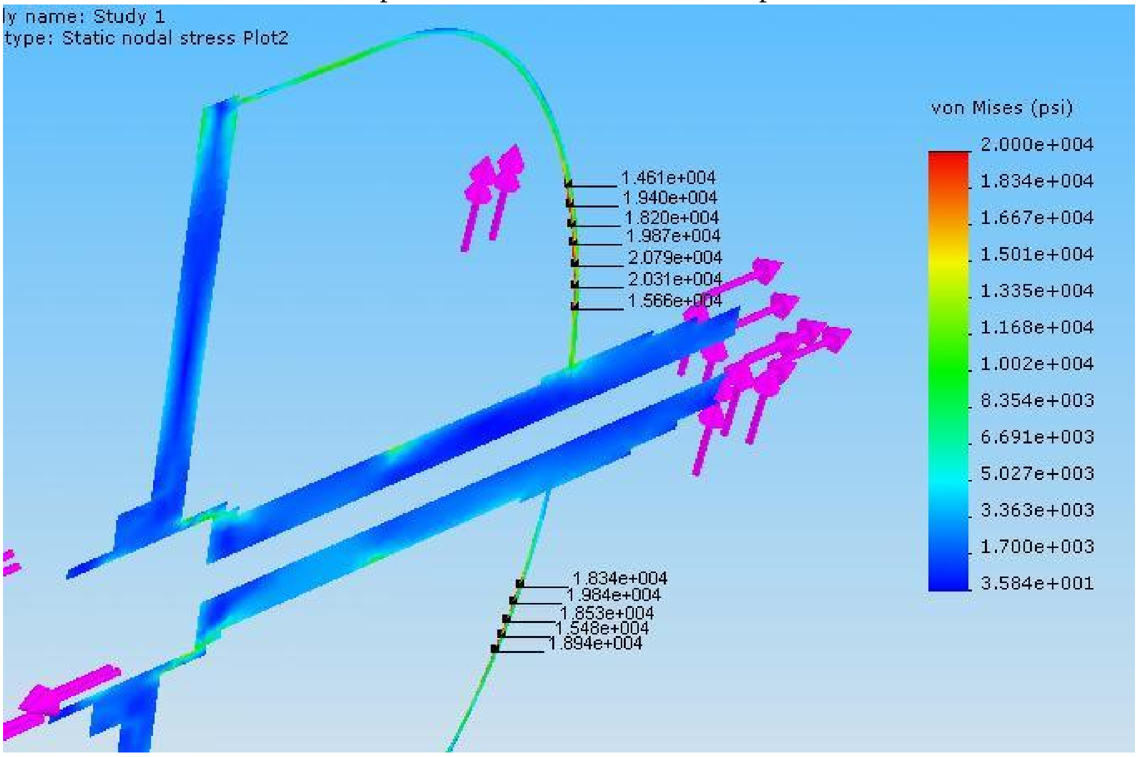


Fig. 5.6: peak stress at short rib support corner

Stresses are below 3 x Sa = 60,000psi, acceptable.

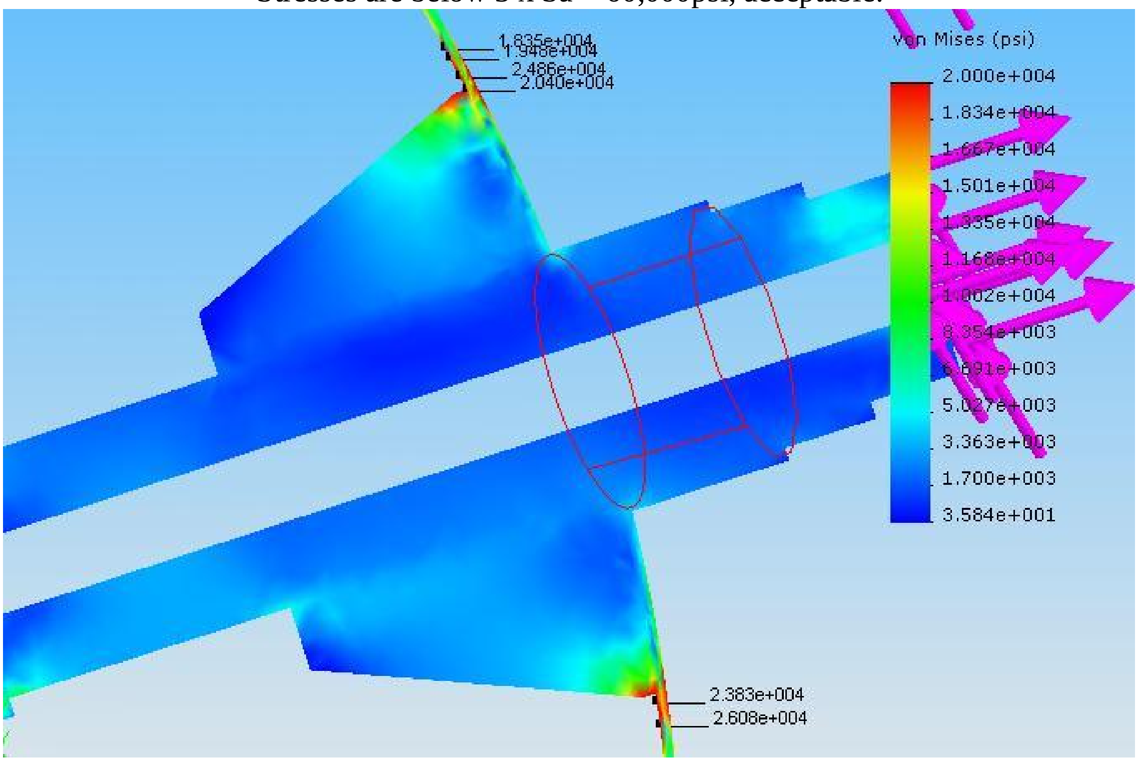


Fig. 6: stresses in the bar to apply torque are artificial and shall be ignored.

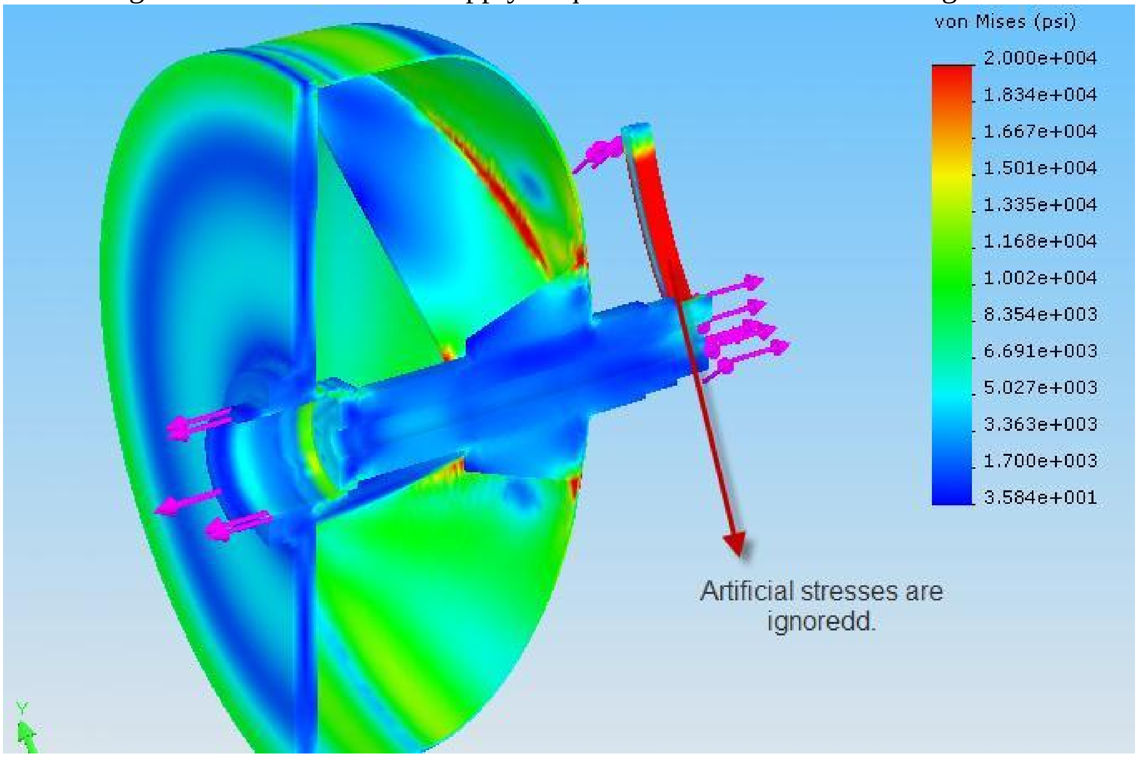
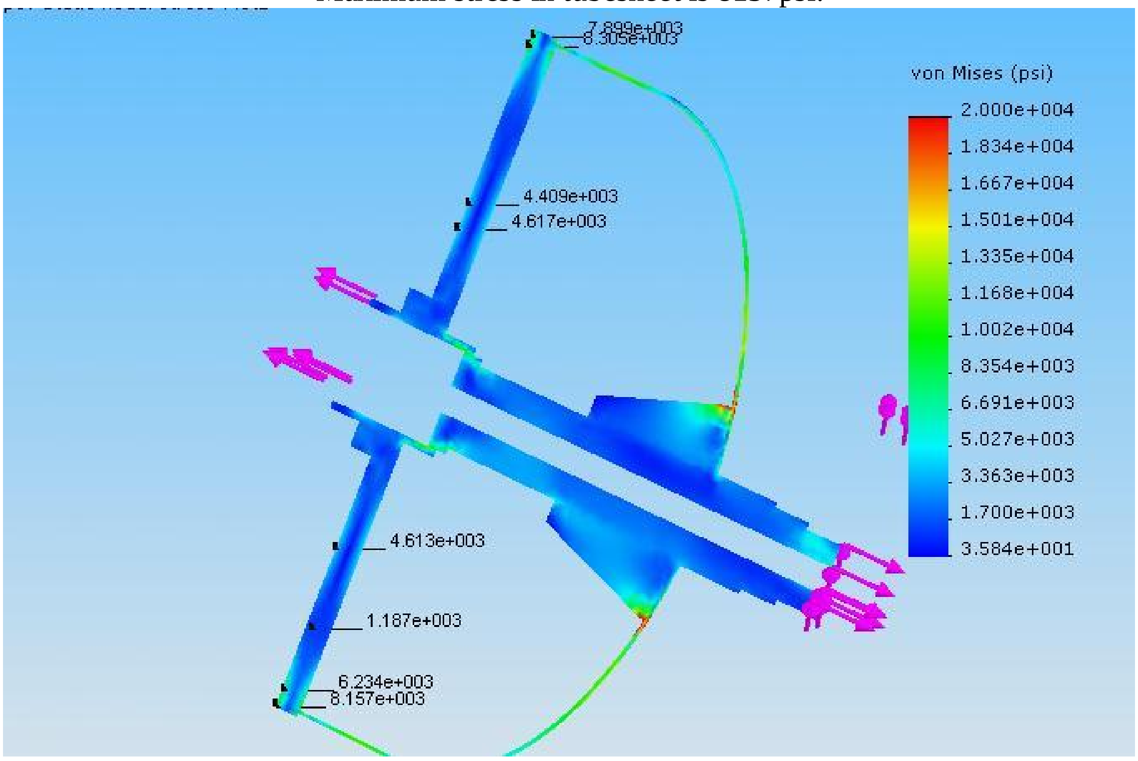


Fig. 7: Stresses in tubesheet - peak stress plane is chosen.
Maximum stress in tubesheet is 8157psi.



Due to the fact that tube holes are not modeled, calculated stresses in tubesheet shall be adjusted by ligament efficiency in UG-39(e)(2).

Adjustment of stresses in tubesheet to UG-39(e)(2):

$e = (p-d)/p = (92.38-51.5) / 92.38 = 0.44$

p: tube hole pitch, 92.38mm

d: tube hole diameter, 51.5mm

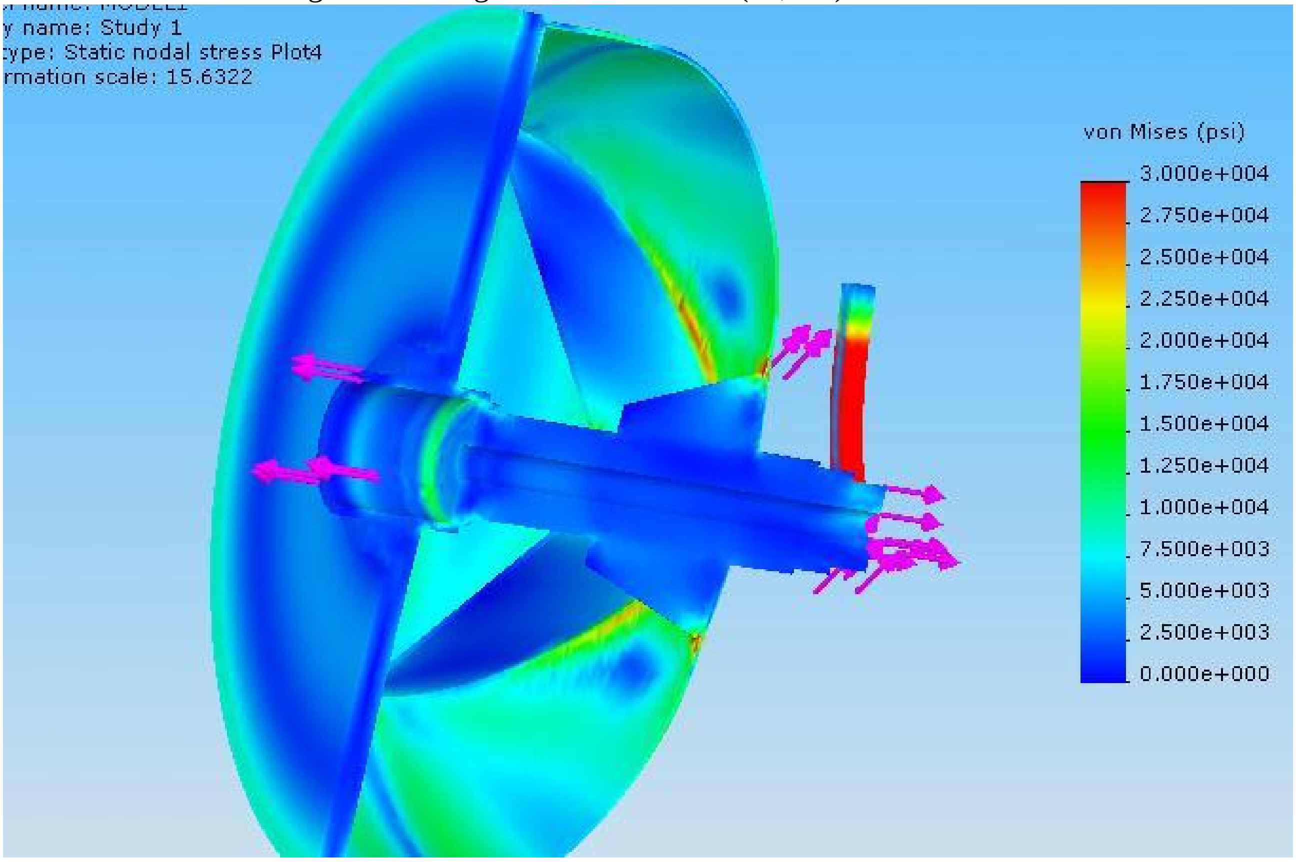
$h = \mathrm{sqrt}(0.5/e) = 1.066$

Stress adjusted:

$S_{ad} = S_{max} / e = 8157 / 0.44 = 18539$ psi < Sa = 20, 000psi.

Tubesheet design is acceptable.

Fig. 8: stresses greater than 1.5 x Sa (30,000) shown in red



Head is also calculated to Section VIII-1 and membrane stresses without ribs & central column are below Sa = 20,000psi. FEA results show stresses at rib joints are above Sa, which is caused by bending due to additional supports. The allowable stress for these areas is 3 x Sa = 60,000psi per Section VIII-2. Actually, all stresses in head are less than 1.5 x Sa. Therefore, head design is acceptable.

Displacement

Fig. 10: displacement multiplied by 50, maximum in head and tubesheet below 1mm. displacement in load application bar is artificial and shall be ignored.

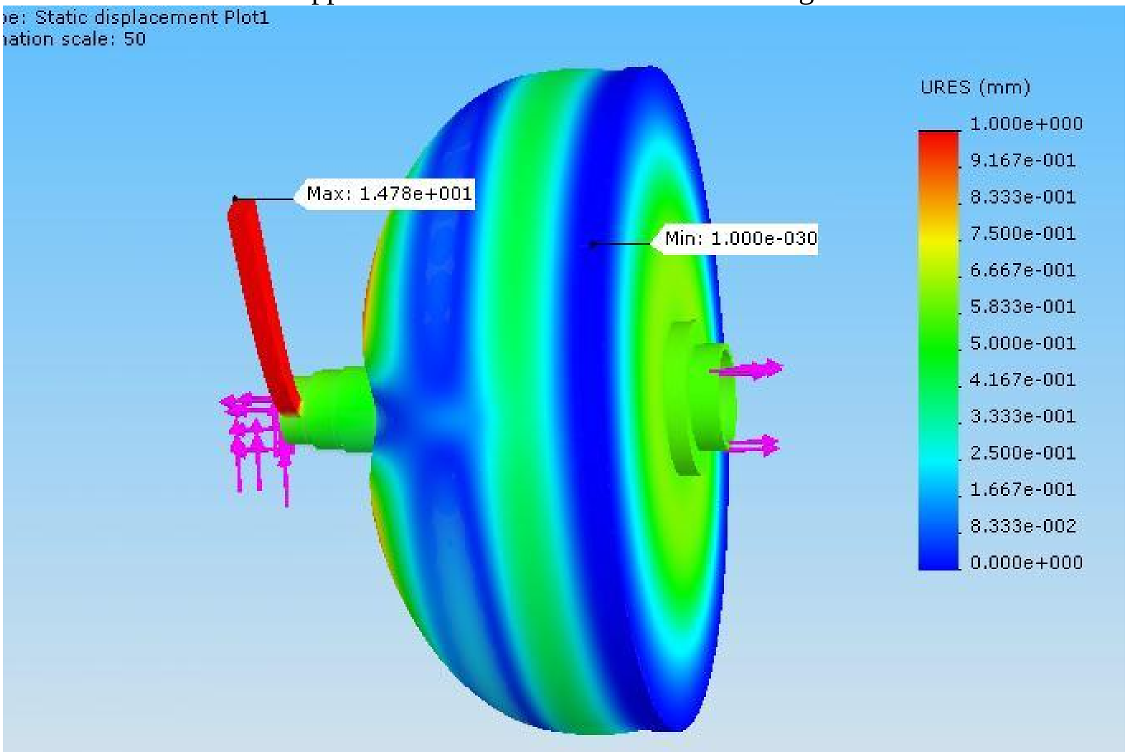
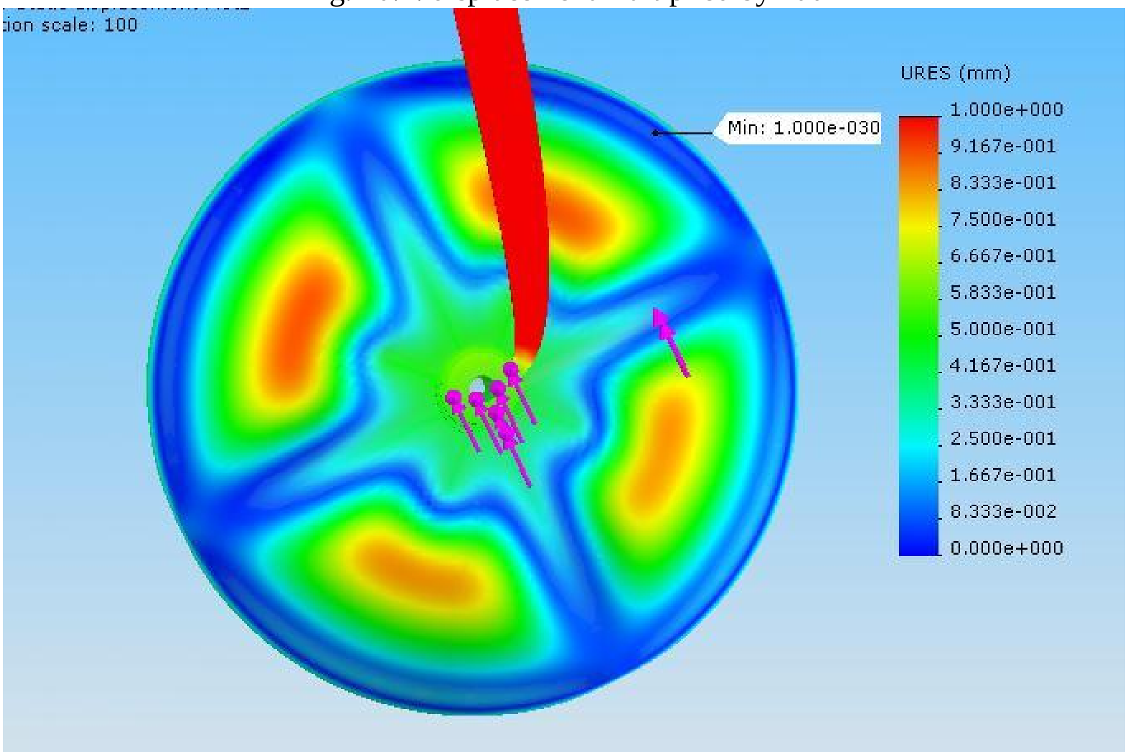
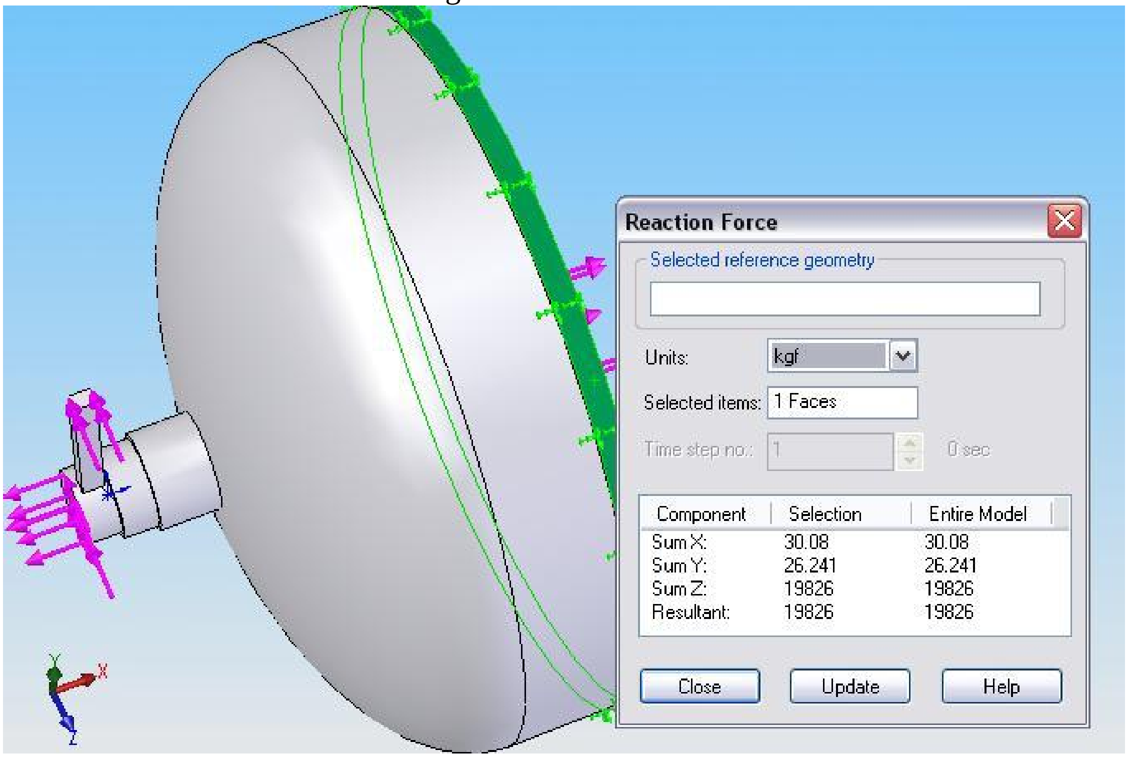


Fig. 10.1: displacement multiplied by 100



Reaction forces check

Fig. 11: reaction forces



X direction: theoretical value is 0; actual force is 30Kgf.

Y direction: theoretical value is 0; actual force is 26Kgf.

Z direction: expected value is 150000 + 44240 = 194240N; actual value is 19826kgf(194295N). The difference is 5.5kgf.

The difference might be caused by: 1. unit conversion – internal pressure uses imperial, but load inputs use metric; 2. dimension decimal places when modeling and calculating pressure loads by hand. This minor difference does not affect design safety and is ignored.

This model is acceptable.

Conclusion

1. Stresses in tubesheet by FEA are lower than that calculated by TEMA. Central stay reduces the bending stresses in tubesheet. TEMA calculations are conservative in this case.
2. Use of ribs inside the head effectively spread the loads from transmission shaft. No obvious peak stress is produced on the central opening.
3. Stay and ribs generate additional bending stresses in head. Stresses (general and local) are within allowable membrane plus bending stress limit of 1.5 x Sa (30,000psi). Stresses in head are acceptable.

Design is acceptable.