

Electric Turbo Pump

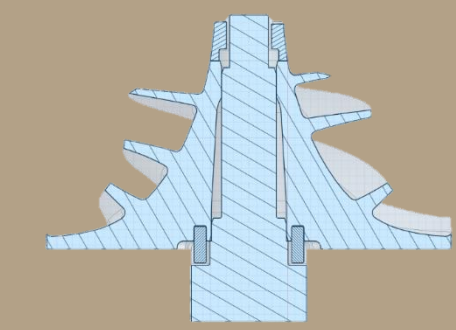
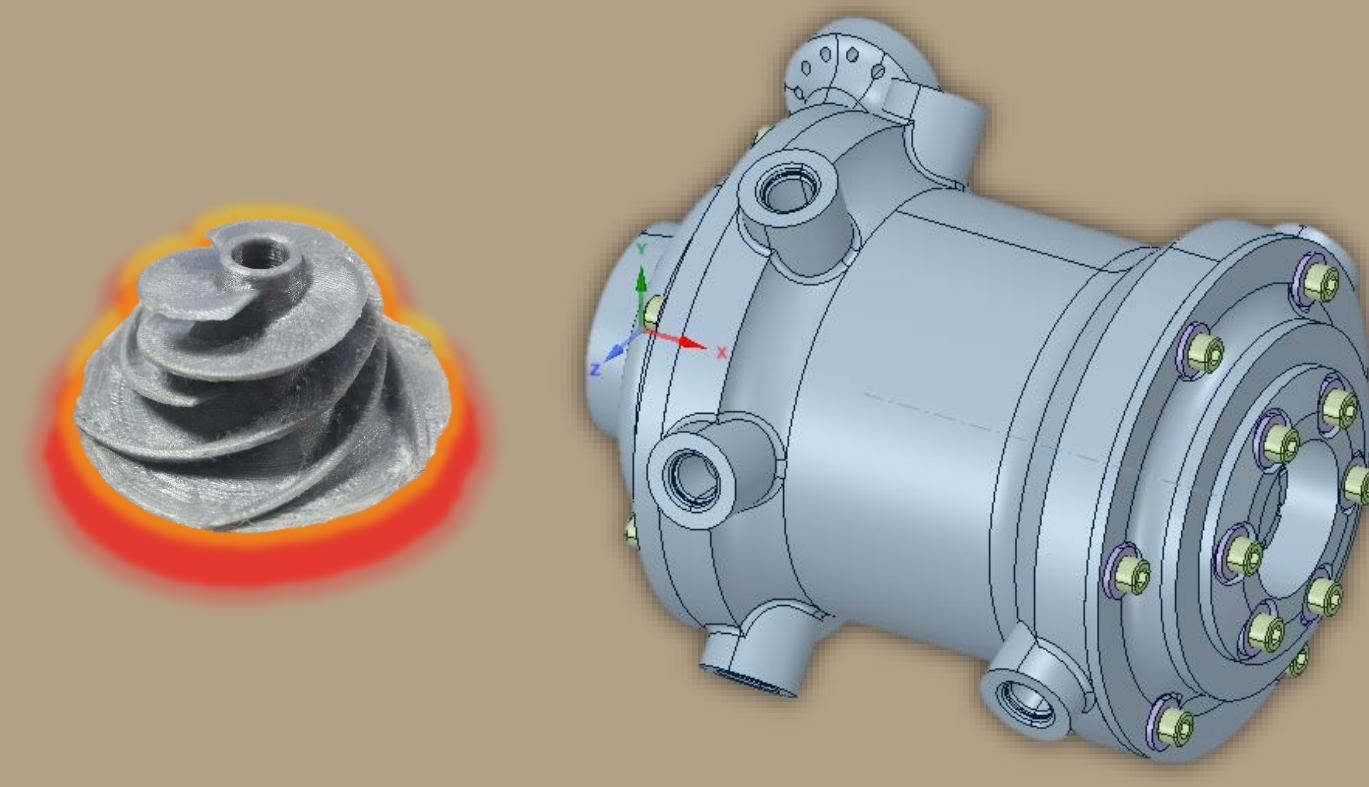
Jessica Steckler – ER41 Propulsion Systems Structural & Dynamic Analysis
Mentor: Luke Scharber



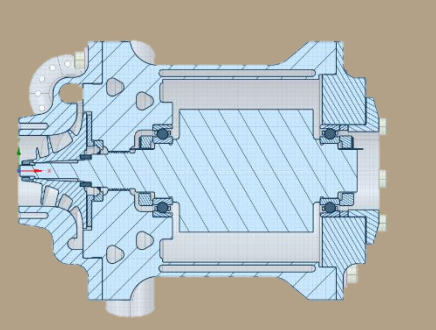
University of Florida – Mechanical and Aerospace Engineering

Background

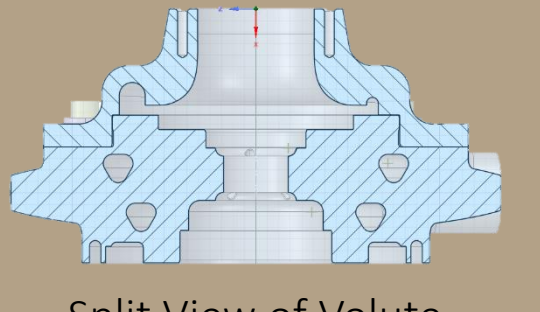
NASA is working in junction with another company on an Electric Turbo Pump. Analysis of the impeller, including the blades, volute housing, and associated components, will take place in ANSYS. Contours of the deformation and stress were recorded to assess the parts. Campbell diagrams will be considered as a method to find the operating regions of the impeller and volute housing, more specifically what speed is ideal to ensure that the impeller does not begin to vibrate at a frequency that will break it. More than one material will be examined as per request by the designer to determine which material is more cost efficient, easy to machine, and can withstand the stress values that will be placed on it.



Split View of Impeller



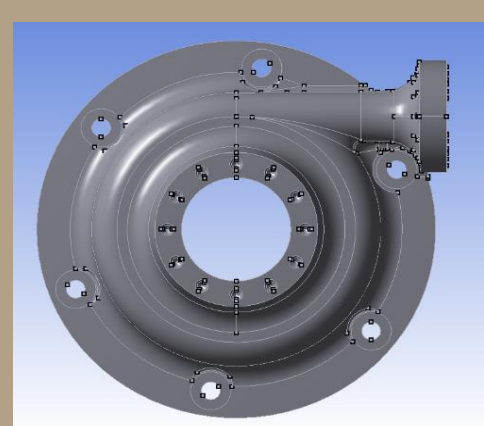
Split View of Full Assembly



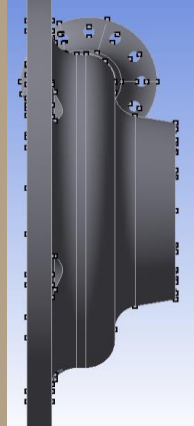
Split View of Volute Housing and Flange

Set Up

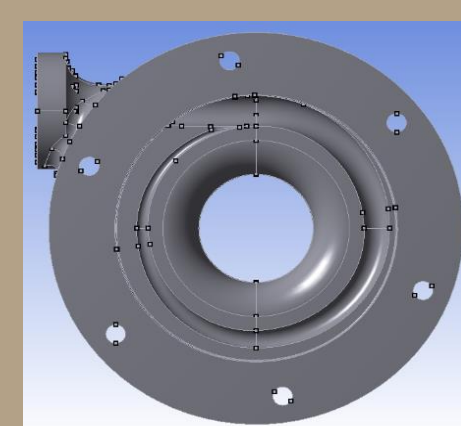
- Geometry files were uploaded into ANSYS.
- Pressure distributions were calculated in excel and imported into ANSYS Engineering Data.
- Separate models were created to account for the different materials and boundary conditions:
- Engineering data such as material properties were added to the models for accurate analysis



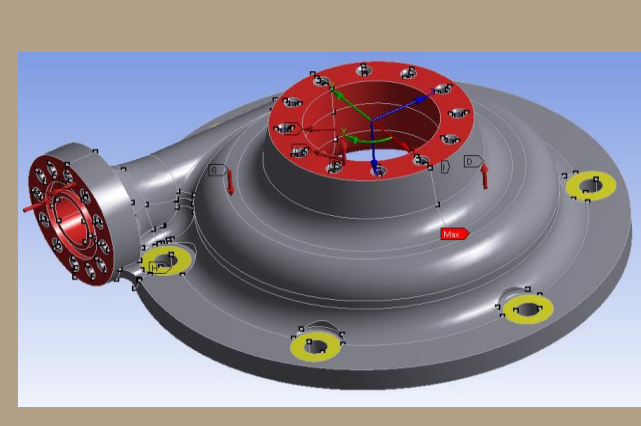
Volute Housing Top View



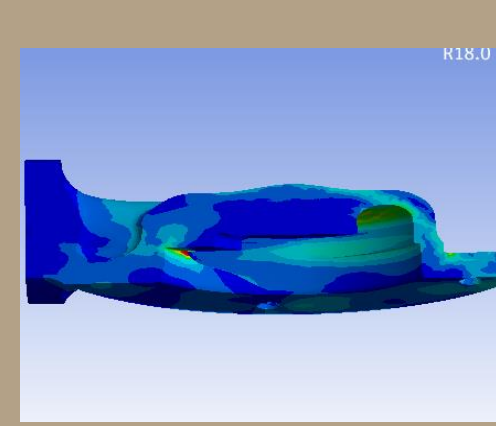
Volute Housing Side View



Volute Housing Bottom View



View of Volute Housing with Pressures, Forces, and Boundary Conditions



View of Maximum Stress Location

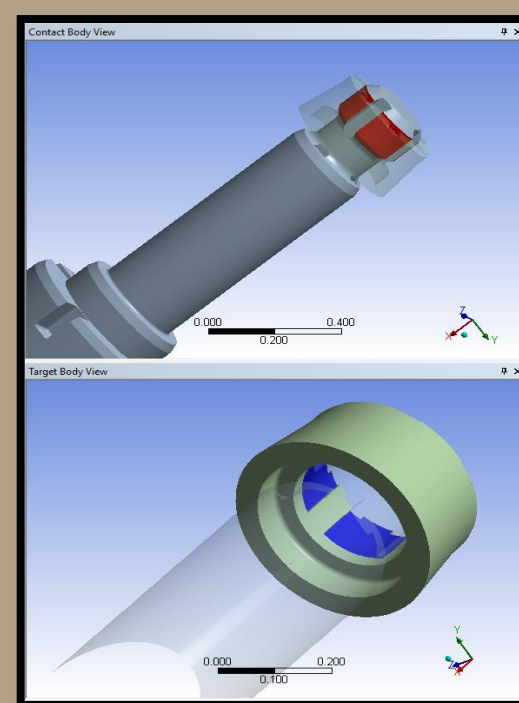
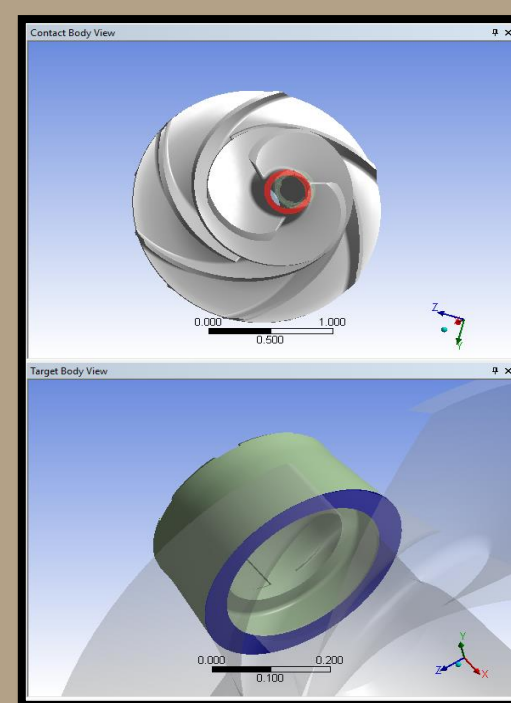
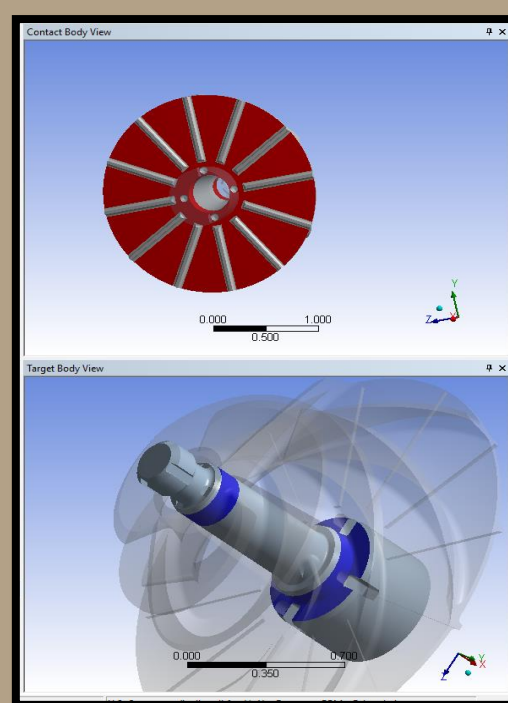
Material Assignment

- Alloy 17-4PH is a precipitation-hardening, martensitic stainless steel used for parts requiring high strength and good corrosion and oxidation resistance up to 600°F. The alloy is available in all product forms.
 - Impeller
 - Shaft
- 718 alloy is a vacuum-melted, precipitation-hardened nickel-base alloy. It can be welded easily and excels in its resistance to strain-age cracking. It is also readily formable.
 - Volute Housing
 - Flange
- 316 stainless steel for the for shear pins
- A-286 for the bolts and washers

Contact

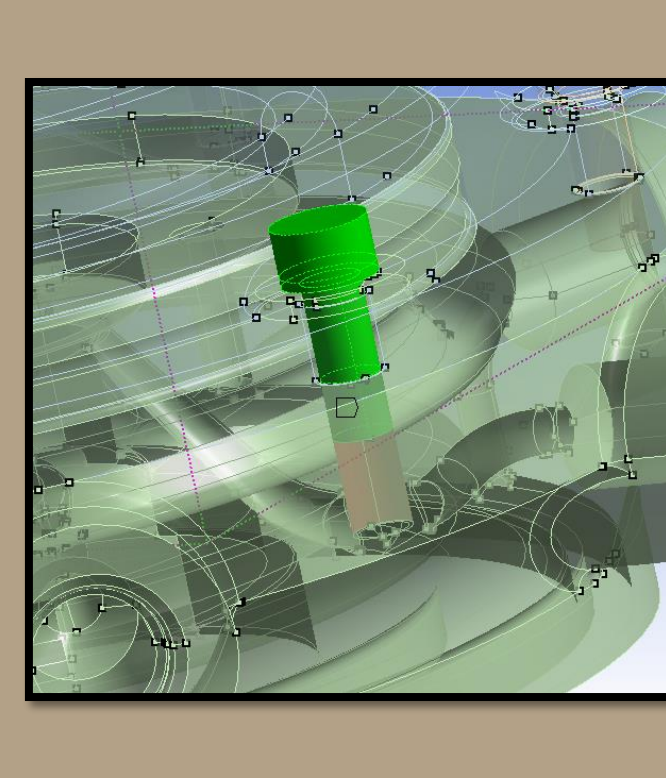
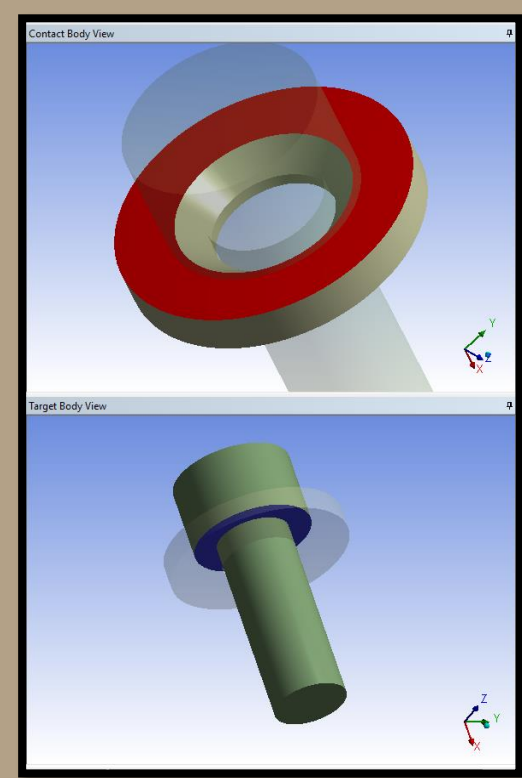
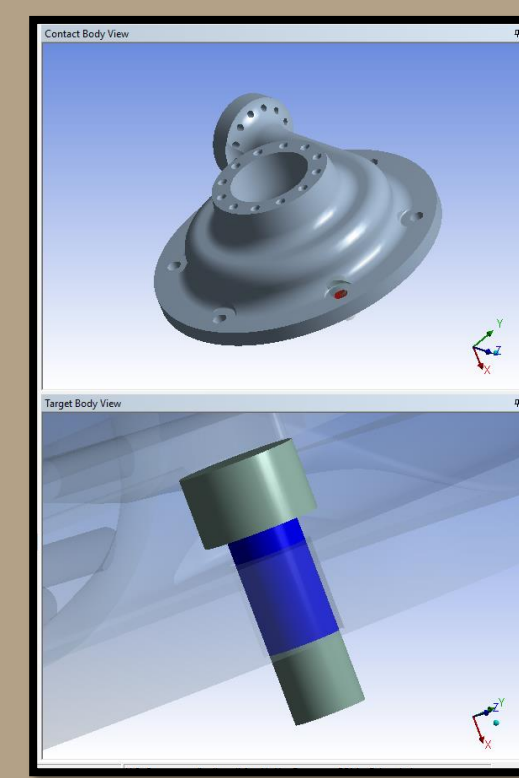
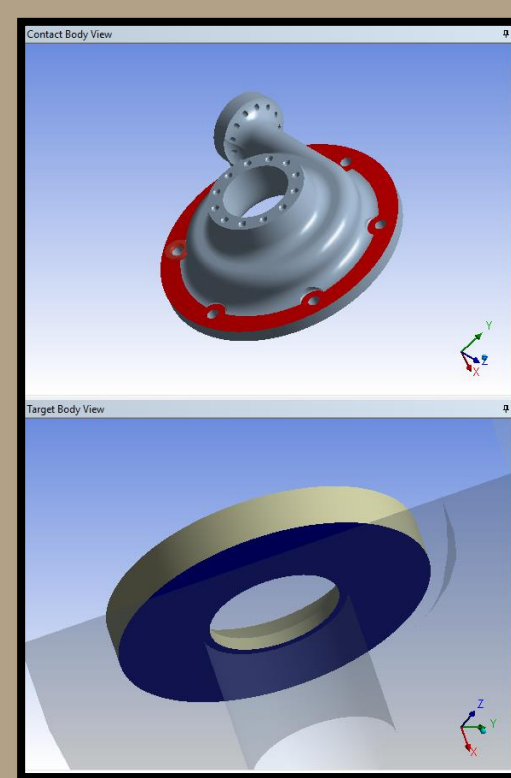
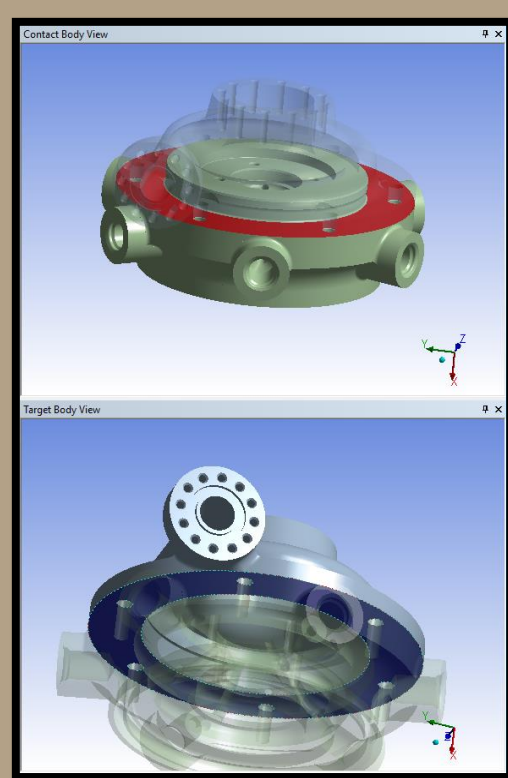
The following images are the depictions of the contact between the parts of the Impeller subassembly.

- Frictionless contact between shaft and impeller
- Frictionless contact between nut and impeller
- Bonded contact between nut and shaft



The following images are the depictions of the contact between the parts of the Volute housing and Flange assembly.

- Frictionless contact between Volute Housing and Flange
- Frictionless contact between washer and Volute Housing
- Frictionless contact between bolt and Volute Housing bolt holes
- Bonded contact between bolt and washer
- Bonded contact between the threaded part of the bolt and the Flange



Modal Analysis 1-12

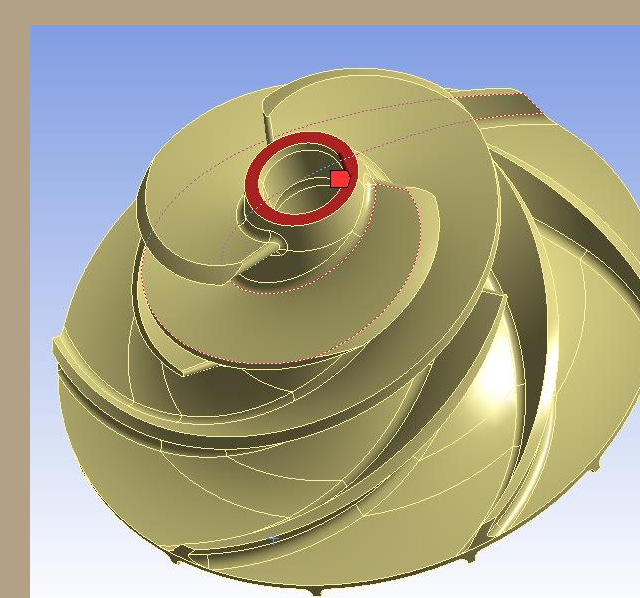
- Modal analysis is the study of the dynamic properties of systems in the frequency domain.
- Modal analysis is performed on a part when there is reason to believe that there exists a frequency to which the part will naturally vibrate, called the natural frequency.
- Modal analysis was performed on the impeller at three speeds (the nominal speed, a higher speed, and a lower speed), using a Campbell Diagram to illustrate where the lines cross. These intersection points denote the speeds at which the part cannot operate due to a “destructive” frequency.

Final Statements and Future Work

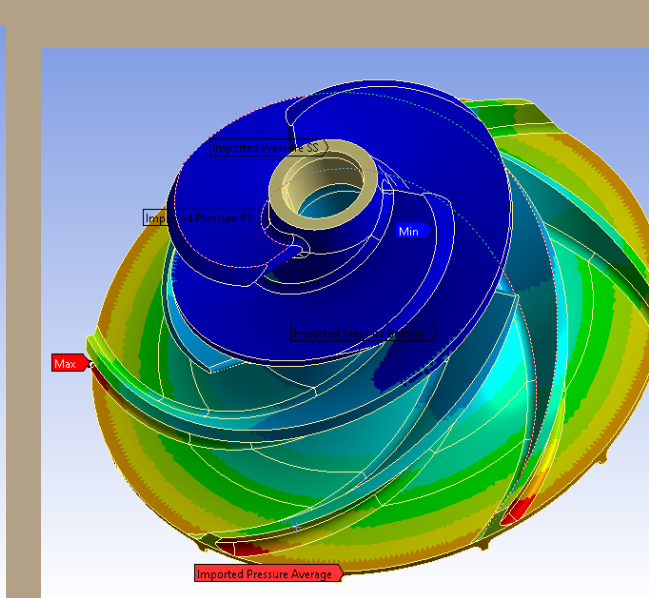
- High Cycle Fatigue (HCF)
- Integration of models with data from 2D stack up performed by another team member
- More thorough Modal Analysis to ensure the operation zones are clear of destructive frequencies
- Presentation development and delivery to the department
- Finally, production of parts

Loads and Boundary Conditions

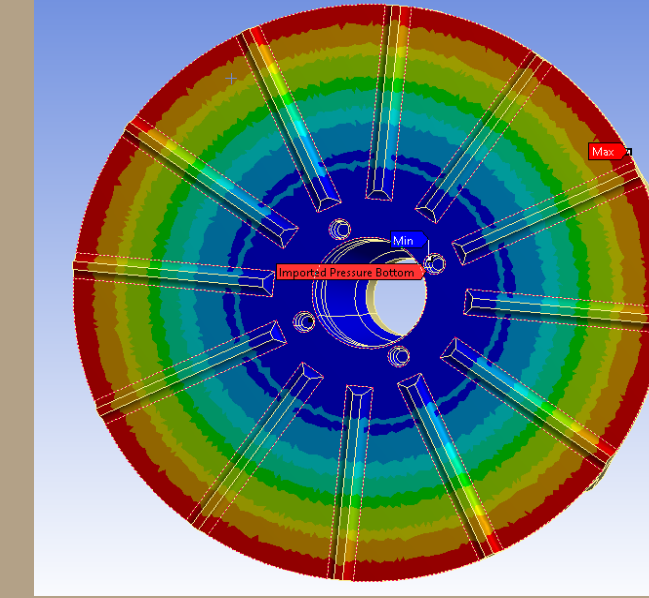
- There is an inlet pressure that comes through the top of the impeller, pressurizing the nut and top of the shaft.
- The pressures are then distributed on the suction side and pressure sides of the blades, the flow surface of the impeller, the bottom of the impeller, and the shaft inside and outside of the impeller.
- There are pressures on the nut and shaft that match the pressures on the impeller.



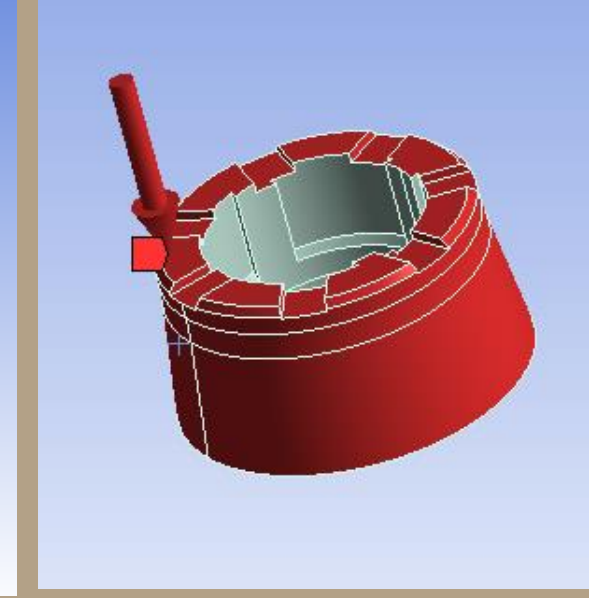
Inlet Pressure



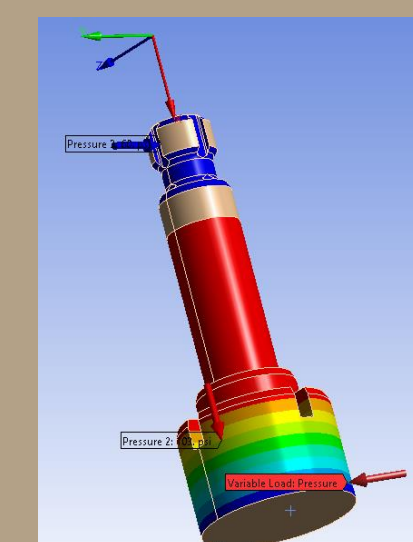
Blade Pressures



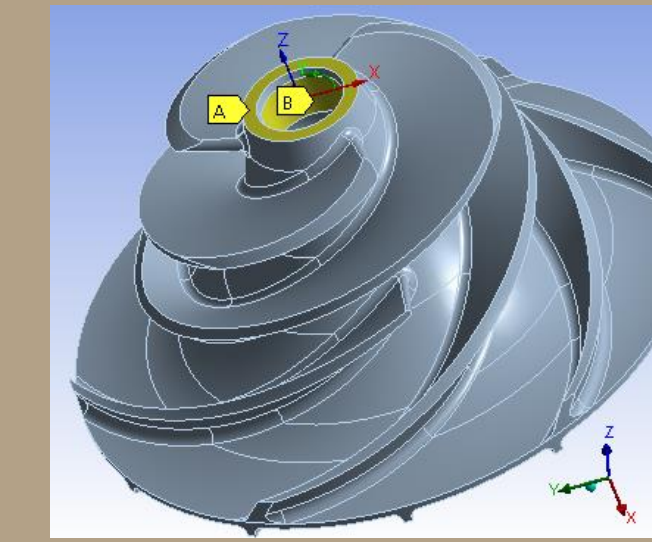
Bottom and Inner Pressure



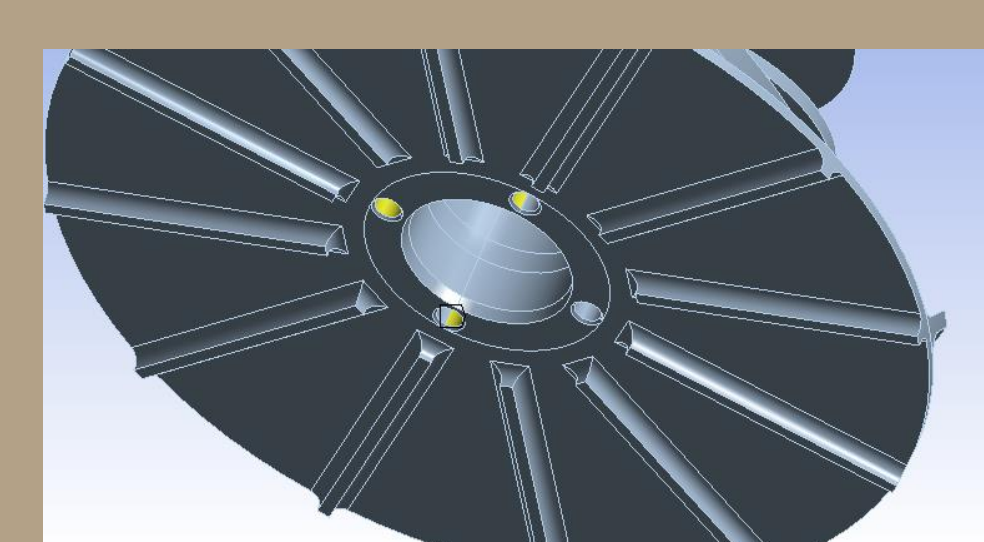
Nut Pressure



Shaft Pressures

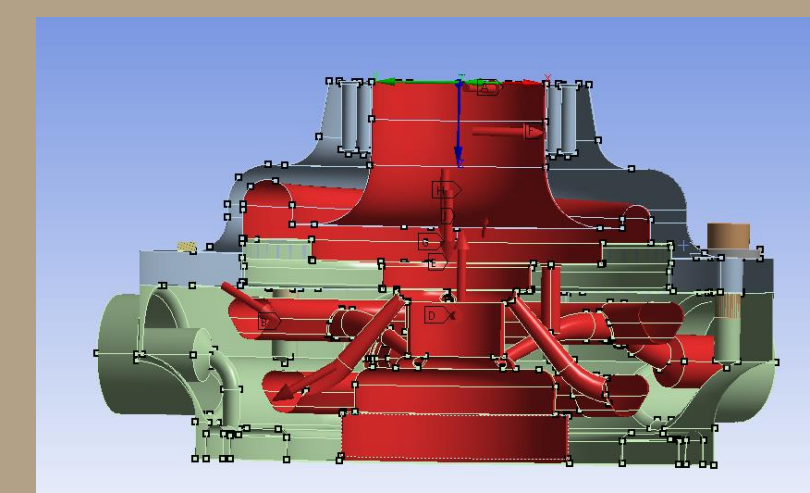


Axial and Radial Constraints

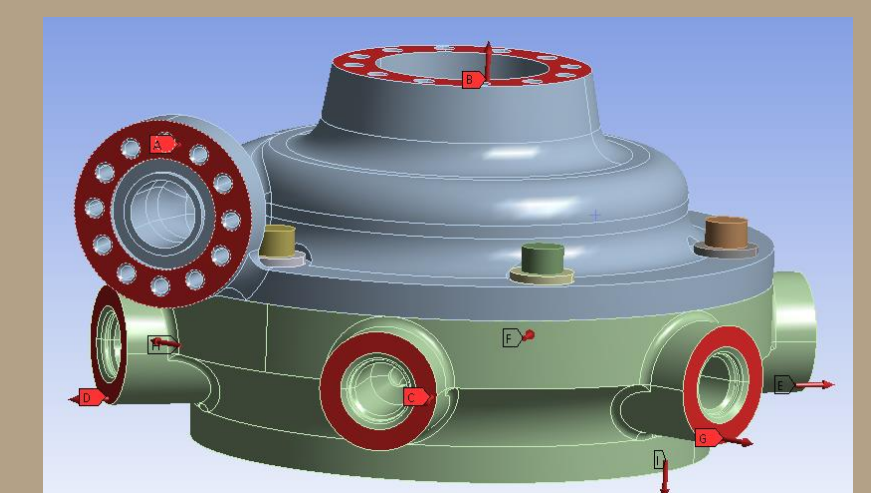


Rotational Constraint

- There are pressures inside the Volute Housing and the Flange.
- There are blow off loads on the inlet, outlet, and measurement outlets.



Pressures inside Housing



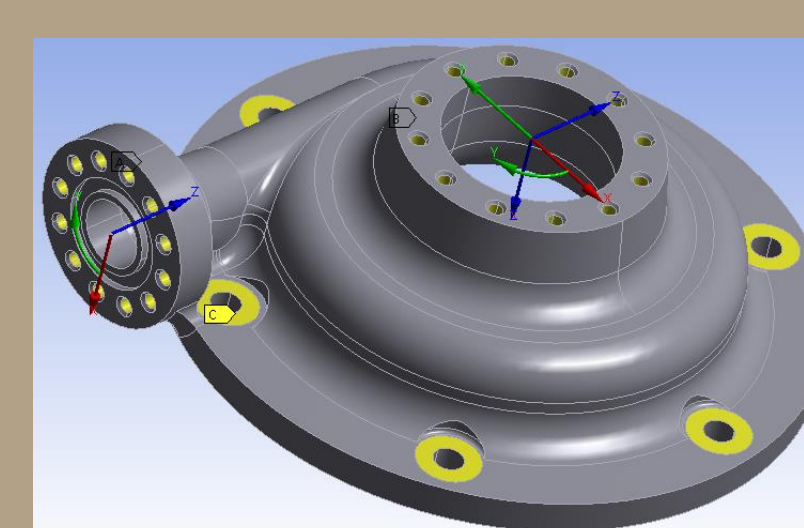
Blow off Loads

Trade Study for Boundary Conditions

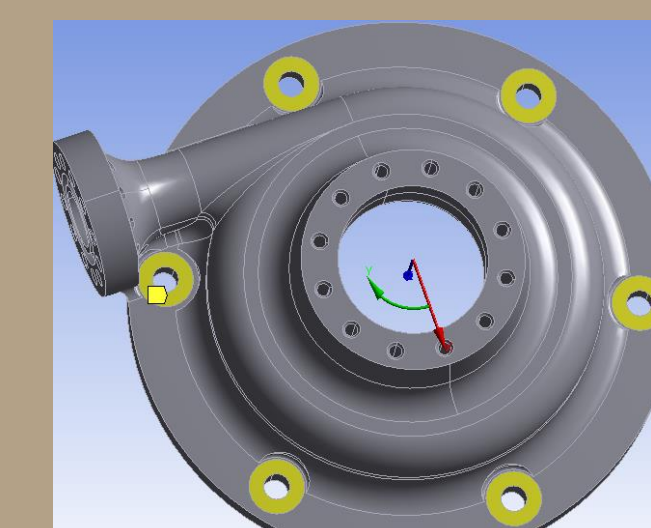
The following images are of the stress contours for the Volute Housing with three different boundary conditions

1. Constrained axially and rotationally at the inlet and outlet (defined by their respective local cylindrical coordinate systems); constrained axially through the bolt holes
2. Constrained axially and rotationally at the inlet (defined by its local cylindrical coordinate system); constrained axially through the bolt holes
3. Constrained axially and rotationally through the bolt holes

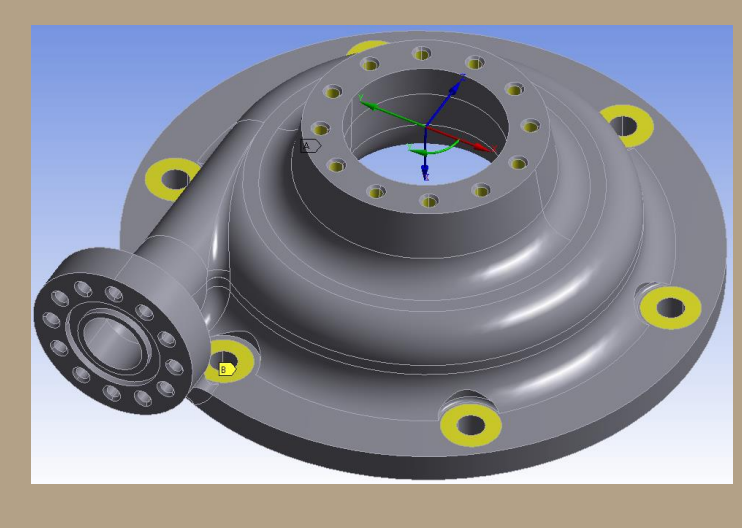
It is interesting to note that the stress contours are look very similar despite the three different boundary conditions. Even the maximum stress is in the same location with similar values.



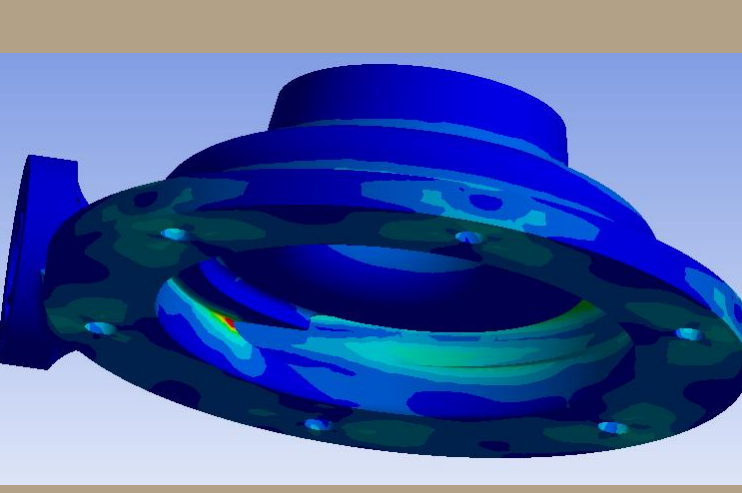
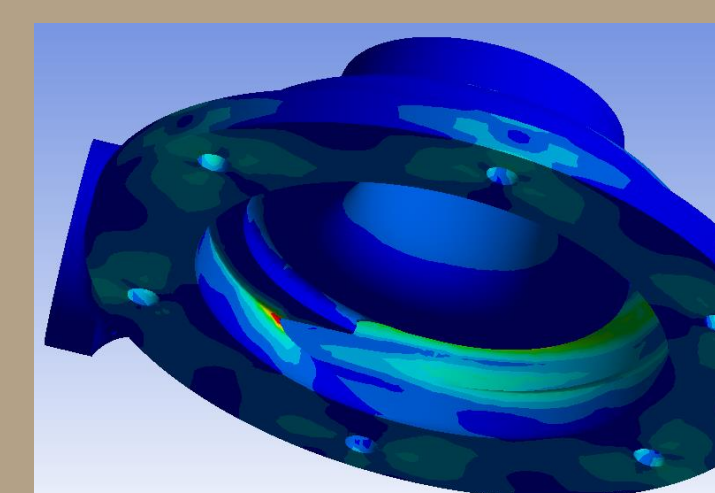
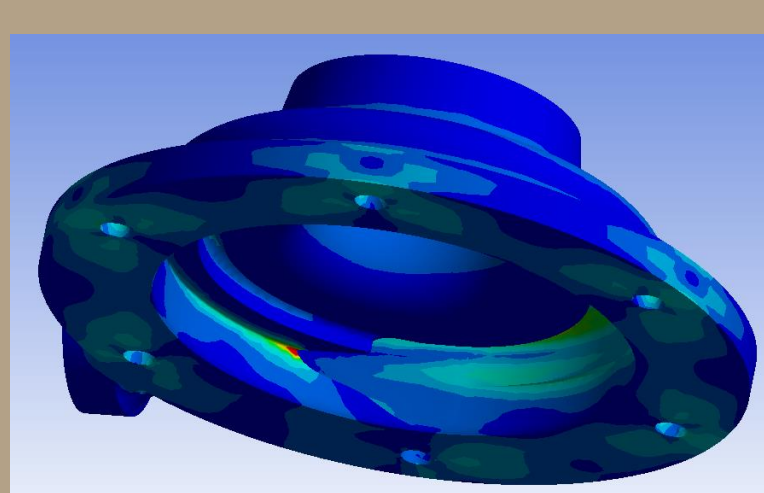
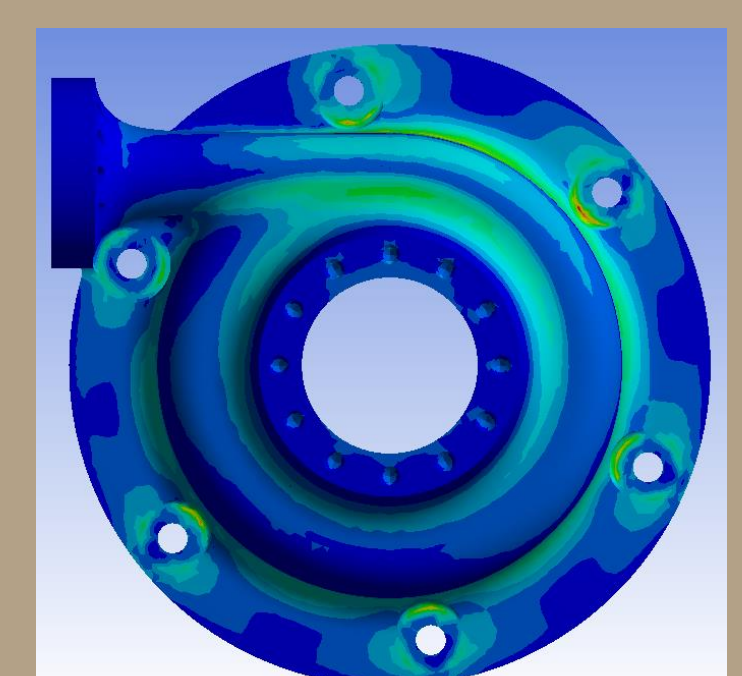
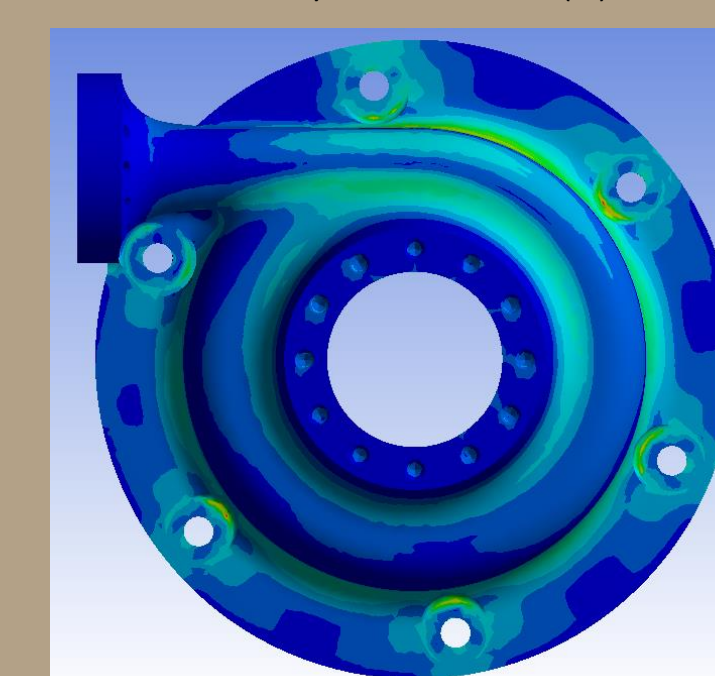
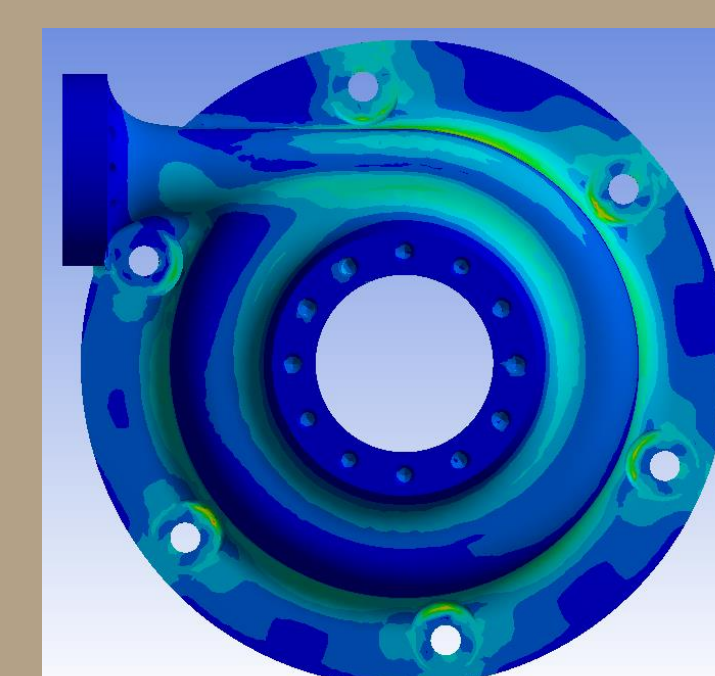
Boundary Conditions (1)



Boundary Conditions (2)



Boundary Conditions (3)



Acknowledgements

I would like to thank my mentor Luke Scharber for his help and making this internship a memorable and educational experience. I would also like to thank Patrick Rogers for making this internship possible, as well as the rest of ER41.