FEA- Finite Element Analysis

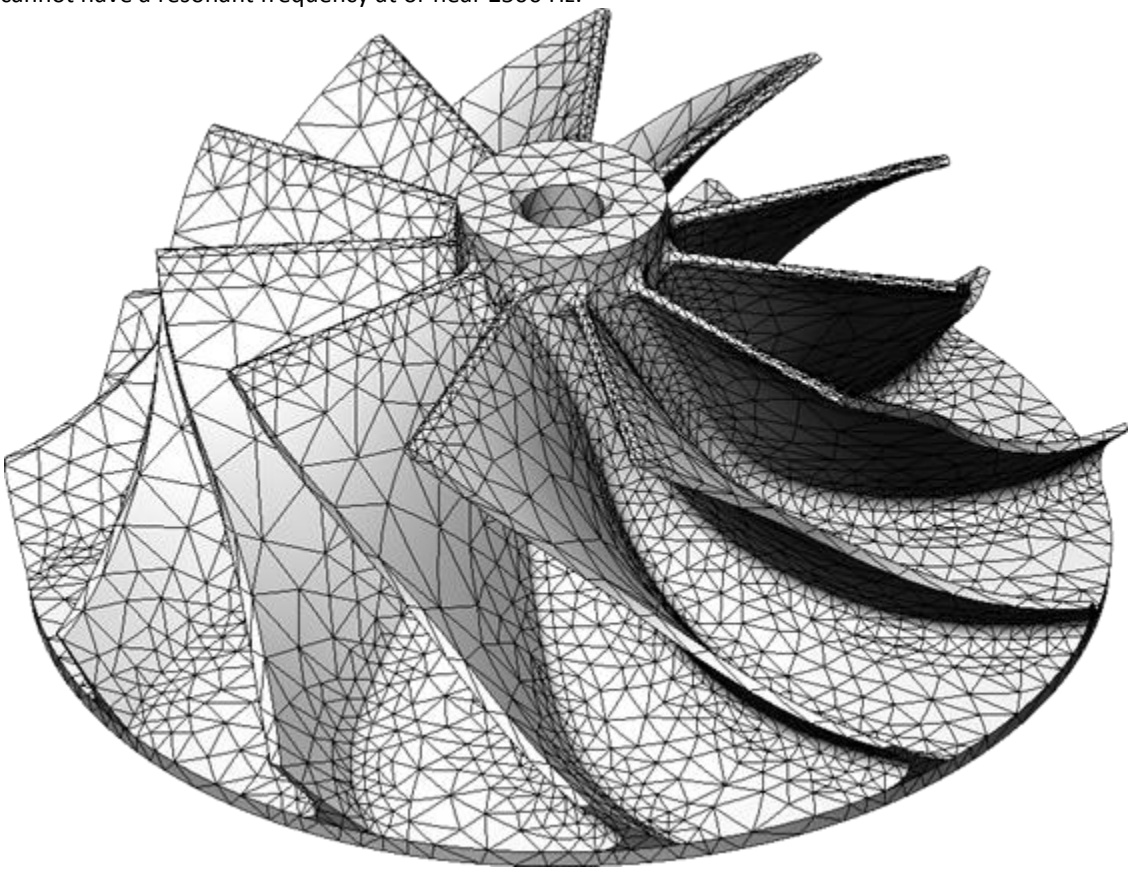
LDI Laser Design Inc

Case Study: Turbo Impeller Design

Problem Statement:

The existing impeller design is failing due to excessive displacement and colliding with the turbo housing wall. The impeller shown is redesign number three. The customer has decided to utilize FEA analysis to better solve the issue and virtually test and make design changes.

The impeller needs to be checked that the maximum outward radial displacement does not exceed 0.3mm for the combined loading criteria (below). In addition because the impeller has an induced frequency due to the rotational nature of the system the impeller cannot have a resonant frequency at or near 2500 Hz.



Loading Criteria:

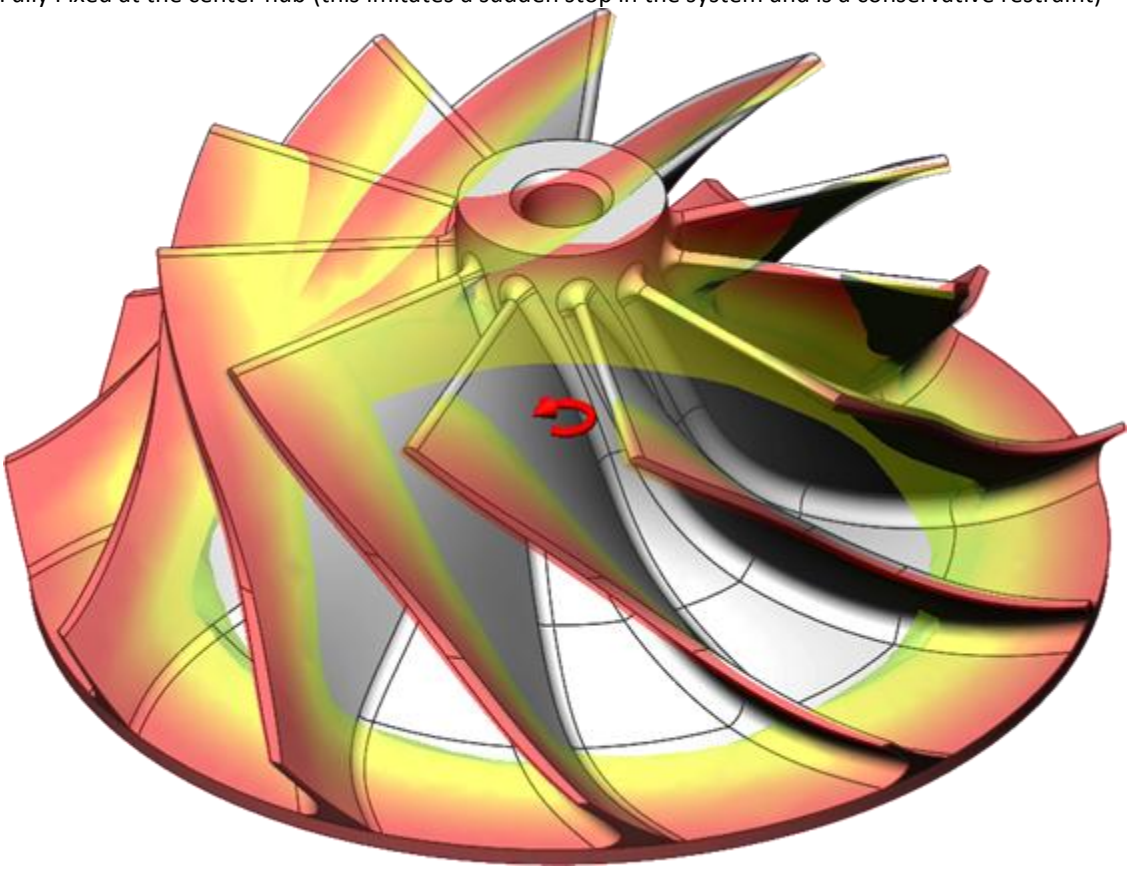
Impeller has a prescribe operating rpm of 150,000
Impeller has an operating temperature of 1050 degrees Celsius (exhaust gas temperature)
Impeller has an induced frequency of 2500 Hz per the operating rpm.

Two analysis were applied to the customer's design of the impeller.

Static Analysis Load Condition:

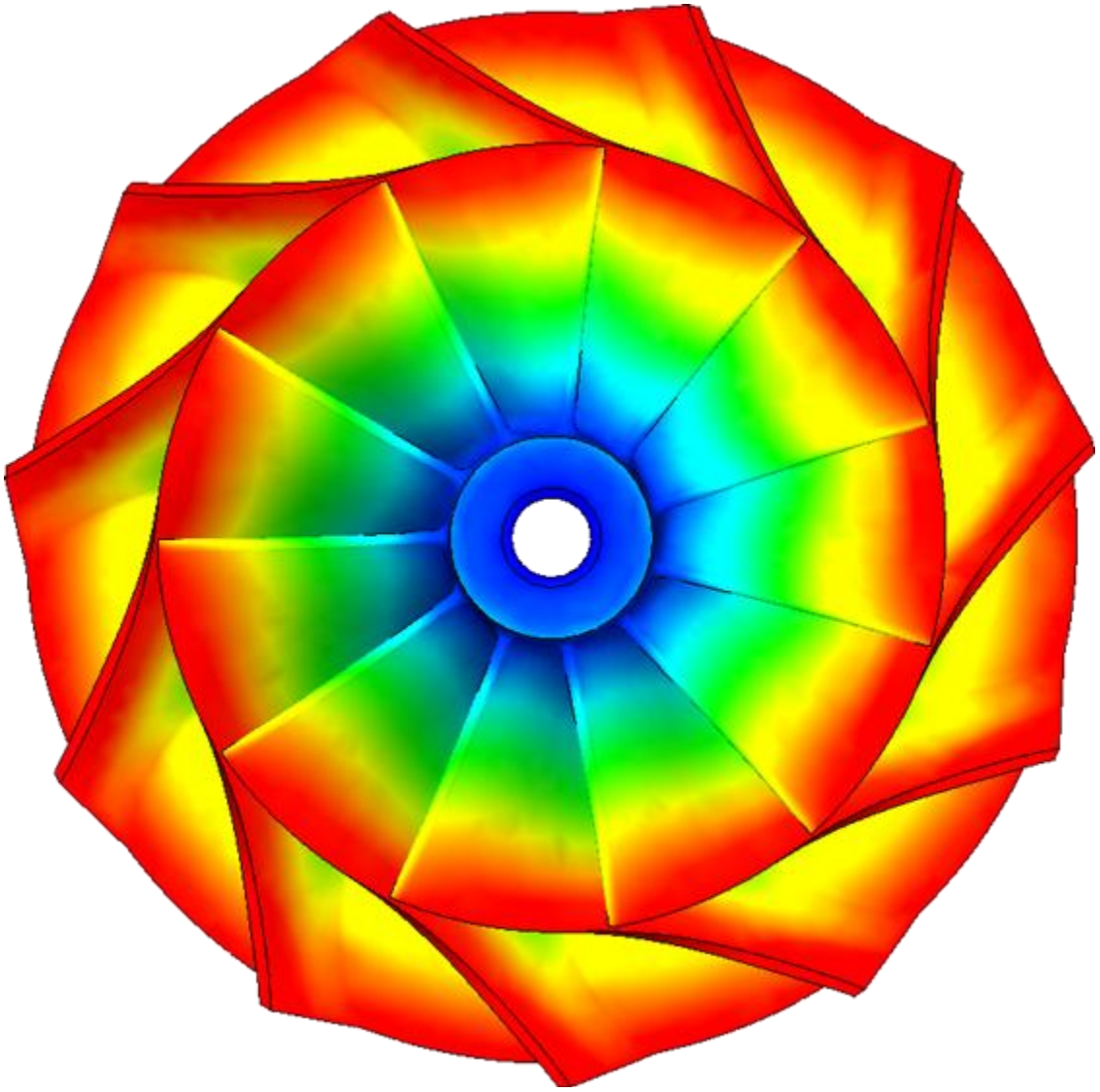
Centrifugal Load of 150,000 rpm
Thermal load of 1050 degrees Celsius steady state with a reference temperature of 94 degrees Celsius

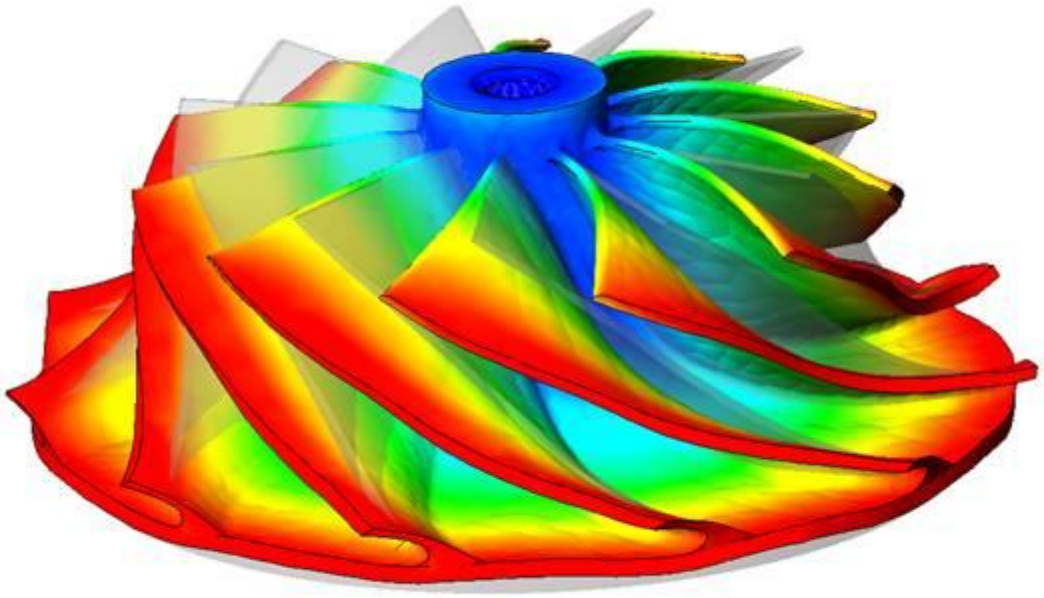
Fully Fixed at the center hub (this imitates a sudden stop in the system and is a conservative restraint)



Results:

Radial displacement of the impeller due to the combined thermal and centrifugal loading showed to be 0.132 mm, compared to the clearance of the turbo housing to impeller of 0.425mm.

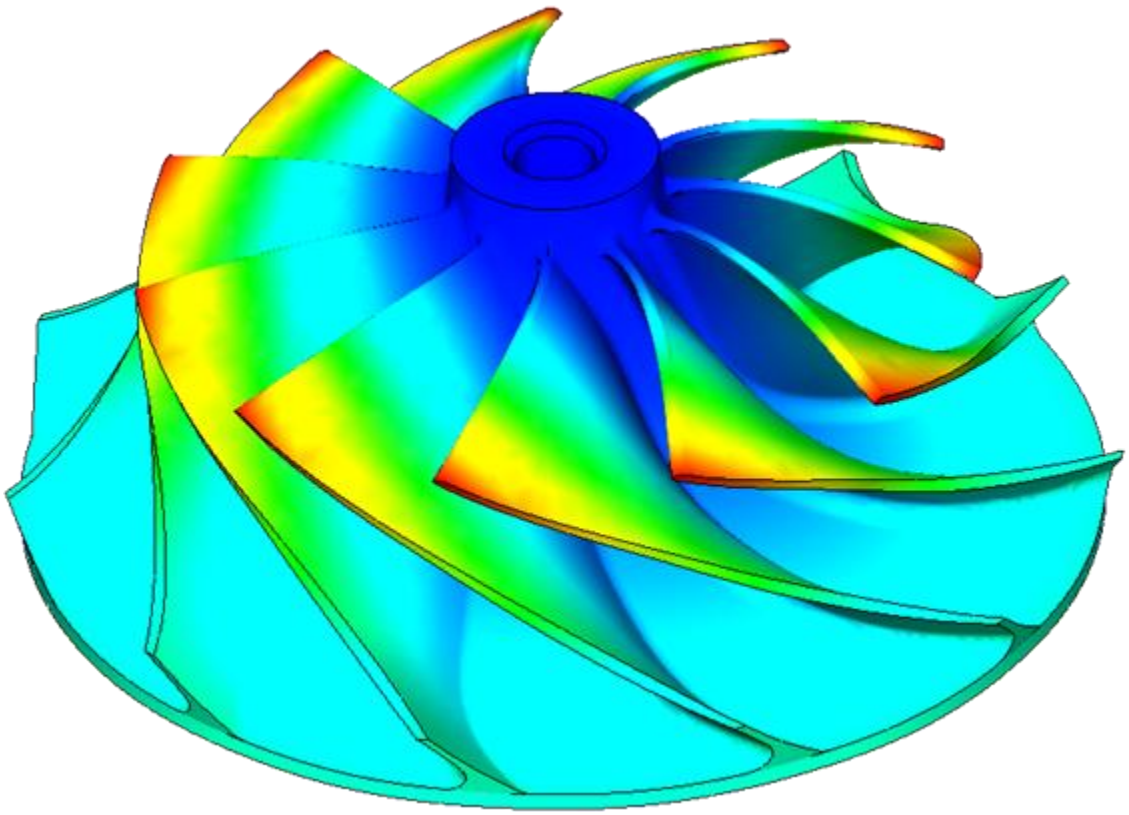




Frequency Analysis Load Condition:

Resonant frequency analysis of the impeller needs to report that the design does not resonate at of around 2500 Hz. Corresponding mode shapes are also required to compare to radial displacement direction.

Results:

The Lowest Natural Frequency and the corresponding mode shape of the impeller are as follows:

The impellers lowest resonant frequency is above the 2500 Hz by 3123 Hz leading to safe operation at and below 150,000 rpm. The corresponding mode shape for the lowest Natural Frequency was a radial "twist" however because the impeller operates below this frequency it is inconsequential.