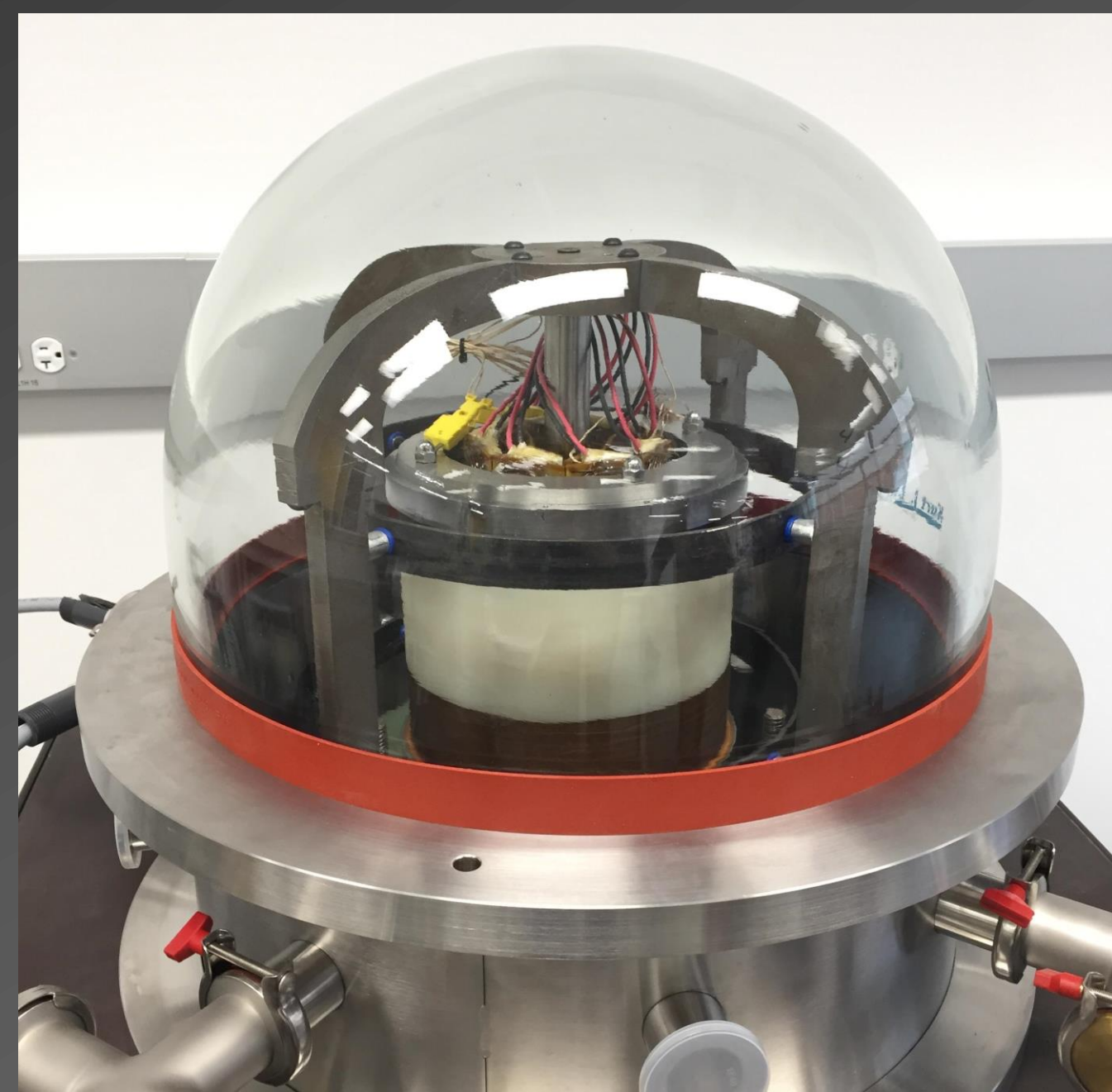


## Mechanical Stator Design

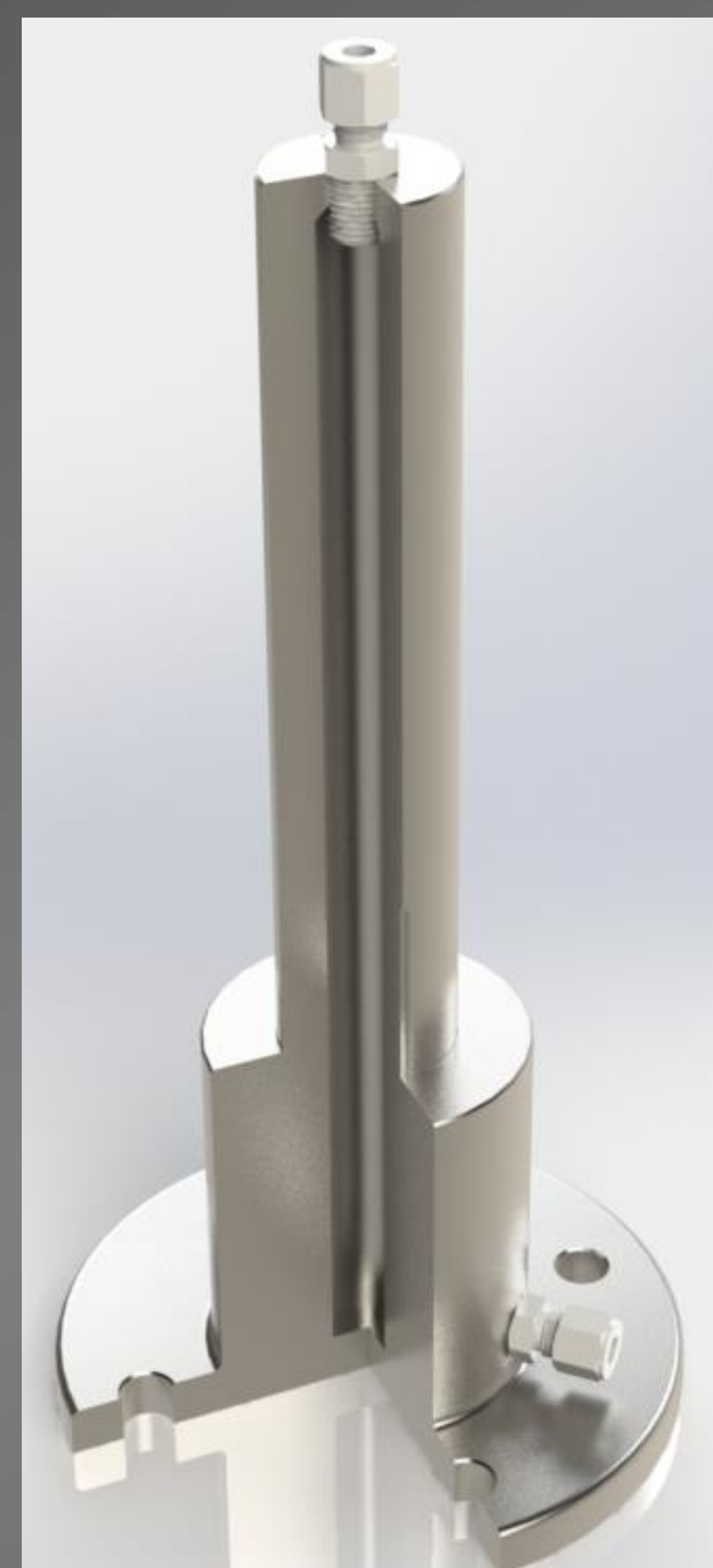
**Motivation:** Design and build high speed flywheel energy storage system for lunar and terrestrial applications

$$KE = \frac{1}{2} I \omega^2 \text{ Kinetic energy storage equation}$$

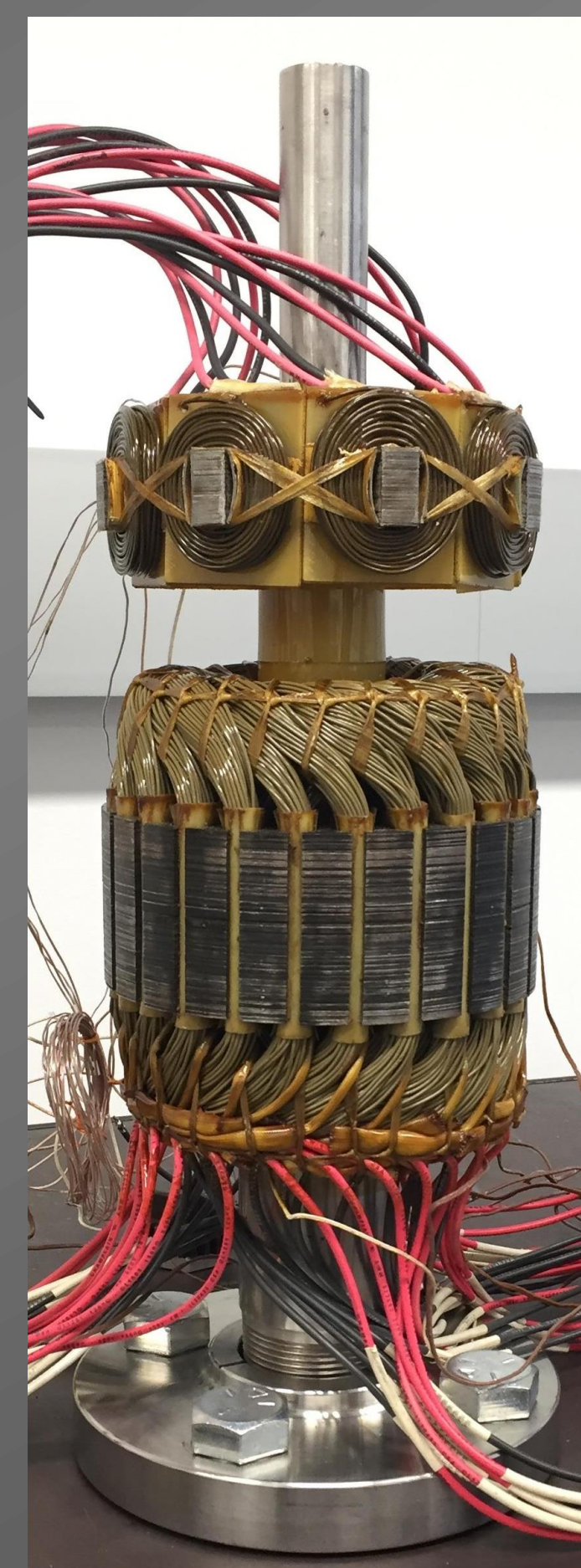
**Project:** Mechanical engineers developing a modular analytical model to calculate parameters for the machine stator. The team's main areas of concern for the system focus on fatigue and thermal modeling. The mechanical team is working in conjunction with electrical engineers to produce a model for the electrical aspects of the machine, which will output parameters for the mechanical model.



Fully assembled Low-Speed Flywheel prototype



3D render of stator design



Detail of Low-Speed Flywheel stator with coils and laminations

### Fatigue Model

- Input is torque from electrical function of current and number of coil windings
- Solves for external diameters of stator shaft and iron hub

$$S_e = \frac{(0.5)S_u K_{size} K_{load} K_{surface}}{K_{notch}}$$

Endurance Limit

$$\sigma_p = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

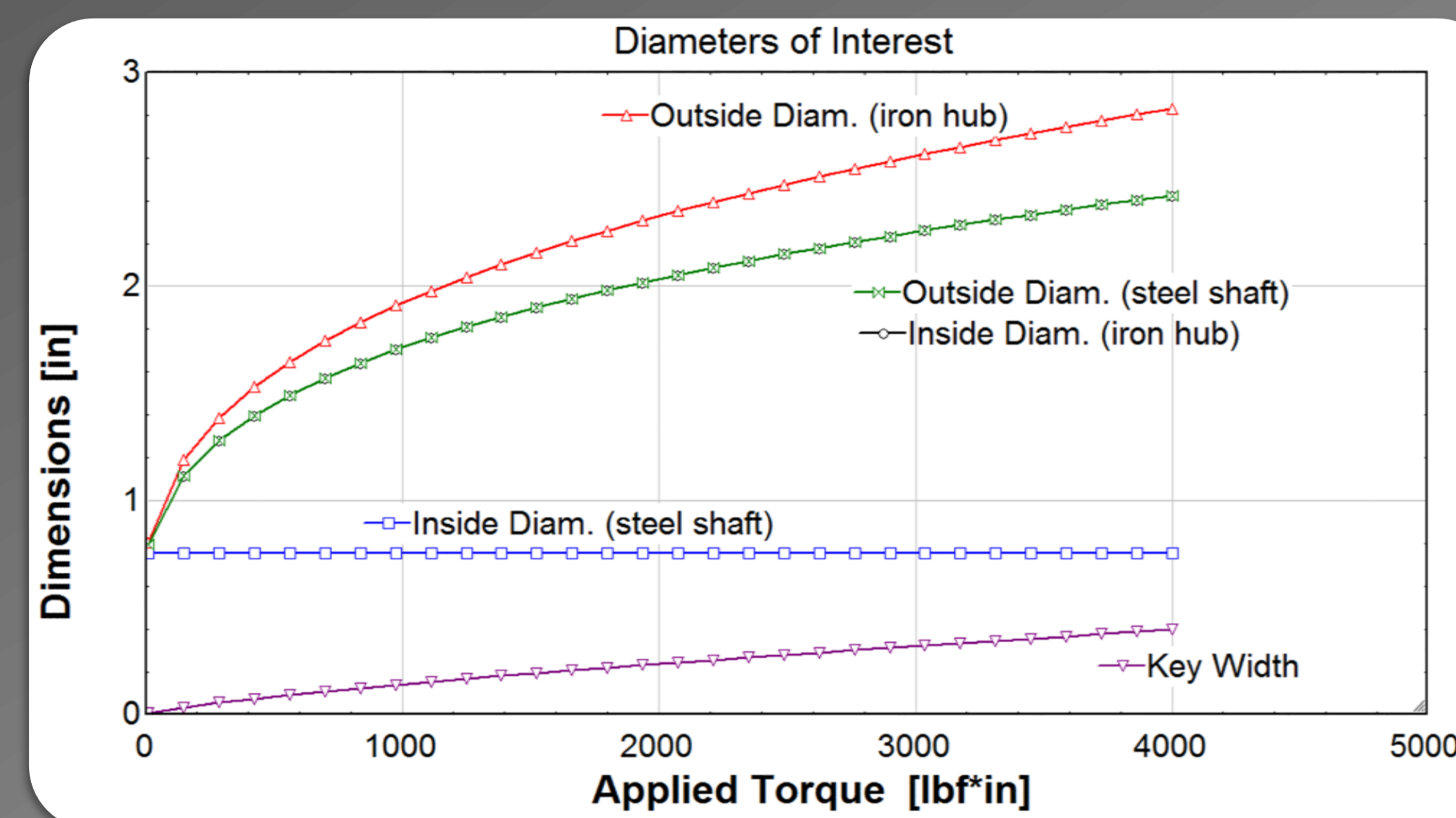
Principle Stress

$$\tau = \frac{T r}{J} = \frac{T \left(\frac{d_o}{2}\right)}{\frac{\pi}{32}(d_o^4 - d_i^4)}$$

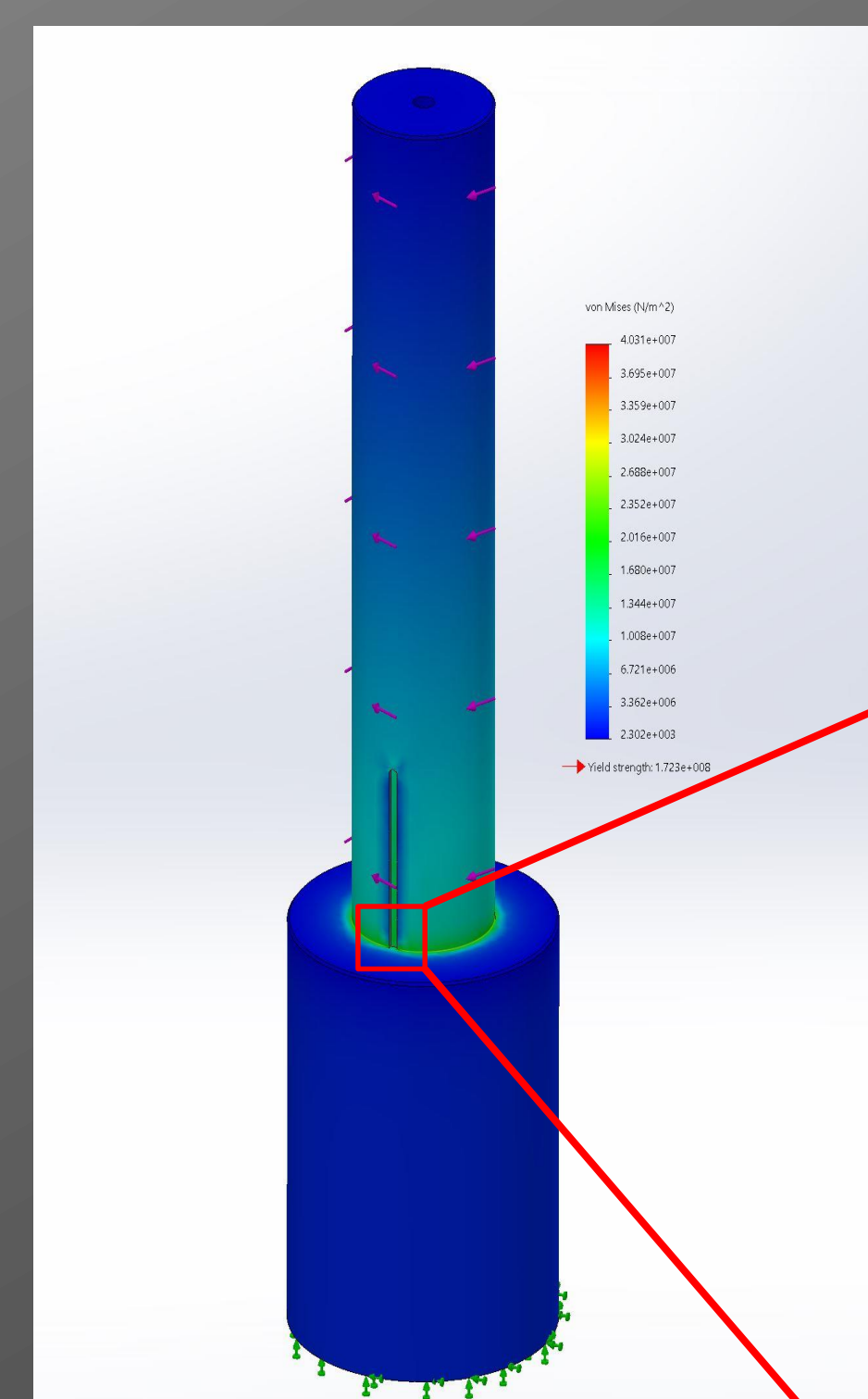
Shear from Torsion

$$\sigma = \frac{M y}{I} = \frac{\left(\frac{2T}{d_o}\right) \left(\frac{L}{2}\right) \left(\frac{d_o}{2}\right)}{\frac{\pi}{64}(d_o^4 - d_i^4)}$$

Normal Stress from Bending

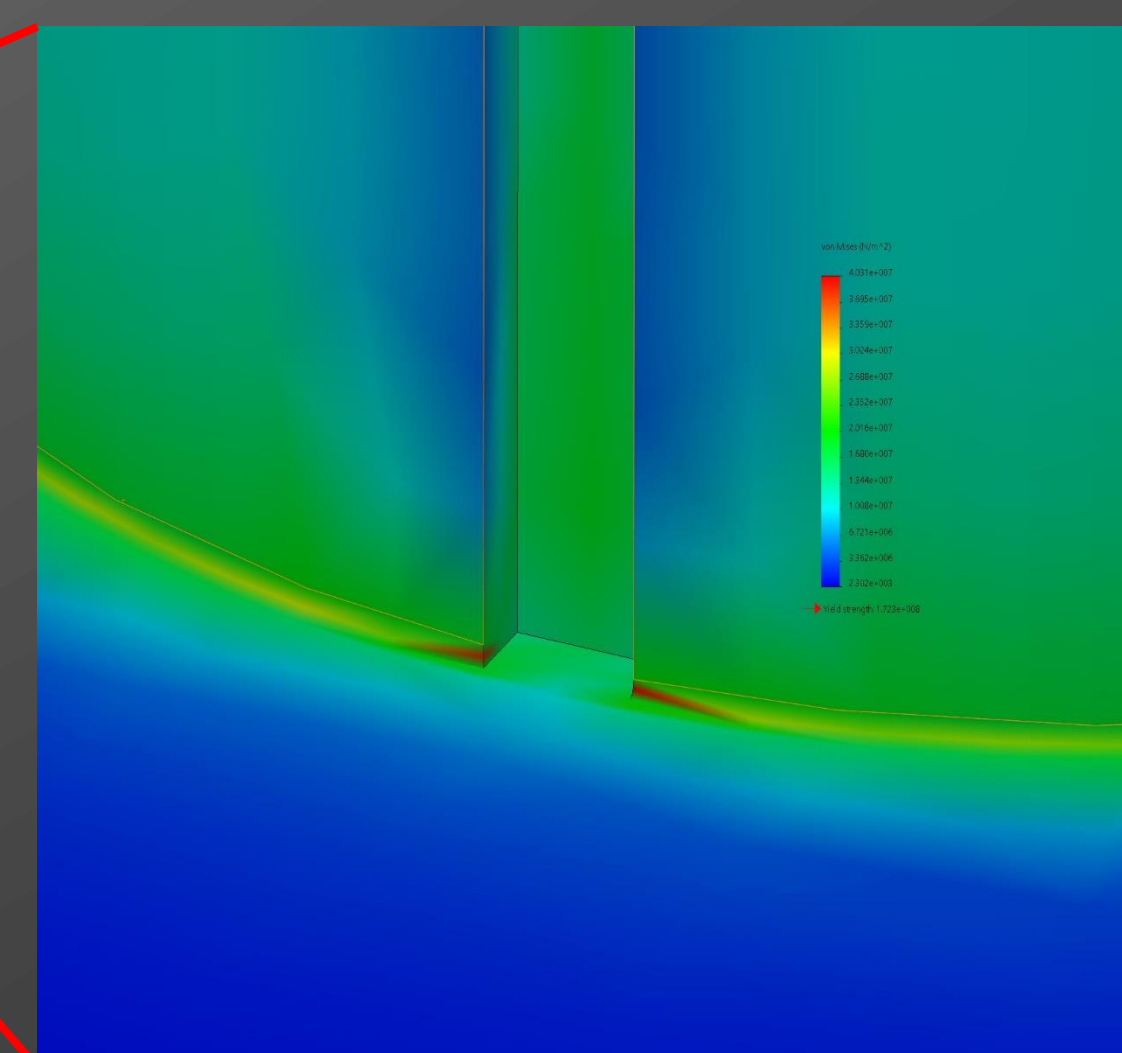


Diameters solved from inner diameter and applied torque using analytical model



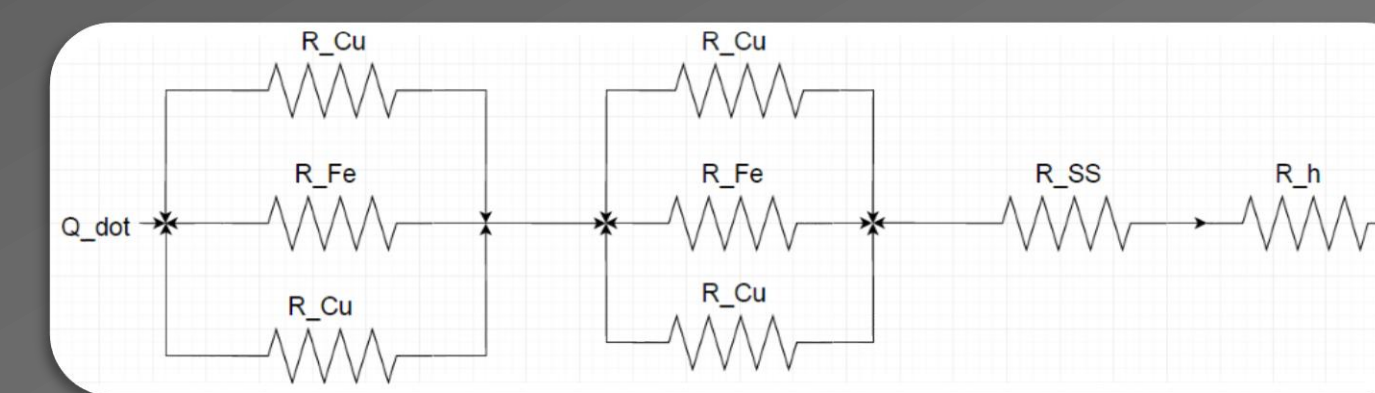
### Keyway Model

- Predicts keyway dimensions based on fatigue model
- Verified using Solidworks FEA simulations
- Shows stress concentration  $K_{notch}$ , accounted for in model



### Heat Transfer Model

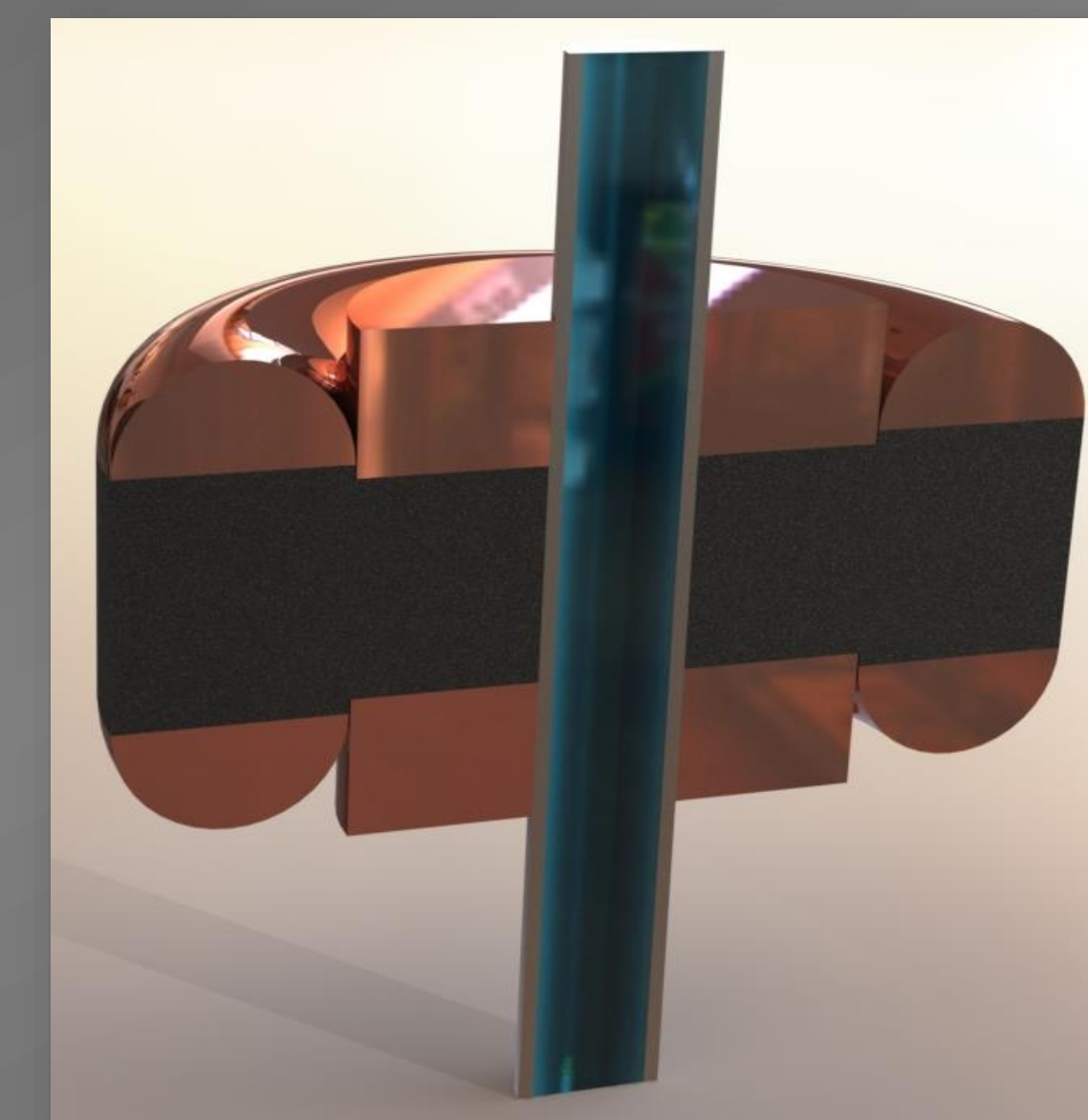
- Input is heat, which is produced when current is passed through the coils
- Predicts temperature distribution across stator



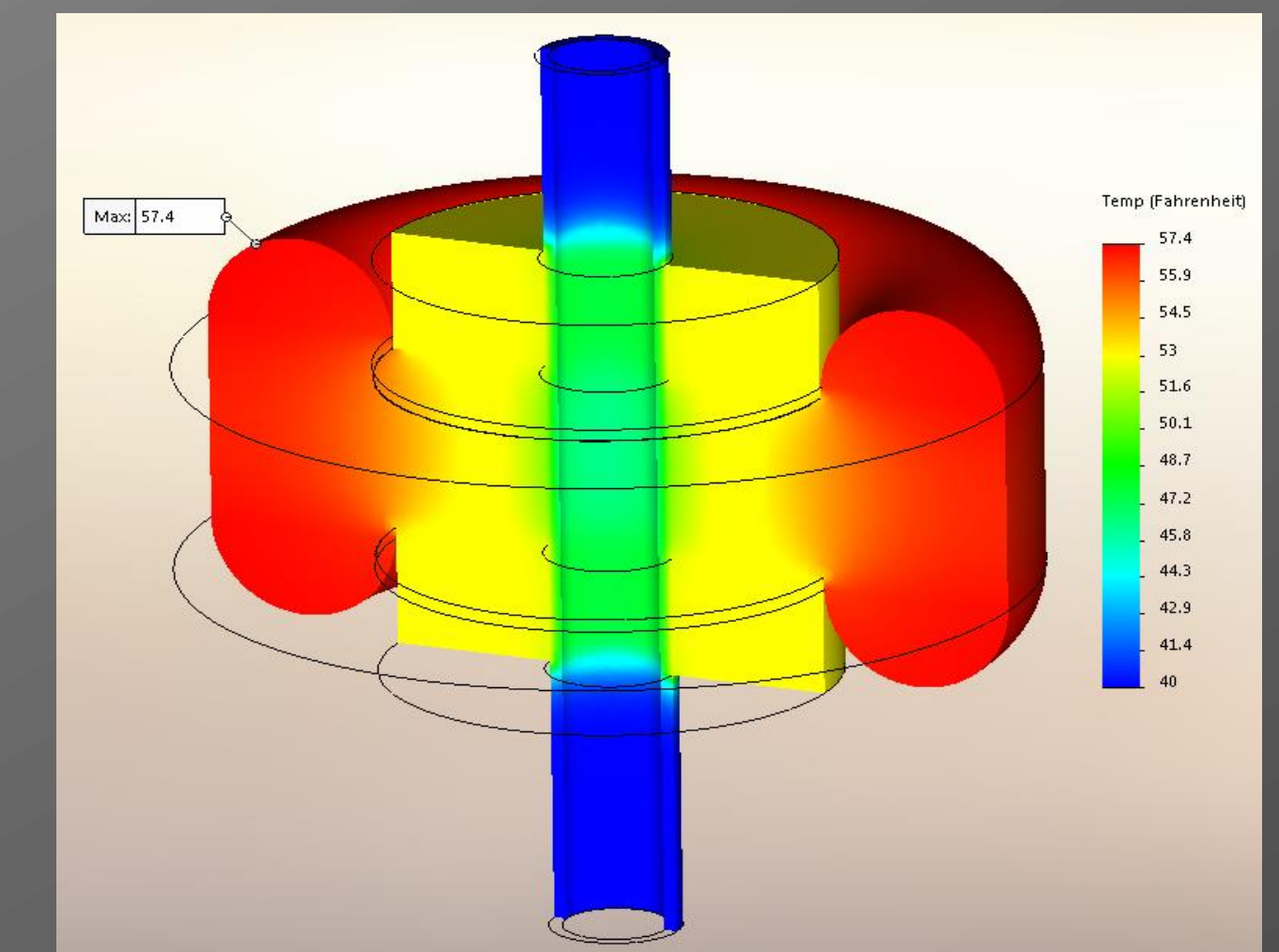
$$Q = \frac{\Delta T}{R} \quad R_{cond} = \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi L K} \quad R_{conv} = \frac{1}{hA}$$

$$R_{total} = \frac{R_{cu} R_{fe}}{2R_{fe} + R_{cu}} + \frac{R_{cu} R_{fe}}{2R_{fe} + R_{cu}} + R_{ss} + \frac{1}{hA}$$

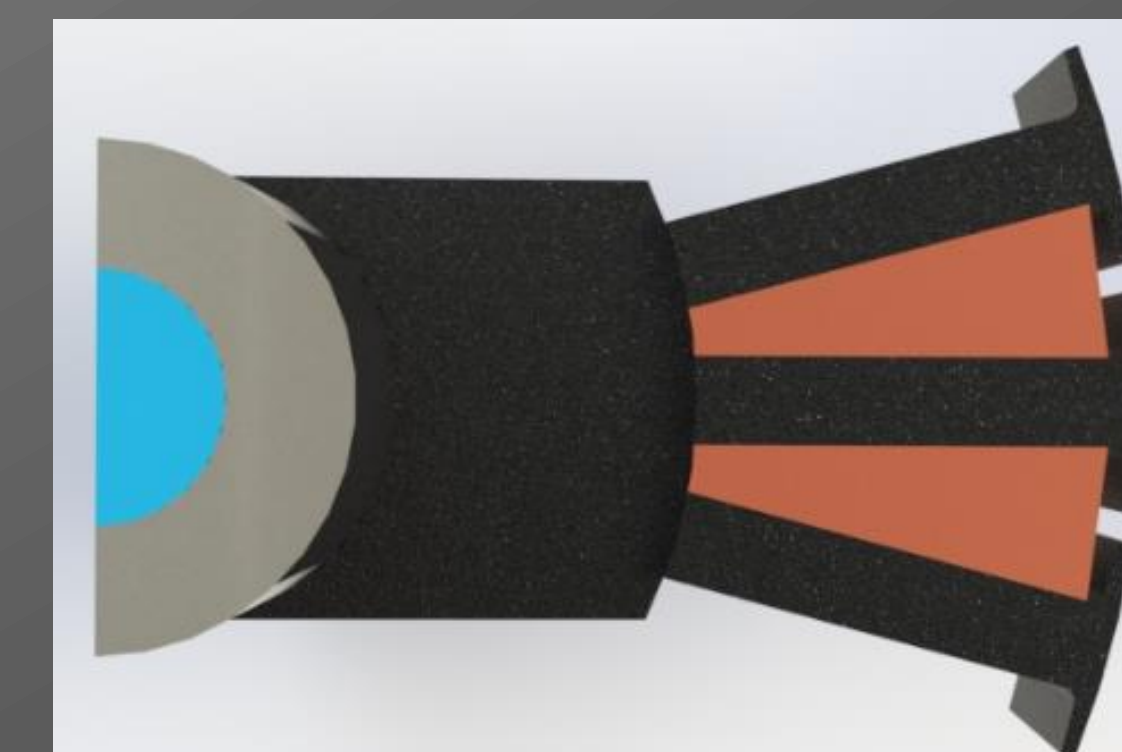
Equations used for thermal resistance analytical model



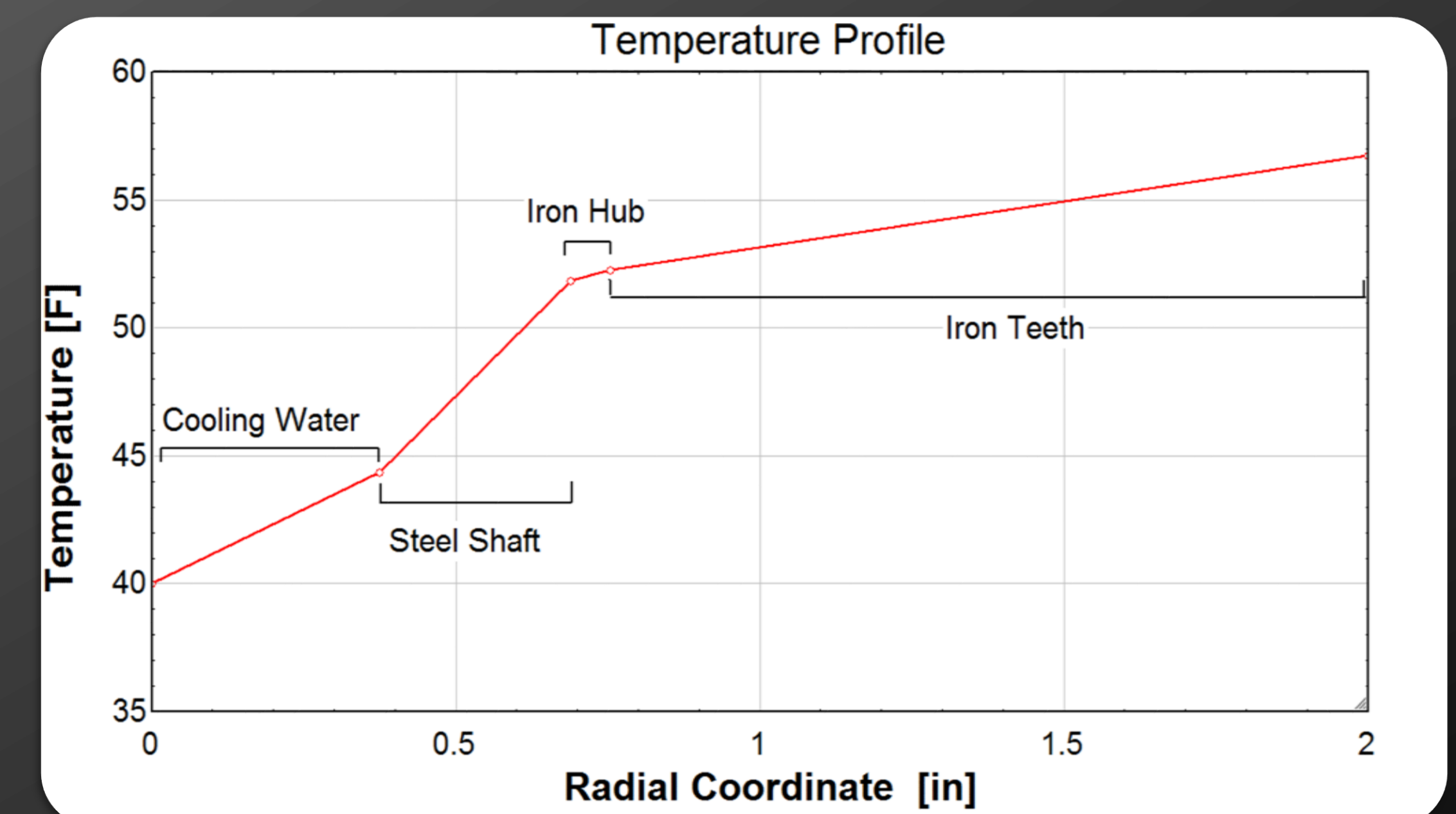
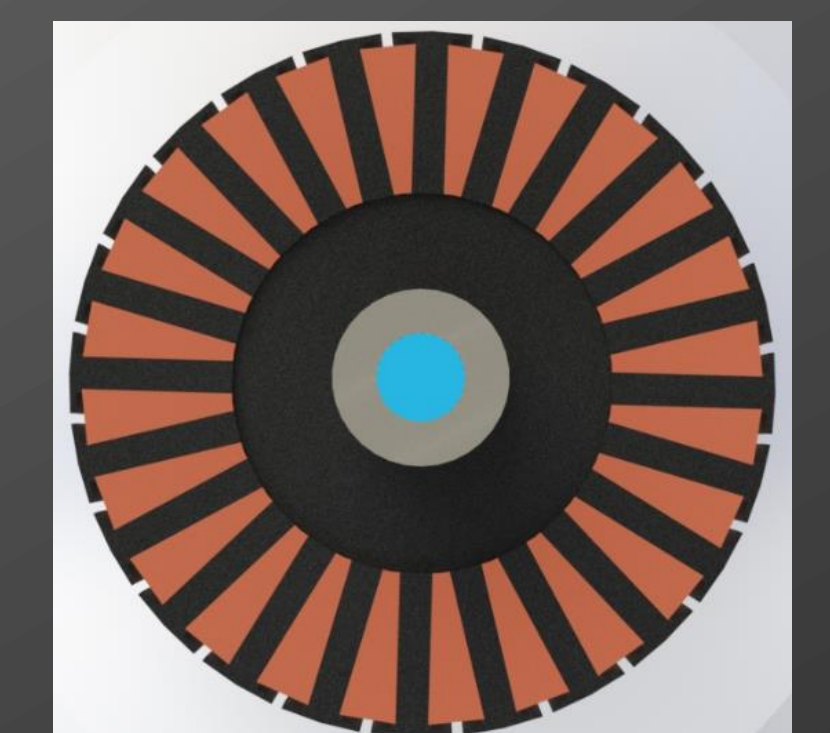
Solidworks model of stator for analytical model



Heat transfer model in FEA simulations to verify results of analytical model.



Cross section detail with cooling water, steel shaft, iron hub, and iron teeth



Temperature profile from the center of the stator going out towards the rotor. Maximum temperature can not exceed 200 °C. This plot was produced from the analytical model.

**Mechanical Engineering Team:**  
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