

Shaft Design

The turbine apparatus uses two main rotary shafts used for connecting the motor to the drive train and the propeller to the drive train. In order to ensure that the apparatus will stand up to both fatigue and static stresses the shafts have to be properly sized. Von Mises Failure Criterion provides good parameters for sizing rotary shafts.

Initial Constraints and Factors:

The shaft will be made of cold rolled low-grade steel with material constants as follows:

$$E := 27.5 \cdot 10^6 \cdot \text{psi} \quad \sigma_y := 40 \cdot 10^3 \cdot \text{psi} \quad \sigma_{ut} := 110 \cdot 10^3 \cdot \text{psi} \quad S_{fprime} := 50 \cdot 10^3 \cdot \text{psi}$$

Mon Mises uses problem dependent safety coefficients that are multiplied by the yield strength (S_f) of the material to make sure the shaft will stand up to the conditions that it will be used in. These coefficients are explained in the text *Machine Design* by Norton.

$$S_f := C_{load} \cdot C_{size} \cdot C_{surf} \cdot C_{temp} \cdot C_{reliab} \cdot S_{fprime}$$

- **Loading Factor:** The shafts will only be loaded axially.

$$C_{load} = 0.7$$

- **Size** less than 3 **Factor:** The shaft will be inches in diameter (dirt).

$$C_{size} := .869 \cdot \text{dirt}^{-.097}$$

- **Surface Factor:** The shaft is cold-rolled so $a = 2.7$ and $b = -.265$

$$C_{surf} := a \cdot S_{ut}^b$$

- **Reliability Factor:** The apparatus is needed for many tests over many years.

$$C_{reliab} = 0.814$$

- **Temperature Factor:** The temp will not have extreme temp changes.

$$C_{temp} = 1$$

- **Moment and Torque:** These shafts will be experiencing both constant and alternating torques caused by the propeller stopping and starting. The bending moments will be restricted in the test apparatus design. From ideal calculations of total torque that could be seen by this shaft:

$$T_{\max} := 22.2 \text{ lbf} \cdot \text{ft}$$

$$T_{\min} := 0 \text{ lbf} \cdot \text{ft}$$

$$T_m := \frac{T_{\max} - T_{\min}}{2}$$

$$T_a := \frac{T_{\max} - T_{\min}}{2}$$

Von Mises Equation:

$$d := \left[\frac{32 \cdot N_f}{\pi} \frac{\sqrt{(k_f \cdot M_a)^2 + .75 \cdot (k_{fs} \cdot T_a)^2}}{S_f} + \frac{\sqrt{(k_{fm} \cdot M_m)^2 + .75 \cdot (k_{fsm} \cdot T_m)^2}}{\sigma_{ut}} \right]^{\frac{1}{3}}$$

Where:

Factor of Safety: $N_f = 2$

Keyway Factors: $K_f, K_{fs}, K_{fm}, K_{fsm} = 1$ (Due to no keyways being used.)

Yield Strength: S_f

$$d = 0.486 \text{ in}$$