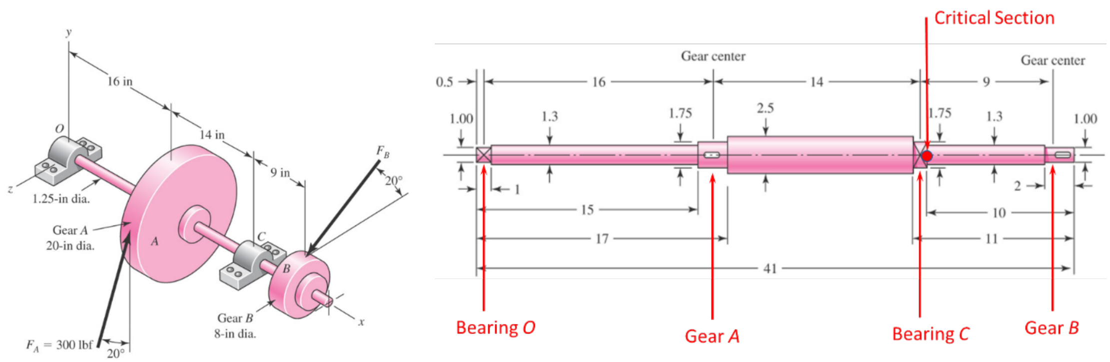
Machine Design - 2

A gear reduction unit uses the countershaft shown in the figure below. Gear *A* receives power from another gear in mesh where the transmitted force is F_A applied at 20° pressure angle as shown. Power is transmitted through the shaft and delivered through gear *B* developing a force F_B at the pressure angle shown.

The proposed detailed shaft design for the application is shown in the figure. The material is AISI 1040 as-forged steel. The gears are set against the shoulders and have hubs for set screws to lock them in place. The effective centers of the gears for force transmission are shown. The shaft shoulders and fillets have a "ground" finish with stress concentrations at the fillets of $K_{tBending} = 2.0$; $K_{tTorsion} = 1.7$. The deep-groove ball bearings at *O* and *C* are press-fit against the shaft shoulders, assume they are designed to carry only radial loads.

All fillets are 1/16 in, dimensions for the shaft are in inches.



AISI 1040 as forged unmodified material properties:

E = 29.0 Mpsi, G = 11.5 Mpsi, S_y = 71 kpsi, S_{ut} = 90 kpsi, S_e' = 29.25 kpsi, σ_f' = 223 kpsi, b = -0.14
q = Notch Sensitivity Factor: $q_{Bending} = 0.80$, $q_{Torsion} = 0.82$.

Marin Fatigue Strength Modification Factors:
- k_a = Surface Factor, ground finish = 0.895.
- k_b = Size Factor, d = 1.3 in, k_b = 0.855.

1. **(20 points)** Determine the torque and transmitted force, F_B, assuming the shaft is running at constant speed.
2. **(20 points)** Given the reactions at bearings *O* and *C* as $R_O = 0\mathbf{i} - 208.5\mathbf{j} + 259.3\mathbf{k}$ and $R_C = 0\mathbf{i} + 183.1\mathbf{j} - 864.5\mathbf{k}$, lbf, determine the bending moment components at Bearing *C*.
3. **(20 points)** Determine the *Nominal State of Stress* at the *Critical Section* (C.S.) shown. The actual change in cross-section at the C.S. is located ½" to the right of the bearing center at C. To simplify the calculation, use the internal forces at bearing *C*, the difference in those internal forces between *C* and the C.S. will be small.
4. **(20 points)** Determine the mean and alternating components of the stress state at the *Critical Section*.
5. **(10 points)** Compute the number of cycles, *N*, to fatigue fracture using $n_{Fracture} = 1.2$.
6. **(10 points)** Draw the Modified Goodman design envelope for the critical section, include the following:
   a. Fracture Line
   b. Yield Line
   c. Design Point
   d. Design Load Line, which is the trajectory to the failure surface.

Problems

Equations:

Stress-Life Curve: $S_{f@N\,cycles} = \sigma_f^{'}\left(2N\right)^b$