SOLUTION TO QUIZ # 1

Quiz #1: Solution

Material: SAE 1020 CD
Properties: Table A-20: $S_{ut} = 68$ Kpsi, $S_y = 57$ Kpsi
$B_h = 1.31$ (Rockwell hardness)

Minimum diameter based on ASME CAYTMA:

$$d = \left\lceil \frac{16 \pi n}{\pi} \left[ \frac{4}{5} \left( \frac{K_f M_n}{S_e} \right)^2 + 3 \left( \frac{K_f M_n}{S_y} \right)^2 \right]^{1/2} \right\rceil^{1/2}$$

Variables:
- $n = 2.5$ safety factor
- $K_f$: fatigue stress concentration factor

$K_f = 1 + \gamma (K_e - 1)$ $K_e$ given 3.5 and 4
$K_f = 1 + \gamma_s (K_s - 1)$ $K_s$ given 2 and 4

$\gamma$, notch sensitivity with $r = 0.02$ in $\Rightarrow$$\gamma_s \approx 0.6$ (Eq. 7-22)

and

$B_h < 2.0 \Rightarrow \gamma_s \approx 0.75$ (Eq. 7-21)

Shoulders:
$K_f = 1 + 0.6 (3.5 - 1) = 2.5$
$K_f = 1 + 0.75 (2 - 1) = 1.75$

Keyways:
$K_f = 1 + 0.6 (4 - 1) = 2.8$
$K_f = 1 + 0.75 (4 - 1) = 3.25$
Moments and Torque:

\[ \text{STADY TORQUE} \implies T_a = 0 \quad \text{and} \quad T = T_m = 7346 \]

Moment at B and C (orthogonal plane)

\[ M_B = \sqrt{M_{Bx}^2 + M_{By}^2} = \sqrt{14^2 + 36^2} = 38.31 \text{ lb-in} \]

\[ M_C = \sqrt{M_{Cx}^2 + M_{Cy}^2} = \sqrt{6^2 + 63^2} = 63 \text{ lb-in} \]

Completely reversible \( \implies M_m = 0, \quad M = M_a \)

Endurance Limit \( S_e \)

\[ S_e = k_a k_b k_c k_d k_e S_e' \]

\[ S_{ut} \leq 200 |K_g| \implies S_e = 0.584 (S_{ut}) \]

\[ S_e = 0.584 (68) = 34.27 \text{ kpsi} \]

\[ *\] \[ K_a = 0.86 \]

\[ 0.20 \text{ C9} \implies a = 2.70, \quad b = -0.625 \]

\[ k_a = 2.70 (68)^{-0.625} \]

\[ k_a = 0.882 \]

* \[ K_b \] assume \( d \) in range of \( 0.11 \leq d \leq 2 \) in

and correct it later: assume \( d = 2 \) in

\[ K_b = 0.879 d^{-0.107} = 0.879 (2)^{-0.107} \]

\[ K_b = 0.816 \]
\[ K_c = 1 \quad \text{bending} \]
\[ K_f = 1 \quad \text{(no info given)} \]
\[ K_s = 1 \quad \text{(no info given)} \]

\[ S_e = (0.882)(0.816)(1)(1)(1)(1)(1) = 84.27 \]

\[ S_e = 24.66 \text{ ksi} \]

\[ S_y = 57.9 \text{ ksi} \]

**Diameter:**

at Point B: Since Keyway is very close to the shoulder and has higher stress concentration factor \( K_f \) and \( K_s \) for Keyway

\[ \frac{d_B}{2} = \sqrt[3]{\frac{16(2.5)}{\pi} \left[ 4 \left( 2.8 \frac{33.1}{24660} \right)^2 + 3 \left( 3.25 \frac{73}{57000} \right)^2 \right]^{\frac{1}{2}}} \]

\[ d_B = 0.5099 \text{ in} \]

**Points C:**

\[ \frac{d_C}{2} = \sqrt[3]{\frac{16(2.5)}{\pi} \left[ 4 \left( 2.5 \frac{63}{24660} \right)^2 + 3 \left( 1.75 \frac{73}{57000} \right)^2 \right]^{\frac{1}{2}}} \]

\[ d_C = 0.5539 \text{ in} \]
The next step will be to use the obtained diameter to find the actual $k_b$ and then use the new $k_b$ to correct $S_e$. 