YOUR NAME: 

PUT YOUR NAME ON ALL SHEETS

- Use pencil. Use your own green “Engineering Computation” paper or other paper. Use one side only.
- If you use MathCAD, please submit your entire MathCAD worksheet along with hand sketches and calculations. Also, you MUST display all intermediate values for full or partial credit.
- This exam is OPEN BOOK / OPEN NOTES / (no solutions or worked out problems of any type permitted)
- Show ALL WORK for full or partial credit.
- You have one hour fifty minutes to complete the exam.

Question 1 (55 points)
A simply supported shaft is shown below. Find the shaft diameter. The following information is known:

- Shaft subjected to a constant torque of 3000 in-lb
- Steel
- Ground surface finish
- Room Temperature
- 50% Reliability
- Infinite Life
- Sut = 150 ksi
- Sy = 72 ksi
- Safety Factor = 2.5
- No stress concentrations
- Distributed load, P, fluctuates from 500 to 1000 lb/in

\[ P \]

\[ 4'' \quad 1'' \quad 2'' \]
Question 2 - Short Answer (45 points) – 15 points each

(a) DS Incorporated buys a machine from Italy that contains a gear with a module of 25. After several years of use the gear fails and must be replaced. An engineer for DS Incorporated suggests buying a replacement gear out of the Grainger catalog that has a Diametral Pitch of 1.

Using 2 or 3 sentences please comment on the engineer’s decision.

Although this might appear at first to be a good decision— it isn’t. US + Metric gears are not compatible. If the replacement gear ever was "wedge" into place it could cause rapid failure of the metric gear. "DS" stands for Digitally Printed.

(b) After reviewing the design of a shaft, an engineer notices that the diameter is too small to achieve infinite life with a safety factor of 3. The shaft is ready to be sent out for machining the next day.

Advise the engineer by making 2 or 3 worthwhile suggestions.

Depending on what the actually safety factor is this may not be a problem. SF=3 for a life is a very conservative number—usually. The part may last a billion cycles + then break — if this is ok no change is necessary. Really, the application would need to be better understood to make an optimal, yet safe, decision. Fabrication would need to be delayed until a suitable fix were found.

(c) Why should “worst-case” design techniques always be used?

Engineers should never design anything that will unintentionally kill or injure someone. "Worst-case" loading + cycle conditions as well as other environmental factors should always be considered. Hoping that a design will only see "best-case" is a foolhardy wish.
9) \[ \Sigma M_A = 0 \]

\[ B_y (4) - (p \cdot z)(6) = 0 \]

\[ \Sigma F_y = 0 \]

\[ A_y + B_y - P \cdot z = 0 \]

@ \( P = 500 \)

\[ A_y = -500 \]

\[ B_y = 1500 \]

@ \( P = 1000 \)

\[ A_y = -1000 \]

\[ B_y = 3000 \]
\[ M_{\text{max}} = 4000 \]

\[ M_{\text{min}} = 2000 \]

\[ M_m = 3000 \]

\[ M_a = 1000 \text{ in.} \text{lb} \]

\[ T_m = 3000 \text{ in.} \text{lb} \]

\[ T_a = 0 \]
Question 1 (55 points)
A simply supported shaft is shown below. Find the shaft diameter. The following information is known:

- Shaft subjected to a constant torque of 3000 in-lb
- Steel
- Ground surface finish
- Room Temperature
- 50% Reliability
- Infinite Life
- $S_{tu} = 150\ ksi$
- $S_y = 72\ ksi$
- Safety Factor = 2.5
- No stress concentrations
- Distributed load, $P$, fluctuates from 500 to 1000 lb/in

Units:

$kpsi := 10^3 \cdot psi$

Given:

- Applied load $P := 1000$
- Minimum torque $T_{min} := 3000\cdot lb\cdot in$
- Maximum torque $T_{max} := 3000\cdot lb\cdot in$
- Tensile strength $S_{tu} := 150\ ksi$
- Yield strength $S_y := 72\ ksi$
- Design safety factor $N_d := 2.5$
Solution:

1. Create a FBD, shear, bending moment diagrams by hand:

solving for reactions from equilibrium equations:

\[ P := 1000 \]

\[ A_y := 1 \quad B_y := 1 \quad \text{guess values} \]

Given

\[ B_y - P \cdot 2.6 = 0 \]

\[ A_y + B_y - P \cdot 2 = 0 \]

\[ \begin{pmatrix} B_y \\ A_y \end{pmatrix} = \text{Find}(B_y, A_y) \]

\[ A_y = -1 \times 10^3 \]

\[ B_y = 3 \times 10^3 \]

looking at the bending moment diagram:

\[ M_o := 1000 \text{ in-lbf} \]

\[ M_o = 1000 \text{ in-lbf} \]

\[ M_m := 3000 \text{ in-lbf} \]

\[ M_m = 3 \times 10^3 \text{ in-lbf} \]

2. Calculate the mean and alternating components of torque.

\[ T_m := \frac{T_{\text{max}} + T_{\text{min}}}{2} \quad T_m = 3000 \text{ in-lbf} \]

\[ T_a := \frac{T_{\text{max}} - T_{\text{min}}}{2} \quad T_a = 0 \text{ in-lbf} \]

3. Calculate the unmodified endurance limit.

\[ S'_c := 0.5 \cdot S_{uy} \quad S'_c = 75 \text{ ksi} \]
4. Determine the endurance limit modification factors for a rotating round shaft.

\[ d := 1.039 \text{-in} \]

This is an initial guess for \( d \) so that a size factor can be calculated. Re-enter a modified \( d \) once the "ASME" equation (9.6b) is solved.

NOTE: First value entered was a 1, then 1.039

Load

\[ C_{load} := 1 \]

Size

\[ C_{size} := 0.869 \left( \frac{d}{\text{in}} \right)^{-0.097} \]

\( C_{size} = 0.866 \)

Surface

\[ A := 1.34 \quad b := -0.085 \quad \text{(machined)} \]

\[ C_{surf} := A \left( \frac{S_{ut}}{\text{ksi}} \right)^b \]

\( C_{surf} = 0.875 \)

Temperature

\[ C_{temp} := 1 \]

Reliability

\[ C_{reliab} := 1 \quad (R = 50\%) \]

5. Determine the modified endurance limit

\[ S_e := C_{load} C_{size} C_{surf} C_{temp} C_{reliab} S_e' \]

6. Use equation (9.8) with unity for all stress concentration factors as a design equation to find \( d \).

\[ d := \left[ \frac{32 \cdot N_d}{\pi} \left[ \frac{M_a^2}{S_e} + \sqrt{M_m^2 + 0.75 \cdot T_m^2} \right] \right]^\frac{1}{3} \]

\[ d = 1.039 \text{ in} \quad \text{plug this value in to } d \text{ above} \]

Using this value for \( d \), the size modification factor and endurance limit are:

Size modification factor

\[ C_{size} = 0.866 \]

Endurance limit

\[ S_e = 56.8 \text{ ksi} \]