me413_mids

ME413: Machine Design I, midterm exam, Nov. 10, 2004

Department of Mechanical Engineering, University of Saskatchewan

Time: 3:30-4:30 pm **Instructors: G. Watson/R. Fotouhi** **Student ID ....**

Open-book exam, only the text book, class notes, and assignments are permitted. **Calculators** are permitted in this test. Please **answer** only **two questions**. If more than 2 questions are answered, questions 1 and 2 will be marked. Begin each problem on a new page in your answer book. **Show your work**. Place the **exam question inside the exam booklet** when you hand it in.

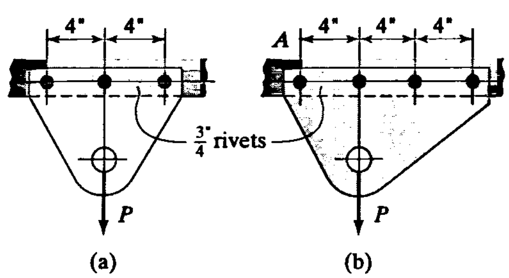
Q1. Estimate the 2×10^5 fatigue strength for a 25-mm-diameter reversed axially loaded steel bar having $S_u = 950$ MPa, $S_y = 600$ MPa, and a hot-rolled surface. For C_S use the closest point on the grid (use only one significant figure).

Indicate your assumptions and comment on your solution. Hint: you need to construct S-N curve.

Q2. A helical coil spring with $D = 50$ mm and $d = 5.0$ mm is wound with a pitch (distance between corresponding points of adjacent coils) of 10 mm. The material is ASTM A227 cold-drawn carbon steel. If the spring is compressed solid, would you expect it to return to its original free length when the force is removed? For K_s use the closest point on the grid (use only two significant figures).

Find also the total resultant shear stress on the inside of the coil and comment on your findings.

Q3. Find the value of P for the two joints shown below based on a working stress of 15,000 psi in shear. Which of the two joints have higher load capacity? Why?

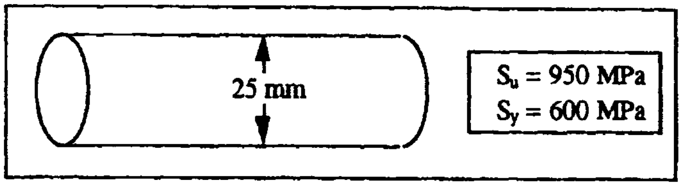


Q 1) SOLUTION (8.18)

Known: A steel bar having known S_u and S_y has a hot rolled surface finish.

Find: Determine the fatigue strength at 2×10^5 cycles for reversed axial loading.

Schematic and Given Data:



Assumptions:
1. Actual fatigue data is not available for this material.
2. The estimated S-N curves constructed using Table 8.1 are adequate.
3. Fig. 8.13 can be used to estimate surface factor, C_S.

1. Endurance limit (10^6 cycle strength)

   $S_n = S_n' C_L C_G C_s$

   For axial,

   $S_n' = 0.5 S_u = 0.5(950) = 475$ MPa

   $C_L = 1$

   $C_G = 0.8$ (between 0.7 and 0.9)

   $C_s = 0.475$

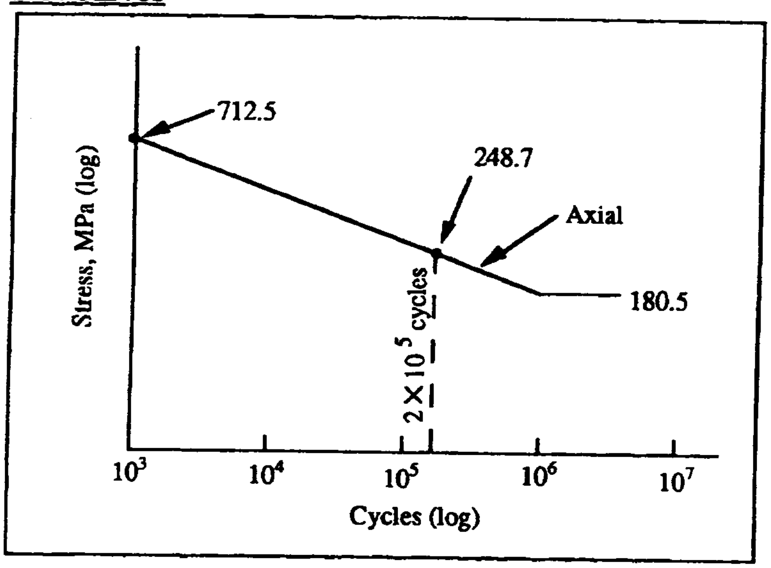
   $S_n = (475)(1)(0.8)(0.475) = 180.5$ MPa ■

2. 10^3 cycle strength

   For axial,

   $0.75 S_u = 0.75(950) = 712.5$ MPa

3. S-N curves



4. 2×10^5 cycle strength

   Axial: 248.7 MPa ■

Comments:
1. The surface factor, C_s is not used for correcting the 10^3-cycle strength because for ductile parts the 10^3 strength is relatively unaffected by surface finish.
2. For critical designs, pertinent test data should be used rather than the preceding rough approximation.
3. Analytically the 200,000 cycle strength for reverse axial loading may be determined by solving

$$[\log(712.5) - \log(180.5)]/(6 - 3) = [\log(S) - \log(180.5)]/(6 - \log(200{,}000)).$$

PROBLEMS

CLASS

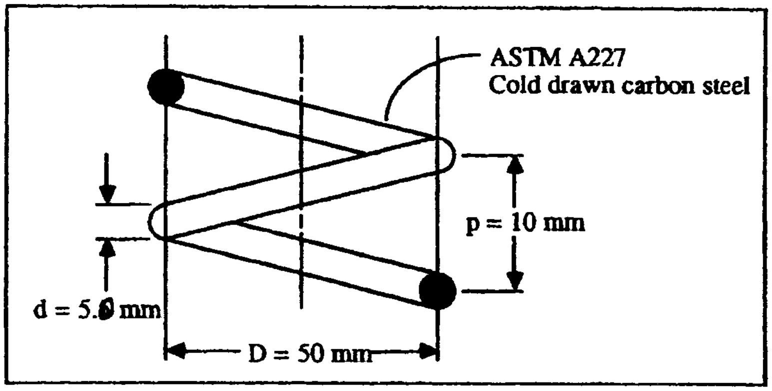
NAME DATE

Q2 SOLUTION (12.10)

Known: A helical coil spring with given D and d is wound with a known pitch value. The material is ASTM A227 cold drawn carbon steel.

Find: If the spring is compressed solid, would you expect it to return to its original free-length when the force is removed?

Schematic and Given Data:



Assumptions:

1. There are no unfavorable residual stresses.
2. Both end plates are in contact with nearly a full turn of wire.
3. The end plate loads coincide with the spring axis.

Force to compress spring solid (eq. 12.7)

$$F = \frac{d^4 G \delta}{8 D^3 N} \quad , \quad \frac{\delta}{N} = p - d = 10 - 5 = 5 \text{ mm} \quad , \quad G = 79 \text{ GPa}$$

$$F = \frac{(5\times10^{-3})^4 (79\times10^9)(5\times10^{-3})}{8\,(50\times10^{-3})^3} = 246.9 \text{ N}$$

$$\tau = \frac{8FD}{\pi d^3} K_s = \left[8(246.9)(50\times10^{-3}) / \pi (5\times10^{-3})^3 \right] 1.05 = 264.1 \text{ MPa}$$

$$C = D/d = 50/5 = 10 \rightarrow K_s = 1 + 0.5/C = 1.05$$

From eq 12.9 $\tau_s \leqslant .45 S_u$, $S_u \simeq 1300$ MPa (Fig 12.7)

Since 264 MPa < (.45 S_u = 585 MPa), no set should occur, and spring should return to its original length.

Stress Concentration factor of the inner surface $K_w = \frac{4C-1}{4C-4} + \frac{.615}{C} = 1.15$

$$\tau = \frac{8FD}{\pi d^3} K_w = 289 \text{ MPa} < 585 \text{ MPa}$$ ← No setting

Q3 Solution

Given Information: The physical dimensions of the joint are shown in Figure 7-19

Assumptions: The loads are applied eccentrically and thus the moment must be taken into account. The moment load on a rivet varies directly with the distance from the center of gravity of the group of rivets.

Solution Method: We will use Eq. (10).

Solution Details: Area in shear $= \frac{\pi}{4}\left(\frac{3}{4}\right)^2 = 0.4418 \text{ in.}^2$, each rivet.

For Joint (a),

$$P = 3 \times 0.4418 \times 15{,}000 = 19{,}880 \text{ lb}$$

For Joint (b),

Moment arm of the load is 2 in.

In Eq. (10),

$$2P = C(2 \times 2^2 + 2 \times 6^2), C = 0.025P$$

For the rivet at A,

$$\text{moment force} = 6 \times 0.025\text{P} = 0.15\,P$$

$$\text{direct force} = \frac{P}{4} = 0.25\,P$$

$$\text{total force} = 0.40P$$

$$\text{stress} = \frac{0.4\text{P}}{0.4418} = 15{,}000$$

$$P = 16{,}570 \text{ lb}$$

Thus, although joint (b) has more rivets and is more expensive to make, its carrying capacity is less than the symmetrical joint (a).