Me413.3 Machine Design I

Winter 2000

Instructions

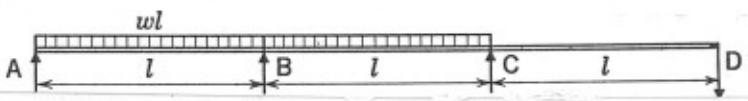
This examination is CLOSED BOOK

Calculators may be used.

Candidates should attempt 5 (FIVE) of the 7 (SEVEN) QUESTIONS

All questions are of equal value, TIME allowed is 3 (THREE) hours

1. Find the maximum transverse deflection of the beam shown below. Would



the addition of an axial tension load increase or decrease that deflection?
Note that when using singularity functions, a concentrated upward acting transverse force F_o at $x = a$ is denoted as

$$F_o < x - a >^{-1}$$

and that the transverse deflection y can be found from the Euler–Bernoulli equation

$$EI\frac{d^4y}{dx^4} = w(x)$$

and that w is the intensity of the transverse load at any point x along the beam.

2. Design a compression coil spring to provide a minimum force of 400 pounds and a maximum force of 1200 pounds. over a 3 inch range. The actual maximum load will be 1200 pounds and should be regarded as static. The steel wire available can be considered to have a ultimate tensile strength of 350ksi. Remember that

$$K_s = 1 + \frac{0.615}{C}$$

$$\tau = \frac{8FCK_s}{\pi d^2}$$

$$k = \frac{dG}{8NC^3}$$

G is 11,500,000 psi

3. Design a square cross section shaft for a fatigue application.

The shaft is supported by two bearings that can be considered to provide simple support with 72 inches between the bearings.

The shaft is to carry a constant torsional load of 500 ft lb and a bending load of 400 pounds at mid span due to a belt drive. Size the shaft for a steel with $S_u = 200,000psi$, $S_y = 150,000psi$.

Detail design has lead to a 2.5 k_t at the point of maximum bending stress and the k_t in torsion is 2.0.

$$k_f = 1 + (k_t - 1)q$$

Consider the shaft to be machined and q to be 0.90. Size the shaft assuming for a safety factor of 3. Remember that the maximum shear stress for a square shaft in tension is given by

$$\tau = \frac{4.5T}{a^3}$$

where a is the 0.25 of the perimeter of the square's cross-section. State any assumptions.

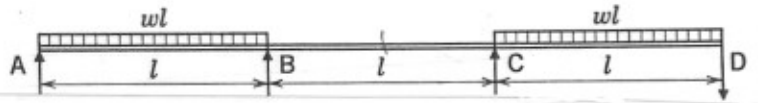
Use the Gerber relationship for fatigue

$$\left(\frac{\sigma_{u_t}}{N}\right)^2 = \sigma_{xx}^{*2} + \sigma_{yy}^{*2} + \sigma_{zz}^{*2} - \sigma_{xx}^{*}\sigma_{yy}^{*} - \sigma_{yy}^{*}\sigma_{zz}^{*} - \sigma_{zz}^{*}\sigma_{xx}^{*} + 3(\sigma_{xy}^{*2} + \sigma_{yz}^{*2} + \sigma_{zx}^{*2})$$

where

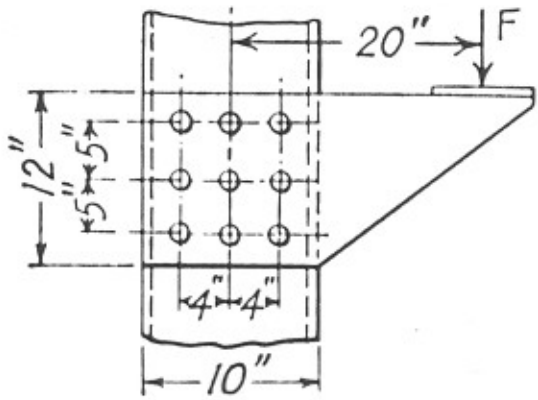
$$\sigma_{uv}^{*} = \frac{1}{2}\left(k_{fc}\sigma_{uc}\frac{\sigma_{uv_a}}{S_{N_c}}\right) + \frac{1}{2}\left[\left(k_{fc}\sigma_{uc}\frac{\sigma_{uva}}{S_{N_c}}\right) + 4\sigma_{uv_m}^2\right]^{1/2}$$

4. Draw shear and moment diagrams for the beam shown below. Find the point(s) of maximum deflection and assuming that the beam is made of steel and has a 1 inch square cross–section find the maximum bending stresses.



$l = 3\,ft.$
$w = 1000\,lb/ft$

5. The bracket shown below is bolted to a frame as shown. Find the loads carried by each bolt.



6. A roller bearing is to carry the following ~~three~~ 4 radial loads, each for 1/4 of the time, 6000 N, 11,000N and 16,000N and 20,000N . Your client wants 99% reliability. The bearing is rated at 11.1 kN for $90X10^6$ revolutions with 90% reliability. How long will the bearings be expected to last if the RPM of the inner race with respect to the outer race is 4000RPM. Note that,

$$L = K_r L_R (C/F_r)^{3.333}$$

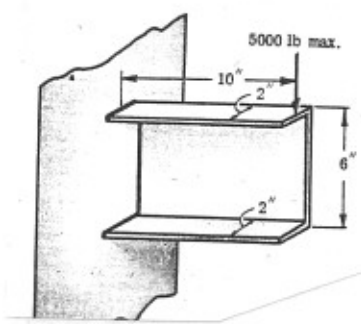
$$C_{req} = F_r (L/K_r L_R)^{0.3}$$

remember

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} = 1$$

What is the name of this relationship?

7. Design a weld for the problem illustrated below. The rod used is E70XX



and the tensile yield stress can be taken to be 57ksi.