Name of Student:____________________________________
(Last) (First)

Class Time (circle one): 7:30 11:30 2:30

ME 452: Machine Design II
Fall Semester 2014

Class Test 1-Division-3 (2:30). Friday, September 19, 2014
OPEN BOOK. CLOSED NOTES.

For full credit please show all your work including complete free-body diagrams.

A 1.5" diameter machined circular shaft rotates at 1000 rpm supporting two wheels, each subjected to the steady radial load, F, as shown below. Assume:

No stress concentration effects
The shaft operates at room temperature
Shaft yield strength, $S_y = 70{,}000$ psi
Shaft ultimate strength, $S_{ut} = 120{,}000$ psi

(a) Plot the bending moment and transverse shear force diagrams for the shaft.

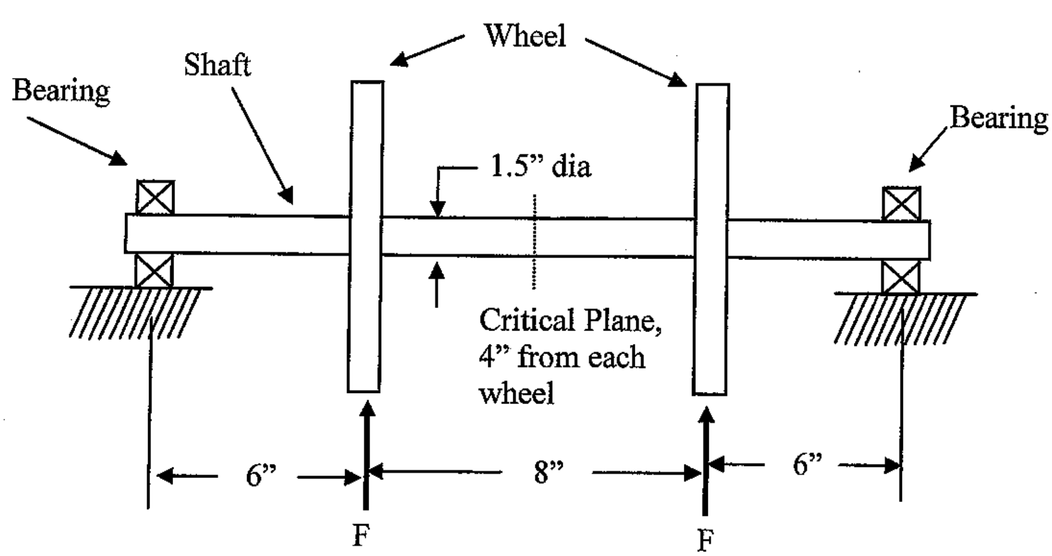
(b) For the critical point on the critical plane, calculate stress(es) in terms of the load F and time. Plot the stress(es) versus time.

(c) Calculate the load, F, lb, that yields the shaft at the critical point.

(d) Calculate the load, F, lb, which has a 1% chance of failing at the critical point in 1,000,000 cycles.

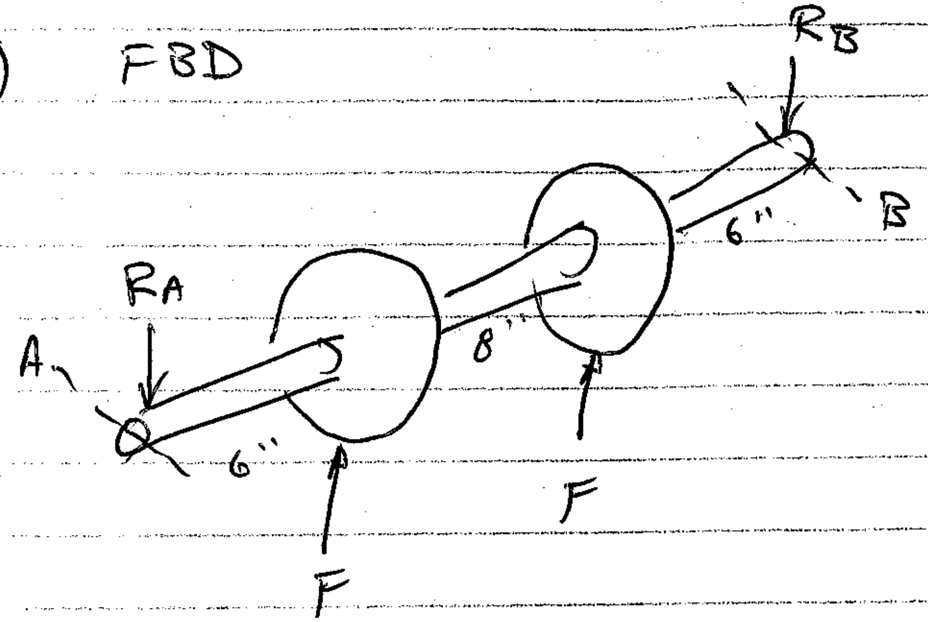
(e) Calculate the load, F, lb, which has a 1% chance of failing at the critical point in 1,000 cycles.

(f) Calculate the load, F, lb, which has a 1% chance of failing at the critical point in 500,000 cycles.



ME 452 (Fall 2014)
Test 1 2:30 Section

(a) FBD

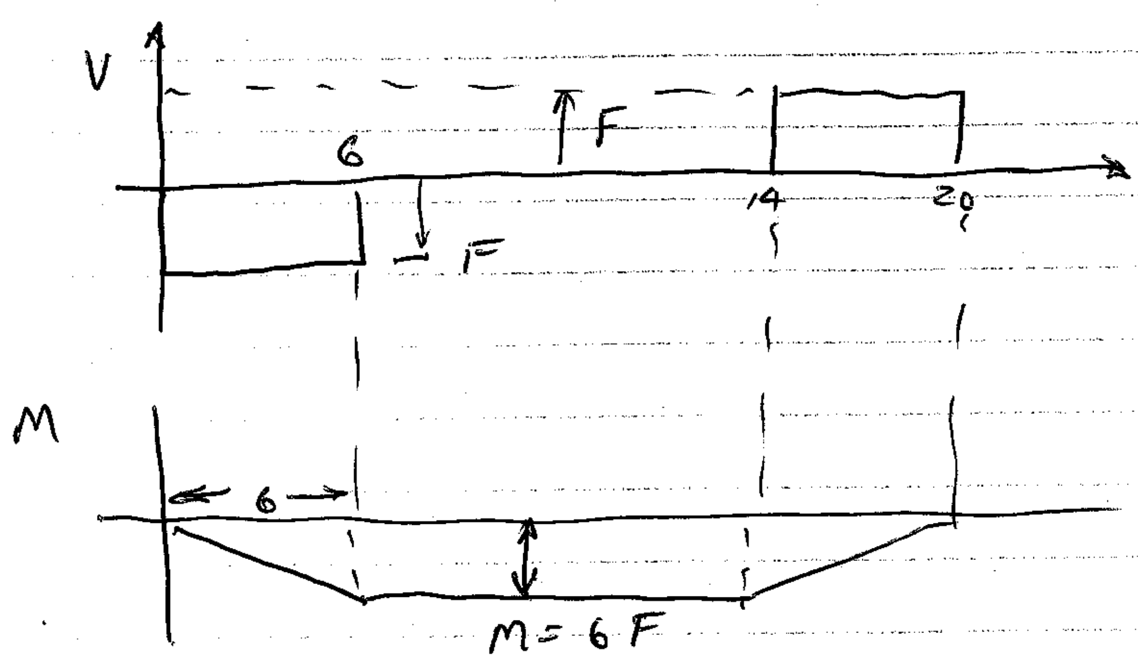


$\Sigma M_A = 0 \qquad 6F + 14F = R_B\,20$

$R_B = F$

$\Sigma M_B = 0 \qquad 20R_A - 4F - 6F = 0$

$R_A = F$



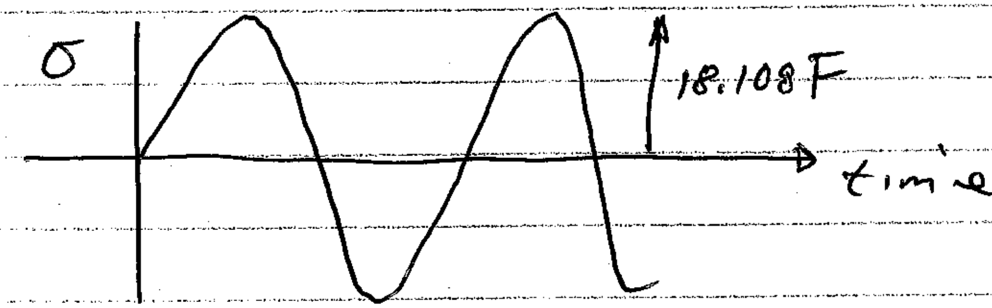
(b) Critical plane has $M = 6F$, $V = 0$

$\Rightarrow$ Bending stress is

$$\sigma_0 = \frac{Mc}{I} = \frac{6F\left(1.5/2\right)}{\pi (1.5)^4/64}$$

$$\sigma_0 = \frac{192\,F}{\pi d^3} = 18.108\,F$$

Since the shaft rotates, all points on the surface are equally critical, and



(c) Yield failure:

$$n_Y = \frac{S_Y}{\sigma_{max}} = 1 \quad (\text{failure})$$

$$1 = \frac{70,000}{18.108F} \Rightarrow \boxed{F = 3866\ \text{lb}}$$

(d) infinite life:

$$S_e = (k_a \cdots k_f)\, S_e'$$

$$S_e' = \tfrac{1}{2} S_{ut} = 60{,}000 \text{ psi}$$

$$k_a = a\, S_{ut}^{\,b} = 2.7\,(120)^{-.265} = .7592$$

$$k_b = (1.5/.3)^{-.107} = .8418$$

(No de needed)

$k_c = 1$ (bending)

$k_d = 1$ (room temp)

$k_e = .814$ (99% reliab ⇒ 1% fail)

$k_f = 1$ (No other effects)

$$S_e = (.7592)(.8418)(.814)(60{,}000)$$

$$S_e = 31{,}213 \text{ psi}$$

$$\Rightarrow \quad 1 = \frac{31213}{18.103F}$$

$$\Rightarrow \quad \boxed{F = 1724 \text{ lb}}$$

(e) 1000 cycles

$f = .82 \Rightarrow fS_{ut} = .82(120)$

$fS_{ut} = 98{,}400$ psi

$$1 = \frac{98400}{18.183F} \Rightarrow \boxed{F = 5435 \text{ lb}}$$

(f) 500,000 cycles

$$a = \frac{(fS_{ut})^2}{S_e} = \frac{(98400)^2}{31213} = 310240$$

$$b = -\tfrac{1}{3}\log\left(\frac{98400}{31213}\right) = -.1662$$

$$S_f = aN^b = 310240(500{,}000)^{-.1662}$$

$$= 35022 \text{ psi}$$

$$F = \frac{35022}{18.183}$$

$$\boxed{F = 1935 \text{ psi}}$$