ME-340 LAB EXAM-02 February 23, 1999

Name: Solution

(1) A radial load of 1686 pound and an axial load of 1012 pound are applied to a 25-degree angular contact ball bearing. The bearing supports a shaft which is rotating at 2000 rpm. Reliability of the bearings is 99%, the application is heavy impact in a design which operates continuously for 24 hours where reliability is of extreme importance. Select a medium service bearing for this operation.

(2) A 1/2-inch UNC, class 8 bolt, with rolled threads is preloaded to 80% of its proof strength. The clamped members are 5.5 times as stiff as the bolt. Find the factors of safety against static yielding and joint separation when a static external load of 1500 pounds is applied. Design requires a margin of safety of 0.5 in yielding and 1.0 for clamping. Is this design satisfactory? If the clamped members are 2.5 inches thick, what are the stiffnesses of the bolt and clamped members.

(3) A journal bearing operating in an offshore drilling machine, in an extremely corrosive environment, and subjected to cryogenic temperatures, has a diameter of 3 inch, is 3 inch long, and supports a radial load of 600 pound for a shaft that rotates at 750 rpm. The radial clearance ratio is 500. The design uses a 10W oil operating at 140F. Determine the following:

(a) Oil supply and outlet temperatures.
(b) Friction coefficient.
(c) Minimum film thickness.
(d) Oil flow to the bearing and side flow.
(e) Power lost in the bearing.

(4) For the same environment as in problem 3, a 6311 medium deep-groove Conrad-type ball bearing supports a load of 12,900 pounds, and has operated for 1.1 million cycles. A user wants to increase the load to 14,598 pounds; how many cycles of operation can now be expected?

$F_r = 1686$ lb $\qquad \omega = 2000$ rpm

$F_t = 1012$ lb

$F_t / F_r = \dfrac{1012}{1686}$

$= 0.60 < 0.68$

$\therefore\ F_e = F_r$

$C_{req} = F_e K_a \left(\dfrac{L}{K_R L_R}\right)^{0.3}$

$K_a = 2.5$ ~ mean value

$K_R = 0.21$

Life = 150,000 hours – mean value

$L = (150 \times 10^3)(hr)(2000 \frac{rev}{min})(60 \frac{min}{hr})$

$L = 18{,}000 \times 10^6$ cycles

$L_R = 90 \times 10^6$

$C_{REQ} = (1686\ lb)\left(\dfrac{4.45\ N}{1000}\right)\left(\dfrac{1}{1000}\right)(2.5)\left(\dfrac{18{,}000}{.21 \times 90}\right)^{.3}$

$L \frac{kN}{N}$

$C_{REQ} = 147$ kN

$\boxed{Brg = ?}$ off the chart

$\frac{1}{2}$ - UNC ~ $\frac{1}{2}$-24 UNC, gr 8

$A_t = 0.0242 \, in^2$

$S_p = 120 \, ksi$

$F_i = .8 \, S_p A_t$

$F_i = (.8)(120 \times 10^3 \, \frac{lb}{in^2})(0.142 \, in^2)$

$F_i = 13{,}620 \, lb$

$K_m = 5.5 \, K_b$

$N_{yield} = \frac{\sigma_{yp}}{\sigma_b}$

$\sigma_{yp} = 130 \, ksi$

$\sigma_b = \frac{F_b}{A_t}$

$F_b = \left(\frac{K_b}{K_b + K_m}\right) P_{ext} + F_i$

$= \left(\frac{1}{6.5}\right)(1500) + 13{,}620$

$F_b = 13{,}850 \, lb$

$\sigma_b = 105. \, ksi$

$N = \frac{130}{97.6}$

$\boxed{N = 1.3}$ $\quad$ MS = 0.2 < 0.5

$\therefore$ $\boxed{\text{No good in yield}}$

$$N_{sep} = \frac{P_0}{P} = \frac{F_i}{P(1-c)}$$

$$P = 1500 \text{ lb} = P_{ult}$$

$$c = \frac{k_b}{k_b + k_m} = \frac{1}{6.5}$$

$$c = .15$$

$$N_{sep} = 10.7 = \frac{13620}{1500(.857)}$$

$$\boxed{MS = 9.7 >> 1.00 \sim \text{good}}$$

$$K_b = \frac{AE}{l}$$

$$= \frac{(.785)(d^2)(30 \times 10^6)}{2.5}$$

$$K_b = \frac{(.785)(\tfrac{1}{2})^2(30 \times 10^6)}{2.5} \quad \frac{(\text{lbs}/\text{in}^2)(\text{in})^2}{\text{in}}$$

$$\boxed{K_b = 2.36 \times 10^6 \text{ lb/in}}$$

$$K_m = 5.5 K_b$$

$$\boxed{K_b = 13 \times 10^6 \text{ lb/in}}$$

$l = 3$ in, $d = 3$ in $\Big\}$ $l/d = 1$

$W = 600$ lb

$\omega = 750$ rpm

$N = 10$ rev/sec

$r/c = 500$

$T = 140$ F SAE 10 ~ $\mu = 2.2 \times 10^{-6}$ reyn

$$S = \left(\frac{r}{c}\right)^2 \frac{\mu N}{P}$$

$$P = \frac{600 \text{ lb}}{(3)(3) \text{ in}^2}$$

$$P = 66.7 \text{ lb/in}^2$$

$$S = (500)^2 \frac{(2.2 \times 10^{-6})(12.5)}{66.7}$$

$$S = 0.10$$

unk
T_0, ΔT, T_i
$\frac{r}{c} f$, Q_s/Q, $\frac{Q}{rcNL}$
c (7)

(1) $T_0 = T_{avg} + \frac{\Delta T}{2}$

(2) $T_i = T_{avg} - \frac{\Delta T}{2}$

(3) $\Delta T_F = \frac{0.103P}{\left[1 - \frac{1}{2}\left(\frac{Q_s}{Q}\right)\right]} \frac{[(r/c)f]}{(Q/rcNL)}$

(4) $\frac{r}{c} f = 2.8$

(5) $\frac{Q_s}{Q} = 0.74$

(6) $\frac{Q}{rcNL} = 4.5$

(7) $\frac{r}{c} = 500$

$r = 1.5$

$c = \frac{r}{500}$

$c = 0.003 \text{ in}$

$$\Delta T = \frac{(0.103)(66.7)(2.8)}{\left[1 - \left(\frac{.74}{2}\right)\right](4.5)}$$

$\Delta T = 6.78 \text{ F}^\circ$

$$\boxed{\begin{array}{c} T_i = 136.6\,^\circ F \\ T_o = 143.4^\circ F \end{array}}$$

(b) $\frac{r}{c} f = 2.8$

$500 f = 2.8$

$\boxed{f = 0.0056}$

(c) $\frac{h_o}{c} = 0.32$

$\boxed{h_o = 0.00096 \text{ in}}$

(d) $\frac{Q}{rcNL} = 4.5$

$Q = (1.5 \text{ in})(.003 \text{ in})(12.5)(3)(4.5)$

$\boxed{Q = 0.76 \text{ in}^3/\text{sec}}$

$Q_s = .74 Q$

$\boxed{Q = 0.56 \text{ in}^3/\text{sec}}$

(e) $H = \frac{TN}{1050}$

$$H = \frac{(fWr)N}{1050}$$

$$H = \frac{(0.0056)(600\,lb)(1.5\,in)(125\,\frac{rev}{sec})}{1050}$$

$$\boxed{H = 0.06\ HP}$$

(4) Operating life has already exceeded rated load @ rated life. Therefore, no additional cycles, period, can be expected, @ any load.

(Norton - see text)

Miner's $\sum \frac{l_i}{L_i} < 1$

$$\frac{1.1\times10^6}{1.0\times10^6} > 1 \sim \text{fails}$$