ME-340 EXAM #02 *November 12, 1998*

*NAME:*__________________________ *10:00 AM*

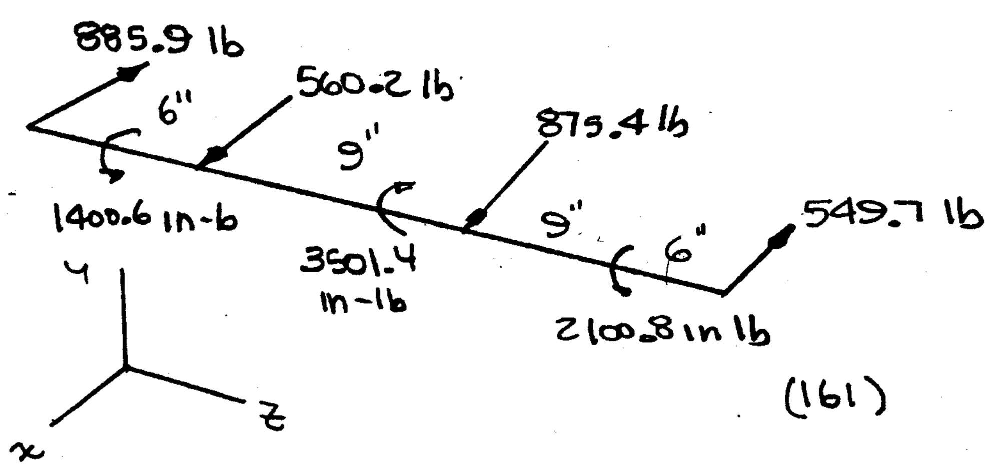
- *Read all problems carefully. Check the board for any additions or corrections.*
- *Show all work, which must be neat and orderly to be graded. That is ,sloppy work will not be graded!*
- *Show no work on this page, and, return this page with your solutions.*

(1) A sliding element bearing has a length of 150-mm, a diameter of 50-mm, a clearance ratio of 700, and a load of 8-kN, corresponding to a rotational speed of 160- rev/minute. The lubricant is SAE 50 oil with a viscosity of 20-mPa-s, at an inlet temperature of 25C. Do you agree with that assumption (yes or no) and show the calculations required to support your decision. If you do not agree what should be done to correct the design engineer's error? Using the original data, determine the temperature rise across the bearing, the outlet oil temperature, coefficient of friction, eccentricity, total and side oil flows, maximum oil pressure, and the power lost in the bearing.

(2) For the design of problem (1) select a 200 series rolling element bearing which has a reliability of 95% and must last for 25,000 hours. The application is moderate impact.

(3) For the figure shown below, verify the free body diagram is correct.

(4) A bearing has been operated at 2,500,000 cycles at 15-kN. Can this bearing be operated at 25-kN for an additional 250,000 cycles. The bearing is an 02 series with a bore diameter of 80-mm.



(1) $l = 150\,mm$, $d = 50\,mm$, $l/d = 3$, $W = 8{,}000\,N$ → $P = \frac{8{,}000\,N}{.150\,m \times .050\,m} = 1.07\,MPa$

$\frac{r}{c} = 700$

$N = 160\,rev/min = 2.67\,rev/sec$

SAE 50

$T_i = 25°C$

$T_{AVG,ASSUMED} = 87°C$ ($\mu = 20\,mPa\,sec$)

ASSUMED TEMP RISE

$\Delta T_{ASSUMED} = 2(T_{AVG,ASSUMED} - T_i) = 124°C$

$T_{out,ASSUMED} = T_i + \Delta T_{ASSUMED} = 149°C$

FIRST CALCULATE THE SOMMERFIELD NUMBER AT THE ASSUMED T_{AVG}

$$S = \left(\frac{r}{c}\right)^2\left(\frac{\mu N}{P}\right) = (700)^2\left(\frac{20\times10^{-3}\,Pa\,sec\,(2.67\,\frac{rev}{sec})}{1.07\times10^6\,Pa}\right) = 0.024$$

NOW CALCULATE THE TEMPERATURE RISE AND SEE IF IT MATCHES

$$\Delta T_c = \frac{8.30\,P}{1-.5\left(\frac{Q_s}{Q}\right)}\,\frac{\left(\frac{r}{c}f\right)}{\left(\frac{Q}{rcNl}\right)} = \frac{8.30\,(1.07)}{1-0.5(.6)}\,\frac{1.1}{(1)} = 14°C$$

NEED BETTER CHART!

TEMP ASSUMPTION NOT CORRECT, ΔT_{CALC} VARIES BY MORE THAN 5%. A NEW TEMP NEEDS TO BE GUESSED AND CHECKED UNTIL THE ASSUMPTION EQUALS THE CALCULATION. TEMP WAY TOO HIGH, SUGGEST NEXT GUESS AROUND ΔT OF 50°C OR LESS.

NOW FIND (USING ORIGINAL DATA/ASSUMPTION; IE SOMMERFIELD NUMBER)...

TEMPERATURE RISE, SEE ABOVE, = 14°C

TEMPERATURE OF OUTLET = $T_i + \Delta T = 25°C + 14°C = 39°C$

① **CONT'D** COEFFICIENT OF FRICTION

$\frac{r}{c} f = 1.1$; $f = \frac{1.1}{700} = 0.00157$ (CHART)

[ORIGINAL DATA/ASSUMPTION SOMMERFIELD # = 0.024]

FIND ECCENTRICITY

$\varepsilon = 0.82 \rightarrow e = \varepsilon c = 0.82(.0357m) = 0.029$ mm

FIND TOTAL AND SIDE OIL FLOWS

$\frac{Q}{rcNl} = 1 \rightarrow Q = 1(25mm)\left(\frac{25}{700}mm\right)\left(2.67\frac{rev}{sec}\right)(150mm) = 358\ mm^3/sec$

$= .358$ cc/sec

$\frac{Q_s}{Q} = 0.6 \rightarrow Q_s = 0.6(.358\ cc/sec) = .214\ cc/sec$

FIND MAXIMUM OIL PRESSURE

$\frac{W}{ld} \approx$ NOMINAL PRESSURE $= 1.07$ MPa $= 155$ psi

$\frac{P}{P_{max}} \approx .45 \rightarrow P_{max} = \frac{155psi}{0.45} = 345$ psig $= 360$ psi $= 2.5$ MPa

FIND POWER LOST IN BEARING

$T = fWr = 0.00157(8{,}000N)(.025m) = .314$ Nm

$H = 2\pi n T = 2\pi\left(2.67\frac{rev}{sec}\right).314Nm = 5.27$ w

(2) SELECT 200 SERIES

RELIABILITY = 95% → $K_R = 0.62$

25,000 HOURS × 2.67 rev/sec × 60 sec/min × 60 min/hr = 2.4×10^8 CYCLES

MODERATE IMPACT → $K_A = 1.75$

$$C_{REQ} = K_a F_e \left(\frac{L}{K_R L_R}\right)^{0.3} = 1.75\,(8\,kN)\left(\frac{2.48E8}{.62(90E6)}\right)^{0.3} = 21.9\ kN$$

CHOOSE 85 mm BORE RADIAL BALL → 217 } OR LARGER
OR 80 mm BORE ANGULAR BALL → 216 } BUILD UP SHAFT!

(3) $\Sigma F_x = -885.9 + 560.2 + 875.4 - 549.7 = 0$

$\Sigma M_z = 1400.6 - 3501.4 + 2100.8 = 0$

$\Sigma M_y = -560.2(6) - 875.4(15) + 549.7(30) = -1.2$ in lb (CLOSE ENOUGH)

THIS FIGURE IS CLOSE ENOUGH TO EQUILLIBRIUM

(4) $l_1 = 2.5E6$

$l_2 = .25E6$

$$\frac{l_1}{L_1} + \frac{l_2}{L_2} = 1 \rightarrow l_2 = \left(1 - \frac{l_1}{L_1}\right) L_2$$

DEEP GROOVE, C = 70.2 kN:

$$L_1 = 1E6\left(\frac{70.2}{15}\right)^{3.33} = 170E6$$

$$L_2 = 1E6\left(\frac{70.2}{25}\right)^{3.33} = 31E6$$

$l_2 = 30.5E6$, THEREFORE OK TO OPERATE

ANGULAR CONTACT, C = 80.6 kN:

$$L_1 = 1E6\left(\frac{80.6}{15}\right)^{3.33} = 270E6$$

$$L_2 = 1E6\left(\frac{80.6}{25}\right)^{3.33} = 49E6$$

$l_2 = 48.5E6$, THEREFORE OK TO OPERATE