MECH 325 - Midterm Book 1

Tuesday, October 24, 2017

Name: Solutions

Student Number: _____

Circle your section

Section 101:	**T1A (2:00pm tutorial)**	**T1B (11:00am tutorial)**	**T1E (3:30pm tutorial)**
Section 102:	**T1C (2:00pm tutorial)**	**T1D (5:00pm tutorial)**	**T1F (3:30pm tutorial)**

Signature: Solutions

Part 1 MC Mark _____ / 15

Part 1 SA Mark _____ / 15

Part 2 LA Mark _____ / 30

Total _____ / 60

Instructions

There are two parts to this exam with different instructions for each. Please read carefully.

Part 1 – Closed-Book (30 marks)

Multiple choice (15 marks: 1 marks per question). Complete all 15 questions by marking your response **in pencil in the computer score card**. Write your name and student number on the computer card and mark your student number in the "ID Field".

Short answer (15 marks). Complete all 7 questions by marking your response in this exam booklet.

After you have completed Part 1, hand in your booklet and Scantron scorecard and you will receive a handout for Part 2 and a separate exam booklet for your answers. You may not return to Part 1 after you hand it in.

Part 2 – Open-Book (30 marks)

Long answer (30 marks): Complete all parts to the questions for Part 2 by marking your responses in the separate exam booklet. This portion of the exam is open-book and open-notes.

Only non-programmable calculators may be used (or programmable calculators with purged memories).

Part 1A: Multiple Choice (15 Points)

Answer all 15 questions. Each is worth 1 mark. Choose the single best response – a given question may have more than one choice that is correct but marks will only be given for the *best* answer.

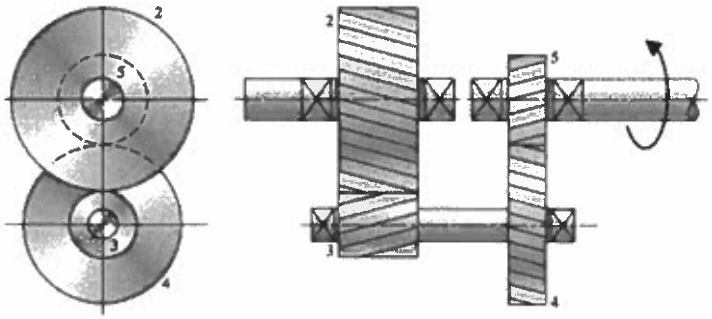
1. **What is the best description of the type of motion between the teeth of two properly meshed worm gears?**
   a) Purely rolling
   b) Some sliding when teeth engage and disengage, but predominantly rolling
   c) Approximately equal parts sliding and rolling
   d) Some rolling when teeth engage and disengage, but predominantly sliding
   e) Purely sliding

2. **For spur gears, backlash is defined at which position on the gear?**
   a) Pitch Circle
   b) Addendum Circle
   c) Dedendum Circle
   d) Clearance Circle
   e) Base Circle

3. **Which of the following gears allows the shafts to be offset and non-intersecting?**
   a) Spur gear
   b) Worm gear
   c) Helical gear
   d) Bevel gear
   e) Hypoid gear

4. **A helical gear has a normal pressure angle of 20°, a helix angle of 25°, a diametrical pitch of 6, and 18 teeth. What is the pitch diameter?**
   a) 0.5236
   b) 3.0
   c) 2.86
   d) 6.62
   e) 3.14

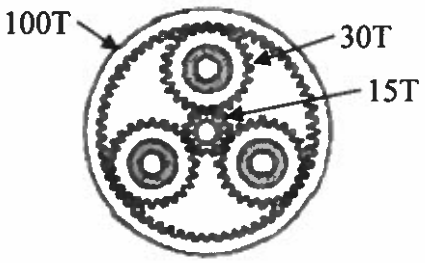
5. **On the following gear set, gear 5 is the driving pinion. Gear 5 has 16 teeth, Gear 4 has 32 teeth, Gear 3 has 14 teeth and gear 2 has 42 teeth. An 1800 rpm motor is driving the gear box in the direction shown (Clockwise). What is the speed and direction of the output shaft?**



a) 300 rpm clockwise
b) 300 rpm counter-clockwise
c) 200 rpm clockwise
d) 200 rpm counter-clockwise
e) 600 rpm clockwise

6. **The motor attached to the gearset in Question 5 above is rated at 750 Watt. What is the torque on the output shaft?**
   a) 15 N-m
   b) 23.9 N-m
   c) 30 N-m
   d) 45.6 N-m
   e) 125 N-m

7. **For the planetary gear train shown, the ring gear rotates at 805 rpm counter-clockwise and the sun gear is fixed. How fast does the arm rotate and in which direction?**
   a) 402.5 rev/min (counter-clockwise)
   b) 700 rev/min (clockwise)
   c) 268.3 rev/min (counter-clockwise)
   d) 402.5 rev/min (clockwise)
   e) 700 rev/min (counter-clockwise)



8. **Comparing a square vs. an ACME power screw, which of the following is true regarding the use of a split-nut:**
   a) A split nut reduces friction on both types of power screw
   b) A split nut allows for backlash adjustment on an ACME power screw
   c) A split nut allows for backlash adjustment on a square power screw
   d) A split nut is required when using a bushing for a friction collar on both types of power screw
   e) A split nut is required when an ACME power screw is non-reversing

9. **Which of the following components of belt tension present in V-Belts but normally ignored in flat belts that is the main consideration when calculating belt life?**
   a) Initial tension (F_i)
   b) Bending tension (F_b)
   c) Centrifugal tension (F_c)
   d) Tight-side tension (F_1)
   e) Slack-side tension (F_2)

10. **A V-belt drive has a driving pulley operating at 200 rpm, a drivetrain value of e = 0.25, a nominal power of H_{nom} = .75 hp, a service factor of K_s = 2.5, and a design factor of n_d = 1.5. TWO belts are to be used in parallel. The following belts are available in the catalogue. Which is the smallest belt that will satisfy the design requirements?**
    a) Allowable power H_a = 0.7 hp
    b) Allowable power H_a = 1.1 hp
    c) Allowable power H_a = 1.5 hp
    d) Allowable power H_a = 2.9 hp
    e) Allowable power H_a = 5.7 hp

11. **A timing belt has a driving pulley with pitch diameter of 20 cm and 50 teeth, and a driven pulley with 100 teeth. The wrap angle is 130°. During operation, the tight side tension is 130 N, slack side tension is 40 N, and the driving pulley rotation rate is 120 rad/sec. What is the torque transmitted from the motor shaft to the driving pulley?**
    a) 6.0 N·m
    b) 9.0 N·m
    c) 60.0 N·m
    d) 100.0 N·m
    e) 600 N·m

12. **Which of the following is NOT a primary design consideration when selecting a roller chain?**
    a) Chordal speed variation
    b) Limiting power for roller fatigue, $H_{lim,\ roller}$
    c) Limiting power for link plate fatigue, $H_{lim,\ l\text{-}p}$
    d) Limiting force for link plate bending, $F_{lim,\ l\text{-}p}$
    e) Limiting power for wear and galling, $H_{lim,\ wear}$

13. **A tapered-roller bearing is best suited for:**
    a) Only large radial loads
    b) Only large axial loads
    c) Small radial loads, plus large axial loads in both directions
    d) Large radial loads, plus large axial loads in both directions
    e) Large radial loads, plus large axial loads in one direction only

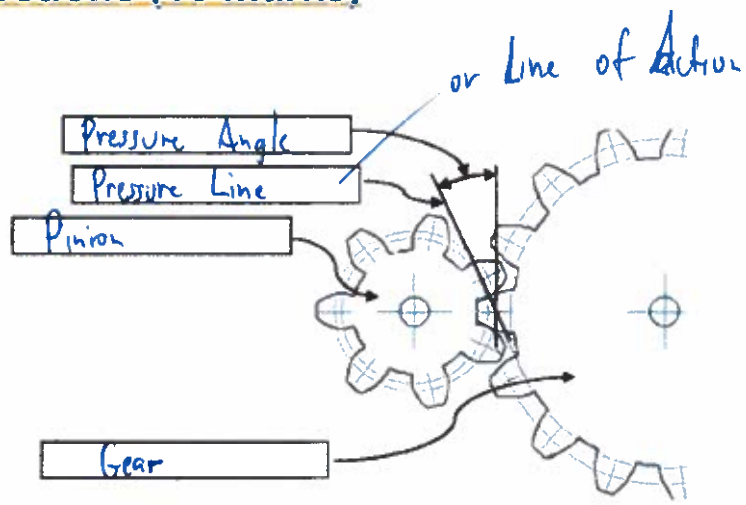
14. **Which of the following parameters should be increased in order to reduce the temperature of a boundary-lubricated bearing in service? (assume all other parameters remain fixed)**
    a) Rotation speed, N
    b) Applied force, F
    c) Coefficient of friction, f_s
    d) Bearing length, L
    e) Wear factor, K

15. **When specifying the working load of wire rope, which of the statements is FALSE:**
    a) one must consider the modulus of elasticity of the wire rope
    b) one must take in account the maximum allowable bearing pressure of the wire rope on the sheave
    c) one must consider the application in order to specify a safety factor
    d) one must determine the maximum sheave diameter
    e) one must consider loads caused by sudden stops and starts

Part 1B – Short-Answer Questions (15 marks)

Answer all questions in the spaces provided.

16. In the boxes provided, label the four terms relating to spur gears. (2 marks)



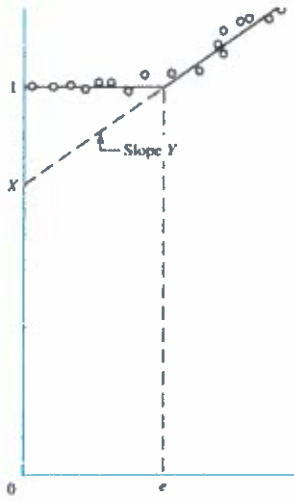
17. In the above gear design, do you expect interference to occur? Why (2 marks)?

1 mark

Yes. The pinion has less than 12 teeth, the accepted minimum number of teeth. One can expect the teeth will make contact outside of the tangent line connecting the two base circles.

1 mk

18. a) Label the x and y axis on the following graph for bearing performance prediction (1 mark)



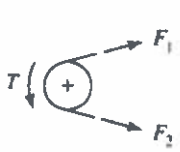
$\frac{F_e}{VF_r}$ $\frac{F_a}{VF_r}$

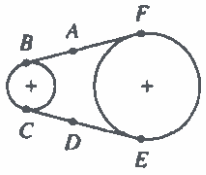
F_e = equiv. radial load
F_r = radial load
F_a = axial load
V = rotation factor
= 1.0 inner ring rotating
= 1.2 outer ring rotating

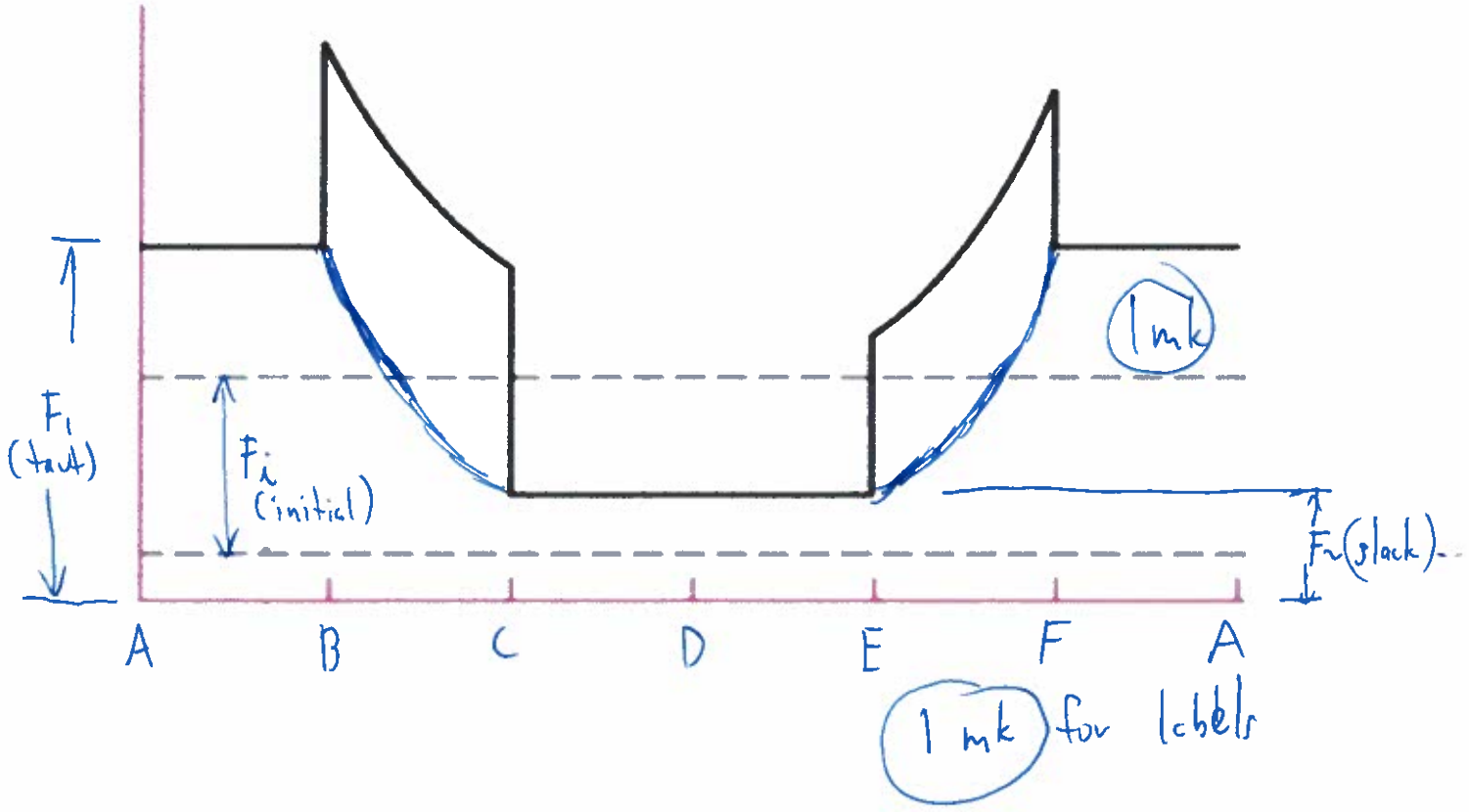
b) What is the significance of the graph (1 marks).

For combined loading on a bearing (axial and radial loads), the graph is used to determine an equivalent radial load that can be used to select a bearing from a catalogue. For low levels of F_a, the F_a/F_R will become 1.0 and only radial load is used

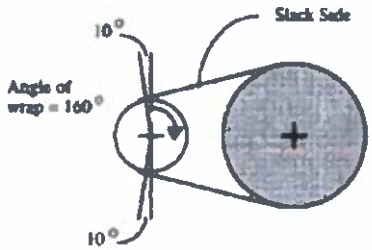
19. The diagram shown below is the tension profile for a V-belt. On this diagram, sketch the tension profile for a flat belt that is transmitting *the same torque*, and has the same linear speed, initial tension, pulley diameters, and belt weight per unit length. Identify the taut, slack, and initial tension and mark the x-axis with the appropriate A to F positions on the diagram. (2 marks)

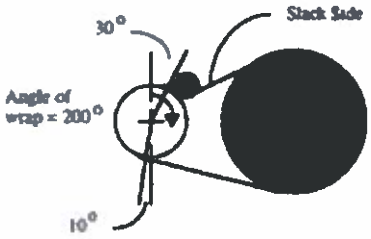






20. a) The angle of wrap on a pulley increases from 160° to 200° without any change in the slack side tension. If the friction coefficient remains constant, explain how this benefits the drive system (1 mark).





Driving torque is a function of wrap angle. The greater the wrap angle the higher the tension we create in the system. This translate to higher power.

Recall $\frac{F_1 - F_c}{F_2 - F_c} = e^{f\phi}$

b) If the friction coefficient is 0.25, estimate the % change in performance. Assume no changes to the driven pulley. (2 marks)

Give $f = 0.25$ Recall $P_1/P_2 = e^{f\phi}$ $160° = 2.79$ radian $200° = 3.49$ radian

for $160° \Rightarrow e^{0.25(2.79)} = 2.10 \Rightarrow P_1 = 2.1 P_2$

$200° \Rightarrow e^{0.25(3.49)} = 2.39 \Rightarrow P_1 = 2.39 P_2$ (1 mk)

for $160° \Rightarrow$ Torque $T_{160} = (P_1 - P_2)r = (2.10P_2 - P_2)r = 1.10 P_2 r$

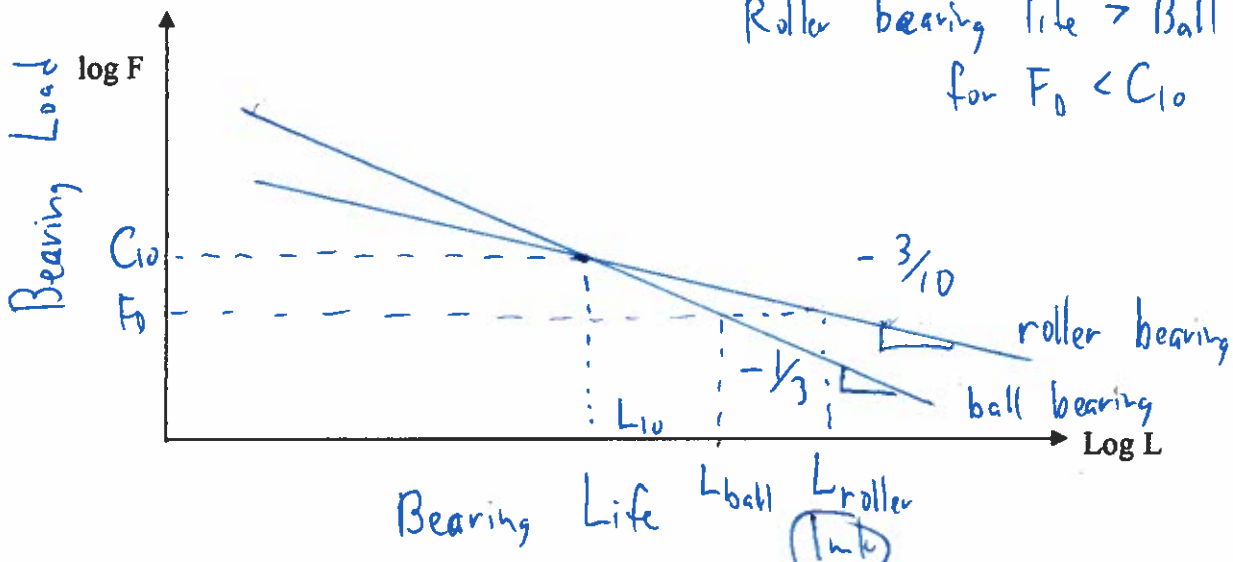
$200° \Rightarrow$ Torque $T_{200} = (P_1 - P_2)r = (2.39 P_2 - P_2)r = 1.39 P_2 r$

$\therefore$ increase in Torque $\Delta T = \frac{T_{200} - T_{160}}{T_{160}} = \frac{(1.39 - 1.10)P_2 r}{1.10 P_2 r} = \frac{0.29}{1.10} = 26.4\%$ increase (1 mk)

21. **Sketch the 90% reliability load-life curves for a ball bearing and a cylindrical roller bearing. The bearings share the same C_{10} and L_{10} values. LABEL BOTH AXES AND BOTH CURVES. (1 pts)**

Clearly indicate on the diagram which bearing lasts longer for a design load (F_D) less than C_{10} (1 pts)

Roller bearing life > Ball bearing for $F_D < C_{10}$



1 mk

1 mk

22. **a) Why is lubrication important in a chain drive train system? (1 mark)**
b) What is meant by "galling?" (1 mark)

a) Lubrication is important in chains in order to reduce friction and wear. Reduced wear means longer life (up to 300 times longer) and reduced friction can lead to higher loading and improved efficiency

b) Some metals (titanium, aluminium) will form a 'welded' bond when subject to contact under stress. These bonds will undergoe shear and fail causing metal erosion

1 mk

1 mk

MECH 325 - Midterm Book 2

Tuesday, October 24, 2017

Name: Solution

Student Number: _____

Circle your section

Section 101:	**T1A (2:00pm tutorial)**	**T1B (11:00am tutorial)**	**T1E (3:30pm tutorial)**
Section 102:	**T1C (2:00pm tutorial)**	**T1D (5:00pm tutorial)**	**T1F (3:30pm tutorial)**

Signature: _____

Q23 _____ / 6

Q24 _____ / 8

Q25 _____ / 8

Q26 _____ / 8

Total _____ / 30

Instructions

Please read carefully.

Part 2 – Open-Book (30 pts)

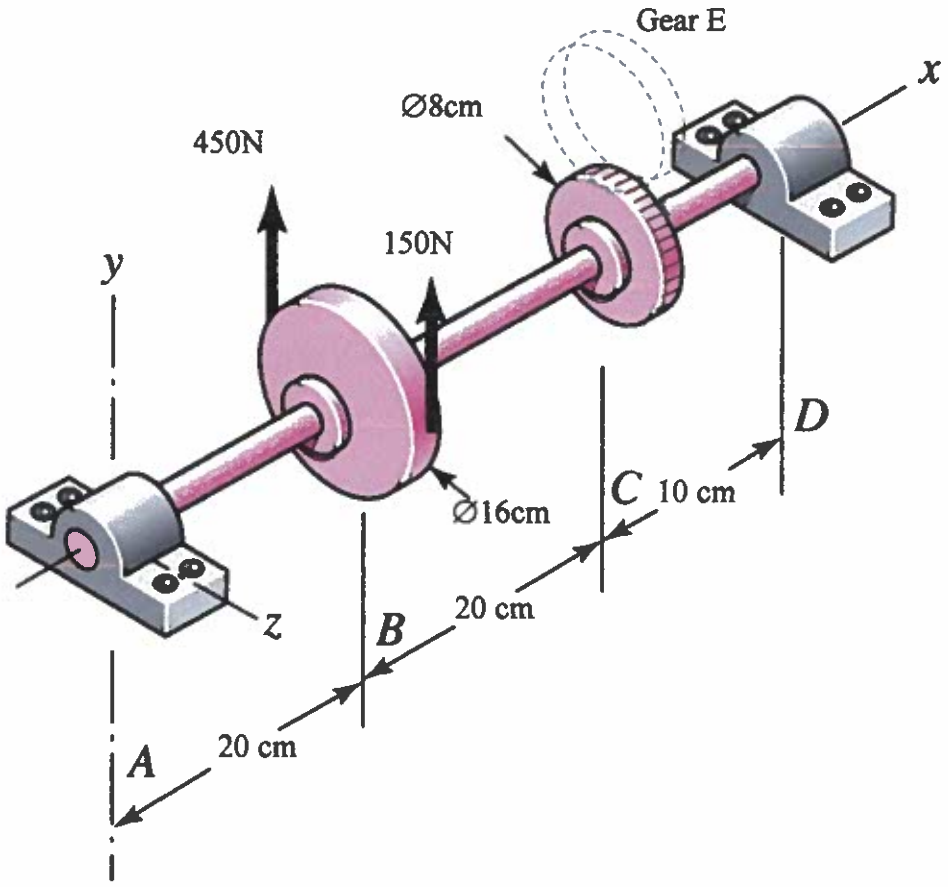
Long answer: Complete all parts to the question by marking your response in the booklet provided. This portion of the exam is open-book and open-notes. **At the end of the exam, return this handout with your answers in the booklet.**

This is a multi-part problem. For each part, use the parameter values given. **Do not carry your answers forward from one part to the next except for dimensions on the figure.** If you cannot complete one part, you may move on and still receive full marks for subsequent parts. **Do not try to back-calculate to previous parts, since the new parameters given are incorrect and contradictory on purpose.** Clearly indicate your final answer to each part by drawing a box around it. Separate different parts with a line drawn across the page.

Only non-programmable (or purged) calculators may be used.

Long Answer Problem (30 marks)

The mechanism below consists of a V-belt pulley (at B) that accepts input power from a motor, and a spur gear (at C) that delivers power to a second gear (Gear E) directly above. The motor connected to the pulley has a maximum output power of 1.8 kW.



23. Pulley B uses a V-belt (drive ratio 1:1, wrap angle 180°) to connect to the motor and has belt tensions as shown. Shaft AD turns at constant speed of 1200 rev/min. The hoop tension in the belt (due to centrifugal force) is 30 N. **Determine (a) the minimum required initial belt tension and (b) the usable power currently being delivered to Pulley B. (6 marks)**

Regardless of your answer in the question above, from this point onward, assume Pulley B receives 3.3 kW of power at 1200 rev/min from the motor.

24. Gear C is an Ø8 cm spur gear with 40 teeth, a module of 2 mm (i.e., diametrical pitch of P = 5 cm^{-1}), and a pressure angle of 20°. It meshes with Gear E, which has 20 teeth and is connected to the output load. **Determine (a) the rotation speed of Gear E, (b) the torque delivered by Gear C to Gear E, and (c) the total contact force magnitude, W, between gears C and E. (7 marks)**

25. The same size deep-groove ball bearing is to be used for both locations A and D. The radial reaction force at A (onto the shaft) is (-290**j** + 88**k**) N and the radial reaction at D (onto the shaft) is (-60**j** + 330**k**) N (Independent of any previous answers). You may assume there is no axial reaction at either bearing. **Select a single deep-groove ball bearing size that is suitable for both location A and location D.** Assume a reliability of 95%, an application factor of 1.6, and a minimum design life of 25,000 hrs. **(8 marks)**

Assume the following parameters for the bearings in Table 11-2:

$L_{10} = 10^6$ $x_0 = 0.02$ $\theta = 4.459$ $b = 1.483$

26. In a completely different application, a chain drive system is required to attach a motor with a rated power of 8hp (6.0 kW) to an industrial grinder. The following information relates to the chain drive:

Sprocket Size	19 teeth
Chain Drive Reduction Ratio	4:1 Reduction
Shock Load	Moderate
Environment	Clean
Operation	Less than 8 hours/day
Temperatures	Indoors
K_S	1.2
Speed	800 rpm

Using a safety factor of 1.5, select a number 40 chain drive appropriate for this application. How many strands are required? Will the safety factor change as a result of your answer? (9 marks).

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23. a) Minimum initial tension $F_i = \frac{F_1 + F_2}{2} - F_c$ (eqn 17.25) (1mk)

$= \frac{450 + 150}{2} - 30 = 270\ N$ (2mk)

b) Power = $H = T\omega$ Torque : $\Delta F \cdot$ radius (1mk)

$T = (450 - 150\ N)(0.08\ m) = 24.0\ N \cdot m$

$\omega = (1200\ rpm)\ 2\pi/60\ sec = 125.7\ rad/sec$ (1mk)

(6mk total)

Power = $T\omega$

$= (24.0\ N \cdot m)(125.7\ rad/sec)$ (1mk)

$H = 3,015.9\ Watts = 3.0\ kW$

24. a) Speed of gear C = speed of shaft = 1200 rpm

This gear set-up is an overdrive configuration

$n_c/n_F = e = 40/20 = 2.0$ (2mk)

(7mk total)

$\therefore$ speed of Gear E = $2.0(n_c) = 2(1200) =$ 2400 rpm

b) Power Gear E = Power Gear C (assume 100% efficiency)

$\therefore T_E \omega_e = T_c \omega_c \Rightarrow T_E \omega_E =$ 3300 W (2mk)

$T_E = 3300/2400(2\pi/60) =$ 13.1 N·m

c) $W_t = T_E/d_{E/2} = 13.1\ N \cdot m / .04/2 = 655\ N$

$d_e = (2\ mm.)(20\ teeth)$

$= 40\ mm. = .04\ m$ (1mk)

so $W = W_t/\cos\phi = 655/\cos 20°$

$W = 697\ N$ (2mk)

25. The total radial load is the vector resultant of the y and z loads

(page intentionally left blank)

$R_A = -290j + 88k$

$R_A = (290^2 + 88^2)^{1/2} = 303.1\ N$

$R_D = -60j + 330k$

$R_D = (-60^2 + 330^2)^{1/2} = 335.4\ N$

2 mks

8 mk total

Location D determines size

Reliability = 95% $a_f = 1.6$ $h = 25{,}000$ hrs

2 mks

so $X_D = L/L_{10} = \dfrac{(25{,}000\ hrs)(200\ rpm)(60\ min/hr)}{1 \times 10^6} = 1800$

$$C_{10} = a_f R_D \left[\frac{X_D}{X_0 + (\theta - X_0)\ln(1/R)^{1/b}} \right]^{1/a} \quad \text{eq'n } 11\text{-}9$$

$$= 1.6(335.4)\left[\frac{1800}{0.02 + 4.439\ln(1/0.95)^{1/1.483}} \right]^{1/3}$$

$= 7659N = 7.7kN$

3 mks

From Table 11-2 select 15mm bore bearings $C_{10} = 7.8kN$

15mm 02 Deep Groove Bearing

2 mks

26 The power that must be transmitted = H_d

$H_{nom} = H_{rated} = 8$ hp. (1 mk)

$H_d = H_{nom} K_s n_d$ (Eq. 17-38)

$H_d = (8)(1.5)(1.2)$

$H_d = 14.4$ hp. (2 mk)

(9 mk total)

The allowable power $= H_a$

$H_a = K_1 K_2 H_{tab}$ (Eq. 17-37)

Correction for teeth other than 17

Table 17-22

K_1 = Pre-extreme hp = 1.13 – link plate ^ fatigue failure

K_1 = Post-extreme hp = 1.18 – fatigue failure of roller

Let's assume fatigue dominates on the link plate

choose lower value of $K_1 = 1.13$ (2 mk)

Now $H_a > H_d$ so $K_1 K_2 H_{Tab} > H_d = 14.4$ hp

For $n = 800$ rpm ANSI 40 chain $H_{Tab\,(17\,teeth)} = 4.48$ hp (Table 17-20

for $n = 1$ $K_1 K_2 H_{tab} = (1.0)(1.13)4.48 = 5.06$ hp < 14.4 hp no

Use Table 17-23

$n = 3$ $K_1 K_2 H_{tab} = (2.5)(1.13)\,4.48 = 12.65 < 14.4$

$n = 4$ $K_1 K_2 H_{tab} = (3.3)(1.13)\,4.48 = 16.70 > 14.4$ yes

so select 4 strands of #40 chain (2 mk)

The safety factor for 4 chain is actually $16.70/(8\text{hp})\, n_{s.f}\,(1.2)$

$n_{s.f} = 1.74$

It is slightly higher than 1.5 (more conservative) (2 mk)