MECH 325 - Midterm Book 1

Tuesday, October 22, 2019

Name: Solution

Student Number: _____

Circle your section

Section 101: Tuesday 9:30 & Thursday 2:00

Section 102: Tuesday 11:00 & Thursday 3:30

Signature: _____

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 (1 marks per question). Complete all 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 6 questions by marking your response in this exam booklet.

After you have completed Part 1, hand in your booklet and Scantron scorecard and you may begin Part 2. 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 exam paper. This portion of the exam is open-book and open-notes.

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.

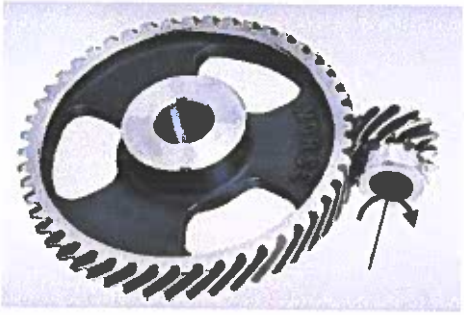
1. **What is the best description of the type of motion between the teeth of two properly meshed worm gears?**
   a) Purely rolling
   b) Some sliding when teeth engage and disengage, but predominantly rolling
   c) Approximately equal parts sliding and rolling
   d) Some rolling when teeth engage and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

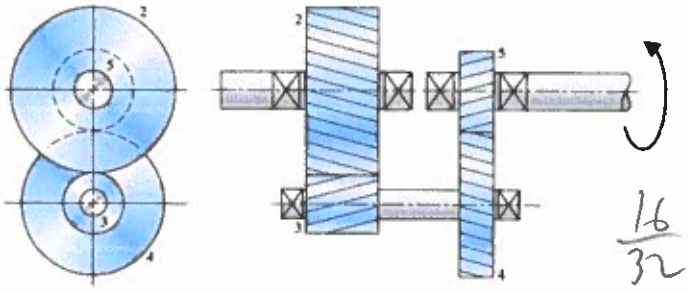
3. **Which of the following gears allows the shafts to be offset and non-intersecting?**
   a) Spur gear
   b) Worm gear
   c) Helical gear
   d) Bevel gear
   e) Hypoid gear

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. **For the crossed-helical gears shown, the pinion has 20 teeth and the gear has 80 teeth. If the pinion is turned at 1000 rpm in the direction shown, what will be the speed and direction of the gear?**
   a) 4000 rpm clockwise from above
   b) 250 rpm clockwise from above
   c) 250 rpm counter-clockwise from above
   d) 1000 rpm counter-clockwise from above
   e) 4000 rpm counter-clockwise from above



6. **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?**



$\frac{16}{32} \cdot \frac{14}{42}$

$2 \quad 3 = 6$

$1800/6 = 300$ rpm

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

7. **The motor attached to the gearset in Question 6 above is rated at 750 Watt. What is the torque on the output shaft?**

$P = T\omega$

$T = [750 / (1800/60 \times 2\pi)] \times 6$

a) 15 N-m
b) 23.9 N-m
c) 30 N-m
d) 45.6 N-m
e) 125 N-m

8. **A power screw engages with a nut with 20 threads. Approximately how much of the load is carried by the first 6 engaged threads, combined, in the power screw?**

a) 10%
b) 20%
c) 50%
d) 80%
e) 100%

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?**

$H_d = (0.75)(2.5)(1.5) = 2.8$

2 belts = 1.4

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

$F = 130 - 40 = 90\,N$
$d = 20\,cm \quad r = 10\,cm$
$T = F_r = 90(a1) = 9.0\,N\cdot m$

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 reasonable safety factor for specifying wire rope for a high speed passenger is:

a) 2
b) 2 to 2.5
c) 3 to 5
d) 9 to 11
e) 20 to 30

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
d) Bearing length, L
e) Wear factor, K

Bings

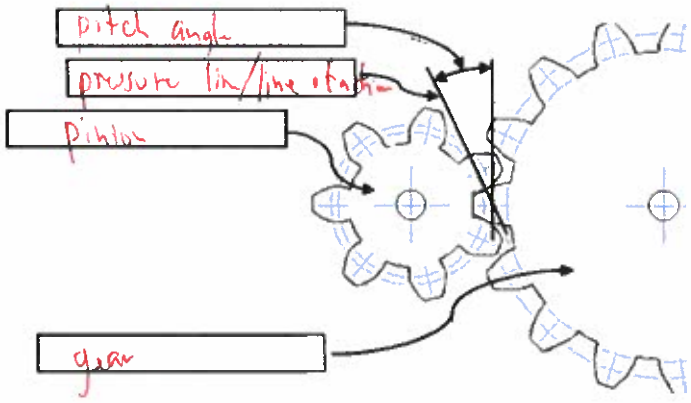
15. When specifying the working load of wire rope, which of the statements is FALSE:

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)?

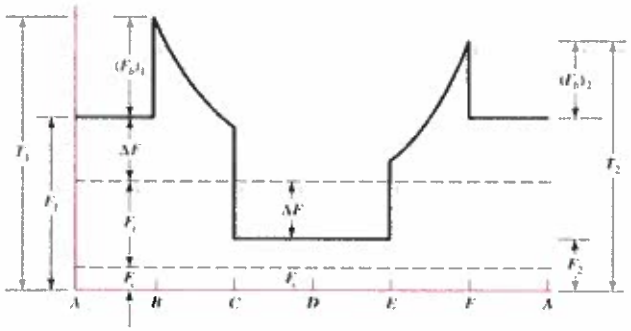
Yes, The pinion has less than 12 teeth, the accepted minimum number of teeth. Hence, one can expect the teeth will make contact outside of the tangent line connecting the two base circles

18. a) What is meant by "Service Factor?" (1 mark)
b) Why is it important?" (1 mark)

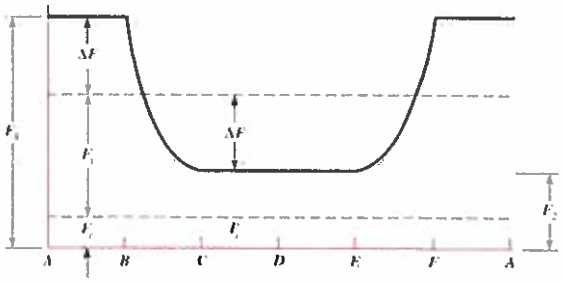
a) A service factor is an overload factor that increases the nominal or rated value of power being input into the drivetrain. It is normally a value greater than 1.0 averaging about 1.3 - 1.5

b) It is important since it allows for factors such as sudden shock and vibration to be included into the calculation of working loads and stresses

19. Answer the questions below based on the tension profiles shown for two different flexible drive types.



Profile A



Profile B

What type of flexible drive is shown in each profile (1 mark):

Profile A V belt

Profile B Flat belt

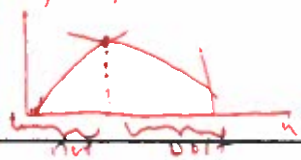
What is the reason for the difference between the two profiles (2 mark)?

Profile A includes the tension developed in the V-belt as it is forced into the sheave. The sheave angle is less than the angle of V-belt itself. Higher bending stresses result from this action.

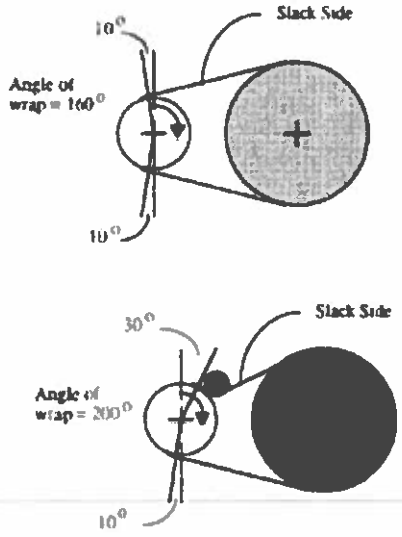
20. a) Why is lubrication important in a chain drive train system? (1 mark)
b) What is meant by "pre-extreme" and "post-extreme" (1 mark)

a) Lubrication is very important in chain drives as it reduces the coefficient of friction and hence the stresses on the components which in turn increases the life.

b) Pre-extreme relates to link plate failure while Post-extreme relates to roller fatigue failure. The extreme point highlights the highest power a chain can endure.



21. 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 (2 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.

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

b) If the friction coefficient is 0.20, estimate the % change in performance. Assume no changes to the driven pulley. (2 marks)

Given $f = 0.20$ Recall $P_1/P_2 = e^{f\phi}$ $160° = 2.79$ Rad

for $160° \Rightarrow e^{.20(2.79)} = 1.75$ so $P_1 = 1.75P_2$ $200° = 3.49$ Rad

for $200° \Rightarrow e^{.20(3.49)} = 2.01$ so $P_1 = 2.01P_2$

for $160° \Rightarrow$ Torque $T_{160} = (P_1 - P_2)r = (1.75P_2 - P_2)r = 0.75P_2r$

for $200° \Rightarrow$ Torque $T_{200} = (P_1 - P_2)r = (2.01P_2 - P_2)r = 1.01P_2r$

$\therefore$ increase in torque $\Delta T = \frac{T_{200} - T_{160}}{T_{160}} = \frac{(1.01 - 0.75)P_2r}{1.01P_2r}$

$= 0.26/1.01 = 25.7\%$ increase

MECH 325 - Midterm Book 2

Tuesday, October 22, 2019

Name: _____

Student Number: _____

Circle your lecture section

Section 101 -Tuesday 9:30 Thursday 2:00

Section 102 -Tuesday 11:00, Thursday 3:30

Signature: _____

Q23 _____ / 8

Q24 _____ / 10

Q25 _____ / 12

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 paper 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 exam.**

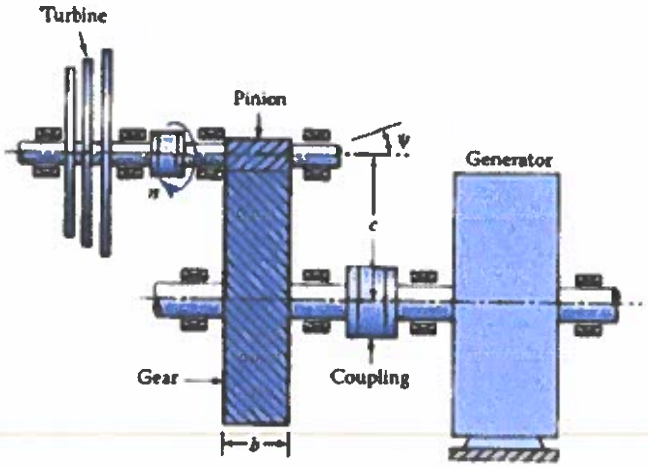
Long Answer Problems (30 marks)

22. A single square-thread power screw is to raise a load of **70 kN.** The power screw turns at a rate of **60 rpm**. The major diameter for the screw is **36mm**. and the pitch is **6mm**. The friction diameter of the thrust collar is **90 mm**. The frictional coefficients are **0.13** for the thread and **0.10** for the collar **(8 marks).**

a) Determine the torque and power required for the power screw.
b) Determine the combined efficiency of the screw and collar. Comment on the results.

23. A gas turbine rotating at **8000 rpm** drives an electrical generator at **1000 rpm**. The generator efficiency is **95%** and outputs a rated power of **250 W (335 HP).** A helical gearbox is required to provide the required gear reduction. The gearbox has the following parameters **(10 marks):**

Helix Angle $\psi = 30°$
Gear Width b = 8 inches
Normal Pressure Angle $\varphi_n = 20°$
Normal Pitch $P_n = 10$
Pinion Teeth = 35 teeth



a) Determine the number of teeth on the Gear, the diametrical pitch of the Gear, the pressure angle (transverse), and the center line distance.

b) Determine the transverse, radial, and axial forces generated by the gearset. What is the maximum normal force on the gear teeth?

24. A **Number 50** chain drive system is required to attach a gas motor (rated output power of **12hp (8.0 kW)**) to an industrial saw. The following information relates to the chain drive **(12 marks):**

Motor Sprocket Speed	800 rpm
Motor Sprocket Size	19 teeth
Chain Drive Reduction Ratio	4.5:1
Environment	Dirty
Operation	Less than 8 hours/day
Temperatures	Indoors
Center line Distance	40 inches (1 m.)
Design Factor	1.2
Minimum Safety Factor	1.4

a) Select a suitable sprocket for the saw (Number 50 Chain). What is the expected rpm for the saw? Is this reasonable?
b) Select a service factor. Justify your answer.
c) How many strands of chain are required? Will the safety factor change as a result of your answer?
d) Determine how many links of chain are required for this installation.

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22. Recall Power = Force × Velocity = Torque × Rotational speed

$FV = T\omega$ (1 mark)

Torque to raise the load

$$T = \frac{Fd_m}{2}\left(\frac{l + \pi\mu d_m}{\pi d_m - \mu l}\right) + \frac{F\mu_c d_c}{2}$$ (2 mk)

d_m = mean dia. = $d_{maj} - P/2 = 36 - 6/2 = 33$ mm

$l = p$ for single thread screw $l = 6$ mm. (1 mk)

$F = 70000$N $\mu = 0.13$ $\mu_c = 0.10$ $d_c = 90$mm

$$\therefore T = \frac{70000(33\times10^{-3})}{2}\left[\frac{(6\times10^{-3}) + \pi(0.13)(33\times10^{-3})}{\pi(33\times10^{-3}) - 0.13(6\times10^{-3})}\right] + \frac{70000(0.10)(90\times10^{-3})}{2}$$

$= 218 + 315$ N·m

$= 533.6$ N·m

$\omega = 60$rpm $= 1$rps $= 2\pi$/sec

Power $= T\cdot\omega = 533.6(2\pi) = 3352$ Watts (1 mk)

b) Efficiency $= \frac{Fl}{2\pi T} = \frac{\text{work done}}{\text{input work}}$ (1 mark)

$e = (70000)(6\times10^{-3})/2\pi(533.6$ N·m$)$

$e = 0.125$ (1 mark)

Comment: This efficiency is very low. One way to improve this value would be to optimize the lead and to reduce friction coefficients. Another option is to look at ways to reduce the collar diameter. (1 mk)

23, a) Given gear ratio 1:8

$N_p = 35 \quad \phi_n = 20° \quad P_n = 10 \quad b = 8'' \quad \psi = 30°$ (1 mk)

For helix gear we have

$$\phi_t = \tan^{-1}\left(\frac{\tan\phi_n}{\cos\psi}\right) = \tan^{-1}\left(\frac{\tan 20°}{\tan 30°}\right) = 22.8° = \phi_t$$ (2 mk)

$$P_t = P_n \cos\psi = 10 \cos 30° = 8.66$$

∴ pinion pitch diameter $= N/P_t = 35/8.66 = 4.04$ inches $= d_p$ (1 mk)

$$N_G = N_p\left(\frac{n_p}{n_g}\right) = 35\left(\frac{8000 \text{ rpm}}{1000 \text{ rpm}}\right) = 280 = N_G$$

so gear pitch diameter $d_g = N_G/P_t = 280/8.66 = 32.3 \text{ inches} = d_g$ (1 mk)

center line distance $c = \frac{1}{2}(d_p + d_g) = \frac{1}{2}(4.04 + 32.3) = 18.17 \text{ inches}$ (1 mk)

b) Since generator efficiency = 0.95 the power the gearbox must deliver is $335 \text{ HP}/0.95 = 353 \text{ HP}$ (1 mk)

transmitted force $W_t = \dfrac{33000 \text{ ft-lb/min (HP)}}{V_{\text{pitch line}}}$

V pitch line $= \pi dn/12 = \pi(4.04'')(8000 \text{ rpm})/12 = 8461 \text{ ft/min}$

$\therefore W_t = (33000)(35)/8461 = 1380 \text{ lbs} = W_t$ (1 mk)

Radial Force $W_r = W_t \tan\phi_t = 1380(\tan 22.8°) = 580 \text{ lbs} = W_r$ (1 mk)

Axial Force $W_a = W_t \tan\psi = 1380(\tan 30°) = 797 \text{ lbs} = W_a$ (1 mk)

Total Force = Normal Force $= W = W_t/\cos\phi_n \cos\psi$

$= 1380/\cos 20° \cos 30 = 1696 \text{ lbs} = W$ (1 mk)

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24. $H_{nom} = 12$ hp motor sprocket = 19 teeth

Chain reduction = 4.5:1 ∴ saw sprocket = 19(4.5) = 85.5 (1 mk)

For Number 50 chain Table 17-21 has 84 or 90 as options

Choose 84 teeth (1 mk)

∴ reduction = 84/19 = 4.42:1 close enough (1 mk)

(3 mk total)

∴ rpm of saw = 180.95 rpm ≈ 181 rpm seems reasonable

b) Service Factor K_s we have gas motor attached to a saw, we can expect at least a moderate shock load and light to medium shock for the motor (2 mk)

∴ $K_s \sim 1.5$ to 1.75 acceptable. Let's use 1.5

c) design factor $n_d = 1.2$ $n_{SF} = 1.4$ at least

$H_d = H_{nom} K_s n_d = 12(1.5)(1.2) = 21.6$ HP (1 mk)

(5 mk total)

Allowable Power $H_a = K_1 K_2 H_{tab}$

From Table 17-20 $H_{tab} = 8.71$ HP @ 800 rpm (1 mk)

K_1 = Pre-extreme = 1.13 & Post-extreme = 1.18 for 19 teeth

Use smaller value $K_1 = 1.13$ (link plate fatigue)

$K_2 = 1, 1.7, 2.5, 3.3$

(2 mk)

$n=1$ $K_1 K_2 H_{tab} = (1.0)(1.3)(8.71) = 11.32 < H_d$

$n=2$ $K_1 K_2 H_{tab} = 1.7(1.3)(8.71) = 19.25 < H_d$

$n=3$ $K_1 K_2 H_{tab} = 2.5(1.3)8.71 = 28.31 > H_d$ $n_{SF} = \frac{28.31}{21.6} = 1.3 < 1.4$

$n=4$ $K_1 K_2 H_{tab} = 3.3(1.3)\,8.71 = 37.37 > H_d$ $n_{SF} = \frac{37.37}{21.6} = 1.7 > 1.4$

c) cont. 4 strands gives safety factor of 1.7 which is greater than the 1.4 minimum. Hence we have increased our safety factor by approx 24%. (1 mk)

d) $\frac{L}{p} \approx \frac{2C}{p} + \frac{N_1 + N_2}{2} + \frac{(N_2 - N_1)^2}{4\pi^2 C/p}$

For #50 chain, pitch = $5/8'' = 0.625''$ (1 mk)

$\frac{L}{p} \approx \frac{2(40)}{0.625} + \frac{19+84}{2} + \frac{(84-19)^2}{4\pi^2 40/0.625}$ (2 mk total)

$\frac{L}{p} = 128 + 51.5 + 1.672$

$L = 0.625(181.172) = 113.23$

Since we have 19 teeth, we should use an even number of links so we will choose $L = 114$ links (1 mk)

As a double check (not asked for)

$C = \frac{P}{4}\left[-A + \left[A^2 - 8\left(\frac{N_2 - N_1}{2\pi}\right)^2\right]^{\frac{1}{2}}\right]$ $\quad A = \frac{N_1 + N_2}{2} - \frac{L}{p}$

$A = \frac{19+84}{2} - 114/0.625 = -130.9$

$= \frac{0.625}{4}\left[130.9 + \left(130.9^2 - 8\left(\frac{84-19}{2\pi}\right)^2\right)^{\frac{1}{2}}\right]$

$C = 40.84'' \doteq 40\frac{5}{8}'' \approx 40''$ so this is acceptable.