SAULT COLLEGE OF APPLIED ARTS & TECHNOLOGY

SAULT STE. MARIE, ONTARIO

COURSE OUTLINE

Course Title: MACHINE DESIGN

Code No.: MCH 306

Program: MECHANICAL TECHNOLOGY

Semester: SIX

Date: JUNE 1987

Author: COLIN RISING

New Revision:

APPROVED ///

Chairperson

&?~o$-/lr

Date

CALENDAR DESCRIPTION

MACHINE DESIGN — MCH 306

Course Name — Course Number

PHILOSOPHY/GOALS;

To have the student conversant with, able to solve fundamental problems o design with particular respect to: special structural members, gears, clutches, brakes, couplings, screws, fasteners, joints, flexible elements and springs.

METHOD OF ASSESSMENT (GRADING METHOD);

A
B
C
I

Grading will be on logical solutions, layout, sketches, diagrams and general tidiness of presentation.

TEXTBOOK(S);

Mechanical Engineering Design, Shigley (McGraw Hill)

REFERENCE TEXTS:

"Gear Handbook" - Dudley - McGraw Hill

"Design of Machine Elements" - Spotts - Prentice-Hall

"Design of Machine Elements" - Faires - McMillan

"Machine Design" - Myatt - McGraw Hill

TOPIC NO.	PERIODS	TOPIC INFORMATION	REFERENCE
1	20	Review of Deflection	Shigley 106-13
2	15	Screws, Fasteners, Joints	Shigley 291-35
3	25	Spur Gears	Shigley 458-52
4	10	Helical Gears	Gear Handbook 525-5
	10	Clutches, Brakes & Couplings	Shigley 490-51
	6	Flexible Mechanical Elements	Shigley 521-54
	4	Mechanical Springs	Shigley 284-30

During the sixth semester students are given practical problems which involv- some work at home in addition to time spent in problem sessions. These are submitted in the form of an engineering study.

MACHINE DESIGN

MTY-6

PART 1 - DEFLECTION OF BEAMS

GENERAL OBJECTIVE:

To have a sound understanding of several methods of calculating the deflecti in beams,

SPECIFIC OBJECTIVES:

1. To be able to list and use the following formulae:

   a) Radius of curvature 1. = M = d y

   3 EI dx

   b) Shearing force V = I = dM

   EI EI dx

   c) y = deflection

   dy

   dx slope

   d y = M moment

   dx EI

   d y = V shear

   dx EI

   d y = W loading

   dx EI

2. To be able to use the method of double integration.

3. To be able to use the method of double integration to solve for the deflection of an indeterminate beam,

4. To be able to use the method of double integration to solve for the deflection of an indeterminate beam.

5. To be able to use the area-moment method of find the deflection of a beam.

6. To be able to define energy load.

To be able to list and use the formulae:

a) $V = \frac{Fs}{2}$ strain energy

b) $S = \frac{Fl}{AE}$ deflection

c) $= \frac{F}{A}$ stress

d) $V = \frac{1A}{2E}$ strain energy

To be able to find the energy that each of two bolts can safely absorb gives bolt dimensions and maximum permitted stress and neglecting the effect of the threads.

To be able to define the following: a) shock loads, b) impact loads, c) transient force.

To be able to list a short-cut method for analyzing shock and impact.

To be able to list and use the following formula to determine impact and shock stresses.

a) $= \frac{W}{A} + \frac{W}{A} \; 1 + \frac{2hEA}{Wl}$

b) $= \frac{2W}{A}$

Given a steel bar of fixed length, having to withstand a tensile impact load caused by a fixed weight having a given velocity, the student will be able to find the stress in the bar with a given diameter and the diameter of the bar gives a maximum permissiable stress.

To be able to list and use the following formula for strain energy

a) V = T Al Torsion

46

b) V = F 1 Direct Shear

lAG

c) V = M dx Bending

2E1

14. To be able to find the strain energy in a cantilever beam with a concentrated load at the end.

15. To be able to state the theorem of Castigliano.

16. To be able to list and use the mathematical formula for theorem of Castigliano.

17. To be able to find the maximum deflection of a simply supported beam with a uniformly distributed load.

^P 18. To be able to find the horizontal deflection of a framework such as in fig. 3-15 in the text.

19. To be able to find the deflection due to direct shear on a cantilever beam of rectangular cross section.

20. To be able to list and use the formula for total deflection of a cantilever beam of rectangular cross-section.

21. To be able to find the vertical and horizontal deflection of a curved beam as in fig 3-17.

PART 2 - THE DESIGN OF SCREW FASTENERS

GENERAL OBJECTIVE:

To be able to design power screws, threaded fasteners and welded joints.

SPECIFIC OBJECTIVES;

1. To be able to list 6 methods of fastening joints.

2. To be able to read and use the tables for various thread forms.

3. To be able to define: a) Pitch b) lead c) helixangle.

4. To be able to state that square and acme threads are used on screws when power is transmitted, and each application is special.

5. To be able to define a power screw and list three applications.

6. To be able to use the formulas for finding torque.

   a) $T = \frac{Fdm}{2} \frac{1 + udm}{dm - ul}$ square threads RAISING

   b) $T = \frac{Fdm}{2} \frac{1 + u\,dm\,secx}{dm - ul\,secx}$ acme or unified threads - RAISING

   c) $T = \frac{Fdm}{2} \frac{1 - udm}{dm + ul}$ square threads LOWERING

7. To be able to use the formula for thread efficiency

   $e - \frac{To}{T}$ where $To = \frac{Fl}{2}$

To be able to use the formula for torque required to turn the collar.

To be able to find the torque required to rotate a screw against the load with the load, and overall efficiency of the screw and collar, given the type of threads, the axial load of the collar diameter and the appropriate coefficients of friction.

To be able to describe a ball-bearing screw and list an application.

To be able to list three major steps in the design procedure of a power screw.

To be able to use the following formulae:

a) Average thread shear stress

T = 2F

drh

b) Average thread shearing stress (NUT)

T = 2F

dh

c) Bearing Pressure between threads

G = 4 p

h (d - dr)

To be able to state the requirements of a joint to consider using preloaded bolts.

To be able to state the effect of preload on the joint.

To be able to define Stiffness Constant.

To be able to use the following formulae:

a) Deformation

S = Fl

AE

b) Stiffness Constant

K = F = AE

3 1

c) F = F + F Total load (F)

d) F = K Ft Bolt Load

D + Km

e) F = F + Fi = K Ft + Fi Resultant Load on bolt

K + Km

f) F = KmFt
——————————Resultant Load on members
Kb + Km

To be able to find the resultant tension in the bolt and compression o the members, given the relative stiffness between the member and bolt, initial preload, and the external tensile load.

To be able to list two main desirable effects of preloading of bolts.

To be able to state the effect of elasticity of total load on the bolt in a preloaded joint.

To be able to state how preloaded bolts effect shear loading on the joint.

To be able to list four methods of tightening the bolt to a certain preload.

To be able to use the following formula to determine torque required for a certain preload.

a) T = Fidm tan + u secx + Fuicdc

2 1 - u tan secx 2

b) T = dm tan = u secx + 0.625 Uc Fid

2 1 - u tan secx

c) T = dm tan = u secx + o.625 Uc

2d 1 - u tan secx

To be able to state for average and unlubricated bolts K is about 0.20.

To be able to state that the computed or correct tightening torque should be about 75% of the mean failure torque.

To be able to define a) Proof load b) Tensile stress area

To be able to state that for non gasketed joints the minimum preload on the bolt should be 90% of proof load.

To be able to state two implications of objective #26.

To be able to calculate the tightening torque for a given grade and size bolt, compute tensile and torsional stress and show on a Mohr's Circle Diagram the reduction in principal stress due to the disappearanc of the torsional stress.

To be able to state how a nut carries the load placed on it.

To be able to define "stripping strength".

To be able to state that three full threads are all that is required to develop full bolt strength.

To be able to use the following formulae for bolted tension joints with gaskets.

a) $F = CF + F_i$

b) $C = \dfrac{K_b}{K_b + K_m}$ Stiffness Co-efficient

c) no gasket C = 0
Most flexible gasket C 0.50

To be able to calculate stiffness co-efficient of a given assembly.

To be able to design the bolts to be used on a cover application with a gasketed joint.

To be able to use the following formula for bolted and riveted jointed loaded in shear

a) T = F/A Shear

b) = F/A Tensile Stress

c) = F/A Crushing Stress

To be able to state that stress-concentration effects are not considered in structural design because loads are static and material ductile.

To state that to avoid shearing or tearing of margin of joint, structural practice states that spacing of the rivet at least 1 1/2 diameters away from the margin.

To be able to design a bolted or riveted joint using the following conditions:

a) Direct Shear load (Primary load)

$$T = F/A$$

b) Moment load or secondary shear

c) Direct and Moment load added vectorially.

To be able to design the fitting and fasteners for the end of a given member to transfer the load into the member.

To be able to list the types and uses of keys and pins.

To be able to state the usual practice to choose a key whose size is one-fourth the shaft diameter and the length is adjusted according to hub length and strength required.

To be able to select the appropriate key for a gear keyed to a given shaft and required to transmit a given horsepower at a given R.P.M.

To be able to state applications of welded joints.

To be able to state criteria for welded construction over cast.

To be able to use the following formulae to design welded joints:

a) = F/hl	Normal Stress - Butt Joints
b) T = F/hl	Shear Stress - Butt joints
c) T = F/1.414hl	Shear Stress - Fillet welds
d) i) IT = F/1.414hl	Primary Stress - Fillet weld
ii) T" = Mr/J	Secondary Stress - Fillet welds

where J = Jo + Ar = Al + Ar = A 12 + ro

12 12

46. To be able to read and select correct welding rods from tables of properties for the electrodes.

47. To be able to state that in practice the tensile strength of the rod is matched with that of the material.

48. To be able to check the design of a lap joint using fillet welds in different configurations.

49. To be able to design fillet welded and butt welded joints.

PART 3 SPUR GEARS

GENERAL OBJECTIVES;

To be able to design or check the design of spur gears.

SPECIFIC OBJECTIVES:

1. To be able to define spur gear.

2. To be able to state why a spur gear would be used, i.e., advantages.

3. To be able to define the following: picth circle; addendum circle; addendum; dedendum circle (Root circle); dedendum; working depth; clearance; thickness of tooth; width of space; Backlash; face of the tooth; face width; flank; top land; bottom land; pinion; angle of action; angle of approach; angle of recess; velocity ration; pitch; circular pitch.

4. To be able to use the following formulae:

    a) Velocity Ratio = N = D = N

       N D N

    b) Pitch Line Velocity V = r w = r w

    c) Pitch P = N/D

    d) Circular Pitch P = D/N

5. To be able to list three methods of manufacturing spur gears.

6. To be able to define "tooth system",

7. To be able to read and use the table of proportions for spur gears - standard AGMA and ASA tooth systems.

8. To be able to state that gears cut on long and short addendum system will not be interchangeable on standard center disturbances.

To be able to list two obsolete tooth systems.

To be able to draw free body diagrams of gears in a train showing the forces transmitted in their correct location.

To be able to use the following formulae for transmitted forces:

a) $T = R W$ Torque

b) $V = \frac{D N}{12}$ Pitch Line Velocity

c) $H.P. = \frac{W V}{33,000}$

d) $W = W \tan$ Radial load (force)

e) $W = W \cos$ Transmitted load (force)

To be able to, given sufficient data on a gear train, find the speed of each shaft, find the pitch line velocity, calculate the tangential tooth load at the pitch point, determine the resultant reaction at each shaft and its direction, and find the torque transmitted by each shaft.

To be able to list five limiting design factors in specifying the capacity of any gear train.

To be able to define a) Transmitted load and b) Dynamic load.

To be able to list four equations which try and account for increase in dynamic load*

To be able to state four preliminary design decisions.

To be able to use the formula for basic tooth stresses

a) $= \frac{W}{Fpy}$ b) $= \frac{W p}{Fy}$

To be able to list three or four assumptions that are made using equati in objective #17.

To be able to list the two broad categories of tooth failure that the AGMA uses.

To be able to use the AGMA bending stress formula

$$= \frac{W\ ko}{KV} \frac{P}{F} \frac{KsKm}{J}$$

21. To be able to use the AGMA bending strength of gear teeth formula.

22. To be able to use the fundamental Buckingham Equation.

23. To be able to design or check the design of gear teeth using Buckingham's equation.

24. To be able to use the approximate Buckingham equation.

25. To be able to define wear, pitting, scoring and abrasion.

26. To be able to use the basic A.G.M.A. equation for surface contact stress.

27. To be able to use the AGMA equation for surface durability.

28. To be able to use the AGMA equation for surface strength.

PART 4 - HELICAL GEARS

GENERAL OBJECTIVES:

To be able to design or check the design of helical gears.

SPECIFIC OBJECTIVES:

1. To be able to state why helical gears would be used.

2. To be able to state that parallel helical gears have the same helix angle, but one gear must have a right hand helix and the other a left hand helix.

3. To be able to state that initial contact of helical gear teeth is a point which changes into a line.

4. To be able to state that helical gears subject bearings to radial and thrust loads,

5. To be able to define: helix angle, transverse circular pitch, normal circular pitch, axial pitch and normal diameter pitch.

6. To be able to use the following formulae:

   a) Pn = cos — Transverse Circular pitch

   b) Px = P/tan — Axial Pitch

   c) Pn = P/cos — Normal Pitch

   d) Cos = tan n / tan t

7. To be able to define VIRTUAL NUMBER OF TEETH and be able to use the formula:

8. To be able to use the formula for:

   a) W = W tan   Thrust component

   b) W = W /cos t

9. To be able to find the radial and thrust forces acting on the shafts of a gear train given sufficient information.

10. To be able to use tables to obtain the correct tooth proportions for helical gears,

11. To be able to use the A.G.M.A. bending stress formula for helical gears,

12. To be able to use the A.G.M.A. bending strength formula.

13. To be able to use Buckingham's equation for Helical gears.

14. To be able to use the formula for surface durability of helical gears.

15. To be able to describe crossed helical gears and state two applications of them.

16. To be able to find the pitch diameter of crossed helical gears using: D = N/Pncos

17. To be able to use hand book tables to design the correct tooth proportions for crossed helical gears.

PART 5 - CLUTCHES, BRAKES AND COUPLINGS

GENERAL OBJECTIVES;

To be able to design, or check existing designs of clutches, brakes and couplings.

SPECIFIC OBJECTIVES;

1. To be able to state that clutches, couplings and brakes are devices used to control the flow of mechanical power.

2. To be able to state that a designer may:

   a) design a clutch or brake as a part of a machine
   b) specify a commercial unit

To be able to state the five basic characteristics of positive-contact clutches.

To be able to design a positive-contact clutch.

To be able to list the three elements of an expanding rim clutch.

To be able to list four main considerations in dealing with friction, clutches and brakes.

To be able to list five types of clutches and brakes.

To be able to list the three basic considerations in the analysis of friction clutches.

To be able to analyse the forces acting on a simple hinged shoe type brake or clutch.

To be able to list the requirement to make the brake in #9/ self locking.

To be able to analyse the forces acting on an internal expanding clutch (brake).

To be able to design an internal expanding clutch (brake).

To be able to list four assumptions made in the design of internal expanding elements.

To be able to analyse the forces acting on an external expanding brake (clutch).

To be able to design an external expanding clutch (brake).

To be able to analyse the forces acting on a band-type clutch and brake.

To be able to design a band-type clutch and brake.

To be able to state that frictional-contact axial clutch can be designe on uniform wear or uniform pressure theory.

To be able to design a frictional contact axial clutch using the unifor pressure theory.

To be able to design a frictional contact axial clutch using the unifor wear theory.

To be able to list five characteristics required for friction materials

To be able to describe the operation of a core clutch (brake).

23. To be able to design a core clutch using either the uniform wear or uniform pressure theory.

24. To be able to solve for the energy a brake or clutch must withstand usir the following formulae:

a) T = Jx

b) t = 2 nJ

5T

c) E = 2 Tnt

1,440

d) E = n J

1,800

e) H = E /778

25. To be able to solve for the K.E. of a flywheel and the braking torque necessary to bring it to a stop in a specified time given the size and R.P.M. of a flywheel.

26. To be able to list and describe the opertion of the following devices:

a) Overrunning
b) Eddy-current couplings
c) Magnetic field clutches
d) Hydraulic coupling

27. To be able to use catalogues of commerical units to select a unit for a given set of conditions.

28. To be able to list three decisions to be made in the design of a clutch or brake.

PART 6 - FLEXIBLE MECHANICAL ELEMENTS

GENERAL OBJECTIVE:

To be able to design or check the design of flat belt and V-belt drives.

SPECIFIC OBJECTIVES:

1. To be able to define a "flat belt".

^P 2. To be able to list five advantages of a flat belt drive.

To be able to use the general belt formula for designing flat belts.

a) $\frac{F - F}{F - F} = efo$

b) $F - F = \left(bt - \frac{12Pns}{32.2}\right) \frac{efo - 1}{efo}$

To be able to use the following formulae:

a) $H.P. = \frac{(F - F)\ Ns}{550}$

b) $F = T + Fc$ Total Force in Belts

$F = T + Fc$

c) $T = F - Fc$ Forces Pulling on Pulley

$T = F - Fc$

d) $T + T = F + F - 2Fc$ Pull on Shaft

To be able to use the following formulae:

a) $\text{MAXIMUM STRESS} = \frac{F2}{bt}$

b) EFFICIENCY OF JOINT = Strength of Joint/Strength of Belt

c) Design Stress = (400) (Efficiency of Joint)

To be able to define slip and creep.

To be able to calculate the angle of contact and the length of belts for open and closed belts.

To be able to use text and catalogue tables to determine the rated capacity of flat belts.

To be able to determine the size of flat belt required for any type flat belt drive, given adequate information.

To be able to draw a sketch and label the parts in the X-section of U-belt.

To be able to list six factors which affect the power-transmitting capacity and life of U-belt drives.

To be able to use textbook and catalogue charts to find the rated horsepower of U-belts in order to design a U-belt drive.

13. To be able to find the length of belt and the centre distance in a V-belt drive.

14. To be able to list four advantages of U-belt drive.

PART 7 - SPRINGS

GENERAL OBJECTIVES:

To be able to design helical and flat springs.

SPECIFIC OBJECTIVES:

1. To be able to list four main uses of springs.

2. To be able to use WAHL's formula for stress in a helical spring.

$$T = Ka \frac{8FDm}{D}$$

3. To be able to find the deflection in a round wire helical spring using the formula:

$$= \frac{8Fc\ Nc}{G\ Dw}$$

4. To be able to find the scale of a spring.

5. To be able to list the three significant dimensions of a helical spring

6. To be able to calculate the solid height of a helical spring.

7. To be able to design helical springs for any application given sufficie information,

8. To be able to select suitable material for a spring.

9. To be able to calculate the energy absorbed by a spring.

10. To be able to design a helical spring so that "surge" does not occur.

11. To be able to design helical springs taking buckling of compression into account.

12. To be able to design concentric helical springs.

13. To be able to design tension helical springs.

14. To be able to design helical springs with rectangular wire.

15. To be able to design torsion springs.

16. To be able to design helical springs accounting for variable stresses
17. To be able to design Flat Springs.
18. To be able to design leaf springs.