Indian Institute of Engineering Science & Technology, Shibpur

B.E. (Mechanical) Part III 6th Semester Final Examination, 2014

Design of Machine Elements – II (ME – 601)

Time : 3 hours **Full Marks: 70**

Use separate answer scripts for each half.
Answer any **SIX** questions, taking **THREE** from each half.
The questions are of equal value.
Assume any other data that may be necessary.

FIRST HALF

1. (a) Deduce an expression based on the uniform wear theory, for the axial force and torque transmitting capacity of a frictional clutch having a single pair of contact surface in terms of the maximum intensity of pressure and geometrical parameters of the disc clutch.
   (b) A multiple disc clutch has 5 steel and 4 bronze plates. The clutch is required to transmit 8 kW at 900 rpm. The ratio of inner to outer diameters is 0.7. The coefficient of friction is 0.3. The permissible normal pressure is 0.35 MPa. Find the inside and outside diameters and also the axial force required.

2. (a) Two co-axial machine rotors having the moments of inertia, I_1 and I_2 and operating at uniform speeds, ω_1 and ω_2 respectively are engaged by a frictional disc clutch. If the clutch torque remains constant, show that the total energy lost in the clutch during slipping is given by

$$\frac{1}{2}\cdot\frac{I_1 I_2}{I_1 + I_2}\cdot(\omega_1 - \omega_2)^2$$

   (b) Two flywheels A and B are mounted on two shafts in line which can be coupled together by a frictional clutch during the engagement of which the frictional moment or clutch torque remains constant at a value of 18 N-m. The moments of inertia of the flywheels A = 1.6 kg – m^2 and B = 2.8 kg – m^2 and initially A revolves freely at 800 rpm while B is at rest. The clutch is then engaged and slipping ceases after a certain period of time. Find –
      (i) the time required for entire clutching operation
      (ii) final speed of revolution of the drive
      (iii) total energy lost in the clutch during slipping

3.(a) Derive the expression for the pitch cone distance in terms of the pitch circle diameter of bevel pinion and gear.
   (b) A pair of straight bevel gears is mounted on the shafts which are intersecting at right angles. The number of teeth on the bevel pinion is 24. Teeth are 14.5° full

depth involute type. The pinion shaft is connected to an electric motor developing 13.5 kW at 600 rpm. The drive has a speed ratio of 4:3. The service factor can be taken as 0.8. The pinion and gear are made of cast steel for which the allowable static working stress, σ_w is 150 MPa and are heat treated to a surface hardness of 360 BHN. In the initial stage of gear design, assume that the pitch line velocity; v is approximately 8 m / s.
Determine the module at the larger diameter and face width only. Checking of design against the dynamic and wear loads is not needed.
Assume the following data:
Young's modulus for cast steel = 210 GPa

Velocity factor (C_v) $= \dfrac{6}{6+v}$, v is in m / s.

Lewis form factor (Y) $= \pi\left(0.124 - \dfrac{0.684}{z}\right)$, z = no of teeth

(c) Assume that the sense of rotation of bevel pinion is anticlockwise when viewed in front of the apex of the pitch cone. Determine the followings: -
 (i) the radial and axial forces on the shaft mounting the bevel gear
 (ii) the resultant tooth load on gear or pinion
Draw a neat sketch of the forces acting on the tooth of bevel gear only.

4. (a) What is bevel factor? Mention several steel category materials of bevel gears.
(b) In a hoisting machine, a pair of straight tooth bevel gears has shafts intersecting at right angles and a rotational speed ratio of driver to driven shaft of 3:2. The pinion which transmits power of 9 kW at 1200 rpm has no. of teeth of 28. The teeth of gears are 14.5° full depth involute, cut by the generating process. Estimate module, face width and pitch circle diameters of gears. Check the design against dynamic and wear loads only.
In the initial stage of design, assume that the pitch line velocity, v is approximately 12 m / s.
Assume the following data:

	Pinion	Gear
Material:	Forged steel	Bronze
Permissible working stress (σ_w)	180 MPa	85 MPa
B.H.N. value	380	330
Young's modulus (E)	210 GPa	100 GPa

Service factor (C_s) of the drive = 0.75

Deformation factor (λ) for teeth = 120 kN / m

Speed factor, $C_V = \dfrac{5.6}{5.6+\sqrt{V}}$, surface endurance limit, $\sigma_{ens} = 2.8 \times (BHN) - 70$ MPa

Load – stress factor, $K_w = \dfrac{\sigma_{ens}^2 \sin\phi . \cos\phi}{1.4}\left[\dfrac{1}{E_p} + \dfrac{1}{E_g}\right]$

Lewis form factor, $Y = \pi\left(0.124 - \dfrac{0.684}{Z}\right)$, Z = no. of teeth

5.(a) With a neat sketch, define the followings of a bevel gear.

(i) pitch cone (ii) pitch cone centre (iii) pitch cone distance (iv) back cone

(b) Explain the concept of formatic spur gear related to bevel gear.

(c) Mention only the main factors to be considered in selecting a type of clutch.

(d) Discuss briefly the advantages of disc clutches in applications.

SECOND HALF

Answer any TWO from Q. No. 6, 7, 8 and any ONE from Q. No. 9, 10

Note: *In case you make any assumption, state it clearly. Assume and state any unstated data that may be required to solve problems. Use the following in appropriate form, as and when necessary. Symbols have usual meaning.*

Lewis form factor: $Y = \pi\left(0.154 - \dfrac{0.912}{T}\right)$ Dynamic Load: $F_d = F_t + \dfrac{21V\left(\lambda b\cos^2\psi + F_t\right)\cos\psi}{21V + \sqrt{\lambda b\cos^2\psi + F_t}}$;

where V is in m/s and $\lambda = \dfrac{0.111e}{\dfrac{1}{E_p} + \dfrac{1}{E_g}}$; Load stress factor $k_s = \dfrac{\sigma_{ens}^2}{1.4}\sin\phi_n\left(\dfrac{1}{E_p} + \dfrac{1}{E_g}\right)$; where

$\sigma_{ens} = \{2.75(BHN) - 70\}$ in MPa

6a) A semi-elliptic leaf spring is nipped in such a way that the final stress (after loading) in the full length leaves is 10% higher than the graduated length leaves for same deflection. Show that the final bending stress in the full length leaves may be expressed as $\dfrac{66Fl}{(11n_f + 10n_g)bt^2}$, the central external load and effective length of the spring being 2F and 2ℓ respectively. Symbols n_f, n_g, b, t have usual meaning.

b) A locomotive semi-elliptical laminated spring has an overall length of 1 m and sustains a load of 70 kN at the centre. The spring has three full length leaves and 15 graduated length leaves with a central band of 100 mm width. All the leaves are equally stressed to 400 MPa when fully loaded. The ratio of the total spring depth to that of the width is 2. Determine: (i) thickness and width of the leaves, (ii) load in the u-bolts after the spring is assembled, and (iii) deflection of the spring. No derivation is necessary. [7+5=12]

7a) Compare between optimum design process and conventional design process.

b) State and discuss necessary and sufficient conditions for the minimum of a multivariable function f(X).

c) A log of length L is in the form of frustum of a cone whose ends have radii a and b (a>b). It is required to cut from it a beam of uniform square section with the maximum volume. Identify design variables, formulate the optimization problem in standard form and solve it by the Lagrange Multiplier method to prove that the beam has a length of $\dfrac{aL}{3(a-b)}$. [3+3+6=12]

8a) What is the formative number of teeth of a helical gear? Show that the formative number of teeth of a helical gear is $T/\cos^3\psi$ when T is the actual number of teeth and ψ is the helix angle.

b) With reasons, establish a relation between face width and normal module of a helical gear.

c) A pair of single helical gears is required to give a speed reduction of 4.2:1. The gears are to have a normal module of 3 mm, a normal pressure angle of 20° and a helix angle of 30°. If the shaft centre-lines are to be approximately 400 mm apart, determine the number of teeth on each wheel and the exact centre distance. The pinion is supported midway between its bearings. 75 kW is transmitted at a pinion speed of 1000 rpm. Find the end thrust on the pinion shaft and the transverse load on each of its bearings. Assume that the end thrust is carried by a separate thrust bearing and neglect the eccentric effect of the axial thrust. [(1+3)+3+5=12]

9) Design the module, face width, pitch circle diameters and centre distance of a pair of 20° full depth external straight tooth spur gear to transmit 50 kW from a pinion running at 750 rpm to a gear running at 150 rpm. Go for a compact design and check your design both against dynamic and wear load. In case of failure in any checking, do not repeat calculations but suggest possible remedies to overcome such failure. Forged C30 steel with UTS of 500 MPa and CI (grade 35) with UTS of 350 MPa may be used as pinion and gear material respectively. Load is steady with no shock and the service condition is normal. Factor of safety may be taken as 1.5.

The gears are cut with class 2 accuracy with the tooth action error as 0.03mm. Surfaces are so heat treated so that the gears have an average BHN of 250. Take E_p = 210 GPa and E_g = 105 GPa. Standard modules (first choice) in mm are: 1, 1,125, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 16, 20. Velocity factor may be taken as $\frac{3}{3+V}$; V being the pitch line velocity in m/s. [11]

10) Two helical gears are used in a speed reducer that is to be driven by an internal combustion engine. Power transmitted is 75 kW at a pinion speed of 1200 rev/min. The speed ratio is 3:1. Determine the normal module, face width, number of teeth in each gear for a compact design based on strength. The pinion is made of C-30 forged steel with UTS of 550 MPa while the gear is made of cast steel with UTS of 420 MPa. Young's modulus for both the material may be taken as 210 GPa. The design is to be checked against dynamic load and wear load with the permissible tooth action error as 0.02 mm. Take $C_v = \frac{15}{15+V}$, V is the pitch line velocity in m/s. Service factor may be taken as 1.0. Normal pressure angle of the teeth is 20°. If you assume any relation in doing the design, state it clearly. Surfaces are so heat treated so that the gears have an average BHN of 300. [11]