B.E. (Mech.) Part- III 6th Semester Final Examination, 2013
Design of Machine Elements – II (ME-601)

Time: 3 hours | Full Marks: 70

Use separate answerscript for each half.
Answer SIX questions, taking THREE from each half.
The questions are of equal value.

FIRST HALF

1. (a) Two co-axial machine rotors having moments of inertia, I_1 and I_2 and running at uniform speeds, ω_1 and ω_2 respectively are engaged by a frictional clutch. If the clutch torque remains constant, find-
   (i) time required for entire clutch engagement
   (ii) energy lost in clutch during slipping

   (b) Two flywheels A and B are mounted on two shafts in line which can be coupled together by a frictional clutch. The moments of inertia of the flywheels, A = 1.5 kg – m^2 and B = 2.5 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 4 seconds. If the clutch torque remains constant during the engagement, find (i) clutch torque (ii)final speed of revolution (iii) energy dissipation during slipping

2. (a) Deduce an expression based on 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 7 steel and 6 bronze plates. The clutch is required to transmit 6 KW at 850 rpm. The ratio of inner to outer diameters is 0.7. The coefficient of friction for frictional materials is 0.25. The permissible normal pressure is 0.3 MPa. Find the inside and outside diameters and also the axial force required.

3. (a) With a neat sketch, define the followings:
   (i) pitch cone (ii) pitch cone centre (iii) pitch cone distance (iv) back cone

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

   (c) A pair of straight bevel gears is mounted on shafts which are intersecting at right angles. The number of teeth on the bevel pinion is 24 and teeth are 20^0 full depth involute type. The pinion shaft is connected to an electric motor developing 15 kW at 800 rpm. The drive has a speed ratio of 4: 3. The module at the larger end of teeth is 4 mm and the face width is 26 mm. Determine the radial and axial forces on the shaft mounting the bevel gear. What is the resultant tooth load?

Assume that the pinion is rotating in the clockwise direction when viewed in the front of its pitch cone.

4. (a) Derive the expression for the pitch cone distance in terms of pitch circle diameters of bevel pinion and gear.

(b) In a hoisting machine, a pair of straight tooth bevel gears have shafts intersecting at right angles and a rotational speed ratio of driver to driven shaft of 4 : 3. The pinion which transmits power of 13.5 kW at 600 rpm has a number of teeth of 24. The teeth of pinion and gear are 14.5^0 full depth involute, cut by the generating process which has achieved the tooth accuracy of grade six. Both pinion and gear are made of forged steel for which the allowable static stress, σ_w is 240 MPa and are heat treated to a surface hardness of 395 BHN. The service factor can be taken as 0.85.

In the initial stage of design, assume that the pitch line velocity, V is approximately 5 m / sec. Determine the module (m), face width (b), pitch cone distance (l) and pitch circle diameters of pinion and gear(d_p and d_g). Check the design against the dynamic and wear loads.

Assume the following data:

Deformation factor (λ) for grade six accurate teeth = 125 kN / m

Young's modulus for forged steel material = 210 GPa

Velocity factor, $C_v = \dfrac{5.6}{5.6+\sqrt{V}}$

Lewis form factor, $Y = \pi\left(0.124 - \dfrac{0.684}{Z_f}\right)$

Z_f = formative number of teeth

Surface endurance strength for steel category, $\sigma_{ens} = 2.8\times(\text{BHN}) - 70$ MPa

Load – stress factor, K_w for the combination of pinion and gear materials:

$$K_w = \frac{\sigma_{ens}^{\ 2}\sin\phi.\cos\phi}{1.40}\left(\frac{1}{E_p}+\frac{1}{E_g}\right)$$

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

(b) Explain uniform wear theory applicable to frictional clutches and its applications.

(c) Discuss the advantages of disc clutches in applications.

(d) Prove that the no. of pairs of identical frictional surfaces in a multiple disc clutch is even number.

SECOND HALF

ɔ) Design an external spur gear drive (i.e., estimate module, face width and centre distance) from the consideration of strength to transmit 65 kW at 800 RPM to a shaft running at 200 RPM. The gears have 20° full depth involute teeth. The pinion is to have 20 teeth and is made of heat treated cast steel having E = 210 GPa and σ_{en} (bulk endurance strength) = 300 MPa. The corresponding values for the gear material are E = 105 GPa and σ_{en} = 200 MPa. Check the design against dynamic load and wear. Relevant information is as below.

Lewis form factor: $Y = \pi\left(0.154 - \frac{0.912}{T}\right)$. Velocity factor: {6/(6+V)}; where the pitch line velocity V is in m/s. Dynamic load = $F_t + F_i$; where $F_i = \frac{21V(\lambda b + F_t)}{21V + \sqrt{\lambda b + F_t}}$; V is in m/s.

$\lambda = \frac{0.111e}{\frac{1}{E_p} + \frac{1}{E_g}}$ and the tooth action error(e)for the gears is estimated as 0.0222 mm.

The surface endurance strength of the pinion material is 800 MPa. Service factor and factor of safety may be taken as 1 and 1.5 respectively. If you assume any other data, mention clearly. Symbols have their usual meaning. In case of failure against checking, state remedial measures but do not repeat calculations.

7a) A pair of spur gears having 30 and 40 teeth are in mesh externally. The teeth have 20° full depth involute form. Module is 5mm. If the smaller wheel is the driver and rotates at 1200 rpm, find (i) the contact ratio, (ii) velocities of sliding at the points of engagement and disengagement.

b) What is the pitting failure in a gear drive? Explain the reasons behind pitting.

8a) For a helical gear deduce the relationship between (i) normal module and transverse module, (ii) normal pressure angle and transverse pressure angle and (iii) Formative number of teeth and actual number of teeth. Draw neat sketches wherever necessary.

b) A pair of parallel helical gears transmit 5kW at 720 rpm of the pinion. The normal module and normal pressure angle are 5mm and 20° respectively. If the helix angle is 23° and the pinion has 20 teeth, calculate the magnitude of the components of forces acting on the pinion.

9) Two helical gears are used to transmit 75kW at a pinion speed of 1200 rpm. The speed ratio is 3:1. The teeth are 20° full depth in the normal plane and the helix angle is 25°. The material of the pinion is C30 forged steel with an allowable stress of 200 MPa and the gear is made of cast steel with an allowable stress of 150 MPa. Tooth action error is 0.02mm and the average BHN may be taken as 170. For a compact design, find out the normal module, face width and the number of teeth in each gear. Take $E_p = E_g = 207$

GPa. Check your design against dynamic load and wear. Assume any other data that may be necessary, but state them clearly. Normal module may be selected from the following first preference values:
1.0, 1.125, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0 (in mm).

10a) Find the point (values of x_1, x_2) that makes the function $f(x_1, x_2) = 3x_1^2 - 2x_1x_2 + 5x_2^2 + 8x_2$ stationary. Now show that this point actually minimizes the function.

b) A straight beam of circular cross section has to be cut from a right circular conical log of height h and base radius r. Find the radius and height of the cylindrical beam so that its volume is maximum. Formulate this optimization problem, express it in standard form and solve by the Lagrange multiplier method.