

**BITS PILANI, DUBAI CAMPUS
DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI
FIRST SEMESTER 2011-2012**

COMPREHENSIVE EXAMINATION

ME C451 MECHANICAL EQUIPMENT DESIGN

Date: 12-01-2012

Time: 3 hrs.

Marks: 40

Weightage: 40%

Note: 1. Answer all questions.

2. Marks are shown in the brackets against each question.

3. Use the data sheet enclosed to the question paper.

4. Assume missing data if any logically.

5. THIS QUESTION PAPER CONTAINS 4 PAGES.

Question 1

A pair of straight teeth spur gears having 20° involute full depth is to transmit 12 kW at 300 rpm of the pinion. The speed ratio is 3:1. The allowable static stresses for gear of cast iron and pinion of steel are 60 MPa and 105 MPa respectively. Number of teeth on pinion is 16 and face width is 14 times the module. The tooth form factor y is given by $y = 0.154 - 0.912/(\text{No. of teeth})$ and the velocity of factor C_v as $C_v = 4.5/(4.5 + v)$, where v is in m/s. Determine the module, face width and pitch diameter for gears. Check the gears for wear if endurance strength for cast iron and steel are 600 MPa and 350 MPa respectively, moduli of elasticity for the pinion and gear materials are 200 MPa and 100 MPa respectively. Assume service factor as unity. [8M]

Question 2

A motor shaft rotating at 1400 rpm has to transmit 16 kW to a low speed shaft with reduction of 4:1. The teeth are $14 \frac{1}{2}^\circ$ involute of 8 mm module with 25 teeth on pinion. Both the gear and pinion are made of steel with a static stress of 200 MPa. The service factor is 1.0.

Velocity Factor, $C_v = 3/(3 + v)$, v = pitch line velocity in m/s.

Tooth form factor for 20° stub teeth, $y = 0.124 - 0.684/T$, T = Number of teeth.

The weights of gear and pinion are 69 N and 38 N respectively. Find the resultant loads on gear and pinion. Design suitable diameters for the gear and pinion shafts if the shear stress of the shaft material is 40 MPa. Assume overhang of gear and pinion on shafts as 100 mm. [8M]

Question 3

A pair of straight bevel gears, with 20° pressure angle, consists of a 20 teeth pinion meshing with a 30 teeth gear. The module is 4 mm while the face width is 20 mm. The material for the pinion and gear is steel ($\sigma_b = 200$ MPa). The pinion rotates at 500 rpm and receives power from the electric motor. Find the bending load, pitch angles and cone

distance. The tooth form factor y is given by $y = 0.154 - 0.912/(\text{No. of teeth})$. Draw a neat free hand sketch of the bevel gear drive, showing dimensions. [6M]

Question 4

A pair of worm and worm wheel is designated as 3/60/10/6. The worm is transmitting 5 kW power at 1440 rpm to the worm wheel. The coefficient of friction is 0.1 and the normal pressure angle is 20° . Determine the components of gear tooth force acting on the worm, worm wheel and efficiency of the drive.

Draw a neat free hand sketch of the drive with dimensions.

[6M]

Question 5

A tube with 50 mm and 75 mm as inner and outer diameters respectively is reinforced by shrinking a jacket of outer diameter 100 mm. The compound tube is to withstand an internal pressure of 35 MPa. $E = 207 \text{ GPa}$. Find the deformation and internal diameter of jacket.

[6M]

Question 6

A cast iron pipe used in hydraulic circuit is subjected to an internal pressure of 45 MPa. The inner diameter of the pipe is 25 mm. Design the thickness using suitable equation and find the maximum and minimum values of radial and tangential stresses across the pipe thickness.

The ultimate stress is 200 MPa. Assume a factor of safety as 5.

[6M]

MECHANICAL EQUIPMENT DESIGN DATA SHEET

SPUR GEARS

Dynamic tooth load – Buckingham load $W_D = W_T + W_I$

$$W_I = \frac{21 * v * (b * C + WW)}{21 * v + \sqrt{(b * C + WT)}}$$

C = deformation factor

$$\text{Wear tooth load } WW = d_p * b * Q * K$$

W_w = Maximum or limiting load for wear

d_p = Pitch circle diameter of pinion

Q = Ratio factor

$$K = \text{Load stress factor} = \frac{\sigma_{es}^2 * \sin \phi}{1.4} * \left(\frac{1}{E_p} + \frac{1}{E_g} \right)$$

$$Q = \frac{2T_g}{T_g + T_p} \text{ + for external gears, - for internal gears}$$

BEVEL GEARS

$$\text{Bending load } F_b = \sigma_b * y * m * b * \left(1 - \frac{b}{L} \right)$$

σ_b = bending stress

y = form factor

m = module

WORM GEARS

$$F_{1a} = F_{2t} = F_{1t} * \frac{\cos \alpha_n - \mu * \tan \gamma}{\cos \alpha_n * \tan \gamma + \mu}$$

α_n normal pressure angle

$$\text{Torque on wheel } m_2 = m_1 * \frac{d_2}{d_1} * \left[\frac{\cos \alpha_n - \mu * \tan \gamma}{\cos \alpha_n * \tan \gamma + \mu} \right]$$

$$\text{Efficiency } \eta = \left[\frac{\cos \alpha_n - \mu * \tan \gamma}{\cos \alpha_n + \mu * \cot \gamma} \right]$$

$$\text{Separating force } F_s = F_{1t} * \frac{\sin \alpha_n}{\cos \alpha_n * \sin \gamma + \mu * \cos \gamma}$$

~~PRESSURE VESSELS~~
PRESSURE VESSELS

Thick cylinders

$$\sigma_l (\text{constant}) = \frac{\pi * D_i^2}{D_o^2 - D_i^2}$$

$$\sigma_r = \frac{-p_i * D_i^2}{D_o^2 - D_i^2} * \left[\frac{D_o^2}{4r^2} - 1 \right]$$

$$\sigma_r \left[r = \frac{D_i}{2} \right] = -p_i$$

$$\sigma_r \left[r = \frac{D_o}{2} \right] = 0$$

$$\sigma_t = \frac{p_i * D_i^2}{D_o^2 - D_i^2} * \left[\frac{D_o^2}{4r^2} + 1 \right]$$

$$\sigma_t \left[r = \frac{D_i}{2} \right] = \frac{p_i (D_o^2 + D_i^2)}{D_o^2 - D_i^2}$$

$$\sigma_t \left[r = \frac{D_o}{2} \right] = \frac{2p_i * D_i^2}{D_o^2 - D_i^2}$$

$$\text{Total deformation } \delta = \frac{p * D_2}{E} * \left[\frac{2 * D_2^2 * (D_3^2 - D_1^2)}{(D_3^2 - D_2^2) (D_2^2 - D_1^2)} \right]$$

$$\text{Maximum stress } \sigma_t = \frac{p * (D_3^2 + D_2^2)}{(D_3^2 - D_2^2)}$$

D1, D2, D3 are the diameters of the compound cylinders.

p = shrinkage pressure.

Internal diameter (ID) of jacket = Outer diameter (OD) of cylinder – deformation

DESIGN EQUATIONS FOR THICK CYLINDERS

$$\text{Lame's Equation } t = \frac{D_i}{2} * \left[\sqrt{\frac{\sigma_t + p_i}{\sigma_t - p_i}} - 1 \right]$$

$$\text{Clavarino's equation } t = \frac{D_i}{2} * \left[\sqrt{\frac{\sigma_t + (1 - 2\nu) * p_i}{\sigma_t - (1 + \nu) * p_i}} - 1 \right]$$

$$\text{Birnie's equation } t = \frac{D_i}{2} * \left[\sqrt{\frac{\sigma_t + (1 - \nu) * p_i}{\sigma_t - (1 + \nu) * p_i}} - 1 \right]$$

t = thickness

σ_t = allowable stress = $\sigma_{\text{ultimate}} / \text{Factor of Safety}$

D_i = inner diameter

p_i = internal pressure

ν or μ = Poisson's ratio

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**T E S T II (Open Book)
ME C451MECHANICAL EQUIPMENT DESIGN**

Date: 22-12-2011

Time: 50 minutes

Marks: 20

Weightage: 20%

Note: 1. Answer all questions

2. Marks are shown in the brackets against each question.

3. Prescribed text book and hand-written class notes are only allowed.

4. Draw free hand sketches.

Question 1

A pair of worm and wheel is designated as 2/60/10/5. The worm is transmitting 6kW power at 1500 rpm to the worm wheel. Determine the diameters, tangential forces and axial forces on worm and wheel. The efficiency of the drive is 80%. **[4M]**

Question 2

The inner diameter of a thin cylindrical tank for liquefied gas is 300 mm. The gas pressure is limited to 15 MPa. The outer and inner diameters are 300 mm and 250 mm respectively. Find all the stresses. **[4M]**

Question 3

A thick cylindrical tube with 60 mm and 85 mm as inner and outer diameters respectively is subjected to an internal of 100 MPa. Draw the radial and tangential stress distribution diagram proportionate to the data. **[6M]**

Question 4

A thick cylindrical cast iron pipe used in hydraulic circuit is subjected to an external pressure of 46 MPa. The inner and outer diameters of the pipe are 25 mm and 45 mm respectively. Plot the distribution of both radial and tangential stresses across the pipe thickness. **[6M]**

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TEST I
ME C451MECHANICAL EQUIPMENT DESIGN

Date: 03-11-2011

Marks: 25

Time: 50 minutes

Weightage: 25%

Note: 1. Answer all questions

2. Marks are shown in the brackets against each question.

3. Assume the data suitably if necessary.

4. Use the datasheet.

5. Draw the free hand sketches for all questions.

Question 1

A spur gear drive is required to transmit a maximum power of 22.5 kW. The velocity ratio is 1:2 and speed of pinion is 200 r.p.m. The center distance between the shafts is 600 mm. The static stresses for the gear and pinion materials are 120 MPa and 100 MPa respectively and face width is 10 times the module. Find the module, face width and number of teeth on each gear.

Lewis form factor

$$= 0.154 - 0.912/T$$

Velocity factor

$$= 3/(3 + v)$$

Service factor

$$= 0.8$$

[10M]

Question 2

A pair of straight bevel gears is mounted on perpendicular shafts, consists of a 25 teeth pinion meshing with a 50 teeth gear. The module is 6 mm. Calculate the pitch circle diameters and pitch angles of the pinion and gear and the cone distance. Draw the sketch of the gear drive, showing the diameters and pitch angles.

[5M]

Question 3

A motor shaft rotating at 1500 rpm has to transmit 15 kW to a low speed shaft with reduction of 3:1. The teeth are $14 \frac{1}{2}^{\circ}$ involute of 6 mm module with 30 teeth on pinion. Both the gear and pinion are made of steel with a static stress of 220 MPa. The service factor is 1.0.

Velocity Factor, C_v

$$= 3/(3 + v), v = \text{pitch line velocity in m/s.}$$

Tooth form factor for 20° stub teeth, $y = 0.124 - 0.684/T$, T = Number of teeth.

The weights of gear and pinion are 75 N and 60 N respectively. Find the resultant loads on gear and pinion. Design suitable diameters for the gear and pinion shafts if the shear stress of the shaft material is 50 MPa.

[10M]

NAME: _____
ID NO: _____

B

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QUIZ II

Max. Marks: 14
Weightage: 7%

Date: 12-12-11

Duration: 20 Min.

- Answer all questions.
 - Marks are shown in brackets against each question.
-

Question 1

Draw the free hand sketch of worm gear drive.

[1M]

Question 2

Find the power transmitted for a gear drive, in which worm is rotating at 300 rpm. The tangential load is 3 kN. Take diameter of worm as 200 mm.

[2M]

Question 3

Draw the free hand sketch of tangential and radial stress distribution for a thick cylinder subjected to internal pressure..

[2M]

Question 4

What is the criteria used for identifying thin or thick cylinders?

[1M]

Question 5

What are the maximum and minimum values of radial stress in a thick cylinder? [1M]

Question 6

What are the parameters on which radial, tangential and longitudinal stresses depend? [2M]

Question 7

What is the principle on which worm is working?

[1M]

Question 8

How do you designate worm gear unit? What are the parameters in its designation?

[2M]

Question 9

Which is the driver in the worm gear drive?

[1M]

Question 10

What is the formula used for efficiency of worm unit?

[1M]

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QUIZ

Max. Marks: 16

Duration: 20 Min.

Weightage: 8%

- Answer all questions.
 - Marks are shown in brackets against each question.
-

Question 1

Give the types of gears used according to the position of shafts.

[2M]

Question 2

What is Lewis Equation? Give its significance.

[2M]

Question 3

Give possible remedies for bending and pitting tooth failures.

[2M]

Question 4

What are reasons for dynamic load on teeth?

[2M]

Question 5

What is Strength factor?

[2M]

Question 6

If the wear tooth load, static tooth load and incremental load are 50 kN, 25 kN and 4 kN respectively. Taking pressure angle as 60° , check whether the design is safe or not? [3M]

Question 7

Find the power transmitted for a gear drive, in which pinion is rotating at 300 rpm driving a spur gear at transmission ratio 3:1. The pinion has 18 teeth with a module of 8 mm. The tangential load is 9 kN. The service factor is 1. . [3M]