BITS, PILANI – DUBAI
Dubai International Academic City
III Year MECH
ME C422 DYNAMICS OF MACHINES & VIBRATIONS
II SEMESTER 2008-2009

Comprehensive Examination (Closed Book)

Max. Marks: 80 **Duration: 3 Hrs.**
Date: 01-06-2009

- **Answer all questions.**
- **Marks are shown in brackets against each question.**
- **Draw suitable sketches, wherever necessary.**
- **Assume missing data if any logically.**
- **Use the formala sheet attached.**

Question 1

(a) State D'Alembertt's principle. **[2M]**

(b) The lengths of crank and connecting rod of a vertical reciprocating engine are 100 mm and 400 mm respectively. The crank is rotating at a speed of 200 rpm.The mass of connecting rod is 50 kg and that of reciprocating parts is 60 kg and the distance of centre of gravity of the rod from the piton pin is 180 mm. When the crank position is 35^0 from the IDC. Find graphically the acceleration of the centre of gravity of connecting rod and then determine all the forces on reciprocating mechanism including approximate torque on the crank shaft. **USE KLEIN'S CONSTRUCTION ONLY.** **[8M]**

Question 2

(a) State the condition of equilibrium for a dynamically equivalent system. **[2M]**

(b) The length of connecting rod of an engine is 500 mm between the centers and its mass is 18 kg. The centre of gravity is 125 mm from the crank pin centre and crank radius is 100 mm and it is rotated through 40^0. Determine dynamically equivalent system keeping one mass at the small end. The crank is rotating at uniform speed of 2 rad/s clock-wise.

If the connecting rod is replaced by two masses located at two centres, find the correction couple that must be applied for complete dynamical equivalence of system, if the moment of inertia of connecting rod is 20,000 kg mm^2. **USE graphical method to find angular acceleration of connecting rod.** **[8M]**

Question 3

(a) Derive an expression for Coriolis component of acceleration. **[4M]**

(b) A link **OR** is rotating about point **O**. At a particular instant when $\theta = 90^0$ with x- axis, the angular velocity of the link is 2 rad/s counter-clockwise and angular acceleration is 5 rad/s^2 counter-clockwise. A slider **P** is sliding from point **O** is 2 m (**OP = 2M).** The corresponding point on the rod is **Q**. The velocity and acceleration of point **P** at that instant with respect to point **Q** are 3 m/s and 4 m/s^2 both radially outwards. Find all the components of acceleration with their directions. **Draw both the configuration and acceleration diagrams to scale.** **[6M]**

Question 4

(a) Distinguish between flywheel and governor. **[2M]**

(b) A steam engine runs at 150 rpm. Its turning moment diagram gave the following area moments taken in order above and below mean torque line:
500, -250, 270, -390, 190, -340, 270, -250 (all in mm^2). The scale is turning moment 1 mm = 500 Nm and crank displacement 1 mm = 5^0.
If the total fluctuation of speed is 1.5 % of the mean speed, determine the cross-section of the rim of the flywheel assumed rectangular with axial dimension equal to 1⅓ times the radial dimension. The hoop stress is limited to 3 MPa. and density of the material of the flywheel is 7500 kg/m^3. **[8M]**

Question 5

(a) Explain briefly various types of governors. **[2M]**

(b) Calculate the change in vertical height of a Watt governor when the speed increase s from 40 to 41 rpm and from 200 to 201 rpm. Justify whether this is suitable for high speeds or not. **[3M]**

(c) Calculate the minimum speed, maximum speed and range of speed of a Porter governor which has equal arms each 220 mm long. The mass of each ball is 5 kg and the central mass on the sleeve is 25 kg. The radius of rotation of the ball is 110 mm when the governor begins to lift and 120 mm when the governor is at maximum speed. **[5M]**

Question 6

(a) A ship has a propeller of mass moment of inertia 2100 kg m^2. It rotates at a speed of 350 rpm. Determine gyroscopic couple
(i) when the ship moves at 36 km/hr and steers to the left at a radius of 210 m.
(ii) when it pitches and moves up and down with an amplitude of 12^0 and time period of 23 sec. **[6M]**

(b) An air craft consists of a propeller and engine whose mas moment of inertia is 150 kg m^2. The engine rotates at 3600 rpm. It completes half circle of radius 100 m towards left when flying at 360 km / hr. Determine gyroscopic couple on the air craft. **[6M]**

Question 7

(a) A cantilever shaft of length 250 mm carries a mass of 60 kg placed 250 mm placed at the free end. If E = 200 GPa and diameter of shaft is 50 mm, find the natural frequency of vibration. **[5M]**

(b) A vertical shaft 100 mm diameter and 1 m length has its upper end fixed and the other end carries a disc of weight 5 kN. If E = 200 GPa, find the frequency of vibration. **[5M]**

Question 8

(a) Explain briefly the variation in tractive effort and swaying couple. **[2M]**

(b) Four masses A, B, C and D are attached to a rotating shaft with radii 50 mm, 62.5 mm, 100 mm and 75 mm respectively. The distances between planes A and B; between planes B and C and between planes C and D are 600 mm each. The masses A and D are 14 kg and 8 kg respectively. If the shaft is to be in balance, then find the magnitudes and directions of balancing masses B and D. The angular position of four masses A and D are 155^0 and 100^0 respectively. **[8M]**

FORMULA SHEET

Deflections of various shafts:

1. Cantilever with point load **W** at the free end: $\delta = WL^3/3EI$

2. Simply supported with point load **W** at the mid point: $\delta = WL^3/48EI$

3. Simply supported with point load **W** in between the ends: $\delta = Wa^2b^2/3EIL$

4. Simply supported with UDL of intensity **w** in between the ends: $\delta = 5WL^4/384EI$

5. Fixed ends with point load **W** in between the ends: $\delta = Wa^3b^3/3EIL^3$

6. Vertical shaft: $\delta = WL/AE$

L = length of the shaft
a = distance of point load from the left end
b = distance of point load from the right end
E = modulus of elasticity of the material
I = moment of Inertia of cross section
A = Area of cross section

7. Natural frequency, $f_n = \frac{1}{2\pi}\sqrt{g/\delta}$

Gyroscope:

(a) couple = $I\,\omega\,\omega_p$ $\omega_p = v/R$ (STEERING) { FOR SHIPS/AIR CRAFTS}

(b) couple = $I\,\omega\,\omega_p$ $\omega_p = 2\pi\Phi/\tau$ (PITCHING) { FOR SHIPS ONLY}

Governors:
Watt governor

Initial height = $h_1 = g/\omega_1^2$

Final height = $h_2 = g/\omega_2^2$

Change in height = $h_1 . h_2$

Porter governor

$\omega_1^2 = (m + M)g / m h_1$
$\omega_2^2 = (m + M)g / m h_2$
minimum speed $= N_1$
maximum speed $= N_2$

h_1 = height at radius r_1
h_2 = height at radius r_2

$h_1^2 = l^2 - r_1^2$
$h_2^2 = l^2 - r_2^2$

m = mass of each ball
M = mass of sleeve load
l = length of each upper and lower arm

range of speed = $N_2 - N_1$

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T E S T II
(OPEN BOOK)

Max. Marks: 40 **Duration: 50 Min.**
Weightage: 20% **Date: 03-05-2009**

NOTE:

- **Answer all questions.**
- **You are allowed to use prescribed text book and hand-written class notes only.**
- **Marks are shown in brackets against each question.**
- **Assume logically missing data if any.**

Question 1

The turning moment diagram for a multi-cylinder engine has been drawn to scale of 1 mm = 320 Nm vertically and 1 mm = 4^0 horizontally. The areas above and below the mean torque line are -26, +378, -256, +306, -302, +244, -380, +261 and -225 mm^2. The engine is running at a mean speed of 500 r.p.m. The total fluctuation of speed is not to exceed ±2% of mean speed. Design a fly wheel of suitable diameter if its mass is 100 kg. Draw the free hand sketch of turning moment diagram. **[10M]**

Question 2

The torque developed by the engine is given by $T = 14{,}000 + 2300\sin 2\theta - 1750\cos 2\theta$, where T is in Nm and θ is angle turned by crank shaft from IDC. The resisting torque is constant throughout the cycle. Find the speed if the coefficient of fluctuation of speed is 0.01 and moment of inertia of flywheel is 1250 kg m^2. Design the flywheel of suitable diameter if the maximum centrifugal stress is to be 6 MPa and the density of material of fly wheel is 8 Mg/m^3. **[10M]**

Question 3

(a) How do you justify that balancing of reciprocating masses is only partial? **[2M]**

(b) Derive expressions for finding balancing of a single mass by two masses in different planes, situated on the left side of the disturbing mass. Draw the free hand sketch. **[5M]**

(c) Find the balancing masses, each rotating at 0.8 m radius, situated at a distance of 125 mm and 170 mm from the disturbing mass of 220 kg rotating at a radius of 200 mm. **[3M]**

Question 4

Three rotating masses. A = 14 kg, B = 11 kg and C = 21 kg are carried on a shaft, with radii of rotation 275 mm, 400 mm and 150 mm respectively from the shaft axis. The angular positions of Band C are 60^0 and 135^0 respectively from A, measured in the same direction. The distance between the planes of rotation of A and B is 1.35 m, and between those of A and C is 3.6 m, B and C being on the same side of A. Find the magnitude and direction of balancing masses, each rotating at 225 mm radius. The planes first and second balancing masses are situated midway between A and B, B and C. respectively. **USE GRAPHICAL METHOD.** **[10M]**

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T E S T I (REGULAR)

Marks: 25 **Duration: 50 Min.**
Weightage: 25% **Date: 29-03-2009**

- **Answer all questions.**
- **Assume any missing data.**
- **Marks are shown in brackets against each question.**

Question 1

(a) Find out number of degrees of freedom in both planar and spatial pairs with suitable free hand sketches. **[4M]**

(b) Define inversion of a mechanism and explain briefly various inversions. **[4M]**

Question 2

A small connecting rod 250 mm long between centres has a mass of 2 kg and moment of inertia of 0.04 kg.m^2 about its centre of gravity, which is located at a distance of 120 mm from the small end centre. If the connecting rod is to be replaced by 2 masses, find the correction couple to be applied for a complete dynamically equivalent system. Take angular acceleration of connecting rod as 20,000 rad/s^2. Draw the suitable sketch, showing the system. **[8M]**

Question 3

The length of connecting rod of a horizontal double acting steam engine is 1.5 m. The diameter of the cylinder is 380 mm and the stroke of the engine is 6000 mm. The crank is rotating at 300 rpm in the clock-wise direction. The crank has accelerated through 40^0 from IDC. The steam pressure on either side of piston is 0.6 N/mm^2 and 0.06 N/mm^2. The diameter of the piston rod is 60 mm. Find all the forces on the mechanism and also approximate turning moment on the crank shaft. Neglect the friction. Take acceleration of piston from Klein's acceleration diagram only.

Draw the sketch of the reciprocating engine mechanism, showing clearly all the forces acting on it. **[9M]**

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Q U I Z III

Max. Marks: 10 **Duration: 15 Min.**
Weightage: 5% **Date: 12-05-2009**

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

Question

The turning moment diagram of for a multi-cylinder engine has been drawn to a vertical scale of 1mm = 325 Nm and a horizontal scale of 1 mm = 4.5^0. The areas above and below the mean torque line are -30, +382, -262, +312, -302, +244, -380, +267 and -231 mm^2. The fluctuation of speed is limited to 1.8% of mean speed which is 300 rpm. Determine a suitable diameter and cross-section of the fly wheel rim for a limiting value of the safe centrifugal stress of 6 N/mm^2. The density of the rim material may be assumed as 7000 kg/m^3. The width of the rim is 4.5 times its thickness.

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Q U I Z II

Max. Marks: 10 **Duration: 30 Min.**
Weightage: 5% **Date: 24-03-2009**

- **Answer all questions.**
- **Put √ mark in the brackets provided against the suitable answer.**
- **Marks are shown in brackets against each question.**

Question 1 Which of the following is considered as a dynamically equivalent system? For finding the actual torque on crank shaft? **[1M]**

A Piston [ ]

B Crank shaft [ ]

C Connecting rod [ ]

D Cylinder [ ]

Question 2 Thrust on the cylinder walls is **[1M]**

A Parallel to the line of stroke. [ ]

B Perpendicular to the line of stroke. [ ]

C Parallel to the connecting rod. [ ]

D Parallel to the crank shaft. [ ]

Question 3 For a dynamically equivalent rigid body, its radius of gyration about the centroidal axis is **[1M]**

A Geometric mean of the distances of two masses from the centre of gravity. [ ]

B Harmonic mean of the distances of two masses from the centre of gravity. [ ]

C Arithmetic mean of the distances of two masses from the centre of gravity. [ ]

D Mean of the radii of gyration of two masses. [ ]

Question 4 Which of the following is not the condition for a dynamically equivalent Sysem? **[1M]**

A Mass of the rigid body is equal to the sum of the two masses at its ends. [ ]

B The moments of the two masses about the centre of gravity of rigid body must be equal. [ ]

C The radii of gyration of rigid body about its centre of gravity must be equal to the sum of radii of gyration of two masses. [ ]

D The moment of inertia of the rigid body about its centre of gravity must be equal to the sum of moments of inertia of the two masses. [ ]

Question 5 Piston effort for a horizontal engine depends on the following forces **[1M]**

A Force on piston, inertia force and gravity weight. [ ]

B Force on piston and inertia force. [ ]

C Force on piston only. [ ]

D Ineria force only. [ ]

Question 6 Find the net force on the piston due to a gas pressure of 700 kN/m^2 if the bore of cylinder is 160 mm. **[1M]**

Question 7 The connecting rod has a radius of gyration about it centroidal axis is 600 mm. Calculate the equivalent length of connecting rod if one of the masses is at a distance of 1 m from its centre of gravity. **[1M]**

Question 8 The length of the stroke of an engine is 500 mm. If the crank pin effort is 20 kN, Determine the approximate torque on the crank shaft is **[1M]**

Question 9 The angle and radius of crank shaft are 30^0 and 100 mm respectively. If the correcting force at the crank pin is 90 N, find correcting torque on the crank shaft is **[1M]**

Question 10 If the angle of connecting rod and piston effort arc 8^0 and 30 kN respectively, Find the force along the connecting rod. **[1M]**

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Q U I Z 1

Max. Marks: 10 **Duration: 15 Min.**
Weightage: 5% **Date: 25-02-2009**

- **Answer all questions.**
- **Each question carries 1 mark.**
- **Write the answers below each question.**

Question 1
What is degree of freedom ?

Question 2
Write down the Gruebler's equation.

Question 3
Find dof in a reciprocating engine mechanism.

Question 4
Draw the sketches, showing revolute and prismatic pairs.

Question 5
Draw the free hand sketch, showing higher pair.

Question 6
How do you say that a screw pair is single dof pair ?

Question 7
How many dof lost in a spherical pair ?

Question 8
What is the difference between revolute pair in a plane and space ?

Question 9
Draw the free hand sketch sketch , showing all dof of a rigid body in space.

Question 10
How do you physically identify crank and rocker in a mechanism?