DARBHAMGA COLLEGE OF ENGINEERING
DARBHANGA, BIHAR

COURSE FILE
OF
DYNAMICS of MACHINERY
(02 1513)

FACULTY NAME:
PRASHANT KUMAR SINGH
ASSISTANT PROFESSOR,
DEPARTMENT OF MECHANICAL ENGINEERING

Vision of the Mechanical Engineering Department:

To bring forth quality engineers embodying societal ethics to serve national and multinational organisations as well as harping on higher studies.

Mission of the Mechanical Engineering Department:

1. To create a modern ambiance focusing on advanced pedagogy and tools for mechanical engineers.
2. To collaborate with domain industry and research institutes to enhance the skills and knowledge of the graduates.
3. To inject necessary professional skills to serve the industry and the nation.
4. To inculcate humanitarian ethical values in graduates through various social-cultural activities.

Program Educational Objectives (PEOs) :

PEO 1	The graduates will be able to demonstrate knowledge and skills of mechanical engineering to obtain solution to engineering problems.
PEO 2	The graduate will able to apply the mechanical engineering concepts while pursuing academic and research activities.
PEO 3	The graduates will be able to showcase professional skill and expertise.

Program Outcomes (POs) :

PO 1	**Engineering knowledge:** An ability to apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to get the solution of the engineering problems.
PO 2	**Problem analysis:** Ability to Identify, formulates, review research literature, and analyze complex engineering problems.
PO 3	**Design/development of solutions**: Ability to design solutions for complex engineering problems by considering social, economic and environmental aspects
PO 4	**Conduct investigations of complex problems:** Use research-based knowledge to design, conduct analyze experiments to get valid conclusion.
PO 5	**Modern tool usage:** ability to create, select, and apply appropriate techniques, and to model complex engineering activities with an understanding of the limitations.
PO 6	**The engineer and society:** Ability to apply knowledge by considering social health, safety, legal and cultural issues.
PO 7	**Environment and sustainability:** Understanding of the impact of the adopted engineering solutions in social and environmental contexts.
PO 8	**Ethics:** Understanding of the ethical issues of the Mechanical engineering and applying ethical principles in engineering practices.
PO 9	**Individual and teamwork:** Ability to work effectively as an individual or in team, as a member or as a leader.
PO 10	**Communication:** An ability to communicate clearly and effectively through different modes of communication.
PO 11	**Project management and finance:** Ability to handle project and to manage finance related issue
PO 12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning.

Program Specific Outcomes (PSOs) :

PSO 1	Students will be oriented towards research in engineering technologies like Advance Manufacturing, 3 D Printing, Alternative Fuels to contribute the evolving research and development in the field of Mechanical Engineering.
PSO 2	Students will be able to learn and apply software like AutoCAD, Ansys, Catia for various applications.

Course Objectives

The objective of this book is to provide the techniques necessary to study the motion of machines. A focus is placed on the application of kinematic theories to real-world machinery. It is intended to bridge the gap between a theoretical study of kinematics and the application to practical mechanisms. Students completing a course of study using this book should be able to determine the motion characteristics of a machine. The topics presented in this book are critical in machine design process as such analyses should be performed on design concepts to optimize the motion of a machine arrangement.

- provide the techniques necessary to study the motion of machines
- bridge the gap between a theoretical study of kinematics and the application to practical mechanisms
- Encourage students to link synthesis and analysis.
- Encourage students to link fundamental concepts with practical component specification.

Course Outcomes

At the end of the course students will be able to

1. Understand the vibration produced in machinery with the help of harmonic motion to avoid resonance.
2. Apply the concept of balancing in inline and radial engines.
3. Analyse the dynamic forces in mechanisms.
4. Calculate the gyroscopic couple induced in vehicles.
5. Grasp the significance of cam and follower to replace complex mechanisms.

DARBHANGA COLLEGE OF ENGINEERING

COURSE FILE

OF

DYNAMICS OF MACHINERY

(021513)

Mr. Prashant Kumar Singh

Assistant Professor

Department of Mechanical Engineering

College Name	**Darbhanga College of Engineering**		
Program Name	**B.Tech Mechanical Engineering**		
Course Name	Dynamics of Machinery		
Course Code	021513	Course Credit	5
Lecture/Tutorial Per Week	03/00		
Course Coordinator Name	Mr. Prashant Kumar Singh		

1. Scope and Objectives of the Course

In this course students will probably start with basic understanding of design of Dynamics of Machinery, whether it is an automobile or other consumer products. In this course we will study to balance an existing machine or new machine with the help of knowledge of scientific principle, technical information and imagination.

The objectives of the course are to teach students:

- Concepts of generalised forces and static and dynamic equilibrium.
- Concepts of static and dynamic mass balancing in machines and mechanism.
- Concepts of gyroscopic effect on vehicles.
- Vibration induced in different machines.
- Cam and follower to replace complex mechanism.

2. Text Books

TB 1: Theory of Machines by S S Rattan, Third Edition ,Mc Graw Hill publication

TB 2: Theory of Mechanism and Machines by A. Ghose and A. Mallik, East West publication.

TB 3: Theory of machines by Thomas Bevan

3. Reference books

RB1: Theory of machines by Shah and Jadhwani Mechanical Vibration by William Thompson

RB 2: Mechanical Vibration by William Thompson

4. Other readings and relevant websites :

S. No.	Link of websites
1	http://nptel.ac.in/downloads/112105125/
2	https://www.youtube.com/watch?v=nqhyCzrFp1s&list=PLHpC4_VH4uh0bIKMtFg0hXFckep6sBzwi

5. Course Plan

Lecture No.	Date of Lecture	Topics	Web links for video lectures	Text Books, Reference Books and other reading materials	Page numbers of the text books
1- 3		**Force analysis of mechanism**		TB 1, RB 2	1- 75
		Dynamics of plane motion of rigid body, dynamically equivalent two mass system, correction torque, force in mechanism and machine	https://www.youtube.com/watch?v=mzWMdZZaHwI&list=PL3D4EECEFAA99D9BE		
		Assignment 1			
4- 6		**Turning Moment Diagram**		TB 1, RB 2	76- 84 and 101- 177
		Fluctuation of crank shaft speed and energy in a direct acting engine mechanism, flywheels	https://www.youtube.com/watch?v=2xLHFiBOA4M&index=7&list=PL3D4EECEFAA99D9BE		
		Assignment 2			
7- 14		**Cam and Follower Mechanism**			231- 235, 272- 325 and 768- 791
		Types of cam, types of follower, concentric and offset radial cam profile by graphical method, cam with specified contours: tangent cam with radial follower, circular arc cam with flat faced follower	https://www.youtube.com/watch?v=C5ZPaCvoigw&list=PL3D4EECEFAA99D9BE&index=22		
		Assignment 3			

15- 21		**Analysis of gyroscopic motion**		TB 1,TB 2 and RB 2	TB 1 (330- 376), TB 2 (181- 190)
		Principle of gyroscope, gyroscopic couple and reactive gyroscopic couple, gyroscopic effect on the movement of ships, aeroplanes, two and four wheeled vehicles, gyrostablisers	https://www.youtube.com/watch?v=dKfriV8H9-8&index=34&list=PL3D4EECEFAA99D9BE		
Assignment 4					
22- 30		**Effect of inertia of reciprocating masses on engine frame**		TB 1 and RB 2	184- 206, 499- 540, 393- 439 and 448- 496
		Unbalance primary and secondary forces, and couples, balancing of primary and secondary forces, partial balancing of locomotive, balancing of multi cylinder in line and radial engines, direct and reverse cranks methods for balancing of radial engines.	https://www.youtube.com/watch?v=PEKfS2Q1WqM&list=PL3D4EECEFAA99D9BE&index=19		
Assignment 5					
31- 42		**Mechanical Vibrations**			
		Basic concepts, degree of freedom, types of damping and viscous damping, free, damped free and damped forced vibration of a single degree of freedom spring mass system, vibration isolation and transmissibility, whirling of shaft, elementary treatment of two degree of systems,			

		torsional vibration of single and two rotor systems, transverse vibration of simply supported beam, energy method, Rayleigh's method and Dankerley method			

6. Evaluation Scheme

Component 1	Mid semester examination	20
Component 2	class test	5
Component 3	TA	5
Component 4	End Semester Examination	70
Total		100

7. Syllabus

Topics	No. of lectures	Weightage
Force analysis of mechanism: Dynamics of plane motion of rigid body, dynamically equivalent two mass system, correction torque, force in mechanism and machine	3	7%
Turning moment diagram: Fluctuation of crank shaft speed and energy in a direct acting engine mechanism, flywheels	3	7%
Cam and follower mechanism: Types of cam, types of follower, concentric and offset radial cam profile by graphical method, cam with specified contours: tangent cam with radial follower, circular arc cam with flat faced follower	8	19%
Analysis of gyroscopic motion: Principle of gyroscope, gyroscopic couple and reactive gyroscopic couple, gyroscopic effect on the movement of ships, aeroplanes, two and four wheeled vehicles, gyrostablisers	7	17%
Effect of inertia of reciprocating masses on engine frame: Unbalance primary and secondary forces, and couples, balancing of primary and secondary forces, partial balancing of locomotive, balancing of multi cylinder in line and radial engines, direct and reverse cranks methods for balancing of radial engines.	9	22%
Mechanical Vibration: Basic concepts, degree of freedom, types of damping and viscous damping, free, damped free and damped forced vibration of a single degree of freedom spring mass system, vibration isolation and transmissibility, whirling of shaft, elementary treatment of two degree of systems, torsional vibration of single and two rotor systems, transverse vibration of simply supported beam, energy method, Rayleigh's method and Dankerley method	12	28%

8. This document is approved by

Designation	Name	Signature
Course Coordinator	**Prashant Kumar Singh**	
HOD	**Mr. Vishnu Singh**	
Principal	**Dr. Achintya**	

Darbhanga College of Engineering, Darbhanga

Mechanical Engineering

Subject: Dynamics of Machinery

Assignment- 1

1. A small connecting rod 220 mm long between centres has a mass of 2 kg and a moment of inertia of 0.02 kg-m2 about its centre of gravity. The centre of gravity is located at a distance of 150 mm from the small end centre. Determine the dynamically equivalent two mass system when one mass is located at the small end centre. If the connecting rod is replaced by two masses located at the two centres, find the correction couple that must be applied for complete dynamical equivalence of the system when the angular acceleration of the connecting rod is 20 000 rad/s2 anticlockwise.
2. The length of a connecting rod of an engine is 500 mm measured between the centres and its mass is18kg. The centre of gravity is 125 mm from the crank pin centre and the crank radius is 100 mm. Determine the dynamically equivalent system keeping one mass at the small end. The frequency of oscillation of the rod, when suspended from the centre of the small end is 43 vibrations per minute.
3. A petrol engine 90 mm in diameter and 120 mm stroke has a connecting rod of 240 mm length. The piston has a mass of 1 kg and the speed is 1800 r.p.m. On the explosion stroke with the crank at30°from top dead centre, the gas pressure is 0.5 N/mm2.Find: 1. the resultant load on the gudgeon pin, 2. the thrust on the cylinder walls, and 3. the speed, above which other things remaining same, the gudgeon pin load would be reserved in direction. Also calculate the crank effort at the given position of the crank.
4. A horizontal, double acting steam engine has a stroke of 300 mm and runs at 240 r.p.m. The cylinder diameter is 200 mm, connecting rod is 750 mm long and the mass of the reciprocating parts is 70kg. The steam is admitted at 600 kN/m2 for one-third of the stroke, after which expansion takes place according to the hyperbolic law $p.V$ = constant. The exhaust pressure is 20 kN/m2. Neglecting the effect of clearance and the diameter of the piston rod, find : 1. Thrust in the connecting rod, and 2. Effective turning moment on the crankshaft when the crank has turned through 120° from inner dead centre.
5. The torque exerted on the crank shaft of a two stroke engine is given by the equation: T(N-m) = 14500 + 2300 sin2θ - 1900 cos2θ where θ is the crank angle displacement from the inner dead centre. Assuming the resisting torque to be constant, determine: 1. The power of the engine when the speed is 150 r.p.m. ; 2. The moment of inertia of the flywheel if the speed variation is not to exceed ± 0.5% of the mean speed; and 3. The angular acceleration of the flywheel when the crank has turned through 30° from the inner dead centre.
6. A certain machine requires a torque of (5000 + 500 sin θ) N-m to drive it, where θ is the angle of rotation of shaft measured from certain datum. The machine is directly coupled to an engine which produces a torque of (5000 + 600 sin 2θ) N-m. The flywheel and the other rotating parts attached to the engine has a mass of 500 kg at a radius of gyration of 0.4 m. If the mean speed is 150 r.p.m., find : **1.** the fluctuation of energy, **2.** the total percentage fluctuation of speed, and **3.** the maximum and minimum angular acceleration of the flywheel and the corresponding shaft position.
7. The turning moment diagram for a four stroke gas engine may be assumed for simplicity to be represented by four triangles, the areas of which from the line of zero pressure are as follows:

Expansion stroke = 3550 mm2; exhaust stroke = 500 mm2; suction stroke = 350 mm2; and compression stroke = 1400 mm2. Each mm2 represents 3 N-m. Assuming the resisting moment to be uniform, find the mass of the rim of a flywheel required to keep the mean speed 200 r.p.m. within ± 2%. The mean radius of the rim may be taken as 0.75 m. Also determine the crank positions for the maximum and minimum speeds.

DARBHANGA COLLEGE OF ENGINEERIG, DARBHANGA

MID SEMESTER EXAMINATION 2019- 20

MECHANICAL ENGINEERING (5th SEM)

DYNAMICS OF MACHINERY

(021513)

Time: 2 hours **Maximum Marks: 20**

Instructions:

I. All questions are compulsory.
II. All questions carry equal marks.

1. A petrol engine 90 mm in diameter and 120 mm stroke has a connecting rod of 240 mm length. The piston has a mass of 1 kg and the speed is 1800 r.p.m. On the explosion stroke with the crank at30°from top dead centre, the gas pressure is 0.5 N/mm^2. Analyze the dynamic forces and Find: 1. the resultant load on the gudgeon pin, 2. the thrust on the cylinder walls, and 3. the speed, above which other things remaining same, the gudgeon pin load would be reserved in direction. Also calculate the crank effort at the given position of the crank.

OR

A small connecting rod 220 mm long between centres has a mass of 2 kg and a moment of inertia of 0.02 kg- m^2 about its centre of gravity. The centre of gravity is located at a distance of 150 mm from the small end centre. Determine the dynamically equivalent two mass system when one mass is located at the small end centre. If the connecting rod is replaced by two masses located at the two centres, find the correction couple that must be applied for complete dynamical equivalence of the system when the angular acceleration of the connecting rod is 20,000 rad/s^2 anticlockwise.

2. What is the significance of Cam- follower pair. A disc cam is to give uniform motion to a knife edge follower during out stroke of 50 mm during the first half of the cam revolution. The follower again returns to its original position with uniform motion during the next half of the revolution. The minimum radius of the cam is 50 mm and the diameter of the cam shaft is 35 mm. Draw the profile of the cam when the axis of follower passes through the axis of cam shaft.

OR

What is the significance of cam with specific contour.A symmetrical tangent cam operating a roller follower has the following particulars : Radius of base circle of cam = 40 mm, roller radius = 20 mm, angle of ascent = 75°, total lift = 20 mm, speed of cam shaft = 300 r.p.m. Determine : 1. the principal dimensions of the cam, 2. the equation for the displacement curve, when the follower is in contact with the straight flank, and 3. the acceleration of the follower when it is in contact with the straight flank where it merges into the circular nose.

3. The mass of a turbine rotor of a ship is 8 tonnes and has a radius of gyration 0.6 m. It rotates at 1800 r.p.m. clockwise when looking from the stern. Determine the gyroscopic effects in the following cases:
1. If the ship travelling at 100 km / h steers to the left in a curve of 75 m radius, 2. If the ship is pitching and the bow is descending with maximum velocity. The pitching is simple harmonic, the periodic time being 20 seconds and the total angular movement between the extreme positions is 10°, and 3. If the ship is rolling and at a certain instant has an angular velocity of 0.03 rad/s clockwise when looking from stern. In each case, explain clearly how you determine the direction in which the ship tends to move as a result of the gyroscopic action.

4. A single cylinder engine runs at 250 r.p.m. and has a stroke of 180 mm. The reciprocating parts has a mass of 120 kg and the revolving parts are equivalent to a mass of 70 kg at a radius of 90 mm. A

mass is placed opposite to the crank at a radius of 150 mm to balance the whole of the revolving mass and two-thirds of the reciprocating mass. Determine the magnitude of the balancing mass and the resultant residual unbalance force when the crank has turned 30° from the inner dead centre, neglect the obliquity of the connecting rod.

OR

A three cylinder radial engine driven by a common crank has the cylinders spaced at 120°. The stroke is 125 mm, length of the connecting rod 225 mm and the mass of the reciprocating parts per cylinder 2 kg. Show the crank configuration and calculate the primary and secondary forces at crank shaft speed of 1200 r.p.m.

5. Find the natural frequency of a vibratory system shown in fig. 1.

Question Bank

1. What is the significance of Cam- follower pair. A disc cam is to give uniform motion to a knife edge follower during out stroke of 50 mm during the first half of the cam revolution. The follower again returns to its original position with uniform motion during the next half of the revolution. The minimum radius of the cam is 50 mm and the diameter of the cam shaft is 35 mm. Draw the profile of the cam when the axis of follower passes through the axis of cam shaft.
2. What is the significance of cam with specific contour.A symmetrical tangent cam operating a roller follower has the following particulars : Radius of base circle of cam = 40 mm, roller radius = 20 mm, angle of ascent = 75°, total lift = 20 mm, speed of cam shaft = 300 r.p.m. Determine : 1. the principal dimensions of the cam, 2. the equation for the displacement curve, when the follower is in contact with the straight flank, and 3. the acceleration of the follower when it is in contact with the straight flank where it merges into the circular nose.
3. Following is the data for a circular arc cam working with a flat faced reciprocating follower : Minimum radius of the cam = 30 mm ; Total angle of cam action = 120° ; Radius of the circular arc = 80 mm ; Nose radius = 10 mm. 1. Find the distance of the centre of nose circle from the cam axis ; 2. Draw the profile of the cam to full scale; 3. Find the angle through which the cam turns when the point of contact moves from the junction of minimum radius arc and circular arc to the junction of nose radius arc and circular ; and 4. Find the velocity and acceleration of the follower when the cam has turned through an angle of $\theta = 20°$. The angle θ is measured from the point where the follower just starts moving away from the cam. The angular velocity of the cam is 10 rad/s.
4. The mass of a turbine rotor of a ship is 8 tonnes and has a radius of gyration 0.6 m. It rotates at 1800 r.p.m. clockwise when looking from the stern. Determine the gyroscopic effects in the following cases:1. If the ship travelling at 100 km / h steers to the left in a curve of 75 m radius, 2. If the ship is pitching and the bow is descending with maximum velocity. The pitching is simple harmonic, the periodic time being 20 seconds and the total angular movement between the extreme positions is 10°, and 3. If the ship is rolling and at a certain instant has an angular velocity of 0.03 rad/s clockwise when looking from stern. In each case, explain clearly how you determine the direction in which the ship tends to move as a result of the gyroscopic action.
5. A motor car takes a bend of 30 m radius at a speed of 60 km / hr. Determine the magnitudes of gyroscopic and centrifugal couples acting on the vehicle and state the effect that each of these has on the road reactions to the road wheels. Assume that each road wheel has a moment of inertia of 3 kg-m2 and an effective road radius of 0.4 m. The rotating parts of the engine and transmission are equivalent to a flywheel of mass 75 kg with a radius of gyration of 100 mm. The engine turns in a clockwise direction when viewed from the front. The back-axle ratio is 4 : 1, the drive through the gear box being direct. The gyroscopic effects of the half shafts at the back axle are to be ignored. The car has a mass of 1200 kg and its centre of gravity is 0.6 m above the road wheel. The turn is in a right hand direction.
6. Each road wheel of a motor cycle has a mass moment of inertia of 1.5 kg-m2. The rotating parts of the engine of the motor cycle have a mass moment of inertia of 0.25 kg-m2. The speed of the engine is 5 times the speed of the wheels and is in the same sense. The mass of the motor cycle with its rider is 250 kg and its centre of gravity is 0.6 m above the ground level. Find the angle of heel if the cycle is travelling at 50 km / h and is taking a turn of 30 m radius. The wheel diameter is 0.6 m.
7. A single cylinder engine runs at 250 r.p.m. and has a stroke of 180 mm. The reciprocating parts has a mass of 120 kg and the revolving parts are equivalent to a mass of 70 kg at a radius of 90 mm. A mass is placed opposite to the crank at a radius of 150 mm to balance the whole of the revolving mass and two-thirds of the reciprocating mass. Determine the magnitude of the balancing mass and the resultant residual unbalance force when the crank has turned 30° from the inner dead centre, neglect the obliquity of the connecting rod.
8. A three cylinder radial engine driven by a common crank has the cylinders spaced at 120°. The stroke is 125 mm, length of the connecting rod 225 mm and the mass of the reciprocating parts per cylinder 2 kg. Show the crank configuration and calculate the primary and secondary forces at crank shaft speed of 1200 r.p.m.
9. Find the natural frequency of a vibratory system shown in fig.