DRONACHARYA
College of Engineering

LABORATORY MANUAL

B.Tech. Semester- VI

DYNAMICS OF MACHINE
Subject code: LC-ME-316G

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DEPARTMENT OF MECHANICAL ENGINEERING
DRONACHARYA COLLEGE OF ENGINEERING
KHENTAWAS, FARRUKH NAGAR, GURUGRAM (HARYANA)

Table of Contents

Vision and Mission of the Institute

Vision:

"To impart Quality Education, to give an enviable growth to seekers of learning, to groom them as World Class Engineers and Managers competent to match the expanding expectations of the Corporate World has been our ever enlarging vision extending to new horizons since the inception of Dronacharya College of Engineering."

Mission:

1. To prepare students for full and ethical participation in a diverse society and encourage lifelong learning by following the principle of 'Shiksha evam Sahayata' i.e. Education & Help.

2. To impart high-quality education, knowledge and technology through rigorous academic programs, cutting-edge research, & Industry collaborations, with a focus on producing engineers& managers who are socially responsible, globally aware, & equipped to address complex challenges.

3. Educate students in the best practices of the field as well as integrate the latest research into the academics.
4. Provide quality learning experiences through effective classroom practices, innovative teaching practices and opportunities for meaningful interactions between students and faculty.
5. To devise and implement programmes of education in technology that are relevant to the changing needs of society, in terms of breadth of diversity and depth of specialization.

Vision and Mission of the Mechanical Department

Vision:

"To become a Centre of Excellence in teaching and research in the field of Mechanical Engineering for producing skilled professionals having a zeal to serve society."

Mission:

M1: To create an environment where students can be equipped with strong fundamental concepts, various experiments and problem solving skills.

M2: To provide an exposure to emerging technologies by providing hands on experience for generating competent professionals.

M3: To promote Research and Development in the frontier areas of Mechanical Engineering and encourage students for pursuing higher education

M4: To inculcate in students ethics, professional values, team work and leadership skills.

Programme Educational Objectives (PEOs)

PEO 1: Engineers will practice the profession of engineering using a systems perspective and analyze, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO 2: Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO 3: Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO 4: Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO 5: Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Programme Outcomes (POs)

Over completion of the Course our graduates will have ability to

1. Apply knowledge of computing, mathematical foundations, algorithmic principles, and engineering theory in the modeling and design of systems to real-world problems (fundamental engineering analysis skills).
2. Apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline.
3. Design and conduct experiments, as well as to analyze and interpret data (information retrieval skills). Practical application of engineering skills, combining theory and experience, and use of other relevant knowledge and skills.
4. Analyze a problem, identify, formulate and use the appropriate computing and engineering requirements for obtaining its solution(engineering problem solving skills).
5. Understand the appropriate codes of practice and industry standards.
6. Identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques.
7. Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.
8. Communicate effectively, both in writing and orally (speaking / writing skills).
9. Understand professional, ethical, legal, security and social issues and responsibilities (professional integrity).
10. Understand customer and user needs and the importance of considerations such as Aesthetics.
11. Use creativity to establish innovative solutions.
12. Adapt to a rapidly changing environment by having learned and applied new skills and new technologies.
13. To significantly contribute to delivery of desired component, product, or process.
14. Formulate and solve moderately complex engineering problems, accounting for hardware/software/human interactions.
15. Recognize the importance of professional development by pursuing postgraduate studies or face competitive examinations that offer challenging and rewarding careers in computing.
16. Apply the Knowledge of management techniques which may be used to achieve engineering Objectives within that context.

Program Specific Outcomes (PSOs)

On successful completion of the Mechanical Engineering Degree programme, the Graduates shall exhibit the following:

PSO1 Apply the knowledge gained in Mechanical Engineering for design and development and manufacture of engineering systems.

PSO2 Apply the knowledge acquired to investigate research-oriented problems in mechanical engineering with due consideration for environmental and social impacts

PSO3 Use the engineering analysis and data management tools for effective management of multidisciplinary projects.

University Syllabus

1. To perform experiment on Watt and Porter Governors to prepare performance characteristic Curves, and to find stability & sensitivity.

2. To perform experiment on Proell Governor to prepare performance characteristic curves, and to find stability & sensitivity.

3. To perform experiment on Hartnell Governor to prepare performance characteristic Curves, and to find stability & sensitivity.

4. To study gyroscopic effects through models.

5. To determine gyroscopic couple on Motorized Gyroscope.

6. To perform the experiment for static balancing on static balancing machine.

7. To perform the experiment for dynamic balancing on dynamic balancing machine.

8. Determine the moment of inertial of connecting rod by compound pendulum method and triflair suspension pendulum.

NOTE: At least seven experiments are to be performed in the Semester.

Course Outcomes (COs)

Course Outcomes: At the end of the course, the student shall be able to

CO316.1- Understand the various practical demonstrations of forces in mechanism

CO316.2- Knowledge of various Design features of mechanism with practical demonstration.

CO316.3- Learning the Special purpose mechanism (governor, Gyroscope Cam and followers etc used in designing of a machine

CO-PO Mapping

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PO14	PO15	PO16
CO316.1	3	3	3	-	2	-	3	3	3	2	-	3	3	-	-	3
CO316.2	-	3	-	-	2	3	-	-		2	-	3	-	-	2	3
CO316.3	-	-	3	3		3	-	-	3	-	3	-	3	3	-	

CO-PSO Mapping

	PSO1	PSO2	PSO3
CO316.1	3	2	-
CO316.2	2	3	-
CO316.3	3	2	-

Course Overview

This course covers various experiments and studies related to mechanical systems and their behavior. Students will perform experiments on Watt and Porter Governors to prepare performance characteristic curves and analyze stability and sensitivity. Similarly, experiments on Proell Governor and Hartnell Governor will be conducted to understand their performance characteristics, stability, and sensitivity. The course also includes studying gyroscopic effects through models and determining the gyroscopic couple on a Motorized Gyroscope. Students will learn about static balancing by performing experiments on a static balancing machine and dynamic balancing using a dynamic balancing machine. Additionally, the course involves determining the moment of inertia of a connecting rod through the compound pendulum method and triflair suspension pendulum. These experiments provide hands-on experience and insight into the behavior and properties of mechanical systems

List of Experiments

S.No.	NAME OF EXPERIMENTS	Course Outcomes
1.	To perform experiment on watt and Porter Governors to prepare performance characteristic Curves, and to find stability & sensitivity.	CO316.1, CO316.2
2.	To perform experiment on Proell Governors to prepare performance characteristic Curves, and to find stability & sensitivity.	CO316.1, CO316.3
3.	To perform experiment Hartwell Governors to prepare performance characteristic Curves, and to find stability & sensitivity.	CO316.1, CO316.2
4.	To study gyroscopic effects through models.	CO316.2, CO316.3
5.	To determine gyroscopic couple on Motorized Gyroscope.	CO316.1, CO316.2
6.	To perform the experiment for static balancing on static balancingmachine.	CO316.1, CO316.3
7.	To perform the experiment for dynamic balancing on dynamic balancing machine.	CO316.1, CO316.2
8.	Determine the moment of inertial of connecting rod by compoundpendulum method and tri-flair suspension pendulum.	CO316.2, CO316.3

DOs and DON'Ts

DOs

1. Work deliberately and carefully.
2. Keep your work area clean.
3. Students must wear college uniform and carry their college ID.
4. Students should have separate note book for practical.
5. Students should have their own pencil, eraser, scale, along with pen and lab note book.
6. Handle the equipment /models carefully.

DON'Ts

1. Do not wander around the room, distract other students, startle other students or interfere with the laboratory experiments of others.
2. Do not eat food, drink beverages or chew gum in the laboratory.
3. Do not open any irrelevant internet sites on lab computer.

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as fire wood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.
2. Unplug the risk of faulty equipment. If main circuit breaker is accessible, turn the circuit off.
3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.
4. Immediately call medical emergency and security. Remember! Time is critical; be best.

Precautions (In case of Fire)

1. Turn the equipment off. If power switch is not immediately accessible, take plug off.
2. If fire continues, try to curb the fire, if possible, by using the fire extinguisher or by covering it with a heavy cloth, if possible, isolate the burning equipment from the other surrounding equipment.
3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.

Emergency: Reception

Security: Main Gate

Lab assessment criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes areassessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

Grading Criteria	Exemplary (4)	Competent (3)	Needs Improvement (2)	Poor (1)
AC1: Pre-Lab written work (this may be assessed through viva)	Complete procedure with underlined concept is properly written	Underlined conceptis written but procedure is incomplete	Not able to writeconcept and procedure	Underlined conceptis not clearly understood
AC2: Program Writing/ Modeling	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied.	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied	Assigned problem is properly analyzed & correct solution designed	Assigned problem isproperly analyzed
AC3: Identification & Removal of errors/ bugs	Program/solution written is readable Able to identify errors/ bugs and remove them	Able to identify errors/ bugs and remove them with little bit of guidance	Is dependent totallyon someone for identification of errors/ bugs and their removal	Unable to understand the reason for errors/ bugs even after theyare explicitly pointed out Solution is not well demonstrated and implemented concept is not clearly explained
AC4: Execution & demonstration	All variants of input /output are tested, Solution is well demonstrated and implemented concept is clearlyexplained	All variants of input /output are not tested, However, solution is well demonstrated and implemented concept is clearlyexplained	Only few variants of input /output aretested, Solution is well demonstrated but implemented concept is not clearly explained	Less than 40 % of the assigned problems are well recorded with objective, design contracts and solution along with
AC5 :Lab Record Assessment	All assigned problems are well recorded with objective, design constructs and solution along withPerformance analysis using all variants of input and output	More than 70 % of the assigned problems are well recorded with objective, design contracts and solution along withPerformance analysis is done with all variants ofinput and output	Less than 70 % of the assigned problems are well recorded with objective, design contracts and solution along Performance analysis is done with all variants ofinput and output	Performance analysis is done with all variants ofinput and output

Guidelines to students for report preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows:

1) All files must contain a title page followed by an index page. The files will not be signed by the faculty without an entry in the index page.

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.

3) For each experiment, the record must contain the following

(i) Aim/Objective of the experiment

(ii) Pre-experiment work (as given by the faculty)

(iii) Lab assignment questions and their solutions

(iv) Test Cases (if applicable to the course)

(v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.
2. Students must ensure that their lab record is regularly evaluated.

Experiment No. - 1

AIM:-To perform experiment on watt and Porter Governors to prepare performance characteristic Curves, and to find stability & sensitivity.

APPARATUS USED: - Watt and Porter Governors.

INTRODUCTION & THEORY: - The function of a governor is to regulate the mean speed ofan engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.
The governors may, broadly, be classified as
Centrifugal governor

Inertia governor

The centrifugal governors may further be classified as follows:
Pendulum type (Watt governor)

Loaded type

Dead weight governor (Porter governor and proell governor)

Spring controlled governors (Hartnell governor, Hartung governor, Wilson- Hartnell governor and Pickering governor)

Watt Governor: - The simplest form of a centrifugal governor is a Watt governor. It isbasically a conical pendulum with links attached to a sleeve of negligible mass. The arms of the governor may be connected to the spindle in the following three ways:
The pivot P may be on the spindle axis.

The pivot P may be offset from the spindle axis and the arms when produced intersect atO.

The pivot P may be offset, but the arms cross the axis at O.

Porter Governor: - The porter governor is a modification of a Watt's governor, with central load attached to the sleeve. The load moves up down the central spindle. This additional downward force increases the speed of revolution required to enable the balls to rise to any to any pre-determined level.

OBSERVATION:-

Mass of the ball (m) =---------- kg.

Weight of the ball (w) = ---------- Newton's

Height of the governor (h) = ---------- meters
Minimum equilibrium speed (N_1) =---------- r.p.m.
Minimum equilibrium speed (N_2) =---------- r.p.m.
Frictional force (F) = ----------Newton
What is the function of a governor? How does it differ from that of a flywheel?

State the different types of governors. What is the difference between centrifugal andinertia type governors?

Explain the term height of the governor. What are the limitations of a Watt governor? Mean equilibrium speed (N) = (N_1 + N_2)/2 in r.p.m

Mass of the central load = ----------kg.
Weight of the central load (W) = ---------- N
Angle of inclination of the arm to the vertical (α) = ------
Angle of inclination of the link to the vertical (β) = ------

CALCULATION:-

N^2 = 895/h (For watt governor)

$N^2 = \frac{m + M(1+q)/2}{} \times \frac{895}{}$ (For porter governor),

Where, q = tan β/ tan αm h

Sensitiveness of the governor = $2(N_1 - N_2)/ N_1 + N_2 = 2 (\omega_2 - \omega_1)/ \omega_2 + \omega_1$

A governor is said to be stable when for every speed within the working range there is a definite configuration i.e.; there is only one radius of rotation of the governor balls at which the governor is in equilibrium. For a stable governor, if the equilibrium speed increases, the radius of governor balls must also increase.

PRECAUTIONS:-

Take reading carefully.
Measure the angle very carefully.
Measure the height of governor carefully.
Speed of governor measure accurate.

Results:

Height of the governor =
Speed of the governor =

Experiment No..- 2

AIM:-To perform experiment on Proell Governor to prepare performance characteristic Curves, and to find stability & sensitivity.

APPARATUS USED: - Proell Governor.

INTRODUCTION & THEORY: - The function of a governor is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.

The governors may, broadly, be classified as

- Centrifugal governor
- Inertia governor

The centrifugal governors may further be classified as follows:

- Pendulum type (Watt governor)
- Loaded type
- Dead weight governor (Porter governor and proell governor)
- Spring controlled governors (Hartnell governor, Hartung governor, Wilson- Hartnell governor and Pickering governor)

Proell Governor :- The porter governor is known as a Proell governor if the two balls (masses) are fixed on the upward extensions of the lower links which are in the form of bent links DFB and EGC (show in fig.).

OBSERVATION:-

Mass of the ball (m) =---------- kg.
Weight of the ball (w) = ---------- Newton's
Height of the governor (h) = ---------- metres
Minimum equilibrium speed (N_1) =---------- r.p.m.
Minimum equilibrium speed (N_2) =---------- r.p.m.
Frictional force (F) = ----------newton
Mean equilibrium speed (N) = (N_1 + N_2)/2 in r.p.m

Mass of the central load = ----------kg.
Weight of the central load (W) = ---------- N
Angle of inclination of the arm to the vertical (α) = ------
Angle of inclination of the link to the vertical (β) = ------

CALCULATION:-

$N^2 = \frac{FM}{BM} \times \left[m + \frac{[M(1+q)]}{2}\right] \times \frac{895}{h}$ (For porter governor) where, $q = \tan\beta / \tan\alpha$

Sensitiveness of the governor $= 2(N_1 - N_2)/ N_1 + N_2 = 2(\omega_2 - \omega_1)/ \omega_2 + \omega_1$

A governor is said to be stable when for every speed within the working range there is a definite configuration i.e.; there is only one radius of rotation of the governor balls at which the governor is in equilibrium. For a stable governor, if the equilibrium speed increases, the radius of governor balls must also increase.

PRECAUTIONS:-

Take reading carefully.
Measure the angle very carefully.
Measure the height of governor carefully.
Speed of governor measure accurate.

Results:

Height of the governor =
Speed of the governor =

Experiment No. - 3

AIM:-To perform experiment on Hartnell Governor to prepare performance characteristic Curves, and to find stability & sensitivity.

APPARATUS USED: - Hartnell Governor.

INTRODUCTION & THEORY: - The function of a governor is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.
The governors may, broadly, be classified as
Centrifugal governor

Inertia governor

The centrifugal governors, may further be classified as follows :
Pendulum type (Watt governor)

Loaded type

Dead weight governor (Porter governor and Proell governor)

Spring controlled governors (Hartnell governor, Hartung governor, Wilson- Hartnell governor and Pickering governor)

Hartnell Governor :- A Hartnell governor is a spring loaded governor as shown in fig.-A. It consists of two bell crank levers pivoted at the points O,O to the frame. The frame is attached to the governor spindle and therefore rotates with it. Each lever carries a ball at the end of the vertical arm OB and a roller at the end of the horizontal arm OR. A helical spring in compression provides equal downward forces on the two rollers through a collar on the sleeve. The spring force be adjusted by screwing at nut up or down on the sleeve.

OBSERVATION :-

Mass of the each ball (m) = ----------kg.
Mass of the sleeve (M)= ---------- Newton's
Minimum radius of rotation (r_1) =---------- metres
Maximum radius of rotation (r_2) = ----------metres
Angular speed of the governor at minimum radius (ω_1) = ---------- rad./s

Angular speed of the governor at maximum radius (ω_2) = ----------rad. /s
Spring force exerted on the sleeve at ω_1 (S_1) =---------- Nt.
Spring force exerted on the sleeve at ω_2 (S_2) =---------- Nt.

Length of the vertical or ball arm of the lever (x) = ----------metres.
Length of the horizontal or sleeve arm of the lever (y) = ----------metres.

Distance of fulcrum 'O' from the governor axis or the radius of rotation when thegovernor is in mid-position (r) =----------metres.

- Minimum equilibrium speed (N_1) =------- r.p.m.
- Minimum equilibrium speed (N_2) =------- r.p.m.
- Frictional force (F) = ----------newton's
- Angle of inclination of the arm to the vertical (α) = ------
- Angle of inclination of the link to the vertical (β) = ------

CALCULATION :-

- $Fc = Fc_1+(Fc_2 - Fc_1)x\frac{(r- r_1)}{(r_2-r_1)} = Fc_2 - (Fc_2 - Fc_1) \times \frac{(r_1-r)}{(r_2-r_1)}$ (when friction is taken)
- $N^2 = Fc \times 3600/4\pi^2 m.r$
- Sensitiveness of the governor = $2(N_1 - N_2)/ N_1 + N_2 = 2 (\omega_2 - \omega_1)/ \omega_2 + \omega_1$
- A governor is said to be stable when for every speed within the working range there is a definite configuration i.e; there is only one radius of rotation of the governor balls at which the governor is in equilibrium. For a stable governor, if the equilibrium speed increases, the radius of governor balls must also increase.

PRECAUTIONS :-

- Take reading carefully.
- Measure the angle very carefully.
- Measure the height of governor carefully.
- Speed of governor measure accurate.

Results:

- Height of the governor =
- Speed of the governor =

Experiment No. - 4

AIM :- To study gyroscopic effects through models.

APPARATUS USED:- Models of Aero plane and ship.

THEORY :- The earliest observation and studies on gyroscopic phenomenon carried out during Newton's time. These were made in the context of the motion of our planet which in effect in a massive gyroscopic. The credit of the mathematical foundation of the principles of gyroscopic motion goes to Euler who derived at set of dynamic equation relating applied mechanics and moment inertia, angular acceleration and angular velocity in many machines, the rotary components are forced to turn about their axis other than their own axis of rotation and gyroscopic effects are thus setup. The gyroscopes are used in ships to minimize the rolling & pitching effects of water.

Effect of the Gyroscopic Couple on an Aeroplane :-

1. When the aeroplane takes a right turn under similar conditions. The effect of the reactive gyroscopic couple will be to dip the nose and raise the tail of the aeroplane.
2. When the engine or propeller rotates in anticlockwise direction when viewed from the rear or tail end and the aeroplane takes a left turn, then the effect of reactive gyroscopic couple will be to dip the nose and raise the tail of the aeroplane.
3. When the aeroplane takes a right turn under similar conditions as mentioned in note 2 above, the effect of reactive gyroscopic couple will be to raise the nose and dip the tail of the aeroplane.
4. When the engine or propeller rotates in clockwise direction when viewed from the front and the aeroplane takes a left turn, then the effect of reactive gyroscopic couple will be to raise the tail and dip the nose of the aeroplane.
5. When the aeroplane takes a right turn under similar conditions as mentioned in note 4 above, the effect of reactive gyroscopic couple will be to raise the nose and dip the tail of the aeroplane.

The effect of gyroscopic couple on the naval ship in the following three cases :
1- Steering 2- Pitching and 3- Rolling

Effect of the Gyroscopic Couple on a Naval ship during Steering :-

1. When the ship steers to the right under similar conditions as discussed above, the effect of the reactive gyroscopic couple will be to raise the stern and lower the bow.
2. When the rotor rotates in the anticlockwise direction, when viewed from the stern and the ship is steering to the left, then the effect of reactive gyroscopic couple will be to lower the bow and raise the stern.
3. When the ship is steering to the right under similar conditions as discussed in note 2 above, then the effect of reactive gyroscopic couple will be to raise the bow and lower the stern.
4. When the rotor rotates in the clockwise direction when viewed from the bow or fore end

and the ship is steering to the left, then the effect of reactive gyroscopic couple will be to raise the stern and lower the bow.

5. When the ship is steering to the right under similar conditions as discussed in note 4 above, then the effect of reactive gyroscopic couple will be to raise the bow and lower the stern.
6. The effect of the reactive gyroscopic couple on a boat propelled by a turbine taking left or right turn is similar as discussed above.

Effect of the Gyroscopic Couple on a Naval ship during Pitching :-

1. The effect of the gyroscopic couple is always given on specific position of the axis of spin, i.e. whether it is pitching downwards or upwards.
2. The pitching of a ship produces forces on the bearings which act horizontally and perpendicular to the motion of the ship.
3. The maximum gyroscopic couple tends to shear the holding-down bolts.
4. The angular acceleration during pitching.

$$\alpha = d^2\theta/dt^2 = -\Phi(\omega_1)^2 \sin \omega_1 t$$ (Differentiating $d\theta/dt$ with respect to t)

The angular acceleration is maximum, if $\sin \omega_1 t = 1$

Therefore Maximum angular acceleration during pitching,

$$\alpha_{max} = \Phi(\omega_1)^2$$

Effect of the Gyroscopic Couple on a Naval ship during Rolling:- We know that, for the effect of gyroscopic couple to occur, the axis of precession should always be perpendicular to the axis of spin. If, however, the axis of precession becomes parallel to the axis of spin, there will be no effect of the gyroscopic couple acting on the body of the ship.

In case of rolling of a ship, the axis of precession (i.e. longitudinal axis) is always parallel to the axis of spin for all positions. Hence, there is no effect of the gyroscopic couple acting on the body of a ship.

APPLICATIONS :- The gyroscopic principle is used in an instrument or toy known as gyroscope. The gyroscopes are installed in ships in order to minimize the rolling and pitching effects of waves. They are also used in aeroplanes, monorail cars, gyrocompasses etc.

Experiment No. - 5

AIM :- To determine gyroscopic couple on Motorized Gyroscope.

APPARATUS USED:- Four wheeler & two wheeler vehicle.

THEORY :- When a body moves along a curved path with a uniform linear velocity, a force in the direction of centripetal acceleration (known as centripetal force) has to be applied externally over the body, so that it moves along the required curved path. This external force applied is known as active force. When a body, itself, is moving with uniform linear velocity along a circular path, it is subjected to the centrifugal force radially outwards. This centrifugal force is called reactive force.
The change in angular momentum is known as active gyroscopic couple ($I.\omega.\omega_p$). When the axis of spin itself moves with angular velocity ω_p, the disc is subjected to reactive couple whose magnitude is same (i.e. $I.\omega.\omega_p$) but opposite in direction to that of active couple.

OBSERVATION :-

- Mass of the vehicle (m) =---------- kg.
- Weight of the vehicle (W) =---------- Newtons.
- Radius of the wheels (r_w) = ---------- metres.
- Radius of curvature (R) =----------meters.
- Distance of centre of gravity, vertically above the road surface(h) = ----------metres,
- Width of track (x) = ----------metres,
- Mass moment of inertia of one of the wheels(I_w) = ----------kg-m^2
- Angular velocity of the wheels or velocity of spin(ω_w) =---------- rad/sec
- Mass moment of inertia of the rotating parts of the engine(I_E) = ---------- kg-m^2
- Angular velocity of the rotating parts of the engine (ω_E) =---------- rad/sec
- Gear ratio = ω_E / ω_w
- Linear velocity of the vehicle (ν) = $r_w \omega_w$
- Angle of heal (θ) =--------- rad.

CALCULATION :-

For 4-wheel drive:

- Gyroscopic couple due to 4 wheels, $C_w = 4\ I_w\ \omega_w\ \omega_p$ where, ($\omega_p = \nu/R$)
- Gyroscopic couple due to the rotating parts of the engine, , $C_E = I_E\ \omega_E\ \omega_p = I_w.G.\ \omega_w.\ \omega_p$
- Net Gyroscopic couple, $C = C_w \pm C_E$

For 2-wheel drive:

- Gyroscopic couple, $C_1 = \nu\ (2\ I_w \pm I_E.G)\ \cos\theta\ /R.\ r_w$

PRECAUTIONS :-

- When rotating parts of the engine rotate in opposite directions, then negative sign is used.
- When C_E ›C_w, then C will be negative. Thus the reaction will be vertically downwards on the outer wheels and vertically upwards on the inner wheels.
- The gyroscopic couple will act over the vehicle outwards i.e. in the anticlockwise direction when seen from the front of the vehicle. The tendency of this couple is to overturn the vehicle in outward direction.

RESULTS :-

- Gyroscopic couple of four wheel drive is =---------- N-m.
- Gyroscopic couple of two wheel drive is = ----------N-m.

Experiment No. – 6

AIM: - To perform the experiment for static balancing on static balancing machine.

APPARATUS USED: - Static Balancing m/c.

THEORY :- A system of rotating masses is said to be in static balance if the combined mass centre of the system lies on the axis of rotation. Whenever a certain mass is attached to a rotating shaft, it exerts some centrifugal force, whose effect is to bend the shaft and to produce vibrations in it. In order to prevent the effect of centrifugal force, another mass is attached to the opposite side of the shaft. The process of providing the second mass in order to counteract the effect of the centrifugal force of the first mass, is called balancing of rotating masses.

The following cases are important from the subject point of view :

1. Balancing of a single rotating mass by a single mass rotating in the same plane.
2. Balancing of a single rotating mass by two masses rotating in different planes.
3. Balancing of different masses rotating in the same plane.
4. Balancing of different masses rotating in different planes.

PROCESURE :- Remove the belt, the value of weight for each block is determined by clamping each block in turn on the shaft and with the cord and container system suspended over the protractor disc, the number of steel balls, which are of equal weight are placed into one of the containers to exactly balance the blocks on the shaft. When the block becomes horizontal, the number of balls N will give the value of wt. for the block.

For finding out W_r during static balancing proceed as follow:

1. Remove the belt.
2. Screw the combined hook to the pulley with groove. This pulley is diff. than the belt pulley.
3. Attached the cord end of the pans to above combined hook.
4. Attached the block no.-1 to the shaft at any convenient position and in vertical downward direction.
5. Put steel balls in one of the pans till the blocks starts moving up. (upto horizontal position).
6. Number of balls give the W_r value of block-1. repeat this for 2-3 times and find the average no. of balls.
7. Repeat the procedure for other blocks.

OBSERVATION :-

S.no.	**Plane**	**Mass (m) kg.**	**Radius ® m**	**Cent. Force ÷ ω^2 (m.r) kg-m**	**Distance from plane x(l) m**	**Couple ÷ ω^2 (m.r.l) kg- m^2**

CALCULATION :- The balancing masses and angular positions may be determined graphically as given below :-

1. First of all, draw the couple polygon from the data which are calculated in table to some suitable scale. The vector distance represents the balanced couple. The angular position of the balancing mass is obtained by drawing, parallel to vector distance. By measurement will be find the angle.
2. Then draw the force polygon from the data, which are calculated in table to some suitable scale. The vector distance represents the balanced force. The angular position of the mass is obtained by drawing, parallel to vector distance. By measurement will be find the angle in the clockwise direction from mass.

PRECAUTIONS :-

1. Couple should be represented by a vector drawn perpendicular to the plane of the couple.
2. Angular position measure carefully in clockwise direction.
3. Vector diagram should be represent with suitable scale.

Results:

Weight of the Block = No. of the ball collected into pan =

Experiment No. - 7

AIM :- To perform the experiment for dynamic balancing on dynamic balancing machine.

APPARATUS USED:- Dynamic balancing m/c.

THEORY: - When several messes rotates in different planes, the centrifugal force, in addition to being out of balance, also forms couples. A system of rotating masses is in dynamic balance when there does not exit any resultant centrifugal force as well as resultant couple.

Pivoted-cradle Balancing M/C:-

In this type of m/c., the rotor to be balanced is mounted on half-bearing in a rigid carriage and is rotated by a drive motor through a universal joint. Two balancing planes A and B are chosen on the rotor. The cradle is provided with pivots on left and right sides of the rotor which are purposely adjusted to coincide with the two correction planes. Also the pivots can be put in the locked or unlocked position. Thus, if the left pivot is released, the cradle and the specimen are free to oscillate about the locked (right) pivot. At each end of the cradle, adjustable springs and dashpots are provided to have a single degree of freedom system. Usually, their natural frequency is tuned to the motor speed.

PROCEDURE:-

First either of the two pivots say left is locked so that the readings of the amount and the angle of location of the correction in the right hand plane can be taken. These readings will be independent of any unbalance in the locked plane as it will have no moment about the fixed pivot.

A trial mass at a known radius is then attached to the right hand plane and the amplitude of oscillation of the cradle is noted.

The procedure is repeated at various angular positions with the same trial mass.

A graph is then plotted of amplitude Vs angular positions of the trial mass to know the optimum angular position for which amplitude is minimum. Then at this position, the magnitude of the trial mass is varied and the exact amount is found by trial and error which reduces the unbalance to almost zero.

After obtaining the unbalance in one plane, the cradle is locked in the right hand pivot and released in the left hand pivot. The above procedure is repeated to obtain the exact balancing mass required in that plane.

Usually, a large number of test runs are required to determine the exact balance masses in this type of machine. However, by adopting the following procedure, the balance masses can be obtained by making only four test runs :

First make a test run without attaching any trial mass and note down the amplitude of the cradle vibrations. Then attach a trial mass m at some angular position and note down the amplitude of the cradle vibrations by moving the rotor at the same speed. Next detach the trial mass and again attach it at 90° angular position relative to the first position at the same radial distance. Note down the amplitude by rotating the rotor at the same speed. Take the last reading in the same manner by fixing the trial mass 180°. Let the four reading be

OBSERVATION:-

S.No.	Trial Mass	Amplitude
1.	0	X_1
2.	m at 0°	X_2
3.	m at 90°	X_3
4.	m at 180°	X_4

CALCULATION & CONSTRUCTION :-

Draw a triangle OBE by taking OE = 2 X_1, OB = X_2 and BE = X_4. Mark the mid-point Aon OE. Join AB.
Now, **OB = OA + AB**

Where, OB = Effect of unbalance mass + Effect of the trial mass at 0°OA = Effect of unbalanced mass
Thus, AB represents the effect of the attached mass at 0°. The proof is as follows:
Extend BA to D such that AD = AB. Join OD and DE. Now when the mass m is attached at 180° at the same radial distance and speed, the effect must be equal and opposite to the effect at 0° i.e. if AB represents the effect of the attached mass at 0°, AD represents the effect of the attached mass at180°.
Since, **OD = OA +AD**

OD must represent the combined effect of unbalance mass and the effect of the trial mass at180° (X_4).

Now, as the diagonals of the quadrilateral OBED bisect each other at A, it is a parallelogram which means BE is parallel and equal to OD. Thus, BE also represents the combined effect of
unbalance mass and the effect of the trial mass at 180° or X_4 which is true as it is made in the construction.

Now as OA represents the unbalance, the correction has to be equal and opposite of it or AO. Thus, the correction mass is given by

m_c = m.OA/AB at an angle **θ** from the second reading at **0°**.

Results:

Trials mass (Angle) = Amplitude (No of balls collected into pans)

Experiment No. - 8

AIM :-Determine the moment of inertial of connecting rod by compound pendulum method and tri-filer suspension pendulum.

APPARATUS USED:- Compound Pendulum and tri-filar suspension system setup.

THEORY :-

Compound Pendulum: - When a rigid body is suspended vertically, and it oscillates with a small amplitude under the action of the force of gravity, the body is known as compound pendulum.

Trifler Suspension (Torsional Pendulum) :- It is also used to find the moment of inertia of a body experimentally. The body (say a disc or flywheel) whose moment of inertia is to be determined is suspended by three long flexible wires A, B and C, as shown in fig.-b. When the body is twisted about its axis through a small angle θ and then released, it will oscillate with simple harmonic motion.

PROCEDURE :-

For compound pendulum :

- Measure the mass of the body.
- Lift the pendulum from the mean position till for suitable height (h).
- Release the pendulum and note down the number of oscillations and time period taken tocomplete the number of oscillation.
- Repeat the above steps for more readings.

For tri-filar suspension :

- Measure the mass of the disc and connecting rod.
- Lift the connecting rod from the mean position till for suitable height (h).
- Release the connecting rod and note down the number of oscillations and time periodtaken to complete the number of oscillation.
- Repeat the above steps for more readings.

OBSERVATION :-

For compound pendulum :

- Mass of the body (m) = ------- kg.
- Distance of point of suspension 'O' from the C.G. of the body (h) = ------- metres.
- Frequency of oscillation (n) = ------ Hz..

For tri-filar suspension :

- Mass of the body (m) = --------kg.
- Distance of each wire from the axis of the disc (r) = ------- metres.
- Length of each wire (l) = -----metres.

S.No.	Number of oscillations	Time period taken

CALCULATION :-

For compound pendulum :

- Frequency of oscillation, $n = 1/ t_p = \frac{1}{2\pi} \times \sqrt{g.h/ k_G + h^2}$
- $I = m.(k_G)^2$ in kg.-m^2

For tri-filar suspension:

- Frequency of oscillation, $n = 1/ t_p = \frac{r}{2\pi k_G} \times \sqrt{g./ l}$
- $I = m.(k_G)^2$ in kg.-m^2

Results:

For compound pendulum:

Moment of inertia =

For tri-filar suspension:

Moment of inertia =

Viva Questions

1. What is the purpose of conducting experiments on Watt and Porter Governors?
2. How do you prepare performance characteristic curves for Watt and Porter Governors?
3. What factors are considered to determine stability in Watt and Porter Governors?
4. How is sensitivity determined in Watt and Porter Governors?
5. What are the objectives of performing experiments on the Proell Governor?
6. Explain the process of preparing performance characteristic curves for the Proell Governor.
7. How is stability assessed in the Proell Governor?
8. What factors affect the sensitivity of the Proell Governor?
9. Hartnell Governor: 9. Why is it important to perform experiments on the Hartnell Governor?
10. Describe the procedure for preparing performance characteristic curves for the Hartnell Governor.
11. How is stability determined in the Hartnell Governor?
12. What factors influence the sensitivity of the Hartnell Governor?
13. What are gyroscopic effects, and why are they important to study?
14. How can gyroscopic effects be demonstrated and analyzed using models?
15. Explain the fundamental principles behind gyroscopic effects.
16. . What is the gyroscopic couple, and how is it determined on a motorized gyroscope?
17. What factors affect the magnitude of the gyroscopic couple?
18. Why is the gyroscopic couple significant in the operation of rotating systems?
19. How is the experiment for static balancing performed on a static balancing machine?
20. What is the importance of achieving static balance in rotating systems?
21. Explain the compound pendulum method for determining the moment of inertia of a connecting rod.
22. Describe the experimental setup and calculations involved in finding the moment of inertia using the compound pendulum method.
23. What is the triflair suspension pendulum method, and how is it used to determine the moment of inertia of a connecting rod?
24. Discuss the advantages of the triflair suspension pendulum method over other techniques for measuring the moment of inertia of a connecting rod.