Ch. Devi Lal State Institute of Engg & Tech
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INSTRUCTION MANUAL

OF

MOTORISED GYROSCOPE

MOTORISED GYROSCOPE

CONTENTS:

MOTORISED GYROSCOPE

1.0 THEORY:

(A) DEFINITIONS:

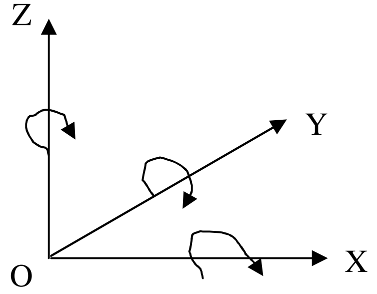

Fig. 1: Axis of spin, Couple and Precession

OX- Axis of Spin
OY- Axis of Couple
OZ- Axis of Precession

(a) Axis of Spin:

If a body is revolving about an axis, the latter is known as axis of spin.

(b) Gyroscopic Effect:

To a body revolving (or spinning) about an axis say OX, if a couple represented by a vector OY perpendicular to OX is applied, then the body tries to precess about an axis OZ which is perpendicular both to OX and OY. Thus the plane of spin, plane of precession and plane of gyroscopic couple are mutually perpendicular. The above combined effect is known as precessional or gyroscopic effect.

(c) Precession:

Precession means the rotation about the third axis OZ, which is perpendicular to both the axis of spin OX and that of couple OY.

(d) Axis of Precession:

The third axis OZ is perpendicular to both the axis of spin OX and that of couple OY is known as axis of precession.

(e) Gyroscope:

Gyroscope is a body while spinning about an axis is free to rotate in other directions under the action of external forces. For example locomotive, automobile and aero plane making a turn. In certain cases the gyroscope forces are undesirable whereas in other cases the gyroscopic effect may be utilized in developing desirable forces. For minimizing rolling, yawing and pitching of ship or air-craft Gyroscope is used. Balloons use Gyroscope for controlling direction.

(B) GYROSCOPIC COUPLE OF A PLANE DISC:

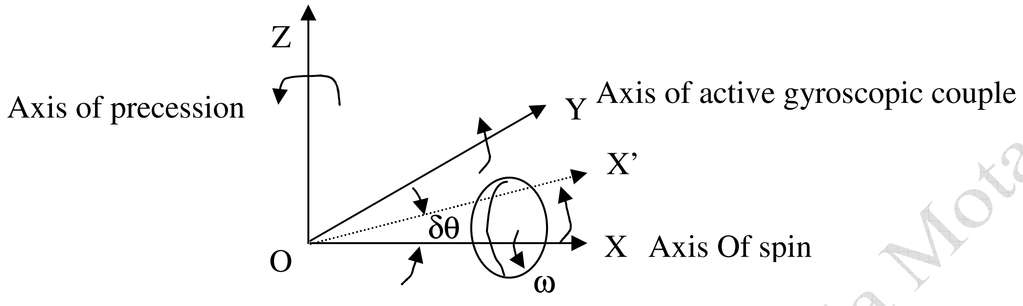

Fig. 2: Gyroscopic couple of a spinning disc

Let a disc of weight W and having a moment of inertia I be spinning with an angular velocity ω about axis OX in an anti clockwise direction viewing from front. Therefore, the angular momentum of disc is Iω. Applying right hand screw rule, the sense of vector representing the angular momentum of disc which is also a vector quantity will be in the direction OX as shown. A couple, whose axis is OY perpendicular to OX and is in the plane XOZ, is now applied to precess the axis OX.

Let axis OX turn through a small angular displacement δθ about axis OZ and in the plane XOY, from OX to OX' in time δt. The couple applied produces a change in the direction of angular velocity, the magnitude remaining constant. This change is due to the velocity of precession. Therefore, 'OX' represents the angular momentum after time δt.

$\therefore$ Change of angular momentum = $\overrightarrow{OX'} - \overrightarrow{OX} = \overrightarrow{XX'}$

$$\text{or rate of change of angular momentum} = \frac{\text{Angular Displacement}}{\text{Time}}$$

$$= \frac{\overrightarrow{XX'}}{\delta t}$$

But rate of change of angular momentum = Couple applied, C

Where, XX' = OX x δθ in direction of XX'

= (Iω)δθ

$$\therefore C = I\omega \frac{\delta\theta}{\delta t}$$

and in the limit, when δt is very small,

$$C = I\omega \frac{d\theta}{dt}$$

Let $d\theta / dt = \omega_p$, the angular velocity of precession of yoke, which is uniform and is about axis OZ.

Thus, we get $C = I\omega.\omega_p$

The direction of the *couple applied* on the body is anticlockwise when looking in the direction XX' and in the limit this is perpendicular to the axis of ω and ω_p.

In the supplied apparatus, the reaction couple exerted by the body on its frame is *equal* in magnitude to that C, but *opposite* in direction.

2.0 OBJECTIVES:

1. Observation of Gyroscopic behavior (Two laws of stability).
2. Experimental justification of the equation $C = I\omega.\omega_p$ for calculating the gyroscopic couple by observation and measurements of results for independent variation in applied couple C and precession ω_p.

3.0 APPARATUS:

Schematic arrangement of the gyroscope is shown in Fig. 3. The motorized gyroscope consists of a disc rotor mounted on a horizontal shaft rotates about XX axis in two ball bearings of one frame. This frame can swing about YY axis in bearings provided in the yoke type frame No. 2. The rotor shaft is coupled to a motor mounted on a trunion frame having bearings in a yoke frame, which is free to rotate about vertical axis ZZ. Thus freedom of rotation about three perpendicular axis is given to the rotor (or the disc can be rotated about three perpendicular axis). Angular scale and pointer fitted to frame helps to measure precession rate. In steady position, frame No.1 is balanced by providing a weight pan on the opposite side of the motor.

4.0 SUGGESTED EXPERIMENTAL WORK:

RULE NO.1:

”The spinning body exerts a torque or couple in such a direction which tends to make the axis of spin coincide with that of the precession”.

To study the rule of gyroscopic behaviour following procedure may be adopted.

Step1: Balance the initial horizontal position of the rotor.
Step2: Start the motor by increasing the voltage with the autotransformer, and wait until it attains constant speed.

Step3: Precess the yoke frame No.2 about vertical axis by applying necessary force by hand to the same (in the clockwise sense seen from above).
Step4: It will be observed that the rotor frame swings about the horizontal axis YY. Motor side is seen coming upward and the weight pan side going downward.
Step5: Rotate the vertical yoke axis in the anti clockwise direction seen from above and observe that the rotor frame swing in opposite sense (as compared to that in previous case following the above rule).

RULE NO.2:

"The spinning body precesses in such a way as to make the axis of spin coincide with that of the couple applied, through 90^o turn".

Step1: Balance the rotor position on the horizontal frame.
Step2: Start the motor by increasing the voltage with the autotransformer and wait till the disc attains constant speed. Note down the speed.
Step3: Put weight (0.5 kg, 1 kg, or 2 kg) in the weight pan, and start the stop watch to note the time in seconds required for precession, through 60^o or 45^o etc.
Step4: The vertical yoke precesses about OZ axis as per the rule No.2
Step5: Speed may be varied by the autotransformer provided on the control panel.

5.0 RESULTS & DISCUSSIONS:

1. Fill up the data sheet.
2. Calculate the gyroscopic couple by the equation $C = I\omega.\omega_p$ for different sets of readings for different weight and different speed..
3. Compare the gyroscopic Couple calculated and observed.

6.0 SAMPLE DATA SHEET:

Name of Experiment: **Experimental justification of the equation $C = I\omega.\omega_p$**

Weight of Rotor, kg :
Rotor Diameter, mm :
Rotor Thickness, mm :
Moment of inertia of the disc, coupling and motor rotor about central axis, I, kg cm sec^2 :
Distance of bolt of weight pan from disc centre, L, cm :

S. No.	Weight, W (kg)	Time required for precession, dt (sec)	Speed, N (rpm)	Angle of precession, dθ (degree)

7.0 APPENDIX-1: Critical data of experiment

Weight of Rotor, kg : 6.91
Rotor Diameter, mm : 300
Rotor Thickness, mm : 10.0
Moment of inertia of the disc,: coupling and motor rotor about central axis, I, kg cm sec^2

$$\frac{W}{g} \times \frac{D^2}{8} = \frac{6.91}{981} \times \frac{(30.0)^2}{8}$$

$$= 0.7924$$

Distance of bolt of weight pan: from disc centre, L, cm 19.0
Motor : Fractional H.P. single phase. 6000 rpm- AC/DC Type
Autotransformer provided for speed regulation.

8.0 APPENDIX-2: Sample Experimental data

Weight of Rotor, kg : 6.91
Rotor Diameter, mm : 300
Rotor Thickness, mm : 10.0
Moment of inertia of the disc,: 0.7924
coupling and motor rotor
about central axis, I, kg cm sec^2
Distance of bolt of weight pan: 19.0
from disc centre, L, cm

S. No.	Weight, W (kg)	Time required for precession, dt (sec)	Speed, N (rpm)	Angle of precession, dθ (degree)
1.	0.5	14	1730	45

9.0 APPENDIX-3: Data Analysis

Angular velocity of disc in rad/sec

$$\omega = \frac{2\,\pi\,N}{60}$$

$$\omega = \frac{2\,\pi \times 1730}{60}$$

$$= 181.17 \text{ rad/sec}$$

Angular velocity of precession of yoke ω_p in rad/sec

$$\omega_p = \frac{d\theta}{dt}$$

Where $d\theta$ is in radian $= 45 \times \pi/180$

$= 0.785$ rad

$\omega_p = 0.785/14$

$= 0.0561$ rad/sec

Experimental justification of the equation:

$\mathbf{C = I\omega.\omega_p}$

$= 0.7924 \times 181.17 \times 0.0561$

$= 8.05$ kg.cm

$C_{actual} = W \times L$

$= 0.5 \times 19.0$

$= 9.5$ kg cm

10.0 PRECAUTIONS:

1. ω_p is to be calculated for short duration of time, as the balance of rotation of disc about the horizontal axis YY due to application of torque, because of which ω_p goes on reducing gradually.
2. Avoid using the tachometer while taking the reading of time as it will reduce the time taken for precession.
3. Autotransformer should be varied gradually.

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STATIC & DYNAMIC BALANCING APPARATUS

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STATIC & DYNAMIC BALANCING APPARATUS

1.0 OBJECTIVE:

To check experimentally the normal method of calculating the position of counter balancing weight in rotating mass system.

2.0 APPRATUS:

The apparatus basically consists of a steel shaft mounted in bell bearings in a stiff rectangular main frame. A set of six blocks of different weights is provided and may be clamped in any position on the shaft, and also be easily detached from the shaft.

A disc carrying a circular protractor scale is fitted to one side of the rectangular frame. Shaft carries a disc and rim of this disc is grooved to take a light cord provided with two cylindrical metal containers of exactly the same weight.

A scale is fitted to the lower member of the main frame and when used in conjunction with the circular protractor scale, allows the exact longitudinal and angular position of each adjustable block to be determined.

The shaft is driven by a 230 volts single phase 50 cycles electric motor, mounted under the main frame, through a belt.

For static balancing of individual weights the main frame is suspended to the supported frame by chains and in this position the motor driving belt is removed.

For dynamic balancing of the rotating mass system the main frame is suspended from the support frame by two short links such that the main frame and the supporting frame are in the same plane.

3.0 SUGGESTED EXPERIMENTAL WORK:

STATIC BALANCING (See Fig.2)

Remove the drive belt. The value of Wr. 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 Wr. for the block.

For finding out 'Wr' during static balancing proceed as follows:

1. Remove the belt.
2. Screw the combined hook to the pulley with groove. (This pulley is different than the belt pulley).
3. Attach the cord-ends of the pans to the above combined hook.
4. Attach 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 block starts moving up. (Upto horizontal position).

6. Number of balls give the ‘Wr’ value of block 1. Repeat this for 2-3 times and find the average no. of balls.
7. Repeat the procedure for other blocks.

DYNAMIC BALANCING (Ref. Fig.1)

It is necessary to leave the machine before the experiment. Using the values of Wr. Obtained as above, and if the angular positions and planes of rotation of three of four blocks are known, the student can calculate the position of the other block(s) for balancing of the complete system. From the calculations, the student finally clamps all the blocks on the shaft in their appropriate positions. Replace the motor belt, transfer the main frame to its hanging position and then by running the motor, one can verify that these calculations are correct ad blocks are perfectly balanced.

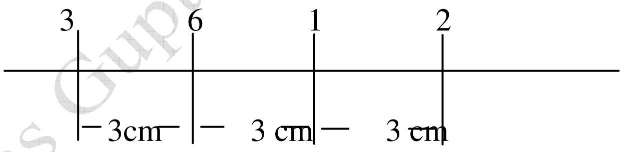
4.0 SAMPLE DATA SHEET:

DYNAMIC BALANCING OF 4 BLOCKS

Obtain Dynamic Balance of a set of four blocks with unbalance as shown, by properly positioning them in angular and lateral position on the shaft.

No.	Unbalance (No of Balls)
1.	54
2.	56
3.	59
4.	64
5	67
6	70

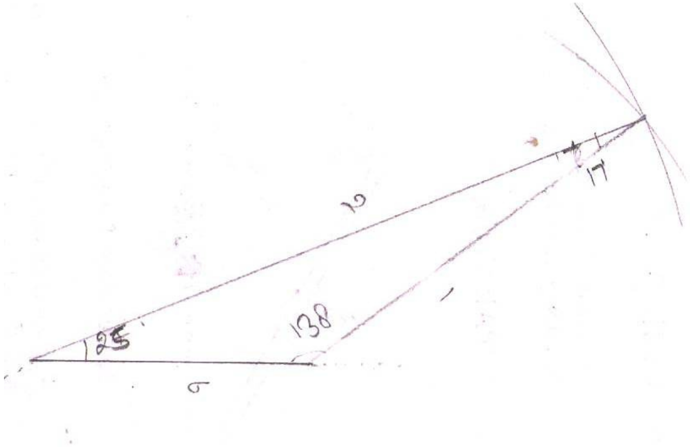
Distance between each block is 3 cm. The arrangement is as shown in Fig



First of all assume that reference plane is 3. Then find out the couples for blocks 1,2 and 6 W.R.T. 3 and then draw couple polygon.

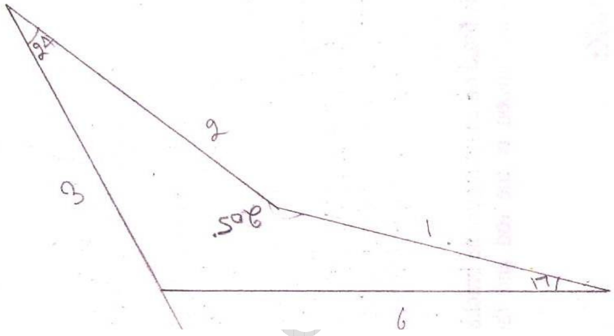
Plane	Wr.	Dist. From No.-3	Couple
3	59	0.	0
6	70	3.	210
1	54	6.	324
2	56	9.	504

Block no. 6 is assumed in horizontal position as shown.



COUPLE POLYGON

Angular positions at 1 and 2 nos. of blocks is obtained from the couple polygon w.r. to block no.6.



FORCE POLYGON

Angular position of No.3 block is obtained from the force polygon and its magnitude is also obtained $F_3 = 70$. Adjust all angular and lateral position properly and find the shaft rotates without vibrations.

5.0 PRECAUTIONS:

1.0 Do not run motor for more time in unbalanced position.

2.0 Place the weight/balls gently in the pan. While placing the balls the pan should be hold gently and check that it should not jump its position.

3.0 Weight setting gauge should be check gently.

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UNIVERSAL GOVERNOR APPARATUS

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UNIVERSAL GOVERNOR APPARATUS

1.0OBJECTIVES:

1. For all types of Governors (Watt, Porter, Proell & Hartnell)

(a) Determination of characteristic curve of governor (spindle) speed against sleeve displacement.

(b) Plotting of Governor characteristic curves of radius of rotation of the ball center against controlling force.

2.0 APPARATUS:

The apparatus is designed to exhibit the characteristics of the spring-loaded governor and dead weight governor. The apparatus consists of a main spindle driven by a variable speed D.C. Motor with variable speed control unit. The motor is connected through ‘V’ belt to drive shaft. Motor and main shaft are mounted on a rigid M.S. Base plate in vertical fashion. The spindle is supported in ball bearings.

The optional governor mechanism can be mounted on spindle. Speed control unit can control the spindle speed. And counter hole over the spindle shaft allows the use of a hand tachometer to determine the speed. A graduated scale is fixed to the sleeve and guided in vertical direction, which measures the sleeve displacement.

The centre sleeve of the porter and proell governors incorporates a weight sleeve to which weights may be added. The Hartnell Governor provides means of varying spring rate, initial compression level and mass of rotating weight. This enables the Hartnell Governor, to be operated as a stable or unstable governor.

3.0 EXPERIMENTAL PROCEDURE:

The governor mechanism under test is fitted with the chosen rotating weights and spring, where applicable and inserted into the drive unit. The following simple procedure may then be follows:

- Connect the motor to speed control unit using four way cable provided.
- The control unit is switched ON and the speed control slowly rotated, increasing the governor speed unit the centre sleeve rises off the lower stop and aligns with the first division on the graduated scale.
- The sleeve position and speed are then recorded. Speed may be determined using a hand tachometer on the spindle. The governor speed is then increased in steps to give suitable sleeve movements, and readings repeated at each stage through out the range of sleeve movement possible.

4.0 RESULTS & DISCUSSIONS:

(a) Graph to be plot:

4. Fill up the data sheet.
5. Note down sleeve displacement 'X' at various speeds 'N'.
6. Find the radius of rotation 'r' at any position.
7. The result may be plotted as curves of speed (on y axis) against sleeve displacement (on x axis).
8. Plot the graph of force (on y axis) v/s radius of rotation (on x axis).
9. Further tests are carried out changing the value of variable at a time to draw curves.

(b) Calculations:

For Watt and Porter Governor

Radius of rotation 'r' can be calculated as follows:

a) Find height $h = (ho - x/2)$
b) Find 'α' by using $\cos \alpha = h/L$
c) Then, $r = 50 + L \sin \alpha$

Force can be calculated as follows:

a) Find the angular velocity 'ω' of the arm and ball about the spindle axis.

$$\omega = \frac{2\pi N}{60} \text{ rad/sec}$$

Where N is the speed of the spindle.

b) Find the centrifugal force acting on the ball

$$\text{Force, } F = \frac{W}{g} \omega^2 \times r_0 \quad \text{in kg}$$

Where g is the acceleration due to gravity. $g = 9.81 \text{ m/sec}^2$

For Hartnell Governor

Radius of rotation 'r' can be calculated as follows:

$$r = ro + \frac{X(a)}{(b)}$$

Where a & b are the length and X is the sleeve displacement.

5.0 SAMPLE DATA SHEET:

Name of Experiment: **Plotting the characteristics curves for any type of governor (Watt, Porter, Proell and Hartnell)**

Name of the student: Semester Batch Session

1. WATT GOVERNOR

Arrangement is shown in Fig.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Initial radius of rotation, R_o, mm = 136
d. Weight of each ball, W, kg = 0.6

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos \alpha = h/L$	Radius of rotation, r $r = 50 + L \sin \alpha$ (cm)	Force F(kg)

2. PORTER GOVERNOR

Arrangement is shown in Fig.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Initial radius of rotation, R_o, mm = 136
d. Weight of each ball, W, kg = 0.6
e. Weight of sleeve, kg = 0.6

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos \alpha = h/L$	Radius of rotation, r $r = 50 + L \sin \alpha$ (cm)	Force F(kg)

3. PROELL GOVERNOR

Arrangement is shown in Fig.

In the Proell Governor, with the use of flyweight (Forming full ball) the governor becomes highly sensitive. Under this conditions large sleeve displacement is observed for very small change in speed. In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Initial radius of rotation, r_o, mm = 141.5
d. Weight of each ball, W, kg = 0.6
e. Weight of sleeve, kg = 0.6
f. Extension of Length BG, mm = 75

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos \alpha = h/L$	Radius of rotation, r $r = 50 + L \sin \alpha$ (cm)	Force F(kg)

4. HARTNELL GOVERNOR

Arrangement is shown in Fig.

a. Length, a, mm = 77
b. Length, b, mm = 122
c. Initial radius of rotation, r_o, mm = 177.5
d. Weight of each ball, W, kg = 0.6
e. Weight of sleeve, kg = 0.6
f. Free height of spring, mm = 102
g. Spring stiffness (P) = 10 & 5 kg/cm.
h. Initial compression of the spring. =

Sr. No.	Sleeve displacement X (mm)	Speed, N (rpm)	Radius of rotation, r $= r_0 + X\,a/b$ (cm)	Force, F (kg)

6.0 PRECAUTIONS:

01. Do not keep the mains “ON’ when trial is complete.
02. Increase the speed gradually.
03. Take the sleeve displacement reading when the pointer remains steady.
04. See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.

05. While closing the test bring the dimmer to zero position and then switch “OFF” the motor.

PERFORMANCE OF WATT GOVERNOR

Following steps are incurred for the performance of Watt governor:

EXPERIMENTAL PROCEDURE:

Step1: Note down the length of each link ‘L’ in mm in data sheet.
Step2: Note down the initial height of governor ‘h_0’ in mm in data sheet.
Step3: Note down the weight of each ball ‘W’ in kg in data sheet.
Step4: The governor mechanism is fitted and inserted into the drive unit.
Step5: Connect the motor to speed control unit using four-way cable provided.
Step6: The control unit is switched ON and the speed control is slowly rotated, increasing the governor speed until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale.
Step7: The sleeve position ‘X’ in mm and speed ‘N’ in rpm are then recorded in the data sheet. Speed may be determined using a hand tachometer on the spindle.
Step8: The governor speed is then increased in steps to give suitable sleeve movements. Step7 is repeated for every reading through out the range of sleeve movement possible.

CALCULATION:

Step9: Find out the actual height ‘h’ in mm of the governor and note down in the data sheet.

$$h = (h_0 - X/2)$$

Step10: Find the angle ‘α’ subtended by the arm with the spindle axis using $\cos \alpha = h/L$ and note down in the data sheet.

Step11: Find the radius of the path of rotation of the ball ‘r’ in mm i.e. horizontal distance from the center of the ball to the spindle axis.

$$r = 50 + L \sin \alpha$$

Step12: Find the angular velocity ‘ω’ in rad/sec of the arm and ball about the spindle axis and note down in the data sheet..

$$\omega = \frac{2\pi N}{60}$$

Step13: Find the centrifugal force ‘F’ in kg acting on the ball

$$\text{Force, } F = \frac{W}{\;} \omega^2 . r$$

g

where, g is the acceleration due to gravity. $g = 9.81$ m/sec^2

SAMPLE DATA SHEET:

Name of Experiment: **To perform experiment on Watt governor and to prepare performance characteristics curves, and to find stability & sensitivity.**

Name of the student: Semester Batch Session

Arrangement is shown in Fig.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Weight of each ball, W, kg = 0.6

S. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos\alpha = h/L$	α (deg)	Radius of rotation, $r = 50 + L \sin\alpha$ (cm)	Angular speed ω rad/sec	Force F (kg)

GRAPH TO PLOT:

Step14: Plot the graph of speed ‘N’ (on y axis) against sleeve displacement ‘X’ (on x axis).
Step15: Plot the graph of force ‘F’ (on y axis) v/s radius of rotation ‘r’ (on x axis).
Step16: Further tests are carried out changing the value of variable at a time to draw curves.

SENSITIVENESS:

For maintaining constant sped of rotation, the movement of sleeve should be as large as possible and the corresponding change of equilibrium speed as small as possible. The bigger the displacement of the sleeve for a given fractional change of speed, the more sensitive is the governor. Sensitiveness is more correctly defined as the ratio of the difference between the maximum and minimum equilibrium speeds to the mean equilibrium speed.

If N_{max} = maximum equilibrium speed
N_{min} = minimum equilibrium speed

N_{mean} = mean equilibrium speed

$$= \frac{N_{max} + N_{min}}{2}$$

$$\text{Then sensitiveness} = \frac{N_{max} - N_{min}}{N_{mean}}$$

A too sensitive governor changes the fuel supply by a large amount when a small change in the speed of rotation takes place. This causes wide fluctuations in the engine speed, resulting in hunting of the governor.

STABILITY:

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

PERFORMANCE OF PORTER GOVERNOR

The Porter governor is a modification of the Watt governor in which a central mass is attached to the sleeve. Arrangement and working is same as of the Watt governor.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Weight of each ball, W, kg = 0.6
d. Weight of sleeve, kg = 0.6
e. Weight on sleeve, kg =

S. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos \alpha = h/L$	α (deg)	Radius of rotation, $r = 50 + L \sin \alpha$ (cm)	Angular speed ω rad/sec	Force F (kg)

PERFORMANCE OF PROELL GOVERNOR

Arrangement is shown in fig.

In the Proell Governor, with the use of flyweight (Forming full ball) the governor becomes highly sensitive. Under this conditions large sleeve displacement is observed for very small change in speed. In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side.

In the Proell governor the extension arms are attached to the links and the balls are attached to the extension links. Again a central mass is attached to the sleeve. Working is same as of the Watt governor/Porter governor.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Weight of each ball, W, kg = 0.6
d. Weight of sleeve, kg = 0.6
e. Weight on sleeve, kg =
f. Extension of length BG, mm = 75

S. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos\alpha = h/L$	α (deg)	Radius of rotation, $r = 50 + L \sin\alpha$ (cm)	Angular speed ω rad/sec	Force F (kg)

PERFORMANCE OF HARTNELL GOVERNOR

Arrangement is shown in fig.

The Hartnell governor is of the spring-loaded type. It consists of two bell crank levers pivoted at points to the frame. The frame is attached to the governor spindle and rotates with it. Each lever carries a ball at the end of the vertical arm and a roller at the other end of the horizontal arm. A helical compression spring provides equal downward forces on the two rollers through the sleeve. The spring force may be adjusted by the nut.

Following steps are incurred for the performance of Watt governor:

EXPERIMENTAL PROCEDURE:

Step1: Note down the length ‘a’ and ‘b’ in mm in data sheet.
Step2: Note down the initial radius of rotation ‘r_0’ in mm in data sheet.
Step3: Note down the weight of each ball ‘W’ in kg in data sheet.
Step4: Note down the weight of the sleeve.
Step5: Note down the free height of spring in mm in data sheet.
Step6: Note down the spring stiffness of the spring in kg/cm in data sheet.
Step7: The governor mechanism is fitted and inserted into the drive unit.
Step8: Note down the initial compression of the spring in mm in data sheet.
Step9: Connect the motor to speed control unit using four-way cable provided.
Step10: The control unit is switched ON and the speed control is slowly rotated, increasing the governor speed until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale.
Step11: The sleeve position ‘X’ in mm and speed ‘N’ in rpm are then recorded in the data sheet. Speed may be determined using a hand tachometer on the spindle.
Step8: The governor speed is then increased in steps to give suitable sleeve movements. Step7 is repeated for every reading through out the range of sleeve movement possible.

CALCULATION:

Step9: Find the radius of the path of rotation of the ball ‘r’ in mm i.e. horizontal distance from the center of the ball to the spindle axis.

$$r = ro + \frac{X(a)}{(b)}$$

Step10: Find the angular velocity ‘ω’ in rad/sec of the arm and ball about the spindle axis and note down in the data sheet..

$$\omega = \frac{2\pi N}{\quad}$$

Step11: Find the centrifugal force ‘F’ in kg acting on the ball

$$\text{Force, } F = \frac{W}{g}\,\omega^2.r$$

where, g is the acceleration due to gravity. $g = 9.81\ m/sec^2$

SAMPLE DATA SHEET:

Name of Experiment: **To perform experiment on Hartnell governor and to prepare performance characteristics curves, and to find stability & sensitivity.**

Name of the student: Semester Batch Session

a. Length, a, mm = 77
b. Length, b, mm = 122
c. Initial radius of rotation, r_o, mm = 177.5
d. Weight of each ball, W, kg = 0.6
e. Weight of sleeve, kg = 0.6
f. Free height of spring, mm = 102
g. Spring stiffness (P) = 10 & 5 kg/cm.
h. Initial compression of the spring. =

Sr. No.	Sleeve displacement X (mm)	Speed, N (rpm)	Radius of rotation, r $= r_0 + X\ a/b$ (cm)	Angular speed ω rad/sec	Force, F (kg)

GRAPH TO PLOT:

Step12: Plot the graph of speed ‘N’ (on y axis) against sleeve displacement ‘X’ (on x axis).

Step13: Plot the graph of force ‘F’ (on y axis) v/s radius of rotation ‘r’ (on x axis).

Step14: Further tests are carried out changing the value of variable at a time to draw curves.

UNIVERSAL GOVERNOR APPARATUS

1. WATT GOVERNOR

Arrangement is shown in Fig.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Initial radius of rotation, R_o, mm = 136
d. Weight of each ball, W, kg = 0.6

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_0 - \frac{x}{2}$ (mm)	$\cos\alpha = \frac{h}{l}$	Radius of rotation, r r = 50 + L Sin α (mm)	Angular Velocity ω rad/sec	Force F(kg)
1.	80	201	54	64.40	162.72	21.03	0.3678
2.	60	190	64	59.20	157.36	19.88	0.3287

Calculations:

$\omega = \frac{2\pi N}{60}$ rad/sec

$$\omega 1 = \frac{2\pi * 201}{60}$$

= 21.03

$F = \frac{W}{g} * \omega^2 * R_0$ kg

$$F1 = \frac{0.6}{9.8} * (21.03)^2 * 136$$

= 0.3678

2. PORTER GOVERNOR

Arrangement is shown in Fig.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Initial radius of rotation, R_o, mm = 136
d. Weight of each ball, W, kg = 0.6
e. Weight of sleeve, kg = 0.6

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_0 - \frac{x}{2}$ (mm)	$\cos\alpha = \frac{h}{l}$	Radius of rotation, r r = 50 + L Sin α (cm)	Angular Velocity ω rad/sec	Force F(kg)
1.	65	244	61.5	60.52	158.81	26.17	0.5421
2.	90	304	49	66.92	164.99	31.81	0.8416

Calculations:

$\omega = \frac{2\pi N}{60}$ rad/sec

$$\omega 1 = \frac{2\pi * 244}{60}$$

= 25.53

$F = \frac{W}{g} * \omega^2 * R_0$ kg

$$F1 = \frac{0.6}{9.8} * (25.53)^2 * 136$$

= 0.5421

3. PROELL GOVERNOR

Arrangement is shown in Fig.

In the Proell Governor, with the use of flyweight (Forming full ball) the governor becomes highly sensitive. Under this conditions large sleeve displacement is observed for very small change in speed. In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Initial radius of rotation, r_o, mm = 141.5
d. Weight of each ball, W, kg = 0.6
e. Weight of sleeve, kg = 0.6
f. Extension of Length BG, mm = 75

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_0 - \frac{x}{2}$ (mm)	$\cos\alpha = \frac{h}{l}$	Radius of rotation, r r = 50 + L Sin α (cm)	Angular Velocity ω rad/sec	Force F(kg)
1.	41	135	73.5	53.98	151.10	14.35	0.1727
2.	70	150	59	61.83	160.19	15.7	0.2133

Calculations:

$\omega = \frac{2\pi N}{60}$ rad/sec

$$\omega 1 = \frac{2\pi * 135}{60}$$

= 14.13

$F = \frac{W}{g} * \omega^2 * R_0$ kg

$$F1 = \frac{0.6}{9.8} * (14.13)^2 * 141.5$$

= 0.1727

4. HARTNELL GOVERNOR

Arrangement is shown in Fig.

a. Length, a, mm = 77
b. Length, b, mm = 122
c. Initial radius of rotation, r_o, mm = 177.5
d. Weight of each ball, W, kg = 0.6
e. Weight of sleeve, kg = 0.6
f. Free height of spring, mm = 102
g. Spring stiffness (P) = 10 & 5 kg/cm.
h. Initial compression of the spring. = 0

Sr. No.	Sleeve displacement X (mm)	Speed, N (rpm)	Radius of rotation, $r = r_0 + X\ a/b$ (mm)	Angular Velocity ω rad/sec	Force, F (kg)
1.	10	252	186.59	27.75	0.7549
2.	38	336	200.5	32.25	1.129

Calculations:

$\omega = \frac{2\pi N}{60}$ rad/sec

$$\omega 1 = \frac{2\pi * 252}{60}$$

= 26.37

$F = \frac{W}{g} * \omega^2 * R_0$ kg

$$F1 = \frac{0.6}{9.8} * (26.37)^2 * 177.5$$

= 0.7549

An

Experimental Set-up

on

"Belt / Rope Brake Dynamometer"

added to

MECHANICAL ENGINEERING DEPARTMENT LABORATORY

"DYNAMICS OF MACHINES (ME 314E), 6TH SEMESTER"

Design and Fabricated by

Dr. Vikas Gupta
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PanniwalaMota, Sirsa, Haryana, India

Preface

Continuing the efforts to improve and enhance the quality education at CDLSIET, the faculty always strives for development of value added infrastructure for the betterment of students. Design and development of Belt/Rope Brake Dynamometer experiment is a step forward in this direction. The experimental set up is dedicated to the Dynamics of machine (DOM) lab in Mechanical Engineering Department at CDLSIET PanniwalaMota. DOM lab is an important component of Mechanical Engineering curriculum. The experimental set up will not only enhance the Lab capability but also provides the flexibility in testing and research by measuring brake horse power of any motor/engine.

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Above all, without the blessings of the God Almighty, this endeavour would not have borne fruit.

Date: Aug.31st, 2017

Dr. Vikas Gupta
AP, MED, CDLSIET PanniwalaMota

Belt and Rope Brake Dynamometer

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Rope and Brake Dynamometer

1.0 THEORY:

A dynamometer is a mechanism which isused for measuring brake power in engines, motors, flywheel and other rotating elements i.e. rotor. The power can be calculated by simultaneously measuring torque and rotational speed (RPM) of rotating element. Dynamometers are classified in two categories; Absorption and Transmission type.

Absorption dynamometers measure and absorb the output power of the engine/motor to which they are coupled. In absorption dynamometers, the measured power is converted into heat by friction or by other means. The power absorbed is lost as heat and is dissipated to the surrounding by some means, like circulating water or air around heated parts where it have no use. Examples of power absorption dynamometers are Prony brake dynamometer, Belt/Rope brake dynamometer, Eddy current dynamometer, Hydraulic dynamometer, etc.

On the other hand, transmission dynamometers measure the power and then instead of absorbing power, they transmit this power either back to the engine or utilize it for any other associated application. The principle of transmission/utilization avoids wastage of power. These dynamometers are also called torque meters.

2.0 OBJECTIVE:

To measure the braking torque and braking horse power of an engine or motor or any other rotor.

3.0 PRINCIPLE:

It is used to apply frictional resistance to a rotating pulley coupled to shaft or motor/rotor/engine, thus, stop or retard it by absorbing its kinetic energy. It measures the frictional resistance applied and used to determine the power developed by the machine, while maintaining its speed at the rated value.

4.0 APPARATUS:

The basic parts of a belt/rope brake dynamometer are as follows:

Belt: A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. In this case, the Belt is looped over pulley and attached with hooks at ends.

Brake Drum/Pulley: A pulley is a wheel on the shaft that is designed to provide friction surface to the belt/rope for measurement of braking power. The pulley is 23 cm in diameter, See.

Weight Balances: Two weight balances are used which are attached to two hooks of the belt. One is a spring fixed to the frame and other is attached to the screw mounted on frame as shown in Fig.1

Tachometer: Non-Contact optical type Tachometer is used.

Frame: Made of Mild Steel angle.

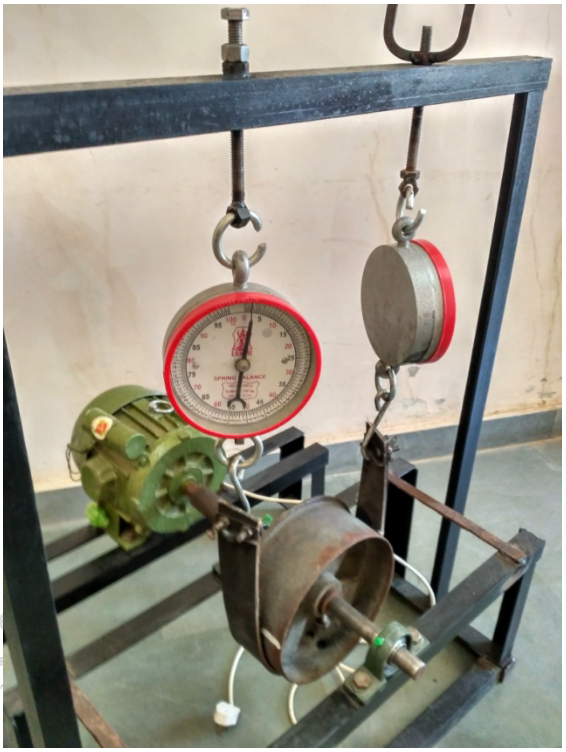

Figure 1: Experimental Set-up

Schematic of the brake drum dynamometer is shown in Figure 1 . A rope or belt is wrapped around the brake drum/pulley attached to the shaft. The two ends of the rope or belt are attached to rigid supports with two spring balances. The loading screw may be tightened to increase or loosened to decrease the frictional torque applied on the drum. When the shaft rotates the tension on the two sides will be different. The difference is just the frictional force applied at the periphery of the brake drum. The product of this difference multiplied by the radius of the drum gives the torque.

TABLE 3.1 Parts of Rope Brake Dynamometer

SR. NO.	DESCRIPTION	MATERIAL	QUANTITY	Specification
01	Rope/Belt	Synthetic Fibers	01	2 ply, 0.5 cm thickness
02	Brake Drum/Pulley	Cast Iron	01	23 cm Diameter
04	Spring Balance	Mix Metal	02	Each 100 kg Capacity

05	Metal Frame	Mild Steel	01	4mm thickness
06.	Tachometer	Mix Metal	01	Digital, range 2.5 to 99,999
07	Motor	Mix Metals	01	0.5 KW, 220 Volts,1440 rpm

5.0 SUGGESTED EXPERIMENTAL WORK:

Step1: Make sure that belt/rope is lose over brake drum, so that brake drum can rotate freely without any resistance from belt/rope.

Step2: Start the motor by increasing the voltage with the voltage regulator, and wait until it attains constant speed at full voltage i.e. 220 V.

Step3: Start tightening the loading screw until the belt/rope start touching the brake drum.

Step4: At this position of loading screw, the speed of brake drum will reduce due to frictional resistance offered by the belt/rope.

Step5: Wait for some time until brake drum attains the constant speed. Take reading of both spring balances (w_1 and w_2) and measure the speed of brake drum (N) using Tachometer.

Step6: Further tighten the loading screw, wait until brake drum attains the constant speed, take second set of readings w_1, w_2 and N.

Step7: Repeat Step6 for four more readings.

Step8: Calculate Torque and Power using Equation 1 and 2 for each set of readings.

Step9: Calculate Average Power (P_{avg}), Equation 3 and Compare it with motor rating (P) to find out %age error, Equation 4.

6.0 EQUATIONS:

$$T = (w_{1} - w_{2})r, \qquad where\ r\ is\ radius\ of\ brake\ drum \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..1$$

$$P = \frac{2\pi NT}{60} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.2$$

$$P_{avg} = \frac{P_1 + P_2 + P_3 + P_4 + P_5 + P_6}{6} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3$$

$$\%age\ Error = \frac{P - P_{avg}}{P} \times 100 \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 4$$

7.0 DATA SHEET AND OBSERVATIONS

S.No.	**W_1** (Newton)	**W_2**(Newton)	**R** (meters)	**N** (rpm)	**Torque T** (Nm)	**Power P_i** (Watt)
1.						
2.						
3.						
4.						
5.						
6.						

8.0 RESULTS & DISCUSSIONS:

10. Fill up the data sheet.
11. Calculate the Average Power.
12. Compare Average power with rated power of Motor and find out %age error.
13. Experiments can also be done for different rated powers using voltage regulator.

9.0 PRECAUTIONS:

1. Please check that when belt/rope is loose, both spring-balances must show zero reading otherwise calibrate the spring-balances accordingly.
4. Voltage through regulator should be made fixed before starting the experiment.
5. Make sure that there is no fluctuation in voltage
6. Tachometer is non-contact type so don’t touch it with brake drum.

7. Make sure that don’t apply too much load on brake drum which may cause stopping the brake drum, thus, heavy load on motor and results in coil burning.