Governors

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 increases, the configuration of the governor changes and a valve is moved to increase the supply of working fluid. Conversely, when the load decreases, the engine speed increases and the governor decreases the supply of working fluid.

Types of Governors.

1. Centrifugal governors.
2. Inertia governors.

Centrifugal Governors.

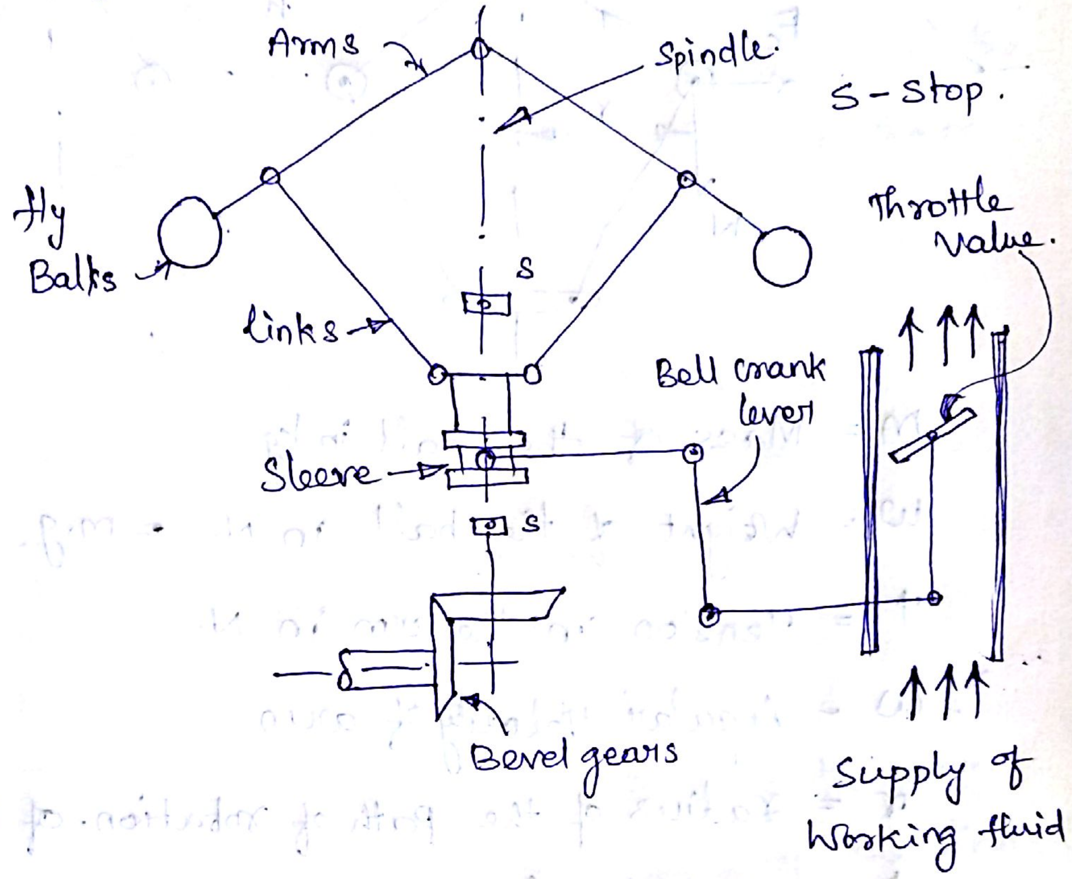
- Pendulum type
  - Watt governor
- Loaded type
  - Dead weight Governors.
    - Porter governor
    - Proell governors
  - Spring controlled governors
    - Hartnell governor
    - Hartung Governor
    - Wilson Hartnell governor
    - Pickering governor.

Centrifugal governors:

The Centrifugal governors are based on the balancing of centrifugal force on the rotating balls by an equal and opposite radial force, known as Controlling force.

It Consists two balls of equal mass which are attached to the arms. These balls are known as governor balls or fly balls.

Centrifugal governor.

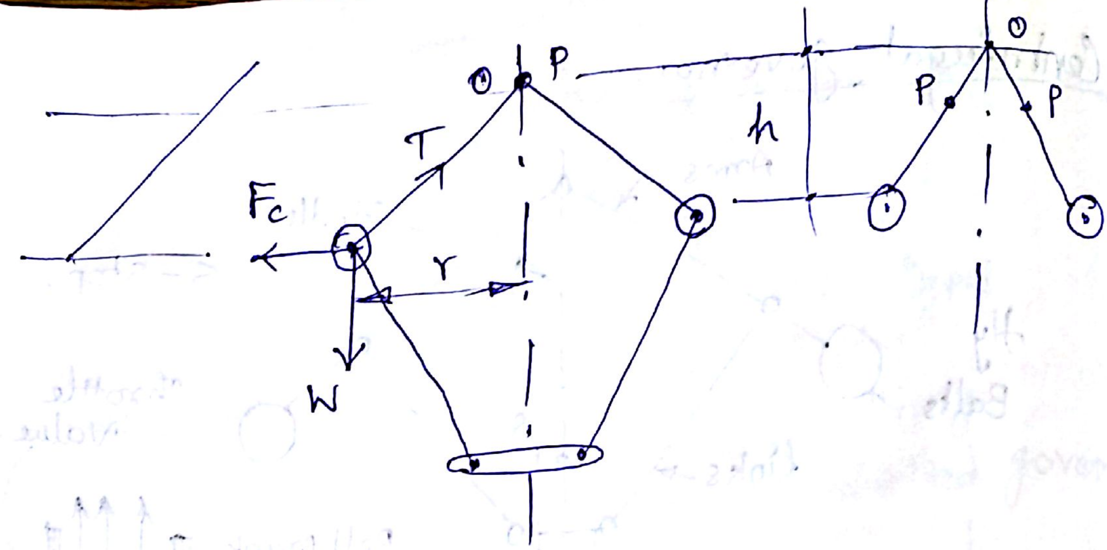


Terms used in govers.

1. Height of a governor.
2. Equilibrium Speed
3. Mean equilibrium speed
4. Max. & min. equilibrium speed.
5. Sleeve lift.

Watt Governor.

The simplest form of a Centrifugal governor. It is basically a Conical pendulum with links attached to a sleeve of negligible mass.



m = Mass of the ball in kg.

w = Weight of the ball in N. $= m.g$.

T = Tension in the arm in N.

ω = Angular velocity of arm

r = radius of the path of rotation of ball

F_c = Centrifugal force.

h = height of the governor in m

$$h = \frac{g}{\omega^2} \; ; \; \omega = \frac{2\pi N}{60}$$

$$\rightarrow \boxed{h = \frac{895}{N^2} \text{ meters}}$$

Porter Governer:-

The porter governor is modification of a Watt's governor, with central load is attached to the sleeve. Though there are several methods of determining the relation between the height of the governor (h) and the angular speed of the balls (ω), yet the following two methods are important from the subject point of view.

Let:

M - Mass of central load

W - Weight of central load.

N - Speed of the balls.

T_1 - Force in the arm

T_2 - Force in the link

α - Angle of inclination of the arm.

β - Angle of inclination of the link.

1. Method of resolution of forces.

$$N^2 = \frac{m + \frac{M}{2}(1+q)}{m} \times \frac{895}{h}.$$

2. Instantaneous Centre method.

$$h = \frac{m + M}{m} \times \frac{g}{\omega^2}.$$

Problem ①

The arms of a Porter governor are each 250 mm long and pivoted on the governor axis. The mass of each ball is 5 kg and the mass of the central sleeve is 30 kg. The radius of rotation of the balls is 150 mm when the sleeve begins to rise and reaches a value of 200 mm for minimum speed. Determine the speed range of the governor. If the friction at the sleeve is equivalent of 20 N of load at the sleeve, determine how the speed range is modified.

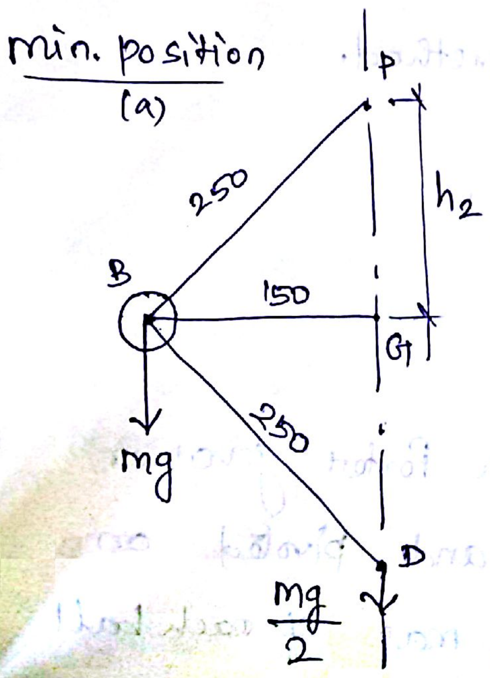
Given:-

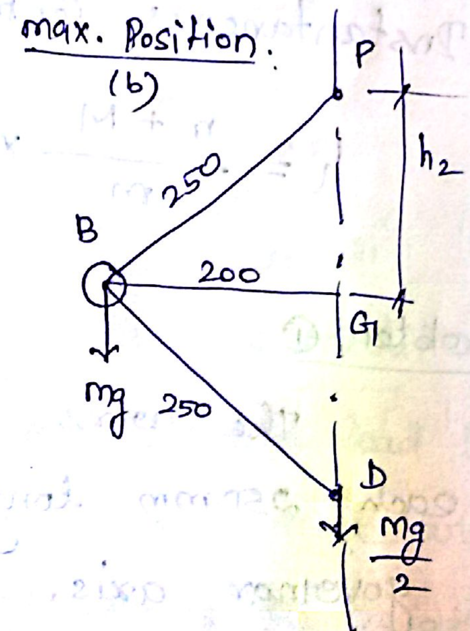
$BP = BD = 250\,mm;$ $r_1 = 150\,mm$

$m = 5\,kg$ $M = 30\,kg.$ $r_2 = 200\,mm.$

Let, N_1 = min. speed when $r_1 = BG = 150\,mm$

N_2 = max. speed when $r_2 = BG = 200\,mm.$





Speed range of the governor.

From fig(a) we find that height of the governor,

$$h_1 = PG = \sqrt{(PB^2) - (BG)^2}$$

$$= \sqrt{250^2 - 150^2}$$

$$h_1 = 200mm.$$

WKT,

$$N_1^2 = \frac{m+M}{m} \times \frac{895}{h_1}$$

$$= \frac{5+30}{5} \times \frac{895}{0.2}$$

$$N_1 = 177 \text{ rpm}.$$

From fig.(b)

$$h_2 = PG = \sqrt{PB^2 - BG^2}$$

$$= \sqrt{250^2 - 200^2}$$

$$= 150mm.$$

WKT,

$$N_2^2 = \frac{5+30}{5} \times \frac{895}{0.15}$$

$$N_2 = 204.4 \text{ rpm}.$$

WKT, Speed range of the governor.

$$= N_2 - N_1 = 204.4 - 177 = 27.4 \text{ rpm}.$$

Speed range when friction at the sleeve is equivalent of 20 N of load (when F = 20N)

WKT,
When the sleeve moves downwards, the frictional force (F) acts upwards and the minimum speed is given by,

$$N_1^2 = \frac{m.g + (M.g - F)}{m.g} \times \frac{895}{h_1}.$$

$$= \frac{(5 \times 9.81) + (30 \times 9.81 - 20)}{(5 \times 9.81)} \times \frac{895}{0.2}$$

$$N_1 = 172 \text{ rpm.}$$

WKT,
when the sleeve moves upwards 'F' acts downwards and the max. speed is given by

$$N_2^2 = \frac{(5 \times 9.81) + (30 \times 9.81 + 20)}{5 \times 9.81} \times \frac{895}{0.15}$$

$$N_2 = 210 \text{ rpm.}$$

WKT,
Speed range of the governor

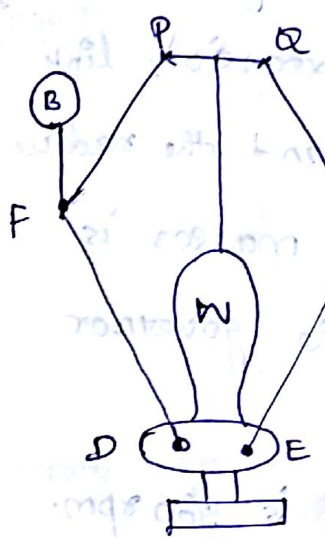
$$= N_2 - N_1$$

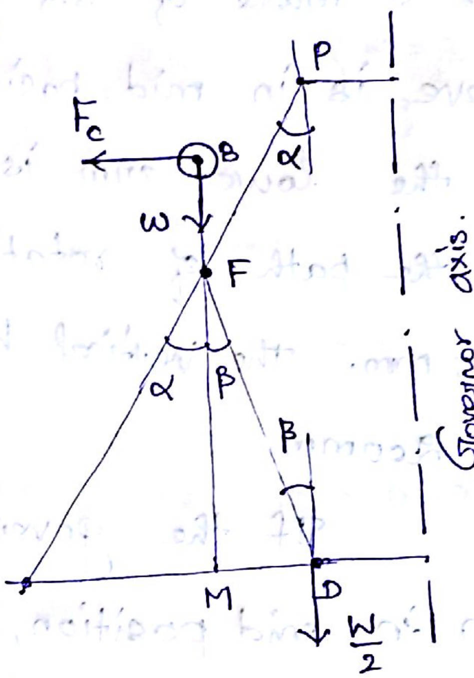
$$= 210 - 172$$

$$= 38 \text{ rpm.}$$

Proell Governor.

The Proell governor has the balls fixed at B and C to the extension of links DF and EG, as shown in fig. The arms FP and GQ are Pivoted at P and Q respectively.





$$N^2 = \frac{FM}{BM}\left[\frac{m + \frac{M}{2}(1+q)}{m}\right]\frac{895}{h}.$$

Where,

$$F_c = m\omega^2 r.$$

$$\tan\alpha = \frac{r}{h}.$$

$$q = \frac{\tan\beta}{\tan\alpha}.$$

Problem (2) A governor of the Proell type has each arm 250mm long. The pivots of the upper and lower arms are 25 mm from the axis. The central load acting on the sleeve has a mass of 25 kg and the each rotating ball has a mass of 3.2 kg. when the governor sleeve is in mid position, the extension link of the lower arm is vertical and the radius of the path of rotation of the masses is 175mm. The vertical height of the governor is 200mm.

If the governor speed is 160 rpm. when in mid position, find : 1. length of the extension link and tension in the upper arm.

Given:-

$PF = DF = 250mm$

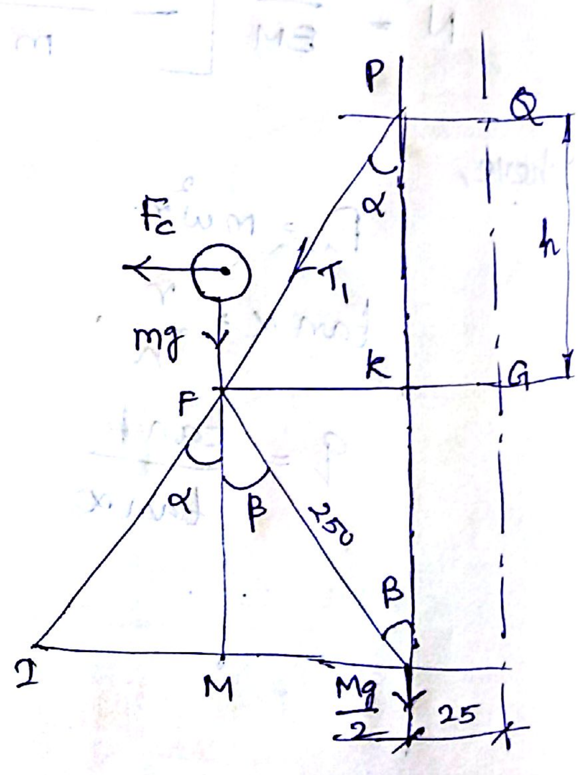
$PQ = DH = KG = 25mm.$

$M = 25\ kg;\ m = 3.2 kg.$

$r = FG = 175m.$

$h = QG = PK = 200mm.$

$N = 160\ rpm.$



1. Length of the extension link.

let BF = Length of the extension link.

The Proell governor in its mid position is shown in fig. From fig.

$$FM = GH = QG = 200\,mm.$$

WKT,

$$N^2 = \frac{FM}{BM}\left(\frac{m+M}{m}\right)\frac{895}{h} \quad \left\{\begin{array}{l}\alpha = \beta;\\ q = 1.\end{array}\right.$$

$$160^2 = \frac{0.2}{BM}\left(\frac{3.2+25}{3.2}\right)\frac{895}{0.2}.$$

$$\underline{BM = 0.308\,m.}$$

From fig.

$$BF = BM - FM = 0.308 - 0.2 = 0.108\,m.$$

2. Tension in the upper arm.

T_1 - Tension in the upper arm.

$$PK = \sqrt{(PF)^2 - (FK)^2} = \sqrt{(PF)^2 - (FG - KG)^2}$$

$$= \sqrt{250^2 - (175-25)^2}$$

$$= 200\,mm.$$

$$\cos\alpha = \frac{PK}{PF} = \frac{200}{250} = 0.8$$

$$T_1 \cos\alpha = mg + \frac{Mg}{2} = (3.2 \times 9.81) + \left(\frac{25 \times 9.81}{2}\right)$$

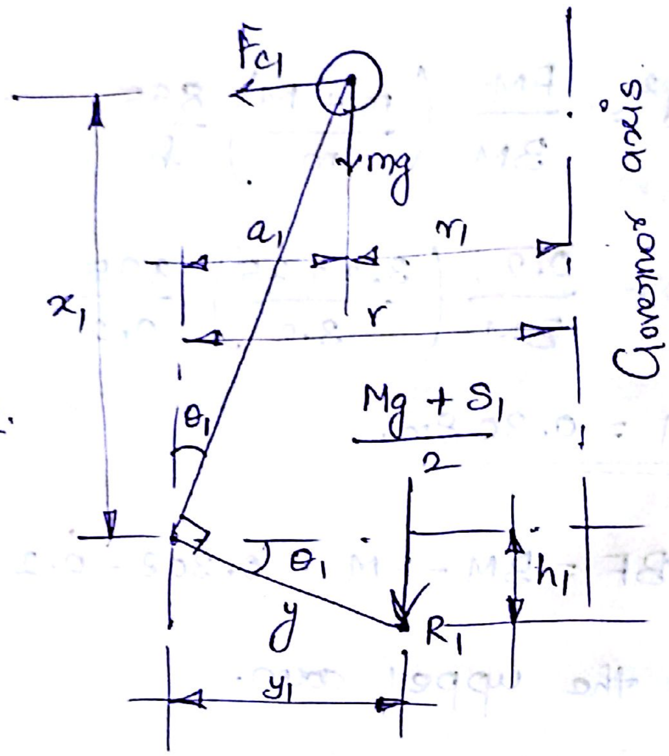
$$\Rightarrow \underline{T_1 = 192.5\,N.}$$

Hartnell Governor.

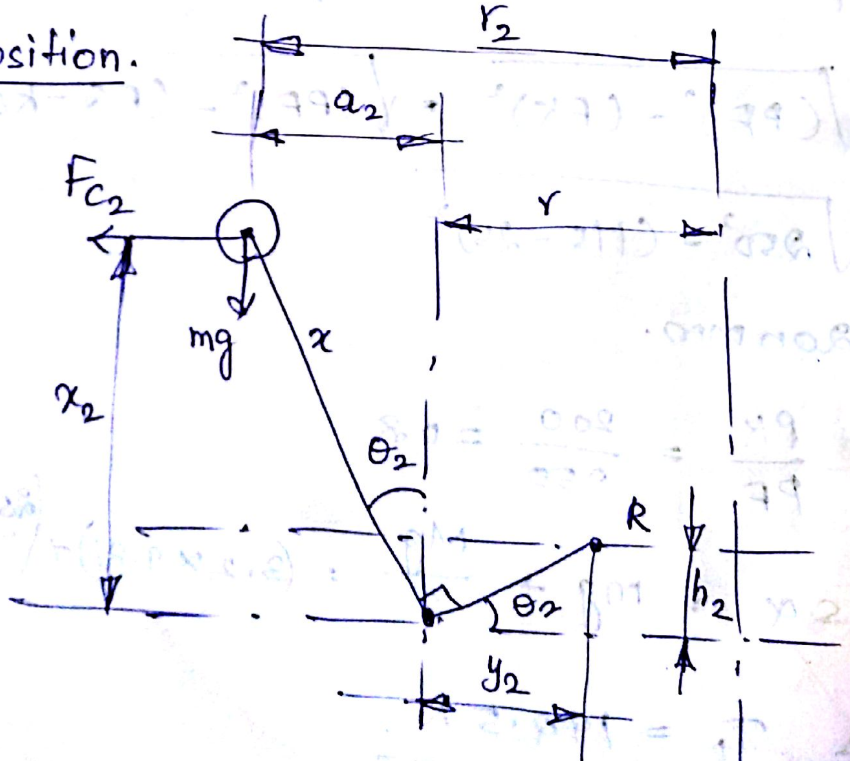
A Hartnell governor is a Spring load governor. ~~as~~ It consists of two bell crank levers pivoted at the points O,O to the frame

Let,

min. Position.



max. Position.



Let, m = mass of each ball in kg.
M = Mass of sleeve in kg.
r_1 = min. radius of rotation in m.
r_2 = max. radius of rotation in m.
ω_1 = Angular speed of the governor at min. radius in rad/s.
ω_2 = Ang. speed of the governor at max. radius.
S_1 & S_2 = Spring force on sleeve at ω_1 & ω_2
F_{c_1} & F_{c_2} = Centrifugal force at ω_1 & ω_2.
s = Stiffness of the spring
x = Length of the vertical or ball arm of the lever in m.
y = Length of the horizontal or sleeve arm of the lever in m.
r = Dist. of fulcrum O from the governor axis or radius of rotation when the governor is in mid. position in m,
h = Compression of the spring when the radius of rotation changes from r_1 to r_2.

$$h = (r_2 - r_1)\frac{y}{x}$$

$$S = \frac{S_2 - S_1}{h} \Rightarrow S = \left(\frac{S_2 - S_1}{r_2 - r_1}\right)\frac{x}{y}.$$

$$\Rightarrow S = 2\left(\frac{F_{C2} - F_{C1}}{r_2 - r_1}\right)\left(\frac{x}{y}\right)^2$$

Problem ③

A Hartnell governor having a Central sleeve Spring and two right angled bell Crank levers moves between 290 rpm and 310 rpm. for a sleeve lift of 15mm. The Sleeve arms and the bell arms are 80mm and 120 mm respectively. The levers are pivoted at 120 mm from the governor axis and mass of each ball is 2.5 kg. The ball arms are parallel to the governor axis at the lowest equilibrium speed. Determine.

1. Loads on the Spring at the lowest and the highest equilibrium Speeds, and,
2. Stiffness of the Spring.

Given:-

$N_1 = 290$ rpm. $\Rightarrow \omega_1 = \frac{2\pi\, 290}{60} = 30\ rad/s$.

$N_2 = 310$ rpm $\Rightarrow \omega_2 = 32.5$ rad/s.

$h = 15$ mm.

$x = 120$ mm ; $y = 80$ mm.

$r = 120$ mm

$m = 2.5$ kg.