

# Improve the Sensitivity of Hartnell Governor with in Alteration Speeds by Introducing Ball Bearing Between Sleeve and Spindle to Reduce the Friction

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**ABSTRACT:** The function of the self-adjustable spring loaded Hartnell governor is to maintain the mean speed of the different engines (low, high and medium speed engines), depends upon the range of speeds with in specified limits whenever there is a variation of the load. The main problem of Hartnell governor is insensitive between two speeds (speed decreases sleeve moves down and speed increases sleeve moves up) due to the friction between spindle and sleeve at constant height of sleeve. The difference between the maximum and minimum speeds at constant height of governor is called alteration speed. In the current investigation hartnell governor is modified such that it improves the sensitivity. In this investigation the governor assembly is modified by introducing ball bearing between sleeve and spindle to reduce friction.

## I.INTRODUCTION

Flywheel which minimizes fluctuations of speed within the cycle but it cannot minimize fluctuations due to load variation. This means flywheel does not exercise any control over mean speed of the engine. To minimize fluctuations in the mean speed which may occur due to load variation, governor is used. The governor has no influence over cyclic speed fluctuations but it controls the mean speed over a long period during which load on the engine may vary.

## Types of Governors

The governors may broadly classified as

1. Centrifugal governors
2. Inertia governors.

## Centrifugal governor

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

## Hartnell Governor

A Hartnell governor is a spring loaded governor as shown in Fig 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 OA 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 may be adjusted by screwing a nut up or down on the sleeve.

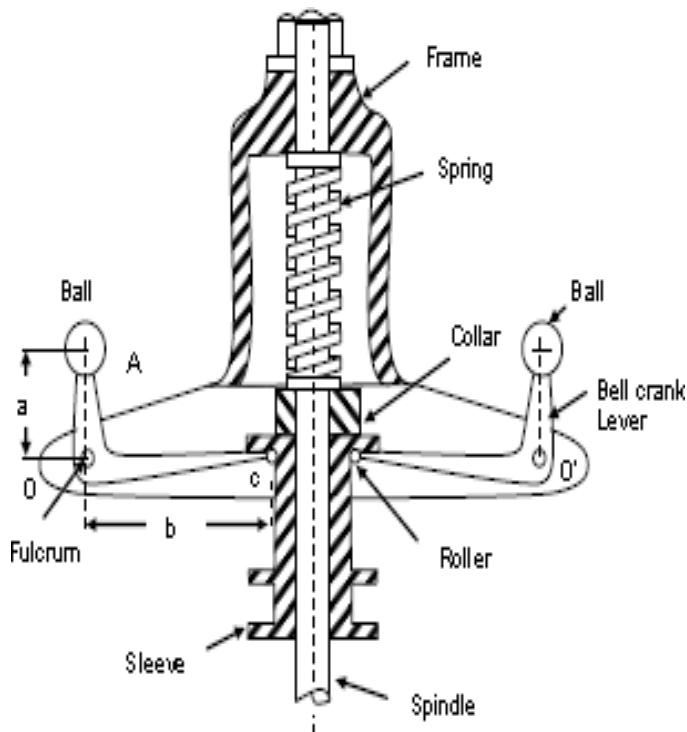


Fig 1 HARTNELL GOVERNOR

### Terms used in hartnell governor:

Let  $m$  = Mass of each ball in kg,

$M$  = Mass of sleeve in kg,

$r_1$  = Minimum radius of rotation in  $N_1$ ,

$r_2$  = Maximum radius of rotation in  $N_2$ ,

$\omega_1$ = Angular speed of the governor at minimum radius in rad/s,

$\omega_2$  = Angular speed of the governor at maximum radius in rad/s,

$F_{S1}$  = Spring force exerted on the sleeve at  $\omega_1$  in N,

$F_{S2}$  = Spring force exerted on the sleeve at  $\omega_2$  in N,

$F_{C1}$  = Centrifugal force at  $\omega_1$  in N

$F_{C2}$  = Centrifugal force at  $\omega_2$  in N

$S$  = Stiffness of the spring N/mm

$a$  = Length of the vertical or ball arm of the lever in m,

$b$  = Length of the horizontal or sleeve arm of the lever in m,

$r$  = Distance of fulcrum O from the governor axis or the radius of rotation when the governor is in Mid – position, in Metres.

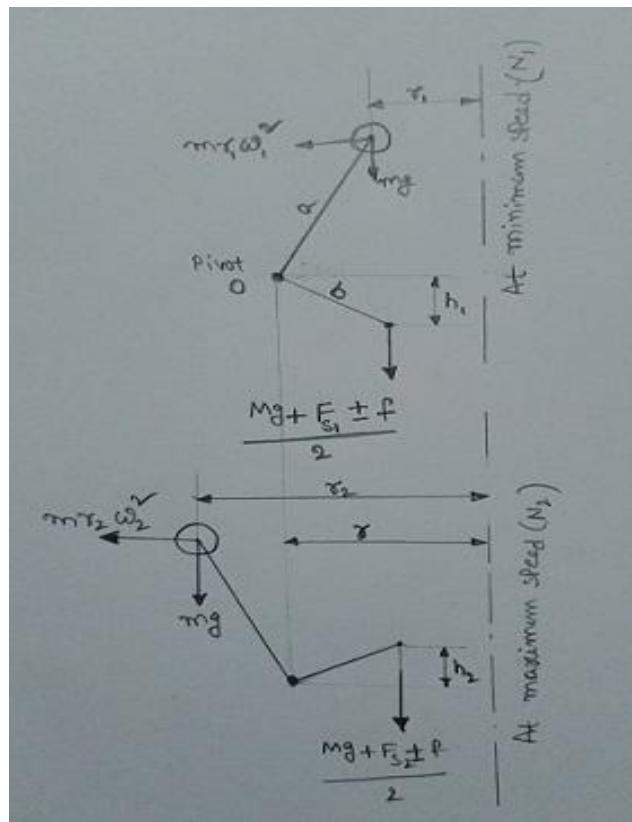


Fig 2: Positions of hartnell governor at minimum and maximum speeds

## II.FORMULAS OF HARTNELL GOVERNOR

For hartnell governor:

$$\begin{aligned} F_1 a_1 &= \frac{1}{2} (Mg + F_{s1} \pm f) b_1 + mgc_1 \\ F_2 a_2 &= \frac{1}{2} (Mg + F_{s2} \pm f) b_2 + mgc_2 \end{aligned}$$

In the working range of the governor,  $\theta$  is usually small so the obliquity effects of the arms of the ball crank levers may be neglected. In that case

$$a_1 = a_2 = a \quad b_1 = b_2 = b \quad c_1 = c_2 = 0$$

$$F_1 a = \frac{1}{2} (Mg + F_{s1} \pm f) b$$

'+' if sleeve moves up

'-' if sleeve moves down

$$F_2 a = \frac{1}{2} (Mg + F_{s2} \pm f) b_1$$

## III.PROBLEM OF HARTNELL GOVERNOR

The main problem of this governor is insensitive with in alteration speed (The range of speed at which governor insensitive at constant height of the governor that difference in range of speed is called alteration speed)

From the diagram force acting on the sleeve is  $\{(Mg + F_{s1} \pm f)\}$  at minimum speed or  $\{(Mg + F_{s2} \pm f)\}$  at maximum speed.

Now if the speed of the engine is increases the balls would tend to move away from the axis, but now as the friction has to act in the downwards direction, the resistance to the motion would be  $\{Mg + F_{s1} + f\}$  or  $\{Mg + F_{s2} + f\}$ .

Same as speed of the engine is decreases the balls would tend to move towards the axis, but now as the friction has to act in the upwords direction, the resistance to the motion would be  $\{Mg + F_{s1} - f\}$  or  $\{Mg + F_{s2} - f\}$ .

At the same height of governor sleeve subjected to two forces.

1.  $\{Mg + F_{s1} + f\}$  or  $\{Mg + F_{s2} + f\}$  at maximum speed at sleeve moves up (friction acting downwards)

2.  $\{Mg + F_{s1} - f\}$  or  $\{Mg + F_{s2} - f\}$  at minimum speed at sleeve moves down (friction acting up wards)

At the same height of governor sleeve subjected to two forces at two different speeds. That means it is insensitive within two speeds or above two forces 1 and 2.

Thus for a given value of 'h', the governor is insensitive between two values of  $\omega$

**Note: (i) spring forces are directly proportional to height of the governor.**

$$F_{S2} - F_{s1} = h_1 s$$

$$F_{S2} - F_{s1} \propto h_1$$

**Note (ii) centrifugal force directly proportional speed of the governor.**

$$F_1, F_2 \propto \omega$$

### Problem:

In a spring loaded hartnell type of governor, the mass of each ball is 4 kg and the lift of the sleeve is 40mm. The governor begins to float at 200 rpm when the radius of the ball path is 90mm. The mean working speed of the governor is 16times the range of speed when friction is neglected. The lengths of the ball and roller arms of the bell-crank lever are 100mm and 80mm respectively. The pivot centre and the axis of governor are 115mm apart. Determine the initial compression of the spring taking into account the obliquity of arms.

Assuming the friction at the sleeve to be equivalent to a force of 15N, determine the total alteration in the speed before the sleeve begins to move from the mid-position.

**Solution:**  $m = 4\text{kg}$ ,  $N_1 = 200 \text{ RPM}$  (minimum speed of governor)

Lift of sleeve( $h_1$ ) = 40mm

At minimum speed radius of governor ( $r_1$ ) = 90mm

Radius at mean speed ( $r$ ) = 115 mm.

Mean speed  $N = N_1 + N_2/2$

$$N = 16(N_2 - N_1)$$

$$200 + N_2/2 = 16(N_2 - 200)$$

$$N_2 = 212.9 \text{ rpm.}$$

Angle turned by Bell - crank lever between two extreme positions.

Lift ( $h_1$ ) /  $b = c_1 + c_2/a$

$$c_1 + c_2 = a/b * h_1$$

$$= 100/80 * 40$$

$$c_1 + c_2 = 50 \text{ mm}$$

$$\text{Here } c_1 = r - r_1 = 115 - 90 = 25 \text{ mm.}$$

$$c_1 + c_2 = 50 \text{ mm}$$

$$c_2 = 25 \text{ mm.}$$

$$\text{From that } r_2 = 115 + 25 = 140 \text{ mm}$$

In the working range of the governor,  $\theta$  is usually small and so the obliquity effects of the arms may be  $\omega = \sqrt{(80^2 - (40/2)^2)}$

$$b_1 = 77.46 \text{ mm}$$

$$a_1 = a_2 = \sqrt{(a^2 - c_1^2)}$$

$$= \sqrt{(100^2 - 25^2)}$$

$$= 96.82 \text{ mm.}$$

$$\omega_1 = 2\pi N_1/60 = 2\pi 200/60 = 20.94 \text{ rad/sec}$$

$$\omega_2 = 2\pi N_2/60 = 2\pi 212.9/60 = 22.29 \text{ rad/sec}$$

in the extreme positions

$$mr_1 \omega_1^2 a = \frac{1}{2} F_{s1} b_1 + m g c_1$$

$$4 * 0.09 * 20.94^2 * 0.09682 = \frac{1}{2} * F_{s1} * 0.07746 + 4 * 9.81 * 25 * 10^{-3}$$

$$F_{s1} = 392.5 \text{ N.}$$

$$Mr_2 \omega_2^2 a_2 = \frac{1}{2} F_{s2} b_2 + m g c_2$$

$$F_{s2} = 698 \text{ N.}$$

Stiffness = Force/ Displacement

$$S = F_{s2} - F_{s1}/h \\ = 698 - 392.5 \text{ N} / 40 \text{ mm} \\ = 7.64 \text{ N/mm}$$

$$\text{Mean speed (N)} = N_1 + N_2 / 2 \\ = 212.9 + 200/2 \\ N = 206.45 \text{ rpm.}$$

At the mid position, taking friction into consideration

$$M r \omega_1^2 a = \frac{1}{2} (F_S + f) b \quad (\text{sleeve moves up})$$

$$4 * 115 * 10^{-3} * \omega_1^2 * 100 * 10^{-3} = \frac{1}{2} (543.3 + 15) 80 * 10^{-3}$$

$$\omega_1^2 = 487.2$$

since  $\omega_1 = 2\pi N_1 / 60$   
 $\omega_1 = 22.07 \text{ rad/sec}$

$$Mr_2 \omega_2^2 a = \frac{1}{2} (F_{s2} - f) b_2 \quad (\text{sleeve moves down})$$

$$\omega_2^2 = 461.13 \quad \text{since } \omega_2 = 2\pi N_2 / 60$$

$$\omega_2^2 = 21.47 \text{ rad/sec}$$

$$N_2 = 205.1 \text{ rpm}$$

$$\text{Alteration of speed} = 210.8 - 205.1 \\ n_1 = 5.7 \text{ rpm}$$

If we decrease friction, then we can reduce the alteration of speed.

If  $f = 14 \text{ N}$

$$4 * 0.115 * \omega_1^2 * 0.1 = \frac{1}{2} (543.3 + 14) 0.08$$

$$\omega_1 = 22 \text{ rad/s}$$

$$4 * 0.115 * \omega_2^2 * 0.1 = \frac{1}{2} (543.3 - 14) 0.08$$

$$\omega_1 = 21.49 \text{ rad/s}$$

$$\omega_1 * 60 / 2\pi = N_1$$

$$N_1 = 210.593 \text{ rpm}$$

$$\text{Like } N_2 = 204.54 \text{ rpm}$$

$$\text{Alteration of speed } n_2 = N_1 - N_2 \\ = 210.593 - 204.54 \text{ rpm} \\ = 5.338 \text{ rpm}$$

If  $f = 13 \text{ N}$

Then Alteration of speed  $n_3 = 5.14 \text{ rpm}$

If  $f = 12 \text{ N}$

Then Alteration of speed  $n_4 = 4.575 \text{ rpm}$

If  $f = 11 \text{ N}$

Then Alteration of speed  $n_5 = 4.186 \text{ rpm}$

If  $f = 10 \text{ N}$

Then Alteration of speed  $n_6 = 3.814 \text{ rpm}$

If  $f = 9 \text{ N}$

Then Alteration of speed  $n_7 = 3.432 \text{ rpm}$

If  $f = 8 \text{ N}$

Then Alteration of speed  $n_8 = 3.06 \text{ rpm}$

If  $f = 7 \text{ N}$

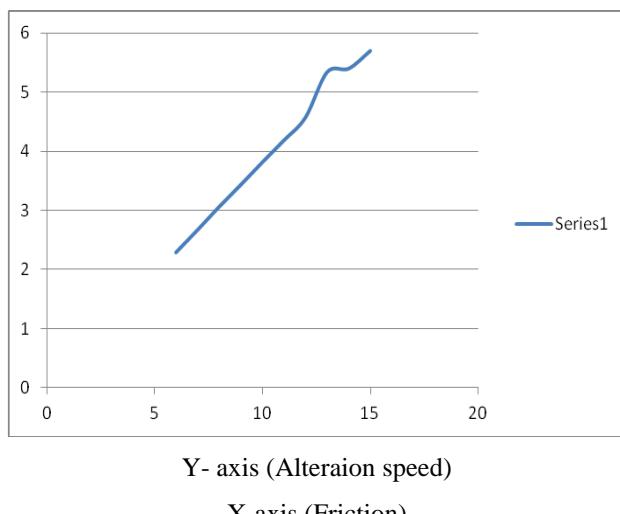
Then Alteration of speed  $n_9 = 2.668 \text{ rpm}$

If  $f = 6 \text{ N}$

Then Alteration of speed  $n_{10} = 2.286 \text{ rpm}$

#### IV.RESULTS AND GRAPHS

S.no	Friction(f) in N	Alteration speed(n) in rpm
1	15	5.7
2	14	5.4
3	13	5.34
4	12	4.575
5	11	4.186
6	10	3.814
7	9	3.432
8	8	3.06
9	7	2.668
10	6	2.286



**Note:** From the above graph we can concluded that alteration speed decreases with the decreasing of friction.

#### V.CONCLUSION

The Hartnell governor is the self-adjustable governor it is suitable for high, low and moderate speed engines. But the main problem is, the governor is insensitive with in alteration of speeds. In this paper, the modification is made to increase the sensitivity of the Hartnell governor. It concludes that the sensitivity can be increased by decreasing friction between spindle and sleeve. Based on the results and graph alteration speed is directly proportional to reduced friction. From that sensitivity increases with the decreasing of alteration of speeds.

#### VI.FUTURE SCOPE

- (i) Introducing the ball bearings between spindle and sleeve to reduce the friction.
- (ii) Dynamic analysis of the hartnell governor will give more accurate results and also calculate the combined stresses acting on the various parts of the governor.

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