Experimental Analysis of Porter Governor Mechanism in Dynamics of Machinery Laboratory

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Abstract. This work is done in the Machine Dynamics Laboratory of Mechanical Engineering Department. All the observations have been recorded using universal governor apparatus set up available in the laboratory. The author studied both the actual as well as theoretical parameters of the porter governor given to the students to perform their experiments. Author noted that, at M= 1, 2 and 3 kg, the actual sensitivity of given porter governor are 24, 11 and 24% respectively. The actual average sensitivity comes to a value of 20%. While with the help of calculations, the theoretical sensitivity of given porter governor are 23, 17 and 8% respectively. The theoretical average sensitivity comes to a value of 16%. Here, it is to be noted that in both the cases, the sensitivity of the studied governor is constant. The research covers both the experimental and numerical approached. The results of this paper may serve a model for researchers in doing research work as per specific necessity in the early stage of their work.

Keywords: Porter governors, Dead weight, fly balls

1. Introduction
There is no central mass on Watt governor. When, we placed a central mass on the central sleeve on Watt governor. It is called Porter governor. When engine speed increases due to lower load on the engine, the governor fly balls haves a tendency to move outwards away from the centre axis of the governor. In this position, the fuel opening is controlled by the throttle and as a result less fuel enters into the engine cylinder. Therefore, the engine speed decreases. Similarly, when there is increased load on the engine then engine speed decreases and governor fly balls move towards the governor axis. In this position, governor communicates the fuel pump to send more fuel into the engine cylinder to maintain the equilibrium speed. The basic work of porter governor is control the fuel opening to the engine cylinder to control the fluctuations in engine speed caused by the changing the loads on the engine. The governor my be centrifugal or inertia type as it depends on the fictions in the engine loads according to the changes in speed variations. The porter governor central spindle is connected to shaft of the engine with the help of rigid coupling . the central sleeve of the porter governor travels up and down because of the centrifugal force acting on the governor balls. When, there is lesser external load on the engine, the governor speed increases and as a result, the governor balls rotate with more radius of rotation due to higher centrifugal force on the flyballs. Because of this phenomenon, governor central sleeve travels in the upside direction due to the action of the bell crank lever. The message of the travelling of the central sleeve of the governor sent to the throttle and as a result the throttle valve is shut as per the requirement. But if the governor speed decreases due to the higher increased external load on the engine, the governor balls rotates with lesser radious of rotation from the governor axis. Again, this message is sent to the throttle and as a result, the throttle valve permit more fuel as per the requirement to enter inside the engine cylinder.
Trupti et.al. [1] proposed the reasons of governor failure due to stress concentration. the authors suggested the failure areas more prone to failures while the governor is rotating at higher speeds. The work is based on the weight of the links of the governors. Vanga et.al. [2] worked on various parts of the governors using important software like Catia as well as ANSYS. Ravindra et.al. [3] worked on specific position of the governor assembly to focus on the stress analysis. Kumar et.al. [4] worked on Watt governor. Thw authors manufatured the Watt governor model the major changing in the position of governor fly balls. The authors noted the pattern of controlling forces on the governor model with variations. Raghavendra and Kumarappa [5] suggested the changes in mechanical governor with the application of electronic. It is named as electronic governor. Burje et.al. [6] worked on rocker mechanisms to control the throttle valve opening and closing. The author justified the proposed work with the data already available in the literature. Ge and Lee [7] studied the static and dynamic working of the different governors with the external disturbances. Surarapu et. al.[8] suggested the variation in Watt governors for the purpose of changing the minimum revolutions per second. The authors designed and manufactured their own governor model for the purpose of the research work. Wankhade et.al. [9] studied on dams with the help of governors. The investigators tried to regulated the dams door by governor mechanisms. Siddappa D. et.al.[10] worked on life self defense on high altitude with the help of governor mechanisms. Kashyap and Mohankrishna [11] worked on special mechanisms to avoid accidents due to collision of vehicle. The scientist used the governor systems in the study along with ultrasonic waves. Miljc and Popovic [12] designed and fabricated their own model of governor mechanism and changes various design parameters frequently for the purpose of study of the static as well as dynamic behavior of the rotating mechanisms.Sakharov and Tarabarin [13] worked theoretically on governor mechanisms. They suggested the different problems along with their solutions. Srinu et.al. [14] designed and manufacture the proell governor mechanism to improve its minimum revolutions per second.

2. Materials and Methodology
Porter governor is the updated Watt mechanism. A universal governor mechanism is in the kinematics of machines (also known as dynamics of machine) laboratory of the department of mechanical engineering and is shown in Fig.1. This mechanism is connected with d.c. motor. The shaft of porter governor mechanism and the motor shaft are connected together with the help of coupling. The governor machine central spindle is housed in ball bearings at both the ends. An optical or mechanical tachometer has been used for the purpose of governor mechanism speed measurement. first of all, we provide the electrical supply to the experimental set up. We record the starting observation of the pointer of the displacement scale. After that, the author placed different dead weights from lower to higher value on the porter governor mechanism and the central sleeve displacements and revolutions per second for each weight. The author repeated the method at the same dead weight with the increase in the spindle speed. Again, increase the dead eight on the sleeve and repeat the procedure. The author has recorded three observations at each dead weight place at the sleeve.
3. Notations Used
- $r_o =$ Initial radius of rotation in mm,
- $r =$ Radius of rotation in mm,
- $h_o =$ Initial height of governor in mm,
- $h =$ Height of governor in mm,
- $l =$ Length of each link in mm,
- $m =$ Mass of each fly ball in kg,
- $M =$ Dead mass on the Sleeve in kg,
- $x_o =$ Initial reading on scale in mm,
- $x =$ Sleeve displacement in mm,
- $d =$ Initial distance of fly ball centre from spindle axis in mm,
- $\alpha =$ Angle of inclination of upper arms to the vertical in degrees,
- $N_1 =$ Minimum spindle speed in RPM,
- $N_2 =$ Maximum spindle speed in RPM,
- $N =$ Mean speed in RPM,
- $N_{act} =$ Actual speed of Spindle in RPM,
- $N_{th} =$ Theoretical speed of Spindle in RPM,
- $F_c =$ Centrifugal Force in Newton = $m r \omega^2$.
- $\omega =$ Governor Spindle speed in rad/s.

4. Observations
Experimental setup Manufacturer’s are: $r_o = 140$ mm, $h_o = 85$ mm, $l = 125$ mm, $m = 0.16$ kg, $d = 50$ mm. Other Observations and calculations are recorded in Table-1 and Table-2 respectively.
Table 1. Experimental Observations for Porter Governor

| S.N. | M (Dead Mass on the sleeve) kg | N_{act} (Actual speed of Spindle) RPM | x (Sleeve displacement) mm |
|------|-------------------------------|--------------------------------------|--------------------------|
| 1    | 1                             | 180.5                                | 34                       |
| 2    | 1                             | 208.1                                | 80                       |
| 3    | 1                             | 229                                  | 89                       |
| 4    | 2                             | 206.5                                | 38                       |
| 5    | 2                             | 212.8                                | 50                       |
| 6    | 2                             | 230.3                                | 75                       |
| 7    | 3                             | 229.5                                | 40                       |
| 8    | 3                             | 241.8                                | 43                       |
| 9    | 3                             | 292                                  | 58                       |

Table 2. Calculations for Porter Governor

| S.N. | h=(ho – x/2) mm | \(\alpha = \cos^{-1}(h/l)^\circ\) | r = 50 + 1\sin(\alpha) mm | Fc = m \cdot r \cdot \omega^2 Newton | N_{tho} = \left[\frac{(895/h)}{(m+M/m)}\right]^{1/2} RPM |
|------|-----------------|-----------------------------------|-----------------------------|----------------------------------------|--------------------------------------------------|
| 1    | 68              | 57.04                             | 154.88                      | 8.85                                   | 309                                              |
| 2    | 45              | 68.89                             | 166.61                      | 12.66                                  | 380                                              |
| 3    | 40.5            | 71.09                             | 168.25                      | 15.48                                  | 400                                              |
| 4    | 66              | 58.13                             | 156.16                      | 11.67                                  | 427                                              |
| 5    | 60              | 61.31                             | 159.65                      | 12.68                                  | 448                                              |
| 6    | 47.5            | 67.66                             | 165.62                      | 15.41                                  | 504                                              |
| 7    | 65              | 58.67                             | 156.77                      | 14.43                                  | 521                                              |
| 8    | 63.5            | 59.47                             | 157.67                      | 16.17                                  | 527                                              |
| 9    | 56              | 63.38                             | 161.75                      | 24.19                                  | 561                                              |

5. Results and Conclusions

Centrifugal force (Fc) - radius of rotation (r) relation is shown in Fig.-2. The author observes that at the lower dead weight on the sleeve, there is less increase in the Centrifugal force but as the radius of rotation increases, the centrifugal force increases parabolic curve. As we increase dead weight on the sleeve, the centrifugal force and radius of rotation are almost directly proportional but at lower dead weight, as we increase the radius of rotation, centrifugal force increases steeply. On the basis of different observations listed in Table-2, the author concluded that this governor mechanism is unstable one. From Centrifugal force Vs radius of rotation graph, we can conclude that at higher value of dead weight on the sleeve, for a slight change in radius of rotation there is a larger variation in centrifugal force acting on fly balls. We see from Table-1, at M= 1, 2 and 3 kg, the actual sensitivity of given porter governor are 24, 11 and 24% respectively. The actual average sensitivity comes to a value of 20%. While with the help of calculations, the theoretical sensitivity of given porter governor are 23, 17 and 8% respectively. The theoretical average sensitivity comes to a value of 16%. Here, it is to be noted that in both the cases, the sensitivity of the governor remains the same.
Figure 2. Effect of radius of rotation (r) on centrifugal force (F_c)

The actual spindle speed Vs sleeve displacement graph is represented in Fig.-3, the author observes that there is a greater increase in central sleeve displacement with increase in actual spindle speed at lower dead weight on the sleeve but as we go towards higher values of dead weights, sleeve displacement increases but with lesser amount as compared to it with lower dead weights.

Figure 3. Effect of actual spindle speed (N_{act}) on sleeve displacement (x)

A graph between ‘N_{act}’ and ‘x’ is represented in Fig.-4. The author observes that slight change in ‘N_{act}’ is associated larger change in ‘x’. Theoretically, the sleeve displacement is dependent with the dead weight on the sleeve.
Figure 4. Effect of theoretical speed (Ntho) on sleeve displacement (x)

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