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Study of Watt Governor Mechanism

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Abstract

Objective: The basic aim of the study is to determine the minimum, maximum speeds and sensitivity of the governor of a universal Watt governor setup available in machine dynamics laboratory in the mechanical engineering department at Jamia Millia Islamia New Delhi. **Methodology:** We used a tachometer to measure the spindle speed in revolution per minute. After assembling the governor setup, the author note down the initial reading of pointer on the vertical scale. After switching on the rotary switch, we slowly increase the governor speed till the sleeve is lifted from its initial position and it should be stabilized. Now, again, we increase the governor speeds in steps to get different position of sleeve lift at different rpm and noted all the observations. **Findings:** The actual minimum and maximum governor speeds are 211 rpm and 276 rpm respectively. The actual sensitivity of the available governor setup is 26.7 %. With the change of governor speed, the radius of rotation also changes. **Novelty:** This Study may be sued as simple guide lines for undergraduate / postgraduate / research scholars as well as scientist to select the suitable governor to perform the required task as per specific necessity in their research work.

Keywords: Governor; rpm; Centrifugal force; sensitivity; fly balls

1 Introduction

Trupti et al.[(1)] presented review comments about the design and analysis of the centrifugal governors. The paper pointed out the effect of the areas like notches, threads, under cuts, key ways etc are more prone to failure due to un even stress concentration with n the material of the governor parts. The paper pointed out the side effects of the weights of the various links on the proper working of the governor. The authors suggested the various materials for governor manufacturing after studying the various specific configuration of the governors. This review paper considers on the comments on centrifugal governors only like design of governor shafts, pins, heads, and sleeves, upper and lower arms along with complete design procedure. Vanga et al.[(2)] studied the design and analysis of the various parts of the governor with the help of computerized software Catia. The study describes the various modes of failures in various parts of the governor and suggested their remedies. There is detailed analysis of the deflection and weight of various parts of the governor. The study suggests various materials for almost all the components of the governor assembly. Juseok Kang[3] suggested a technique to check dynamic equilibrium configuration with the help of constrained mechanical system. The author used dynamic equilibrium equations in the suggested technique. Kumar et al.[4] suggested the modification in the Watt governore to achieve better performance and working. They calculated all the forces acing on the governor including controlling forces. The authors changed the position of fly balls on the lower arms in their models and suggested vearious changes for better working of the governor. Raghavendra and Kumarappa[5] have worked on retrofit mechanical governor to electronic governor for smoother and better performance of engine. Burje et al.[6] apply the principles of mechatronics in their study of the governor mechanisms. The authors applied the applications of microcontrollers and mechanical actuators. The authors validated their results with the already available data in the literature. Ge and Lee[7] studied the static and dynamic characteristics of the mechanisms like governors. The authors studied all the mechanisms working with the help of external forces upon rotation. Surarapu et. al.[8] studied the modification in Watt governors. The authors manufactured a pendulum type Watt governor prototype for studying the variation in its range of speeds. Thy also studied the relocation of fly balls on the lower links for the purpose of increasing the lower speeds of the Watt governors. Wankhade et.al.[9] worked on automatic door opening and closing of dam by using centrifugal governing , by rope mechanism and by using gear mechanism. When the water level goes up, the dam doors will be opened automatically and when water level goes down, the dam doors will be closed automatically. Siddappa et.al.[10] worked on sky saver using centrifugal governor. Sky saver is a life saving , personnel self rescue device. Kashyap and Mohankrishna[11] investigated a collision avoidance system for predicting the potential collision sequences in automotive vehicles. Their system consists of a distance measuring system using ultrasonic waves utilizing microcontroller. Miljic and Popovic[12] presented a mathematical model of governor after changing all the changeable dimensions and other parameters. The authors studied both static as well as dynamics behavior of the governor under study. Sakharov and Tarabarin[13] studied centrifugal governors. Their study is focused on the main problems and their solutions of the governors. Srinu et.al.[14] worked on proell governor to increase its minimum speed. They extend the lower arms and changed the fly ball position in proell governor. Actually, the authors studied the governor named proell governor. They fabricated their governor model and recorded the observations. But most of the studies available in the literature are either impractical or difficult to grasp and their effectiveness needs further testing. Therefore, still more studies, their applications and a calibration of the experimental setup is required essentially. Therefore, in this study, the author calibrated the experimental setup of the Watt Governor that is utilized by almost every engineer during their experiments project work and research purposes. The study covers the theoretical as well as practical aspects of the study. This study will serve as a reference guide to UG/PG Students/Research Scholars/ scientist in carrying out their project work in the initial conceptual stage of Design.

2 Materials and Methodology

A Universal governor experimental setup available in the Machine Dynamics laboratory of Mechanical Engineering Department is shown in Figure 1, which is a motorized setup having a c shaft driven by D.C. motor. The shaft and motor are mounted on a rigid m.s. base frame in vertical position. The spindle is supported in ball bearings. A tachometer is used to measure the spindle speed. Assemble the governor setup including electrical connections. Note down the initial reading of pointer on the vertical scale. Now switch on the rotary switch and slowly increase the governor speed till the sleeve is lifted from its initial position and it should be stabilized. Now, increase the governor speeds in steps to get different position of sleeve lift at different rpm and record all the observations. The author recorded the various observations in real environments. The study does consider the effect of friction on the sleeve up and down movement on the vertical spindle of the governor. The study also does not take the weight of the upper arms and lower links into considerations and as a result , does not take into account the deflections of various parts of the governor. For recording the spindle speeds, the mechanical tachometer is used instead of optical tachometer. For vertical movements, simple plain scale is used.

3 Observations

Notations and constant observations provided by the manufacturer of the experimental setup are as follows:

m = mass of fly ball =160 gm = 0.16 kg,

h_o = Initial height of governor = 85 mm,

l = length of arm = 125 mm,

r_o = radius of rotation = 140 mm,

x_o = initial reading on scale = 46 mm,

distance of pivot to centre of spindle = 50 mm,

α = angle of inclination of upper arm with the vertical in degrees,

x = sleeve displacement in mm,
N_{th} = Theoretical Speed in RPM = $(895/h)^{1/2}$,
N_{act} = Actual Speed in RPM ,
Fc = Centrifugal Force in Newton (N) = $m.r.\omega^2$,
h = Height of governor in mm.

Table 1. Experimental observations and calculations for watt governor

S. N.	N_{act} [RPM]	x [mm]	h = (h_o-x/2) [mm]	α = Cos^{-1}(h/l) [°]	r =(50+l.sinα) [mm]	Fc [N]	$N_{th\ [RPM]}$
1	211	68	51	65.9	164.1	12.8	132
2	221	79	45.5	68.6	166.4	14.2	140
3	236	90	40	71.3	168.43	16.0	149
4	244	98	36	73.2	169.5	17.7	158
5	264	113	28.5	76.8	171.7	21	177
6	266	118	22	79.8	173	21.5	201
7	270	124	20	80.8	173.4	22.1	211
8	276	128	17.5	81.9	173.8	23.1	226
9	280	135	15	83	174	23.93	244

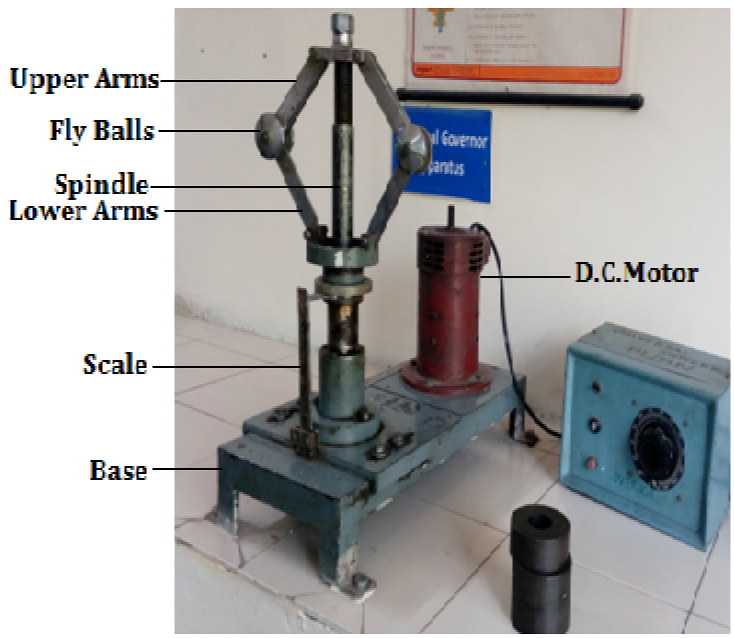

Fig 1. Watt Governor Setup available in Machine Dynamics Laboratory

4 Results and discussion

We see from Table-2, the actual minimum and maximum speeds of the available governor are 211 rpm and 276 rpm respectively. While with the help of calculations, the theoretical minimum and maximum speeds of the available governor are 133 rpm and 195 rpm respectively. We see that the actual sensitivity of the governor available in the laboratory for students is 26.7% while theoretical value is 37.8 %. The error in measuring the sensitivity is 41.6%. From Table-2, we observe that with the change of governor speed, the radius of rotation also changes. Therefore, we conclude that this governor is not stable. From Centrifugal force Vs radius of rotation graph shown in Figure 2, we can conclude that for a very small change in radius of rotation there is a huge change in centrifugal force acting on fly balls. From actual spindle speed Vs sleeve displacement graph shown in Figure 3, we conclude that there is a little increase in sleeve displacement with increase in actual spindle speed. Also, from theoretical spindle speed Vs sleeve displacement graph shown in Figure 4, there is a little increase in sleeve displacement with increase in theoretical spindle speed. In other words, with slight change i.e. increase in RPM, centrifugal force on the masses (balls) increase, increasing the radius of rotation resulting in increased sleeve displacement. As the speed decreases, the radius of rotation decreases slightly resulting in lowering of the sleeve. This phenomenon is used to regulate the fuel supply into an engine, which ultimately regulates the running speed of the engine.

In the end, author would like to conclude by stating that this work presents an exhaustive study of Calibration of experimental setup of Watt Governor in Dynamics of Machinery Laboratory of Mechanical Engineering Department. In the past several studies has been conducted and several will be conducted in future also. Therefore, this study was essential for achieving accurate results for further studies. Our study is quite simple and general in nature and almost all results are validated by other studies Singh [15], Kumar [4] and Surarapa [8] already available in the literature.

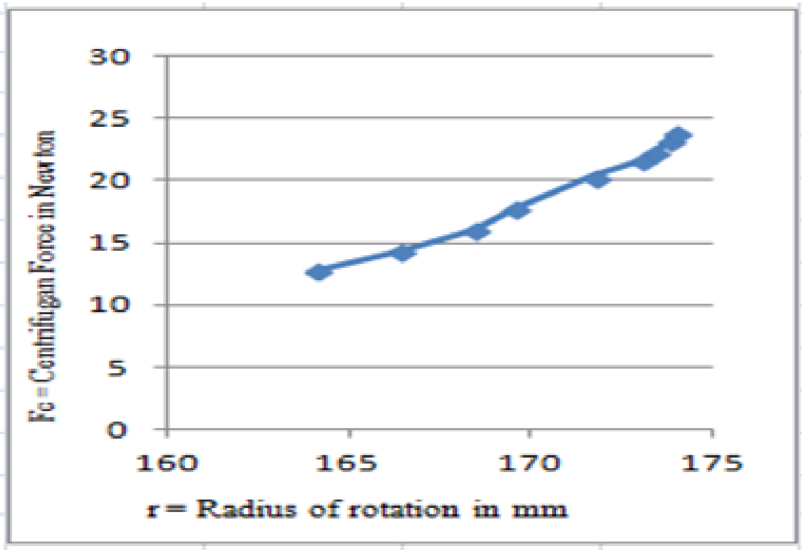

Fig 2. Effect of Radius of Rotation on Centrifugal Force

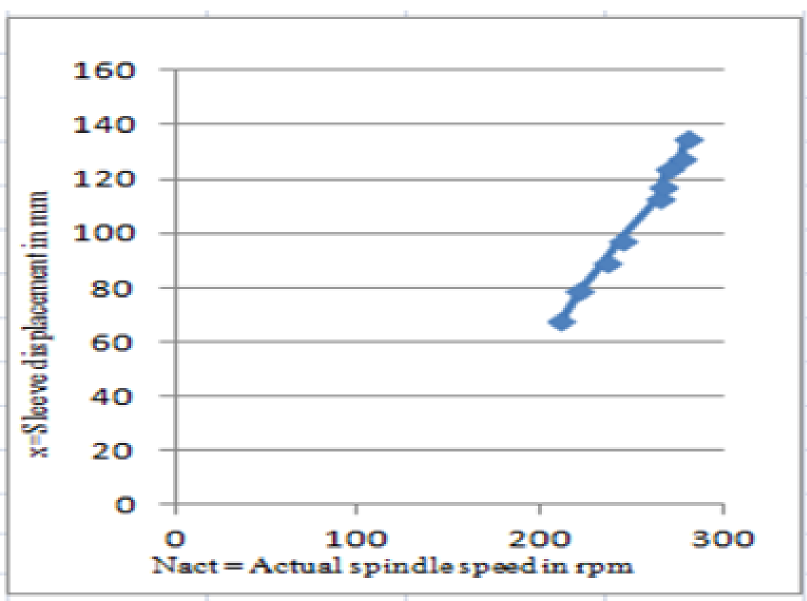

Fig 3. Effect of Actual Spindle Speed on Sleeve Displacement

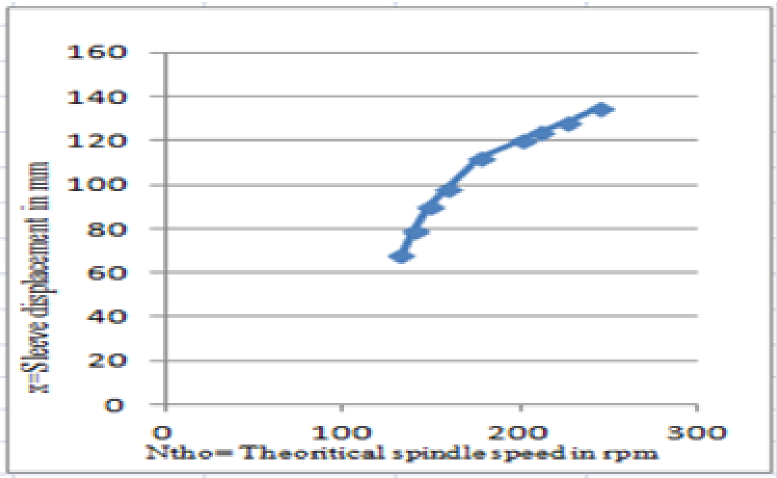

Fig 4. Effect of Theoretical Spindle Speed on Sleeve Displacement

5 Conclusions

From the graph 'F_c' Vs 'r' shown in Figure 2, it is evident that for a very small change in 'r', there is a tremendous change in 'Fc' acting on fly balls. From N_{act} Vs 'x' graph shown in Figure 3, there is a little increase in 'x' with increase in 'N_{act}'. Also, from 'N_{tho}' Vs 'x' graph shown in Figure 4, there is a little increase in 'x' with increase in 'N_{tho}'. In other words, with slight change i.e. increase in rpm, 'Fc' increase, increasing the 'r' resulting in increased 'x'. As the speed decreases, 'r' decreases slightly resulting in lowering of the sleeve. This study can be extended to other centrifugal governors like Porter governor, Proell governor and Hartnell governor also in the future. This study may be based upon sensitivity of the governor in the future. In the future, we can increase the minimum speed of Watt governor by changing the ball position and lengths of different links in the mechanisms.

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