International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 11, November-2018

Design, Multi Rigid Body Dynamic and Modal Analysis of a Centrifugal Governor by using ANSYS

Vanga Padmasri[1]
Student (M.Tech)
Dept. of Mechanical engineering
Warangal institute of technology and science
Warangal (TS), India

Nalla Suresh[2]
Assitant professor
Dept. of Mechanical engineering
Warangal institute of technology and science
Warangal (TS), India

Elumagandla Surendar[3]
Associate professor & HOD
Dept of mechanical engineering
Warangal institute of technology and scince
Warangal (TS), India

M Vidyasagar[4]
Student (M.Tech)
Dept. of Mechanical engineering
Warangal institute of technology and science
Warangal (TS), India

Abstract: **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. On the other hand, when the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits. And keeps the mean speed within certain limits. by an equal and opposite radial force, known as the controlling force. It consists of two balls of equal mass; these balls are known as governor balls or fly balls. The balls revolve with a spindle, which is driven by the engine through bevel gears. The upper ends of the arms are pivoted to the spindle, so that the balls may rise up or fall down as they revolve about the vertical axis. The arms are connected by the links to a sleeve, which is keyed to the spindle. This sleeve revolves with the spindle; but can slide up and down the balls and the sleeve rises when the spindle speed increases, and falls when the speed decreases.**

In this project we model of centrifugal governor individual parts and assembly of individual parts of Centrifugal governor using Catia V5 and Import into ANSYS WORKBENCH 14.5 for Multi Rigid body dynamic Analysis and Modal Analysis, in this Multi body dynamic analysis how the deformation, spring probe and velocity takes in to the structure and in modal analysis how the mode shapes at different natural frequencies.

Key Words: CATIA, Spindle, Weight of the Arms, Centrifugal, Governor Etc.

I. INTRODUCTION

A flyweight mechanism driven by the engine is linked to the throttle and works against a spring in a fashion similar to that of the pneumatic governor, resulting in essentially identical operation. A centrifugal governor is more complex to design and produce than a pneumatic governor. However, the centrifugal design is more sensitive to speed changes and hence is better suited to engines that experience large fluctuations in loading.

Terms Used in Governors:

The following terms used in governors are important from the subject point of view

1. **Height of a governor.** It is the vertical distance from the centre of the ball to a point where the axes of the arms (or arms produced) intersect on the spindle axis. It is usually denoted by ***h***.
2. **Equilibrium speed.** It is the speed at which the governor balls, arms etc., are in complete equilibrium and the sleeve does not tend to move upwards or downwards.
3. **Mean equilibrium speed.** It is the speed at the mean position of the balls or the sleeve.
4. **Maximum and minimum equilibrium speeds.** The speeds at the maximum and minimum radius of rotation of the balls, without tending to move either way are known as maximum and mini- mum equilibrium speeds respectively.
5. **Sleeve lift.** It is the vertical distance which the sleeve travels due to change in equilibrium speed.

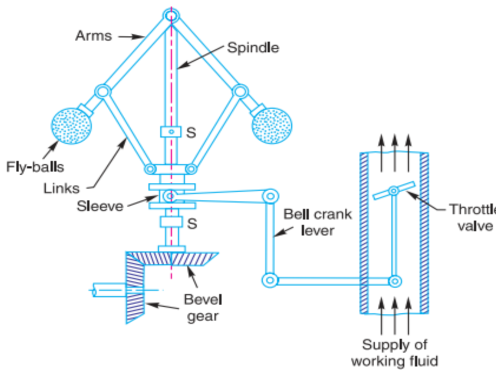


Fig1.1: Centrifugal governor

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 11, November-2018

Types of governors:

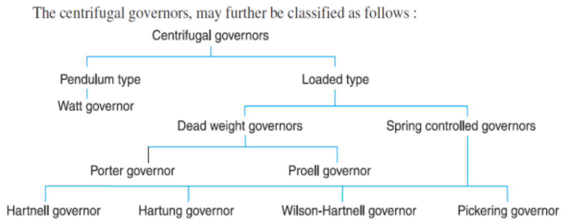


Fig1.2: Types of Centrifugal governors

II. LITERATURE SURVEY

1. Sumit Kumar[1], Rajeev Kumar[2], Harish Kumar[3] There are many types of governors. Watt governor is the simplest form of governors. It is known that the watt governor has low speed range because in watt governor controlling force is less. To improve the range various governor was invented some of them are Porter governor, Proell governor & Hartnell governor in the mentioned the controlling force is increased by dead weight on the sleeve in Porter & Proell governor and by spring in Hartnell governor. In the current investigation watt governor is modified such that it increases the controlling force .in modification the fly-ball is fixed on the lower arm at the small distance below from the point of intersection of arms. The analysis is carried out by mounting the fly ball at the various positions on the lower arm.

2. Jorge Sotomayor, Luis Fernando Mello and Denis de Carvalho Braga In this paper we study the Lyapunov stability and Hop bifurcation in a system coupling a Watt-centrifugal-governor with a steam-engine. Sufficient conditions for the stability of the equilibrium state in terms of the physical parameters and of the bifurcating periodic orbit at most critical parameters on the bifurcation surface are given

3. Surarapu Giribabu[1], Uotkuri Nagamani[2] And Mekala Rajitha[3] The function of the governor is to maintain the mean speed of the engine with in specified limits whenever there is a variation of the load. The objective of our investigation is modifying the Watt Governor (pendulum type) to increase minimum speed limit. Generally we seen that watt governor is best suitable for 60-80r.p.m minimum speeds only, in our study we extend lower arm and fly ball position of the watt governor to the downside from the intersection of link and arm, and then we derive the equation for governor speed. This analysis carried out by extension of lower links of the governor and position of fly balls. And also identify the stress concentration areas, areas which are most susceptible to failure when governor is rotating about its axis, also the value of these stresses is measured. This analysis is carried out with the help of PRO E and ANSYS. Effect of the “WEIGHT OF THE ARMS” is the major area of concern for our study and all the calculations are done considering the weight of the arms. Weight of the arms acts on the centroid of the arms and when the governor assembly rotates, centrifugal force starts acting on the centroid of the arms and tends to deflect the arms, this deflection or bending is to be observed. In our work, we have done the Stress analysis on a particular configuration of governor assembly and then various materials are suggested on a theoretical basis.

1. GiriBabu Surarapu[1], Shashidar PeddiReddy[2], Nagamani Uotkuri[3]:-The function of the governor is to maintain the mean speed of the engine with in specified limits whenever there is a variation of the load. The objective of our investigation is modifying the Watt Governor (pendulum type) to increase minimum speed limit. Generally we seen that watt governor is best suitable for 60-80r.p.m minimum speeds only, in our study we extend lower arm and fly ball position of the watt governor to the downside from the intersection of link and arm, and then we derive the equation for governor speed. We fabricated the model of governor and observed effect of the extension of lower link and fly ball weight on minimum speed of the governor. This analysis carried out by extension of lower links of the governor and position of fly balls.

III. DESIGING AND RIGIDBODY DYNAMIC ANALYSIS

We have been supplied with the .igs file of the Centrifugal Governor; I have designed the Centrifugal Governor according to the dimensions supplied to me in CATIA V5.

Multi body simulation deals with deals with study and analysis of dynamic behavior of system of flexible and/or rigid interconnected bodies. These bodies are subjected to constrain with respect to one another through a kinematic constraints modeled as joints. These systems can represent a space structure with antenna deployment capabilities, an automobile, a robot with manipulator arms, an aircraft as an assemblage of rigid and flexible parts, and so on. The components may be subjected to large displacement, large rotation, and also effects of finite strain.

Multi body systems have conventionally been modeled as rigid body systems with superimposed elastic effects of one or more components. A major limitation of these methods is that non-linear large-deformation, finite strain effects or non-linear material cannot be incorporated completely into model.

The FE method used in ANSYS offers an attractive approach to modeling a multi body system. The ANSYS multi body analysis method may require more computational resources and modeling time compared to standard analysis; it has the following advantages:

•The finite element mesh automatically represents the geometry while the large deformation/rotation effects are built into the finite element formulation.

•Inertial effects are greatly simplified by the consistent mass formulation or even point mass representations.

•Interconnection of parts via joints is greatly simplified by considering the finite motions at the two nodes forming the joint element.

A general steps for FEM for non-linear analysis is as follows:

(i) Build the model: A flexible mechanism usually comprises of flexible and/or rigid body parts connected via joint elements. The modeling the flexible parts with any of the 3-D solid, shell, or beam elements. The flexible and/or rigid parts are connected using joint elements. In one scenario, two parts may be simply connected to ensure that the displacements at the joints are identical. In other scenario, the two connected parts may involve joint such as the universal joint or a planar joint. While modeling these joints, a suitable kinematic constraint is implemented on the relative motion (displacement and rotation) between the two nodes that form the joint.

(ii)Define element types: Simulation of a flexible multi body involving flexible and rigid components joined together subjected to some form of kinematic constraints, using appropriate joint and contact element types.

(iii)Define materials: Defining the linear and non-linear material properties for each components of multi body system.

(iv)Mesh the model: Mesh the all flexible components of multi body system. Two nodes define joint elements and no special meshing is required to define them.

(v) Solve the model: Multi body analyses generally involve large rotations in static or transient dynamics analysis, so non-linear geometric effects must be accounted for.

(vi) Review the results of model: Results from a flexible multi body analysis consist mainly of displacements, velocities, accelerations, stresses, strains, and reaction forces in structural components. Constraint forces, current relative positions, relative velocities, and relative accelerations in joint elements are also available.

Rigid body dynamic Analysis of Centrifugal governor in ANSYS

The procedure for rigid and dynamic analysis of mechanism in ANSYS Workbench software is as follows:

- Selection of types of analysis
- Define engineering data
- Attach geometry
- Define the part behavior
- Define connections
- Apply mesh control and preview mesh
- Establish the analysis setting
- Define the initial conditions
- Description of solve tool

Connections include contact regions, joints, springs, or beams. Explicit analysis connections include body interactions.

Contact conditions arise where bodies meet. On importing an assembly from a CATIA system, contact between various parts is automatically detected. In addition to this contact regions can also be set up manually. It is possible to transfer heat flow across the contact boundaries and structural loads and connects the various bodies. The analysis can be linear or nonlinear, depending on the type of contact.

A joint is an idealized kinematic linkage that controls the relative movement between two bodies. Joint types are characterized by their translational and rotational DOF as being fixed.

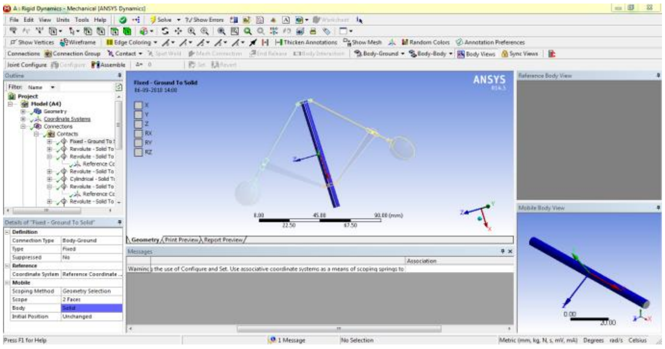


Fig3.1: Fixed joint (body to ground)

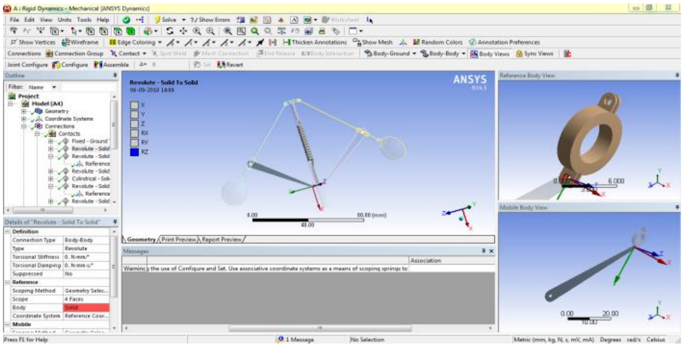


Fig 3.2: Revolute joint (body to body)

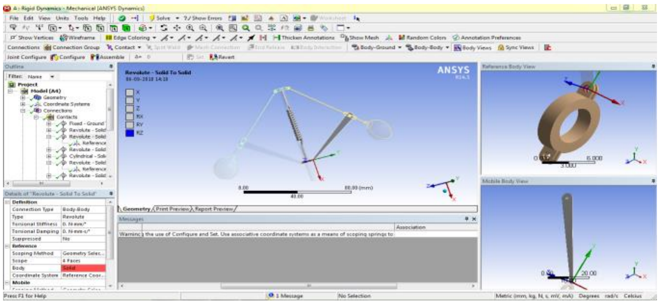


Fig 3.3: Revolute joint (body to body)

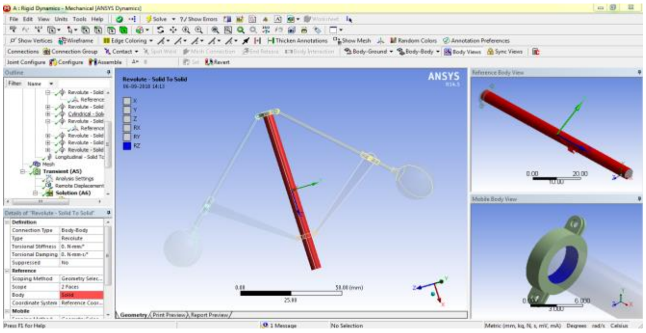


Fig3.4: Cylindrical joint (body to body)

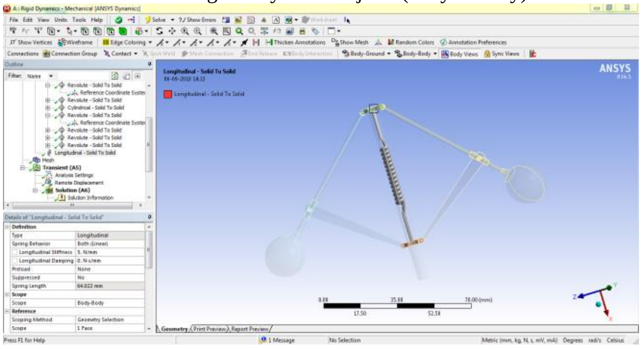


Fig3.5: Spring probe (body to body)

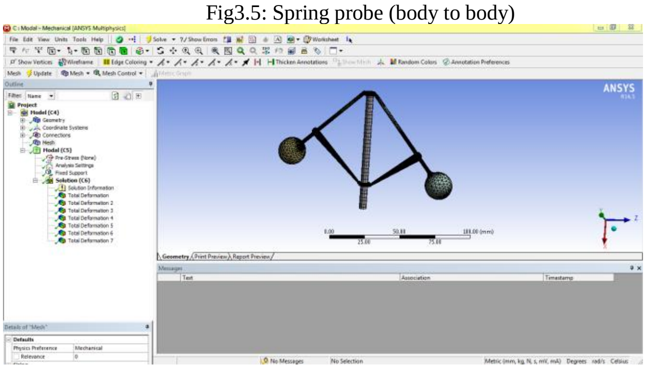


Fig3.6: Mesh model

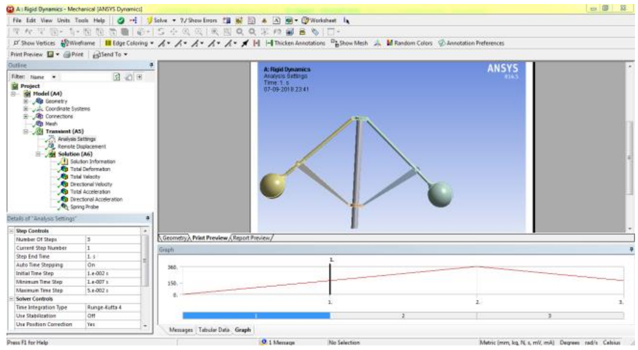


Fig3.7: Step for setting the analysis steps

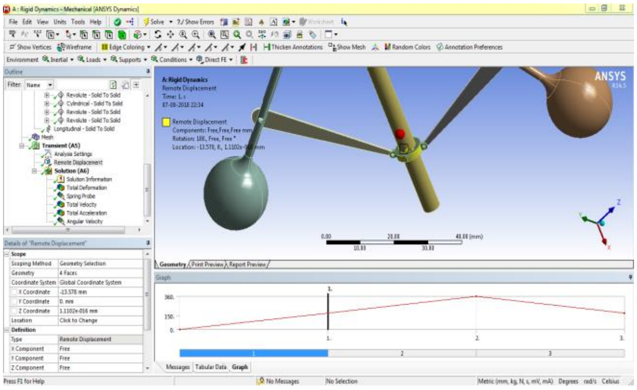


Fig 3.8: Applying remote displacement to modal

IV. RESULTS AND DISCUSSIONS

Total deformation: of centrifugal governor when it is multi rigid body dynamic Analysis:

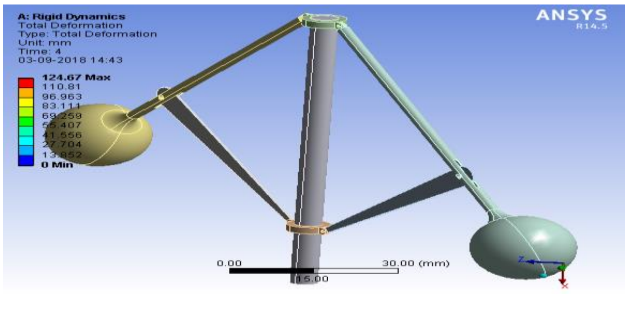
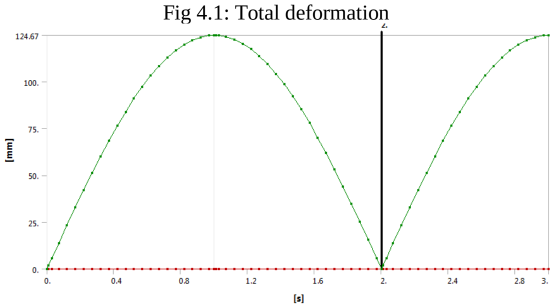


Fig 4.1: Total deformation



Graph 4.1: Total deformation graph (time (sec) vs. deformation (mm))

Total Velocity:

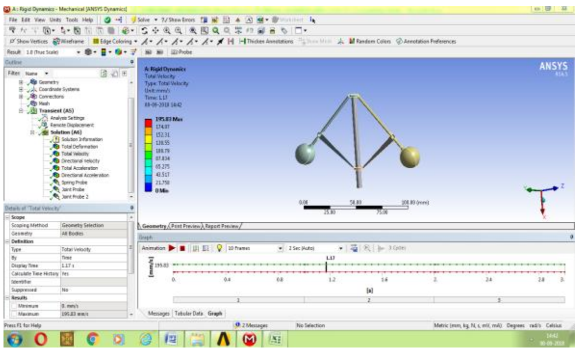
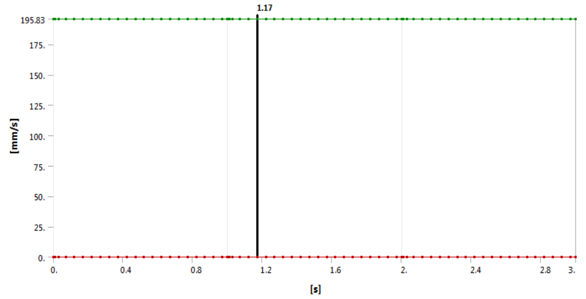
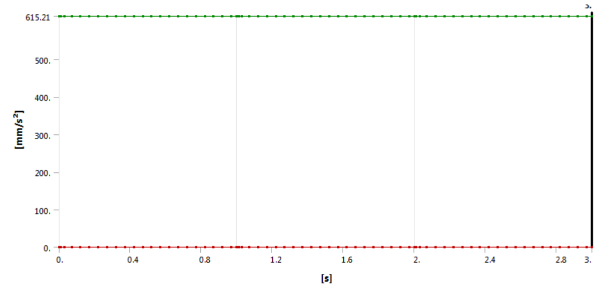


Fig 4.2: Total velocity



Graph4.2: graph between Times (s) Vs total velocity (mm/s)



Graph 4.4: graph between time(sec) Vs total acceleration(mm/s^2)

Directional velocity:

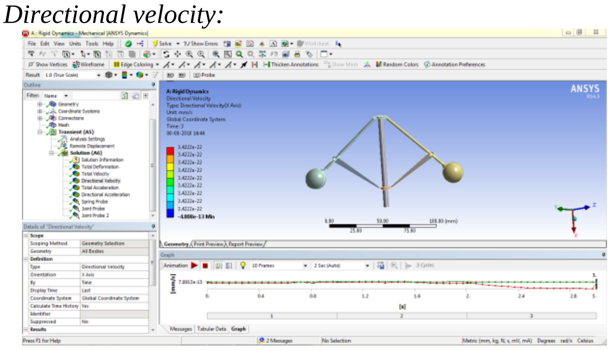
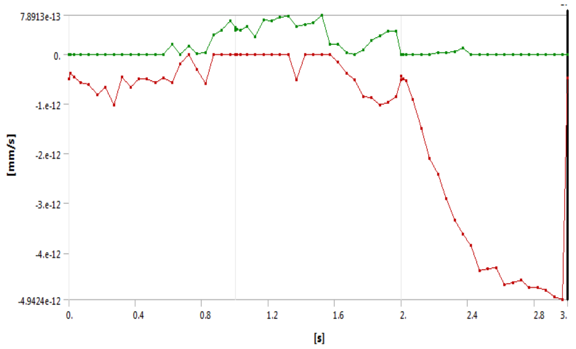


Fig 4.3: total directional velocity



Graph 4.3: total directional velocity graph (Time (sec) Vs Directional velocity (mm/s))

- Red line indicates directional velocity in X-direction
- Green line indicates directional velocity in Z-direction

Total Acceleration:

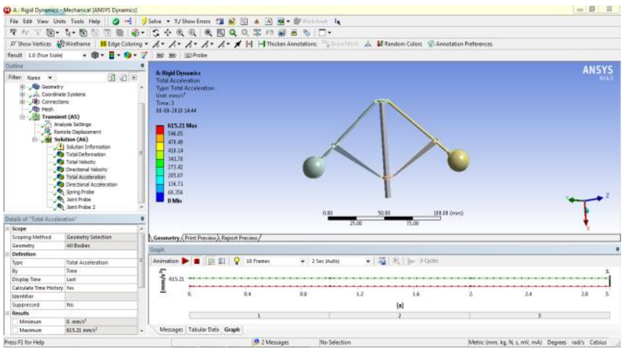


Fig 4.4: Total Acceleration

Directional Acceleration:

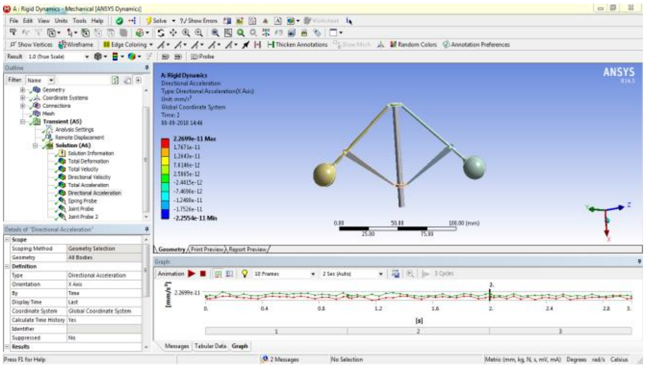
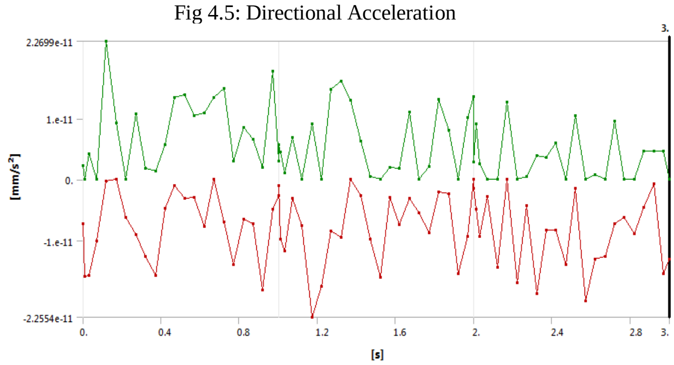


Fig 4.5: Directional Acceleration



Graph 4.5: graph between time (sec) Vs directional acceleration (mm/s^2)

Spring Probe:

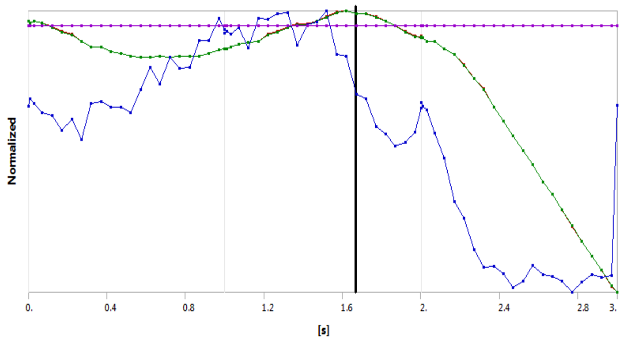
Table 4.1: spring probe force, elongation and velocity

s.no	Time [s]	Spring Probe (Force) [N]	Spring Probe (Elongation) [mm]	Spring Probe (Velocity) [mm/s]	s.no	Time [s]	Spring Probe (Force) [N]	Spring Probe (Elongation) [mm]	Spring Probe (Velocity) [mm/s]
1	0	2.22E-15	4.26E-14	-4.88E-13	19	0.82	-1.42E-14	-2.84E-13	3.66E-14
2	1.00E-02	1.33E-15	2.84E-14	-3.84E-13	20	0.87	-1.42E-14	-2.84E-13	3.87E-13
3	3.00E-02	2.22E-15	4.26E-14	-4.54E-13	21	0.92	-1.29E-14	-2.56E-13	3.90E-13
4	7.00E-02	1.33E-15	2.84E-14	-5.74E-13	22	0.97	-1.11E-14	-2.27E-13	6.84E-13
5	0.12	-4.44E-16	-1.42E-14	-6.15E-13	23	1	-1.07E-14	-2.13E-13	5.35E-13
6	0.17	-2.66E-15	-5.68E-14	-8.09E-13	24	1	-1.07E-14	-2.13E-13	4.87E-13
7	0.22	-4.00E-15	-8.53E-14	-6.67E-13	25	1.01	-1.07E-14	-2.13E-13	5.15E-13
8	0.27	-7.11E-15	-1.42E-13	-9.31E-13	26	1.03	-9.77E-15	-1.99E-13	4.83E-13
9	0.32	-9.77E-15	-1.99E-13	-4.53E-13	27	1.07	-8.44E-15	-1.71E-13	5.66E-13
10	0.37	-9.77E-15	-1.99E-13	-4.25E-13	28	1.12	-7.55E-15	-1.56E-13	2.88E-13
11	0.42	-1.20E-14	-2.42E-13	-4.95E-13	29	1.17	-7.11E-15	-1.42E-13	6.90E-13
12	0.47	-1.29E-14	-2.56E-13	-4.96E-13	30	1.22	-4.00E-15	-8.53E-14	6.77E-13
13	0.52	-1.42E-14	-2.84E-13	-5.77E-13	31	1.27	-2.66E-15	-5.68E-14	7.54E-13
14	0.57	-1.47E-14	-2.98E-13	-2.66E-13	32	1.32	-4.44E-16	-1.42E-14	7.70E-13
15	0.62	-1.47E-14	-2.98E-13	3.45E-14	33	1.37	8.88E-16	1.42E-14	3.35E-13
16	0.67	-1.42E-14	-2.84E-13	-1.86E-13	34	1.42	8.88E-16	1.42E-14	6.06E-13
17	0.72	-1.47E-14	-2.98E-13	1.75E-13	35	1.47	2.22E-15	4.26E-14	6.45E-13
18	0.77	-1.42E-14	-2.84E-13	1.69E-14	36	1.52	4.44E-15	8.53E-14	7.89E-13

Cntd

Cntd

s.no	Time [s]	Spring Probe (Force) [N]	Spring Probe (Elongation) [mm]	Spring Probe (Velocity) [mm/s]		s.no	Time [s]	Spring Probe (Force) [N]	Spring Probe (Elongation) [mm]	Spring Probe (Velocity) [mm/s]
37	1.57	6.66E-15	1.28E-13	2.12E-13		53	2.22	-1.82E-14	-3.69E-13	-1.99E-12
38	1.62	7.11E-15	1.42E-13	1.87E-13		54	2.27	-2.49E-14	-4.97E-13	-2.41E-12
39	1.67	5.77E-15	1.14E-13	-3.26E-13		55	2.32	-2.98E-14	-5.97E-13	-2.65E-12
40	1.72	5.77E-15	1.14E-13	-3.84E-13		56	2.37	-3.82E-14	-7.67E-13	-2.64E-12
41	1.77	4.44E-15	8.53E-14	-7.65E-13		57	2.42	-4.49E-14	-8.95E-13	-2.74E-12
42	1.82	2.22E-15	4.26E-14	-8.59E-13		58	2.47	-5.20E-14	-1.04E-12	-2.92E-12
43	1.87	0	0	-1.02E-12		59	2.52	-5.91E-14	-1.18E-12	-2.84E-12
44	1.92	-2.66E-15	-5.68E-14	-9.67E-13		60	2.57	-6.53E-14	-1.31E-12	-2.63E-12
45	1.97	-4.89E-15	-9.95E-14	-8.42E-13		61	2.62	-7.37E-14	-1.48E-12	-2.75E-12
46	2	-5.77E-15	-1.14E-13	-5.19E-13		62	2.67	-7.95E-14	-1.59E-12	-2.77E-12
47	2	-4.89E-15	-9.95E-14	-4.39E-13		63	2.72	-8.66E-14	-1.73E-12	-2.83E-12
48	2.01	-5.77E-15	-1.14E-13	-4.85E-13		64	2.77	-9.46E-14	-1.89E-12	-2.98E-12
49	2.03	-7.11E-15	-1.42E-13	-5.39E-13		65	2.82	-1.02E-13	-2.03E-12	-2.84E-12
50	2.07	-7.11E-15	-1.42E-13	-8.46E-13		66	2.87	-1.09E-13	-2.17E-12	-2.75E-12
51	2.12	-1.07E-14	-2.13E-13	-1.19E-12		67	2.92	-1.15E-13	-2.30E-12	-2.78E-12
52	2.17	-1.33E-14	-2.70E-13	-1.76E-12		68	2.97	-1.23E-13	-2.46E-12	-2.76E-12
						69	3	-1.26E-13	-2.52E-12	-4.81E-13



Graph 4.5: Graph between time(s) Vs spring probe force (N), spring elongation (mm) and spring probe velocity (mm/s)

Table: 4.2 Detail of cases simulated in present study

S.no	Cases considered for simulation	ANSYS	Importance of study
1	Position analysis	No	Necessary for dynamic analysis
2	Velocity analysis	Yes	
3	Acceleration analysis	Yes	
4	Determination of spring probe force	Yes	

V. MODAL ANALYSIS OF CENTRIFUGAL GOVERNOR

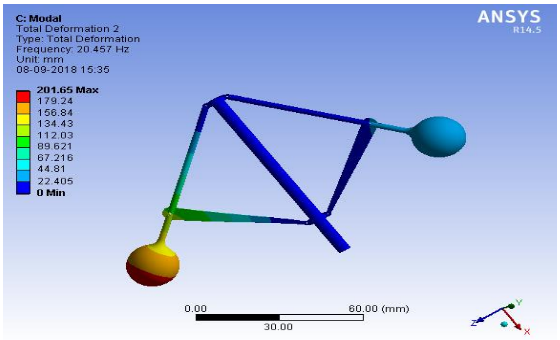


Fig 5.1: First order mode shape latitude deformation

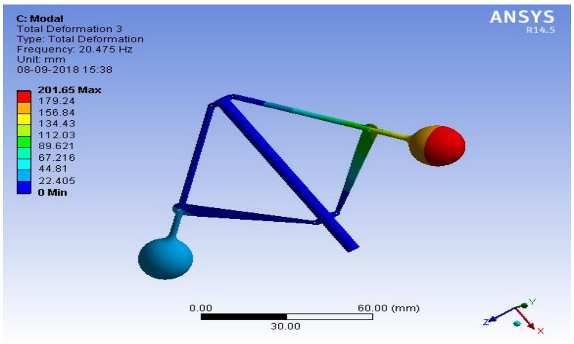


Fig 5.2: Second order mode shape longitudinal deformation

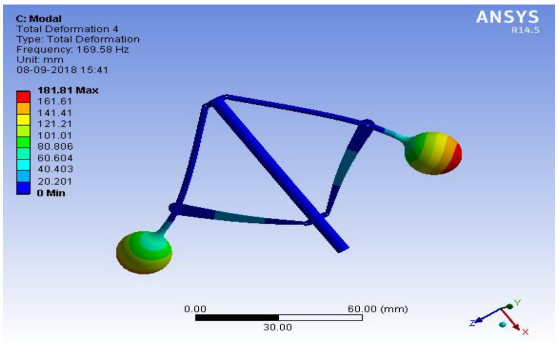


Fig 5.3: Third order mode shape twist deformation

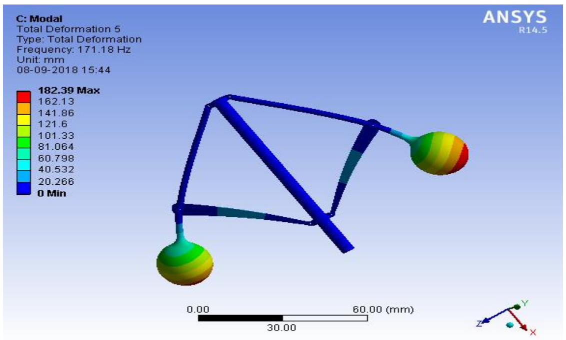


Fig 5.4: Fourth order mode shape bending and torsion deformation

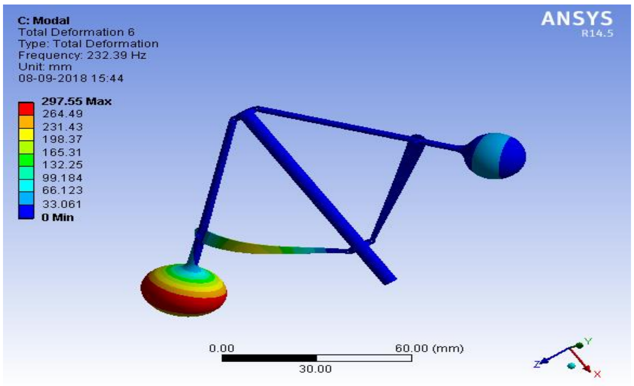


Fig 5.5: Fifth order mode shape bending deformation

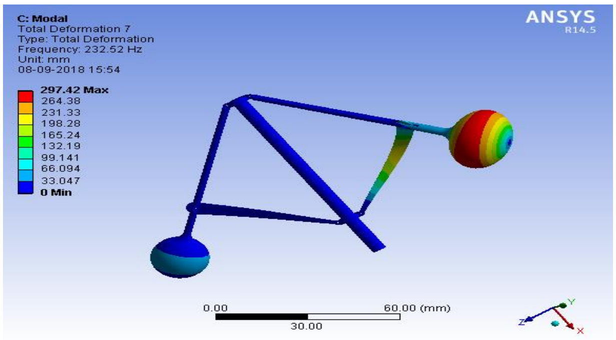


Fig 5.6: sixth order mode shape bending and twist deformation

VI. CONCLUSION AND FUTURE SCOPE

Conclusion:

The analysis type determines the results available for user to examine after solution.

After the solution has been obtained, it is possible to review and interpret the output as explained below:

• Vector Plots - Displays some results in the form of vectors (arrows).

•Probes - Displays a result at a single time point, or as a variation over time, using a table as well as a graph. It is also possible to set up various probes to review results.

• Charts – Shows various results over period of time, or displays one result versus another, for example, Time versus displacement, Time versus velocity, time versus spring probe.

Animation - Animates the change of results over geometry along with deformation of structure.

Future Scope:

- For accurate modeling of Centrifugal Governor using Catia V5, the model was meshed and added constraints, to obtain the first 6 order natural frequency and vibration mode, and the vibration modes are described. The results of this analysis for the following dynamic analysis and structure optimization design provides an important basis, also laid the foundation for more in-depth study on the vibration and noise problems, to provide a reference and basis for the practical experiment.
- Vibration analysis will give better results in accuracy.
- Study on various factors (i.e. stability, sensitivity, and hunting) of the governors.

VII. REFERENCES

[1] R.S. Khurmi, The Technical Writer's Handbook, Theory of machines Surarapu Giribabu, "dynamic analysis of watt and modified watt governor to increase minimum speed," ISSN: 2349-9745, IJMTER.
[2] Ravindra Singh Rana, "Design and stress analysis of watt and porter governor", IJSRP, Volume 2, Issue 6, June 2012 1 ISSN 2250-3153
[3] Amitabha Ghosh, The Technical Writer's Handbook, Department of Mechanical Engineering Indian Institute of Technology, Kanpur
[4] Surarapu Giribabu, "dynamic analysis of watt and modified watt governor to increase minimum speed," ISSN: 2349-9745, IJMTER.
[5] IJSRP, Volume 2, Issue 6, June 2012 ISSN 2250-3153
[6] IJSRP, Volume 5, Issue 2, February 2015 ISSN 2250-3153
[7] THEORY OF MACHINES, Third Edition by S S RATTAN, with Tata McGraw Hill Education (p) L.t.d.
[8] WWW.ANSWERS.COM/TOPIC/GOVER-DE
[9] HTTSP//EN.WIKIPEDIA.ORG/WIKI/GOVER-DE.
[10] http://en.wikipedia.org/wiki/Governo(device)