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Modeling and Analysis of Gear box Using ABAQUS

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Abstract - An attempt is made in this paper the modeling and static analysis of the Gearbox by using the Finite Element Analysis for the different materials such as steel STE-285 & Cast-Iron GG-30. The modeling of Gearbox is done by using CATIA V5 software and then the meshing is done the 73,590 quadratic tetrahedral elements of type C3D10 by using hyper mesh software and then exported to ABAQUS Software with application of Finite Element Analysis. Further. the applied Boundary conditions and with different pressures 20MPa, 40MPa & 60MPa on the Gearbox to draw the stress distribution and displacement contours for Steel STE-285 and Cast Iron GG-30 materials. Finally it is concluded that of the Steel STE-285 and Cast Iron GG-30, the Steel STE-285 is the Best Material.

Keywords: Gearbox, Static analysis, hypermesh, Finite Element Analysis.

I. INTRODUCTION

A gearbox is a mechanical method of transferring energy from one device to another and is used to increase torque while reducing speed. A gear box changes the engine speed into torque when climbing hills of the vehicle. This design is commonly found in automobile transmissions. Most modern gearboxes are used to increase torque while reducing the speed of a prime mover output shaft. In an automobile, there are three types of transmission: automatic, manual, or continuously variable. A manual transmission vehicle provides the best example of a simple gearbox. In both the automatic and continuously variable transmissions, the gearboxes are closed systems, requiring very little human interaction.

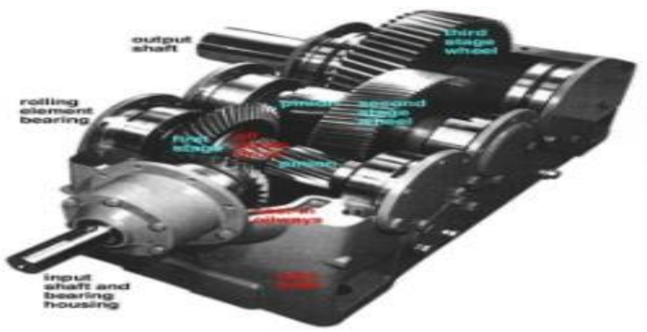

Fig. 1: Gear Box

II. LITERATURE REVIEW

F. K. Choy et al. [1] have provided a comparison and bench marking of experimental results obtained from a damaged gear transmission system with those generated from a numerical model. The vibration signature analysis using a joint time-frequency procedure, the Wigner-Ville distribution (WVD), seems to be quite effective in identifying single and multiple teeth damage in a gear transmission.Lei Wang et al. [2] have done the theory of hybrid-driving differential gear trains and carrying-out experiments on the designed test-bench finally, It concluded that the designed a test-bench of hybrid-driving two degree of freedom differential gear trains and test-bench uses PLC component to enable system control more precise, easy operation, debugging easy, gathering the data accurately and conveniently. B. Venkatesh et al. [3] have obtained Von-Misses stress by theoretical and ANSYS Software for Aluminium alloy, values obtained from ANSYS are less than that of the theoretical calculations. Aluminium alloy reduces the weight up to 55.67% compared to the other materials. Aluminium is having unique property (i.e. corrosive resistance), good surface finishing, hence it permits excellent silent operation.Isad Saric et al. [4], developed parts by using interactive modeling are modeled parameter. While geometric gear modeling in CATIA V5 system, It cannot have to create shape directly, but instead of that, it can put parameters integrated in geometric and/or dimensional constraints. It resulted 3D solid gear model by characteristic parameters are changing. AnoopLega et al. [5], has develop the composite material gear box using computer aided Engineering. The modeling of gears is done using parametric methodology 3D family is generated by set of variables which controls other gear dimensions related gear design laws. Erwin V. Zaretsky et al. [6], developed two computational models to determine the fatigue life and reliability of a commercial turboprop gearbox are compared with each other and with field data. C. Veeranjaneyulu et al. [7], had showed that by observing the structural analysis results using Aluminum alloy the stress values are within the permissible stress value. The weight of the Aluminum alloy reduces almost 3 times when compared with Alloy Steel and Cast Iron since its density is very less.[10]

2.1 Objectives of the paper

The object of this paper is the modeling and to find the static analysis of the Gearbox by using the Finite Element

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Analysis for the different materials such as steel STE-285 & Cast-Iron GG-30. The modeling of Gearbox is done by using CATIA V5 software by meshing done by using hyper mesh software, and then exported to ABAQUS Software.

III. MODELING AND ANALYSIS OF GEAR BOX

The modeling of the Gearbox is done by CATIA V5 software .Then it is meshed by using HYPERMESH software with total number of nodes 1, 15,202 and total number of quadratic tetrahedral elements of type C3D10are around 73,590. Further it is imported to ABAQUS software by using the FEM Analysis. Then the boundary conditions are applied at different positions of the Gearbox.

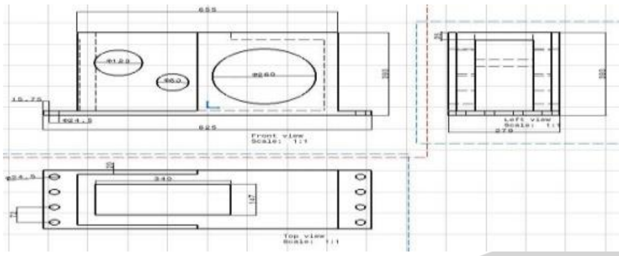

Fig.2: Dimensions of a Gear Box

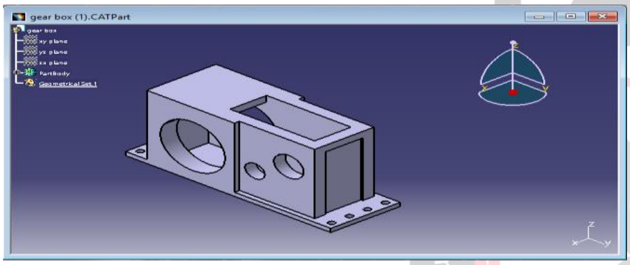

Fig.3: Modeling of the Gearbox

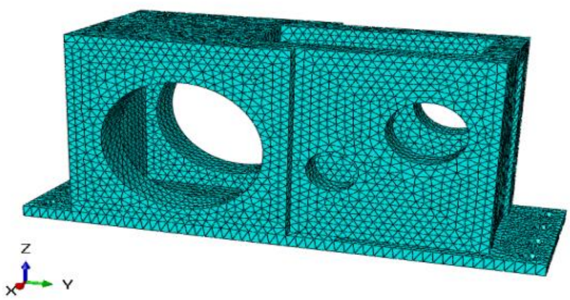

Fig.4: Meshing Model of the Gearbox

3.1 Properties of Materials used for Gearbox[9]

The different materials used for gearbox analysis are Steel STE-285, Cast-Iron GG-30.

3.11 Steel STE-285:

Table1.Chemical composition of Steel STE-285

C	Si	Mn	P	S	N	Al	Cr
0.18	0.4	0.60-1.4	0.035	0.03	0.02	0.02	0.3
Cu	Mo	Ni	Nb	Ti	V	Nb+Ti+V	
0.2	0.08	0.3	0.03			0.05	

Young's modulus (N/mm^2): 2.1e^5

Poisson's ratio: 0.3

Density (ton/mm^3): 7.89e^{-9}

3.12 Cast Iron -GG30:

Table.2 Chemical Composition Cast-Iron GG-30

C	Si	Mn	P	S
2.90 – 3.65	1.80 – 2.90	0.10 – 0.30	0.30 max.	0. 10 max.

Young's modulus (N/mm^2): 1.2e^5

Poisson's ratio: 0.28

Density (ton/mm^3): 7.2e^{-9}

3.2 ANALYSIS USING FINITE ELEMENT METHOD

Finite Element Method is one of the most popular mechanical engineering applications offered by the CAD/CAM systems by involving computerized technique and breaking the geometry into finite elements, framing a series of equations to each solving the equations simultaneously. To evaluate the behaviour of entire system and used when geometry, loading and material properties are complicated and exact analytical solution is difficult to obtain.

STEPS INVOLVED IN FINITE ELEMENT METHOD.[8]

The solution of a general continuum by the finite element method always follows as orderly step-by-step process. The step-by-step procedure for static structural problem can be stated as follows:

Step 1: Discritization of Structure (Domain)

The first step in the finite element method is to divide the structure of solution region in to sub divisions or elements.

Step 2: Selection of proper interpolation model

Since the displacement (field variable) solution of a complex structure under any specified load conditions cannot be predicted exactly, we assume some suitable solution, within an element to approximate the unknown solution. The assumed solution must be simple and it should satisfy certain convergence requirements.

Step 3: Derivation of element stiffness matrices (characteristic matrices) and load vectors.

From the assumed displacement model the stiffness matrix [K(e)] and the load vector P(e) of element 'e' are to be derived by using either equilibrium conditions or a suitable Variation principle.

Step 4 Assemblage of element equations to obtain the equilibrium equations.

Since the structure is composed of several finite elements, the individual element stiffness matrices and load vectors

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are to be assembled in a suitable manner and the overall equilibrium equation has to be formulated as

$$[K]\varphi = P$$

Where [K]is called assembled stiffness matrix,

Φis called the vector of nodal displacement and

P is the vector or nodal force for the complete structure.

Step 5: Solution of system equation to find nodal values of displacement (field variable)

The overall equilibrium equations have to be modified to account for the boundary conditions of the problem. After the incorporation of the boundary conditions, the equilibrium equations can be expressed as,

$$[K]\varphi = P$$

For linear problems, the vector 'φ' can be solved very easily. But for non-linear problems, the solution has to be obtained in a sequence of steps, each step involving the modification of the stiffness matrix [K] and 'φ' or the load vector P.

Step 6: Computation of element strains and stresses

From the known nodal displacements, if required, the element strains and stresses can be computed by using the necessary equations of solid or structural mechanics.

In the above steps, the words indicated in brackets implement the general FEM step-by-step procedure.The procedure for analysis consists of four basic steps. They are as follows.

1) Modelling and meshing
2) Applying boundary conditions and loads
3) Obtaining solutions/results
4) Reviewing the results.

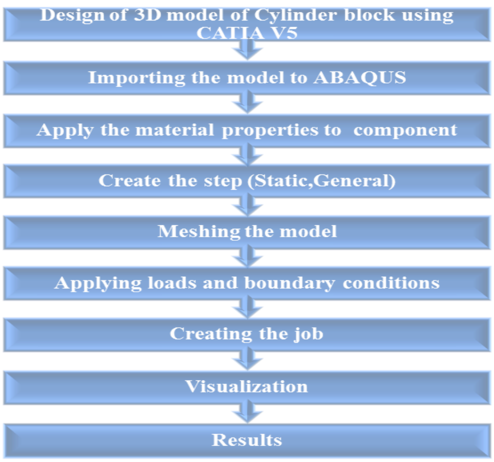

Fig.5 : Flow chart for Static Analysis in ABAQUS

IV. RESULTS AND DISCUSSION

The Results of Static analysis of the Gearbox are discussed below. The Static Analysis Results include the stresses and displacements contours for the gearbox, at different pressures for different materials.

4.1 CAST-IRON GG-30

Cast-Iron GG-30, stresses and displacements at different pressures are given below. At 20 MPa pressure, the stress distribution and displacement contours are shown in figure 6. The maximum stress developed is 312 MPa at the top face.

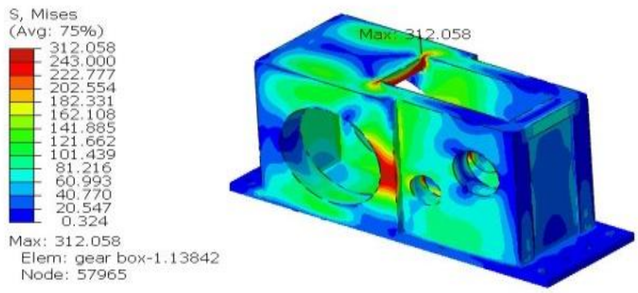

Fig.6 : Stress distribution contours for Cast-Iron GG-30 at 20MPa pressure.

The maximum displacement is 0.804 mm occurs at the middle of the gearbox are shown in figure 7.

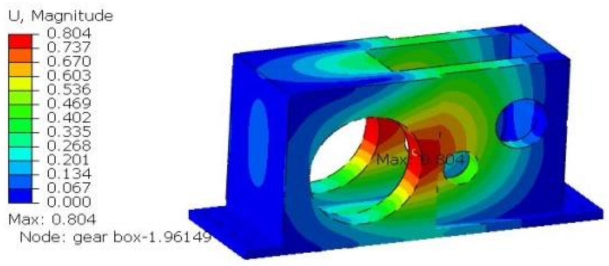

Fig. 7: Maximum Displacement contours for Cast-Iron GG-30 at 20 MPa pressure.

At 40 MPa Pressure, the contours of stress distribution and displacement is shown in figure 8. The maximum stress induced is 409.235 MPa which occurs in the region between them.

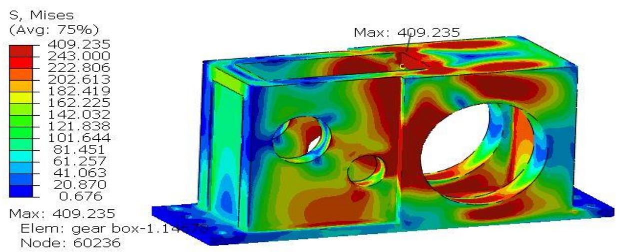

Fig. 8: Stress distribution contours for Cast-Iron GG-30 at 40MPa pressure.

The maximum displacement is 2.035 mm occurs at the middle of the gearbox are shown in figure 9.

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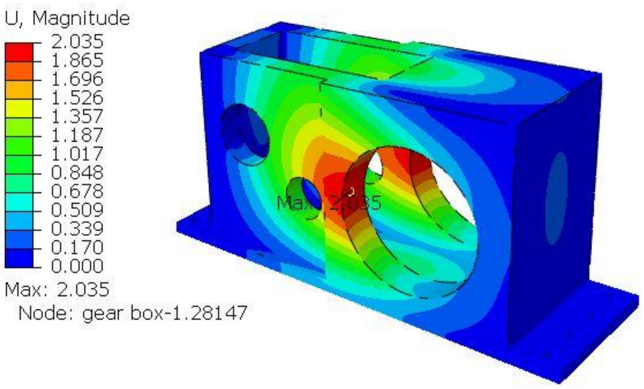

Fig.9: Maximum Displacement contours for Cast-Iron GG-30 at 40 MPa pressure.

At 60 MPa Pressure, the stress distribution and displacement contours are shown in figure 10. The maximum stress induced is 488.544MPa.

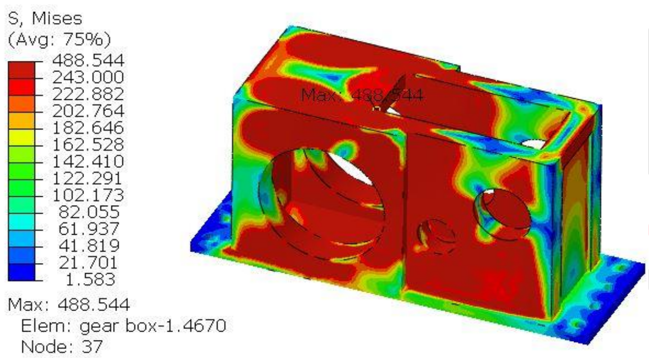

Fig.10: Stress distribution contours for Cast-Iron GG-30 at 60MPa pressure.

The maximum displacement is 4.850 mm occurs at the middle of the are shown in figure 11.

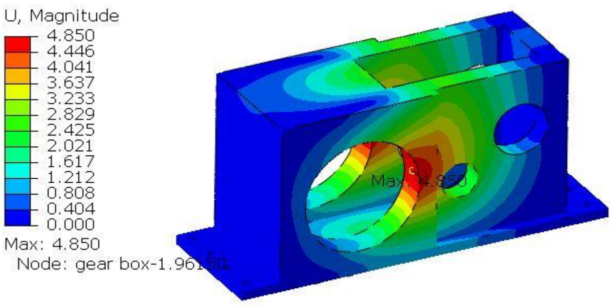

Fig. 11: Maximum Displacement contours for Cast-Iron GG-30 at 60 MPa pressure

4.2 STEEL STE-285

For Steel STE-285, stresses and displacements at different pressures are given below.

At 20 MPa Pressure, the stress distribution and displacement contours are shown in figure 12. The maximum stress induced is 435.359 MPa.

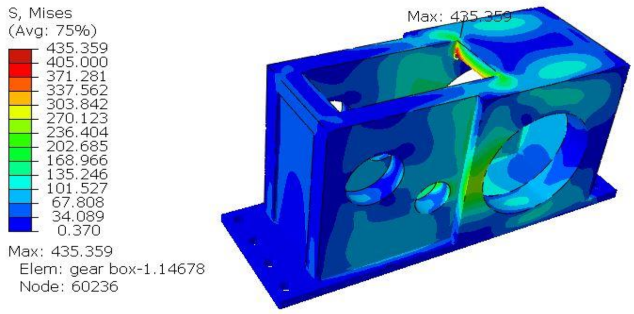

Fig.12: Stress distribution contours for Steel STE-285 at 20 MPa pressure.

The maximum displacement is 0.513 mm occurs at the middle of the are shown in figure13.

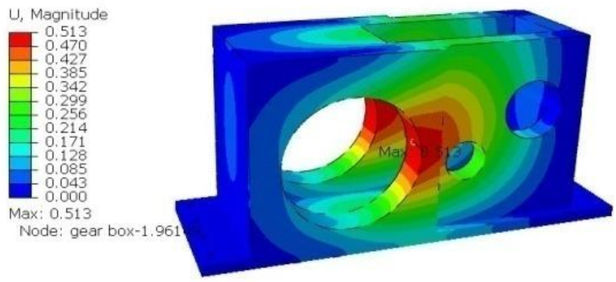

Fig.13 : Maximum Displacement contours for Steel STE-285 at 20 MPa pressure.

At 40 MPa Pressure, the stress distribution and displacement contours are shown in figure14. The maximum stress induced is 713.506 MPa.

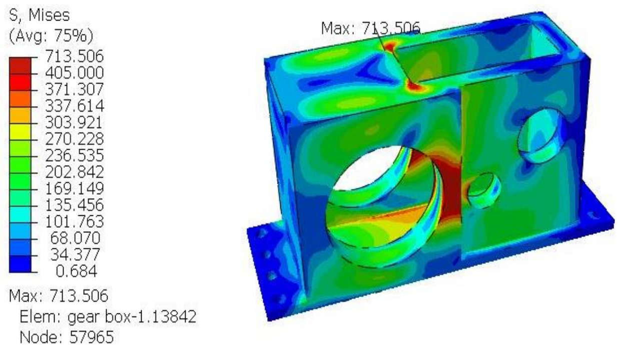

Fig.14 : Stress distribution contours for Steel STE-285 at 40MPa pressure

The maximum displacement is 1.062 mm occurs at the middle of the are shown in figure 15.

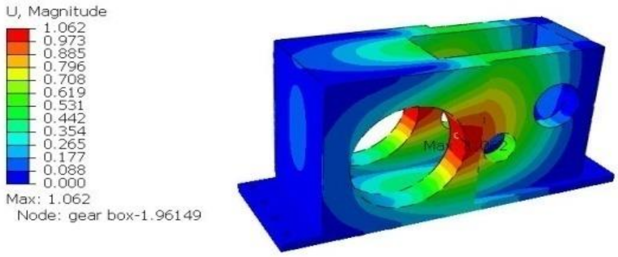

Fig.15 : Maximum Displacement contours for Steel STE-285 at 40 MPa pressure

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At 60 MPa Pressure, the stress distribution and displacement contours are shown in figure 16. The maximum stress induced is 779.790 MPa.

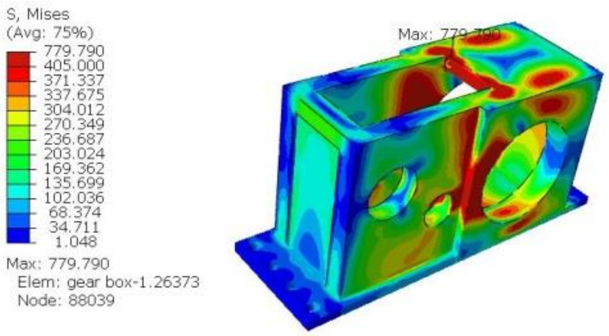

Fig.16: Stress distribution contours for Steel STE-285 at 60MPa pressure.

The maximum displacement is 1.827 mm occurs at the middle of the gearbox are shown in figure 17.

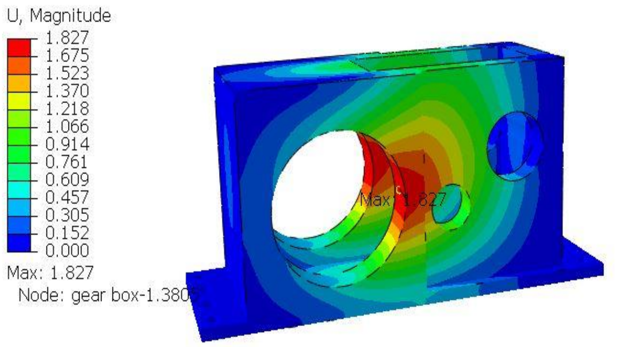

Fig.17 : Maximum Displacement contours for Steel STE-285 at 60 MPa pressure

4.3 COMPARISON OF STATIC ANALYSIS RESULTS

The stress distribution and the deformations under different pressures for different materials are discussed and comparison is made on the various stress distributions and displacements are shown.

By drawing the graph between pressure Vs stress for materials Steel STE-285 & Cast-Iron GG-30 by observing Steel STE-285 materials is more stress when compared to the Cast-Iron GG-30 material and shown in below Figure 18.

S.No	Material	Pressure Applied (Mpa)	Max. Stress Induced (Mpa)	Max Displacement (Mm)
1	Cast Iron GG-30	20	312.058	0.804
		40	409.235	2.035
		60	488.544	4.850
2	Steel STE- 285	20	435.359	0.513
		40	713.506	1.062
		60	779.790	1.827

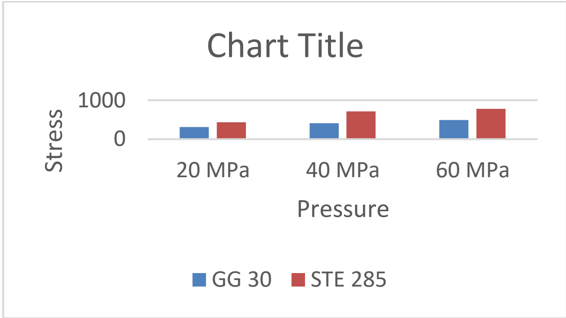

Fig.18 : Graph between Pressure Vs Stress

4.4 Modal Graph between Pressure Vs Displacement :

By drawing the graph between pressure & displacement for materials Steel STE-285 & Cast-Iron GG-30 by observing Steel STE-285 materials is less displacement when compared to the Cast-Iron GG-30 material as shown in figure 19.

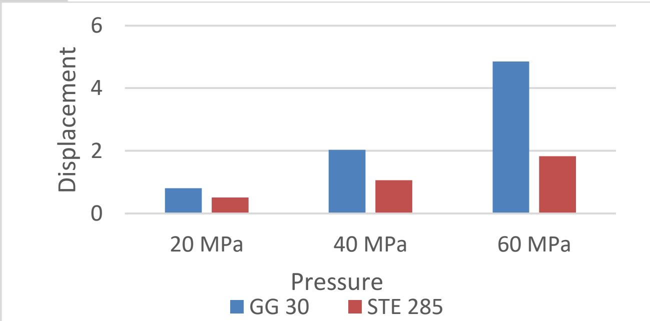

Fig19 . Graph between Pressure Vs Displacement

V. CONCLUSION

- The modeling of the Gearbox is done by CATIA V5 software .Then it is meshed by using by HYPERMESH software analyzed for stresses and displacements for different materials such as Cast-Iron GG 30 & Steel STE-285,for different pressures 20 MPa, 40 MPa and 60 MPa.
- From the static analysis it is observed that the maximum induced stress for Steel STE-285 is 779.790 MPa and Cast Iron GG 30 is 488.544 MPa.
- The maximum induced stress for steel STE-285 is 779.790 at 60 MPa pressure and minimum stress is 435.359 MPa at 20 MPa Pressure.
- The maximum displacement is observed for Cast Iron GG 30 is 4.850mm &Steel STE-285 is 1.827 mm.
- Finally it a concluded that the Best material is Steel STE-285 when compared to Cast Iron GG-30.

VI. FUTURE SCOPE OF WORK

Further this work can be extended for Dynamic

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Analysis, Thermal Analysis and by using composite materials for the Gearbox.

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