ANALYSIS OF GEARBOX CASING AND EFFECT OF FERQUENCY ON STRESS AND STRAIN USING FEA

Neeta T Chavan[1], Gunchita Kaur-Wadhwa[2], Basavaraj S.Talikoti[3]

[1]Student, M.E. Design, Mechanical Department, Pillai Hoc, Maharashtra, India
[2]Assistant Professor, Mechanical Department, Pillai Hoc, Maharashtra, India
[3]Associate Professor, Mechanical Department, PIIT Panvel, Maharashtra, India

Abstract

Gearbox casing is the main component in automobile world which is used to protect components inside the gearbox. It consists of gears, shafts, bearings and oil. It is fluid containing casing which gives support to the moving parts. Gearbox failure occurs mainly due to the design issues, manufacturing defects, oil deficiency, excessive time at stoppage and high loading. In this project loading case is considered. Major challenge for such problems are whether to consider static analysis, dynamic analysis, or perturbation analysis and conditional circumstances for it to be performed. In this work static dynamic as well as perturbation analysis have been performed on gearbox casing. Model is to be developed in Abaqus/CAE and then same model is used for Finite Element Analysis by using Abaqus/Standard 6.10.1 for static analysis and dynamic analysis. Harmonic analysis is also performed by Abaqus software called as perturbation analysis for strain and frequency. Stress and frequency graph in both the cases that is in static and dynamic analysis is performed and results from static and dynamic are compared. Frequency effect on strain levels are linear and no surplus ***strain*** *linearity is produced due to dynamic effect as compared to the static case. By using Abaqus/ standard it is found that results boost for dynamic case as compared to static case.*

Keywords: *Gearbox Casing, Abaqus/CAE, Static stress analysis, Maximum Principle Stress, Minimum Principle Stress Dynamic Analysis*

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1. INTRODUCTION

Gearbox casing is the shell in which assembly of gears are sealed. The components of gearbox casing are gears, bearings, shafts and oil. The gearbox casing act as house the transmission components. The movement of the gear produces vibration in the gearbox casing. Any automobile vehicle requires high torque when they are climbing an elevated surface like a mountain and also at the initial idling, as its speeds is very low. But when vehicle is running with high speeds on plane road high torque is not required due to momentum. Therefore, the device which is required for two reasons, torque speed combination range and to maintain engine speed according to road condition as per drivers need. This device is known as gearbox or transmission box.

Lower gears have high torque and low power. Higher gears have high power but low torque. Due to the engine power stroke, the input shaft rotates once. Hence, the output shaft rotates around 0.5 times. Then two such power strokes are required for one full rotation of output shaft which means that all power is transferred into one rotation. Hence, it has high torque. In case of high gear, the input shaft rotates only once means one power stroke, and the output shaft rotates several times. One power stroke rotates the output shaft several times. Hence the high speed, high power but low torque. Therefore, torque, speed and power are important factors in gearbox.

1.1 Function of Gearbox

Paragraph comes content here. PaThe function of gearbox is to change torque and speed of the vehicle according to road condition. Sometimes it is called as torque convertor because it is used to change the speed and torque according to road and load condition. Gearbox changes the engine speed into torque when they are running on a hilly road. The main function of the gearbox is

- Provision of appropriate torque
- Shifting of Gear for Neutral and Reverse position.

1.2 Gearbox Main Components

In a gearbox four components are required to achieve its function. These components are

- Counter Shaft
- Main shaft
- Gears
- Bearings

2. LITERATURE REVIEW

This chapter provides Review of Literature on topics related to gearbox casing. More work has been done for analysis of gearbox casing by using vibrational analysis by condition monitoring techniqecs, FFT analyser, timefeequency domain analysis also FEA analysis by using ANSYS.

MirunaliniThirugnanasambandam, [1] determined the design and static analysis, natural frequency of casing and torsional, lateral critical speed of two stage gearbox casing. This paper discussed dynamic analysis of casing and observed that most of the gear box housing fails due to the excitation frequencies are very close to natural frequency of casing or critical speed of the rotors.

Amit Aherwar, [2] Studied vibration based techniques for condition monitoring in transmission system, in time ffrequency domain removes noise. In time- frequency domain for multiple defects FFT is not a suitable technique for fault diagnosis. This research proposed that Power Spectrum Density techniques, Hilbert Transform and PSD techniques are better for fault identification and condition monitoring.

Vijaykumar, Mr. Shivaraju, [3] Presented vibration based technique for condition monitoring in gearbox system also determined vibration analysis of gearbox casing using Finite Element Analysis (FEA), ANSYS software for natural vibrational modes and harmonic frequency response for casing to prevent resonance. The paper studied to prevent resonance, frequency ratio must set to 0.25 from first modal natural frequency.

M. S. Patil, [4] Studied vibrational analysis for gearbox casing using finite element analysis (FEA) by applying ANSYS software to determine the natural frequency of gearbox casing. The main aim is to analyze differential gearbox casing of Tata indigo cs vehicle for modal and stress analysis. The theoretical modal analysis validated with experimental results from Fourier frequency transformer (FFT) analysis result shows closeness with FEA results.

Ashwani Kumar, [5] Studied gearbox casing of heavy vehicles and effect of mechanical properties of material on natural frequency and mode shapes. Vibration study of casing by finite element simulation. This research work studied vibration response for gray cast iron, structural steel, Al and Mg alloys shows variation in natural frequency and mode shapes. Further gave satisfactory result by using FEA and also proposed zero displacement constraint based boundary condition with same materials properties.

Vijay N.A., [6] have studied the gear box casing for permanent magnet dc motors. According to author, it is essential to analyze gearbox casing to decide dimensions and predict its behavior under operating conditions, also it support to shaft and bearings. Authors built the model and analyze the casing using ANSYS for Static and Modal analysis. Static analysis was used to analyze deformation and stresses of the Gearbox and executed modal analysis to monitor vibration features to avoid resonance for Gearbox casing components. Conclusions were derived that Static analysis is found in good agreement and modal analysis presented within safe limits.

Bagul A.D., [7] determined natural vibration modes to prevent resonance and free frequency of gearbox casing. FEM modal analysis for gearbox casing is done by ANSYS Workbench software and observed that natural frequencies are separated by 20% from first and second harmonics of excitation frequency. Experimental modal analysis for gearbox results shows close ness with the FEA results.

Ramamurti V, [8] presented design methodology for two stage gearbox, it involves comparison of design stresses obtained from classical methodology and FEM model, also done dynamic analysis of model. The research determined deflection of shaft by using FEM and classical methods under the action of gear forces.

3. THEORIES OF FAILURE USED

Maximum Shear Stress Theory & Distortion Energy theories along with formulae are used for the analysis.

3.1 Maximum Shear Stress Theory

In case of yielding, uni-axial test, the principal stresses are $\sigma 1 = Sy$, $\sigma 2 = 0$ and $\sigma 3 = 0$

The shear strength at yielding is given by,

Ssy = [σ1 - σ2 or σ3 = 0] / 2

$$Ssy = \frac{Sy}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

$$\tau = \frac{\sigma 1 - \sigma 2}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

Where τ= maximum shear stress
$\sigma 1$ = maximum principal stresses
$\sigma 2$= minimum principal stresses

$$\sigma e = (\sigma 1^2 + \sigma 2^2 + \sigma 3^2 - \sigma 1 \sigma 2 - \sigma 2\, \sigma 3 - \sigma 3 \sigma 1) .. 2.3$$

3.2 Distortion Energy Theory

The energy required for shape deformation of a material. in this distortion pure shape of material changes but volume remains same. Distortion energy required per unit volume Ud for three dimensional case is given by

$$\mathrm{Ud} = \frac{1+v}{3E} \left\{ \frac{(\sigma 1 - \sigma 2)^2 \; + (\sigma 2 - \sigma 3)^2 + (\sigma 3 - \sigma 1)(\sigma 3 - \sigma 1)^2}{2} \right\} \quad \ldots\ldots 2.4$$

Distortion energy at the time of failure is given by

$$Ud = \frac{1+v}{3E} \sigma y^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.5$$

3.3 Von – Mises Effective Stress (бe)

These stress are sometimes referred to as equivalent stress is defined as the uniaxial tensile stress that create the same distortion energy as is created by the actual combination of applied stresses. so the condition of failure becomes,

$$\left\{ \sqrt{\frac{(\sigma 1 - \sigma 2)^2 + (\sigma 2 - \sigma 3)^2 + (\sigma 3 - \sigma 1)^2}{2}} \right\} \geq \sigma y \quad \ldots\ldots\ldots\ldots\ldots\ldots 2.6$$

The left hand side of the equation 2.6 is denoted as Von Mises stress.

$$\left\{\sqrt{\frac{(\sigma 1-\sigma 2)^2+(\sigma 2-\sigma 3)^2+(\sigma 3-\sigma 1)^2}{2}}\right\} = \sigma v \quad \ldots\ldots\ldots\ldots.. 2.7$$

From this failure criteria, check whether von mises stresses induced in the material exceeds yield strength of material. So it becomes $\sigma_v \geq \sigma_y$

4. PROBLEM DEFINATION

The main aim of this project is static analysis of casing in presence of generalized modes and critically studying the things for future improvements, in vibration characteristics raised due to stress. Also providing dynamic analysis of casing in presence of generalized modes and critically studying the things for future improvements from stress perspective. To study of interactive dynamics of casing.

4.1 Scope

To complete this project successfully, following scope has been defined

- Development of new methods for analysis
- Development of analytical technique and finite element implementation
- Understanding more physics of problem
- Better design of casing
- Preventing casing from future fatigue with advanced knowledge

4.2 Objectives

To achieve the above stated aim the following objectives are implemented in the project.

- To determine casing response to fluctuations in terms of vibration level
- To carry out static stress analysis by applying load effect in the gearbox casing
- To carryout dynamic stress analysis by applying load effect in the gearbox casing
- To simulate the observed facts in Abaqus

4.3 Methodology

The following are incorporated the research and further to utilize the information gained by the above stated literature review the under defined are used.

- Motivation and literature survey
- Casing problems and evaluation measures
- Modeling and analysis tools
- Nonlinear dynamic analysis of casing
- Harmonic response and interpretations
- Comparison within themselves
- Remark with cantilever beam method
- Conclusion and Future Scope

5. FINITE ELEMENT ANALYSIS BY ABAQUS

5.1 Prepare a Model

- In this analysis dimensions are taken from one of the literature [1]. Dimensions of the housing provided are of 700*450*200. A 6mm plate has been assumed for the gearbox housing and the analysis is performed. Material used is gray cast iron because it has excellent vibration damping capacity. It has high compressive strength, low tensile strength, self-damping, does not vibrate, high resistance to wear. It contains 2.5-3.8% C, 1.1-2.8% Si, 0.4-1 % Mn, 0.15 % P and 0.10 % S. [9]. Also, density- 7200kg/m³, Elastic- Young's modulus- 2 e11 N/m², Poisson's ratio- 0.28 [10]. Due to higher complexity and nonlinearity, Aabaqus has been used. First solid model is to be developed in Abaqus /CEA 6.10.1 and then that can be used for further analysis.

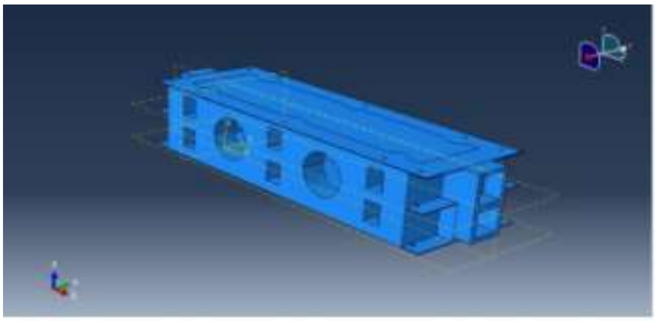


Fig -1: Model of gearbox casing

Meshing is to be done. The element type- C3D10, mesh control- Tetrahedron- Free surfaced elements generated are of 17276

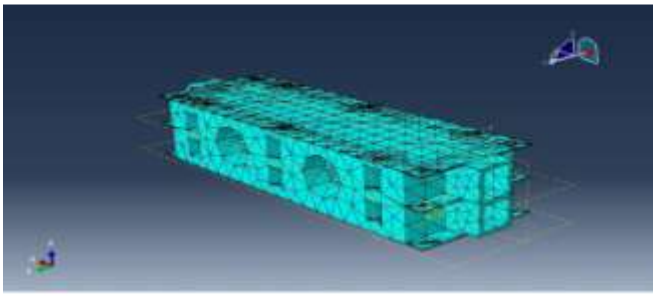


Fig -2: Meshing of gearbox casing

5.2 Static Analysis

Step - Linear perturbation Loads applied- 60000N , Boundary condition- encastre

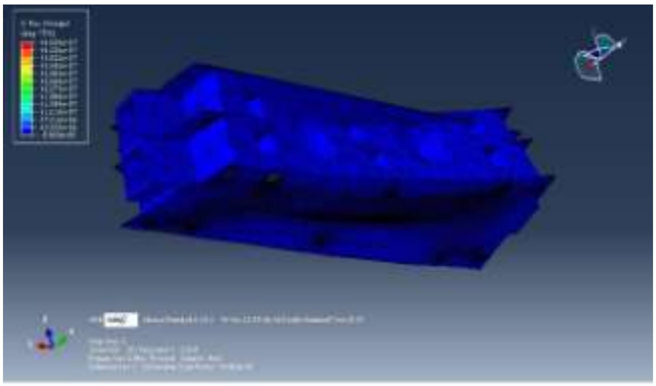


Fig 3: Static Stress by Maximum Principal Stress

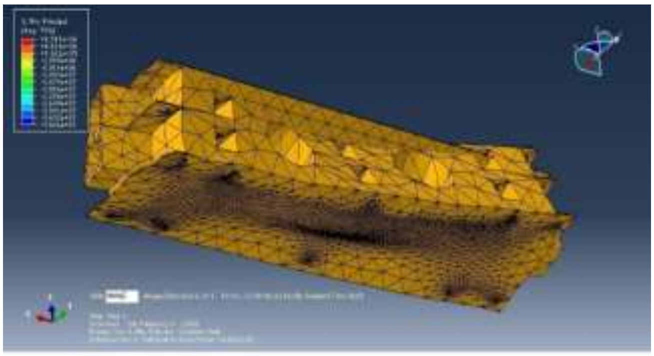
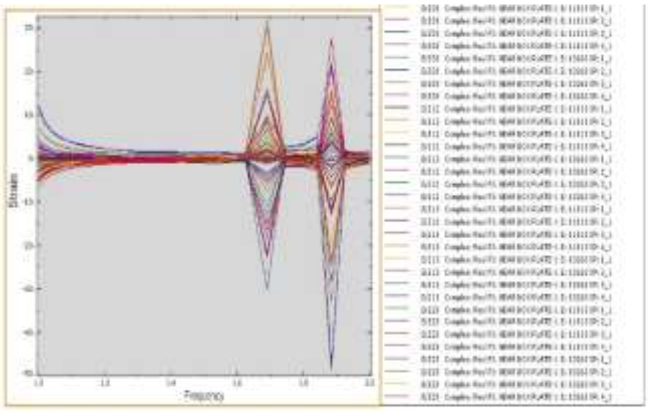
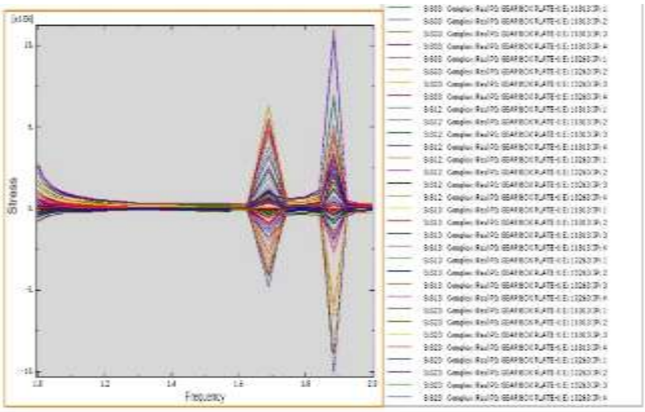


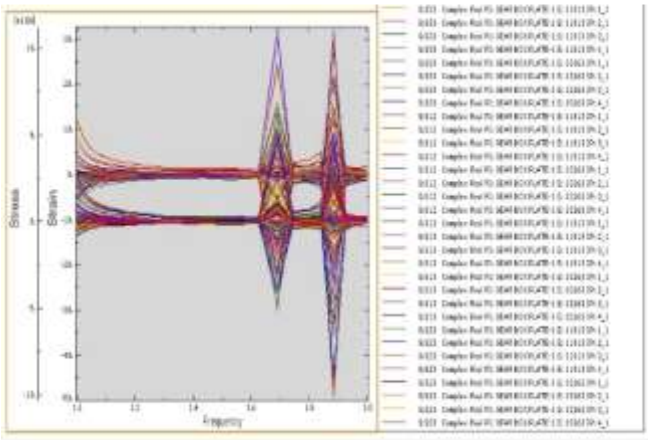
Fig -4: Static Stresses by Minimum Principal Stress



Graph1: Strain vs. Frequency in Abaqus



Graph2: Stress vs frequency in Abaqus



Graph 3: Strain, Stress Vs Frequency in Abaqus

5.3 Dynamic Results

Step- Steady state dynamic- complete complex responseScale- Logarithmic
Data: - Load applied- 60000N

Table 5-1 Data table for harmonic analysis

Lower frequency	Upper frequency	Number of points	Bias
0	10	20	1

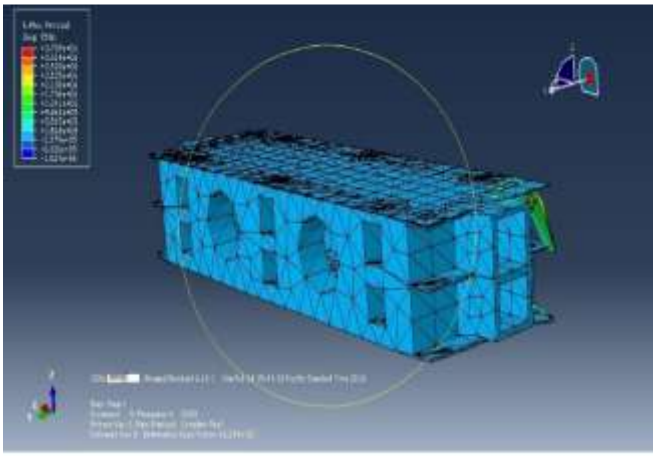


Fig -5 :Dynamic-Stress by Maximum Principal Stress

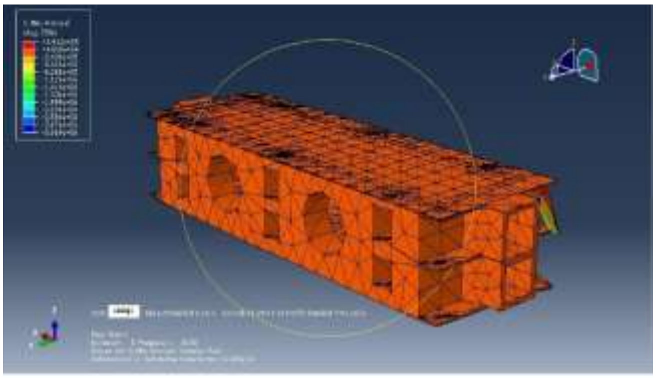
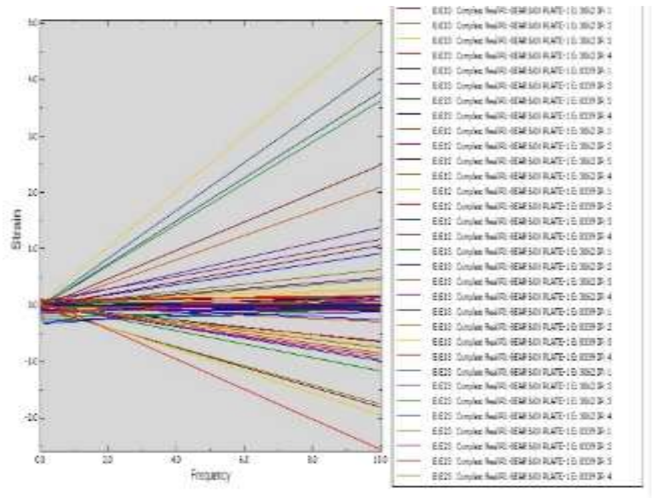
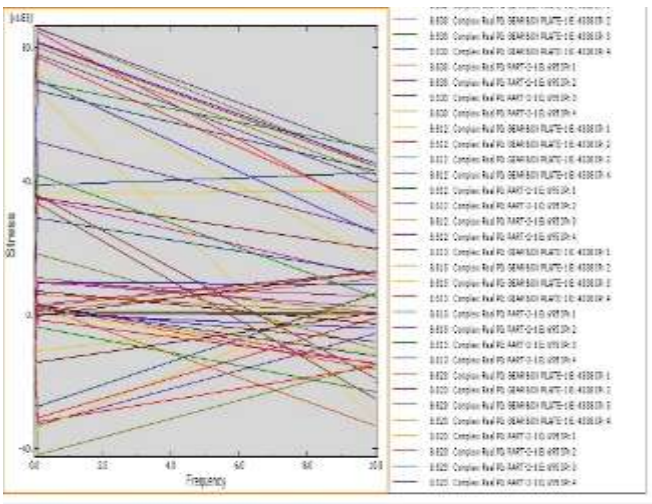


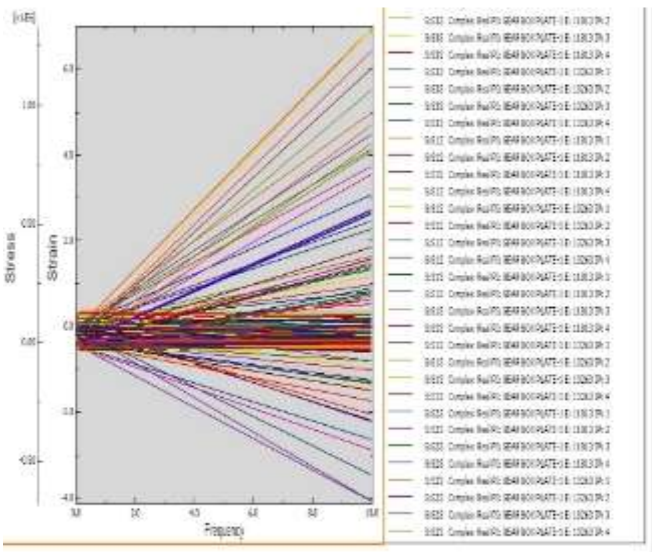
Fig -6: Dynamic stress by Minimum Principle Stress



Graph 4: Dynamic Strain Vs Frequency in Abaqus



Graph 5: Dynamic-Stress Vs Frequency in Abaqus



Graph 6: Dynamic Strain, Stress Vs Frequency in Abaqus

From the above graph for static and dynamic analysis Strain verses frequency graph it can be noted that, for front region of the casing, strain levels though higher but are consistent over frequency range which is not the case for back side of the casing where node strain history is changing with respect to frequency.

Frequency effect on strain levels is linear and no surplus strain linearity is produced due to dynamic effect as against static case.

6. RESULT AND DISCUSSION

Load is applied on the casing and static analysis and dynamic analysis of gearbox casing is done by Abaqus 6.10.1. Harmonic analysis is to be performed by Perturbation analysis and gives strain vs frequency and stress vs frequency graphs. For dynamic case from Strain verses frequency graph, it can be noted that for front region of the casing, strain levels though higher but are consistent over frequency range which is not the case for back side of the casing where node strain history is changing with respect to frequency. For static case jumps are not there as long as stress is considered while for dynamic case jumps are frequent for stress levels.

Stress drop for harmonic analysis as against first analysis is usual as stress relaxations and prestress removal takes place. Static stress is 49.04 MPa in initial stage. As dynamic action starts this situation gets relaxed first. Dynamic stress to compensate static compression, to bring down static effect to zero first reverse resistance develops inside the material. Dynamic stress excluding prestress is 3.709 MPa and total dynamic stress is 52.749 MPa. Maximum principle stress and minimum principle stresspercentage difference values by static and dynamic results are 7.031and 3.7323 which is less than 20% as per industry practice. Results are tabulated are as follows

T**able 6-**1 Comparison of Static and Dynamic Stress analysis

Type	Static Stress (MPa)	Dynamic Excluding Prestress (MPa)	Dynamic Including Prestress (MPa)	Percentage Difference
Maxi. Principle Stress	49.04	3.709	52.749	7.031
Mini. Principle Stress	8.749	0.3412	9.0882	3.7323

7. CONCLUSION

Static analysis and dynamic analysis is to be done with Abaqus /Standard 6.10.1 results shows that dynamic stress boost than static stress. Von Mises stress are significant as against earlier predictions of maximum principle stress & deformations are less significant.

Harmonic analysis is performed for static and dynamic case shows that Frequency effect on strain levels is linear and no surplus strain linearity is produced due to dynamic effect as against static case. All modes are equally responsive to nearly all frequencies. But response boost up lot when forcing frequency matches with corresponding casing frequency.

Future scope is consistent with cantilever beam theory and to reduce costing and as an alternative method to FEA.

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