

Dynamic Vibration Analysis of Gear Box Casing Using ANSYS Software

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ABSTRACT: This technical paper contains the application of ANSYS software and also FFT analyzer to determine natural frequency and mode shapes of industrial gearbox casing. In order to prevent the resonance of the gearbox casing it is necessary to find the natural frequency and mode shapes. From the result, this analysis can show the range of the frequency that is suitable for gearbox casing which can prevent maximum amplitude.

KEYWORDS: Gearbox casing, Natural frequency, Finite element analysis, Ansys, Mode shapes, FFT Analyzer.

I. INTRODUCTION

Noise and vibrations are the main reasons for failure of transmission system, minimizing the noise and vibration in power system is a constant development. Gear defects, internal exciting forces, load and speed variations on gears and gear meshing forces are major sources. Gearbox casing is the metal casing in which a train of gears is sealed. From the movement of the gear it will produce the vibration to the gearbox casing. The casing of gearbox is an important component in a gear box. The gearbox casing is mainly to accommodate and support gear train. Failure of casing may lead to major primary damage of the gearbox. Dynamic analysis of gearbox casing is very essential in order to decide appropriate dimensions and to predict the behaviour of casing under different operating conditions [1]. Most noise and vibration problems are related to resonance phenomena. Resonance occurs when the dynamic forces in a process excite the natural frequencies, or modes of vibration, in the surrounding structures. This is one reason to study the modes and second reason is that they form the basis for a complete dynamic description of a structure. To solve the fatigue failure caused by resonance, it is essential to carryout dynamic analysis and redesigning the existing gearbox casing [2]. The modeling was done in Pro/E software of version wildfire2.0 and manufacturing of complicated shapes and parts. Core cavity required for manufacturing of side engine cover of gear box casing was also prepared by manufacturing module of Pro/E. a prototype model has been manufactured and assembled in mini truck successfully [3]. The present gearbox casing is made using Solid Edge V 19.0 [4] and Nastran (NX8) softwares [5] and analysis is done in Ansys Workbench R 15.0. The optimization is based on the Ansys results, which can be used to enhance the efficiency of the gearbox design process [6].

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II. PROBLEM DEFINITION

A high vibration is observed in the Gear box running at 1100-1200 rpm. It was identified from vibration analysis spectrum (FFT analyzer) gearbox casing was operating dangerously close to resonance. Hence dynamic analysis was taken up on the gear box to identify the causes of high vibration. It was found that the natural frequency of the gear box casing was close to gear meshing frequency.

In order to eliminate this problem the gear box casing natural frequency/frequencies should be shifted away from the operating gear meshing frequency range by suitable modifications. Various trials were done and the most suitable and optimal solution is recommended.

III. VIBRATION LIMITS

Machines were classified according to Vibration severity criteria standard ISO-10816-1.

Table 1: Classification of Machines and there vibration limits as per ISO Standard-10816-1

Velocity		Velocity Range Limits and Machine Class			
mm/s RMS	in/s Peak	Up to 15kW Class I	15 to 75kW II	>75 kW(Rigid) Class III	>75kW (Soft) Class IV
0.28	0.02	Good	Good	Good	Good
0.45	0.03				
0.71	0.04				
1.12	0.06	Satisfactory	Satisfactory	Satisfactory	Satisfactory
1.80	0.10				
2.80	0.16				
4.50	0.25	Unsatisfactory (Alert)	Unsatisfactory (Alert)	Satisfactory	Satisfactory
7.10	0.40	Unacceptable (Danger)	Unacceptable (Danger)	Unsatisfactory (Alert)	
11.20	0.62			Unsatisfactory (Alert)	
18.00	1.00			Unacceptable (Danger)	
28.00	1.56			Unacceptable (Danger)	
45.00	2.51			Unacceptable (Danger)	

In order to determine the vibration amplitude in the gear box casing of mill house the vibration limits for the same has to be find based on the power rates shown in the table 1. Since the power rating of gear box drive is > 75 KW with rigid foundation to ground, so this gear box casing is coming under Class III and operating up to 4.5 mm/s beyond which increasing vibration level.

The design of the component should incorporate a methodology for dealing with factors causing unacceptable levels of vibration or to promote any scientific means of problem solving that would minimizing the harmful effects of resonance [7].

Directions of vibration measurement

There are three universal directions of vibration measurements, they are

- [1] Horizontal
- [2] Axial
- [3] Vertical

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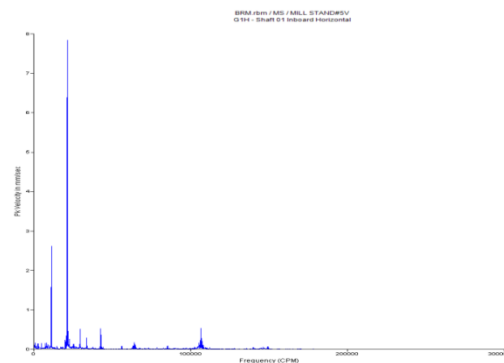


Fig.1 Vibration spectrum of gearbox input horizontal direction

From the graph shown in fig 1 it is reveal that there is high vibration of 7.835 mm/s peak. Hence, gear box is running in unsatisfactory condition in horizontal direction requires monitoring [8] [9].

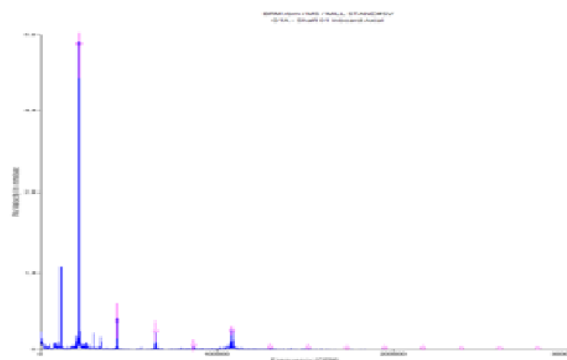


Fig.2 Vibration spectrum of gearbox input axial direction

From the graph shown in fig 2 it is reveal that there is high vibration of 5.603 mm/sec peak. Hence, gear box is running in unsatisfactory condition in axial direction requires monitoring.

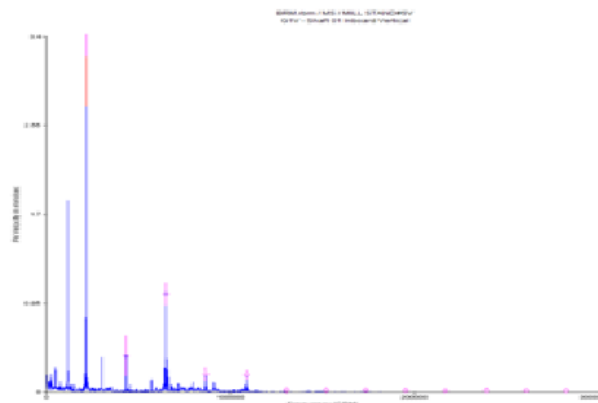


Fig.3 Vibration spectrum of gearbox input vertical direction

From the graph shown in fig 3 it is reveal that there is vibration of 3.562 mm/sec peak. Hence, gear box is running in satisfactory condition in vertical direction.

From above three figures it is found that there is high vibration in horizontal and axial directions indicates high vibration level. It is found that gearbox casing running in resonance condition and in order to minimize this problem it is necessary to redesign/modify the existing gear box casing and check for dynamic analysis [10] [11].

IV. 3D CAD MODEL OF GEAR BOX CASING

FEM analysis is a powerful tool and its reliable results can be used for product performance. FEM based free vibration analysis of gearbox casing for noise and vibration reduction and vibration absorption of gearbox is plays a vital role. This work highlights on dynamic vibration response with fixed constraints. Noise and vibration of transmission system can be reduced by the structural optimization for better performance.

Solid Edge (V19) and Nastran (NX8) softwares are used for designing the gear box casing. The solid CAD model is shown in figure 4. The designed casing consisting of 14 holes at the both side of base used for constraining on ground.

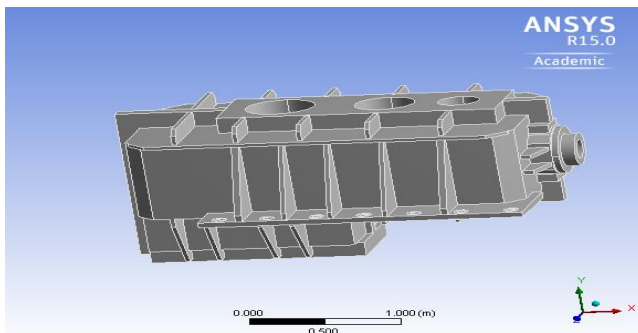


Fig.4 3D model of Existing Gear Box Casing

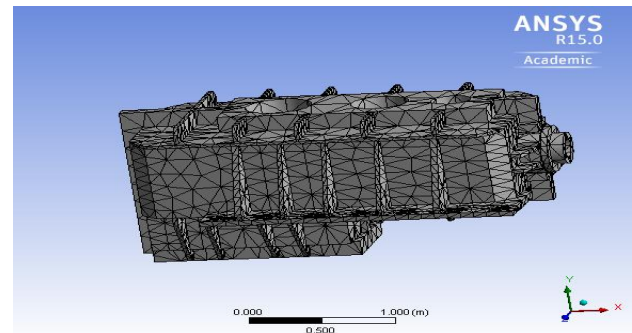


Fig.5 Meshed model of Existing Gear Box Casing

ANSYS 15.0 is FEA based analysis tool for structures. ANSYS 15.0 work on concept of nodes and elements. Elements are connected at a point known as node. This process is known as meshing. The fine meshing ensures more accurate results but increases calculation time. Fig 5 shows the meshed model of industrial gear box casing. The meshed model has 30749 nodes and 16535 elements.

The .iges file of casing is imported in Ansys 15.0 FEA based software used for free vibration analysis. The present study provides the strong base for optimizing the resonance problem of a casing by finding the mode shapes and natural frequencies of existing and modified casing [12]. Obtained first 10 natural frequencies and mode shapes of gearbox were considered.

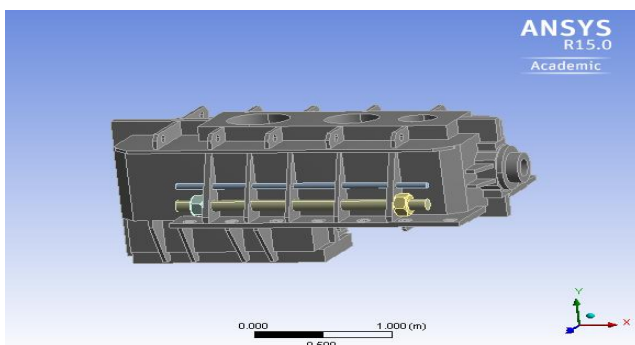


Fig.6 3D model of Modified Gear Box Casing

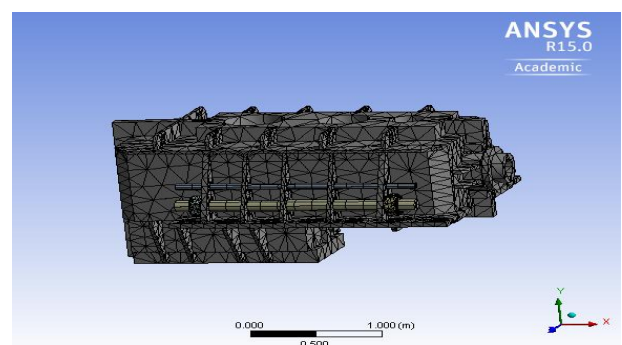


Fig.7 Meshed model of Modified Gear Box Casing

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Fig 6 shows the 3 dimensional model of modified gear box casing. Modification Details as follows

- [1] 2 rods of diameter 120 mm & length 1900 mm with 2 nuts of diameter and side is 120 mm and thickness of the each nut is 100 mm fitted in two sides of the casing (attached near to the base).
- [2] 2 rods of diameter 60 mm & length 1900 mm welded in two sides of the casing (attached near to the top).
- [3] 10 holes of diameter 50 mm made in supporting strips in top face of the casing.
- [4] There are 4 different dimensions of the plates are welded in both sides of the casing body. The dimensions are (271x694) mm, (279x694) mm, (341x694) mm and (364x694) mm.

Fig 7 shows the meshed model of Modified industrial gear box casing. The meshed model has 42014 nodes and 20708 elements.

V. MATERIAL PROPERTIES AND BOUNDARY CONDITIONS

Grey Cast Iron FG200 a damping material has been selected as casing material. It was good on both criteria of vibration and manufacturing prospectus. The Mechanical properties Elastic modulus, Poisson ratio and density were required for free vibration analysis. The grey cast iron FG200 material properties are elastic modulus 1.4×10^{11} Pa, Poisson ratio 0.26, density 7200 kg/m^3 [13].

Gear box casing base is constrained on ground using connecting bolts. There are two types of predefined boundary conditions are available in Ansys for modal and free vibration analysis [14]. These are free-free and fixed-fixed boundary conditions. In free-free boundary conditions all degrees of freedom are unconstrained. Fixed-fixed boundary condition is suitable for the casing analysis since it is constraint on ground by bolts. To provide the fixed-fixed boundary condition we have fixed the base part of the casing in software environment.

In actual condition casing is tightly fixed on the ground using connecting bolts. Fixed-fixed constraint boundary condition is suitable for the gearbox casing analysis; it is constraint the motion of holes positions. First 10 natural frequencies and corresponding vibration modes were evaluated for two cases. Natural frequencies vary from 294.97 Hz to 316.76 Hz.

VI. DYNAMIC ANALYSIS OF EXISTING GEARBOX CASING

The FEM numerical simulation presents the first 10 mode shapes and corresponding natural frequencies for existing gear box casing shown in below figures from fig.8 to fig.17

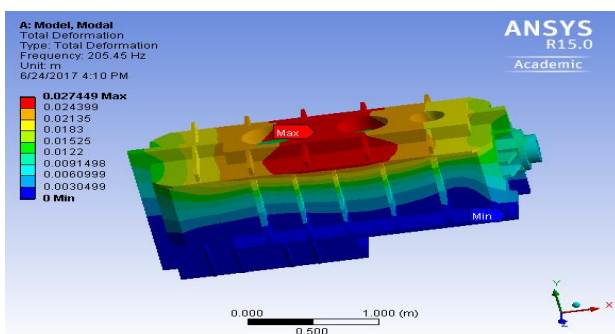


Fig.8 1st Frequency mode range at 205.45 Hz

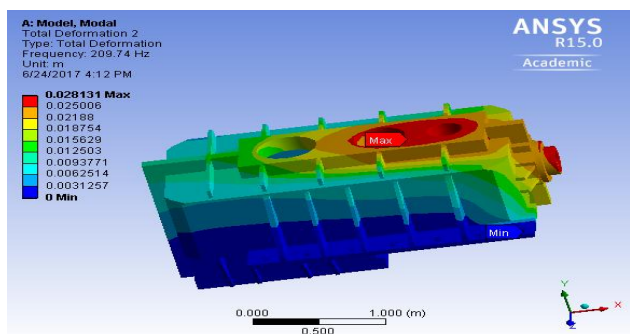


Fig.9 2nd Frequency mode range at 209.74 Hz

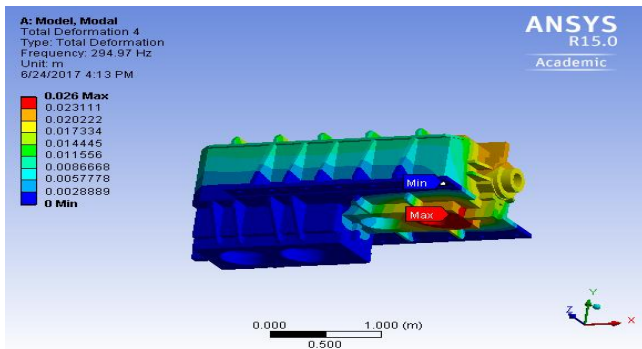


Fig.10 3rd Frequency mode range at 228.18 Hz

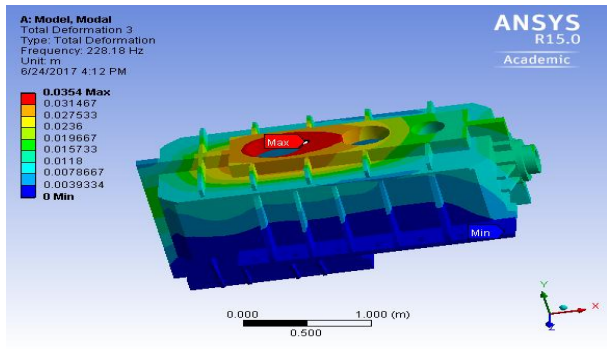


Fig.11 4th Frequency mode range at 294.97 Hz

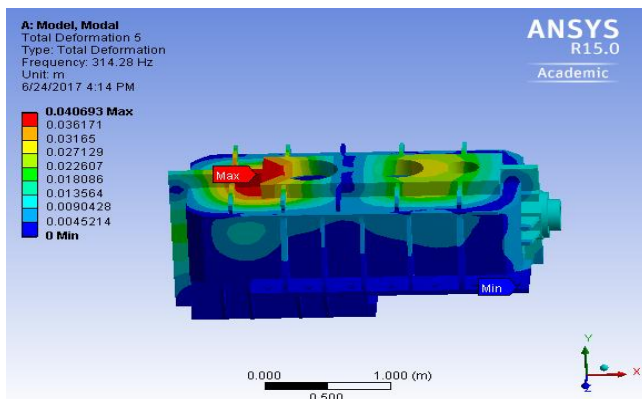


Fig.12 5th Frequency mode range at 314.28 Hz

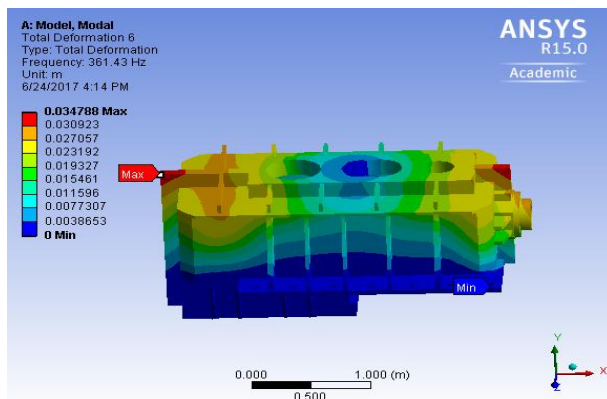


Fig.13 6th Frequency mode range at 361.43 Hz

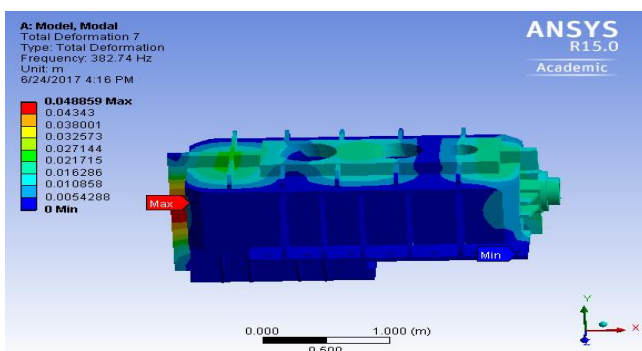


Fig.14 7th Frequency mode range at 382.74 Hz

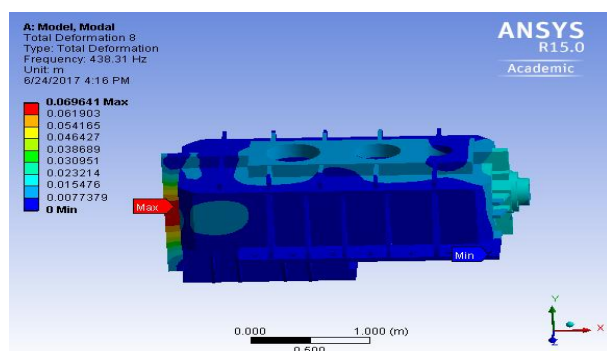


Fig.15 8th Frequency mode range at 438.31 Hz

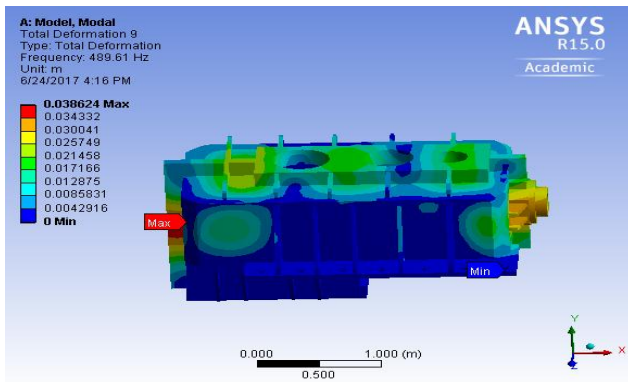


Fig.16 9th Frequency mode range at 489.61 Hz

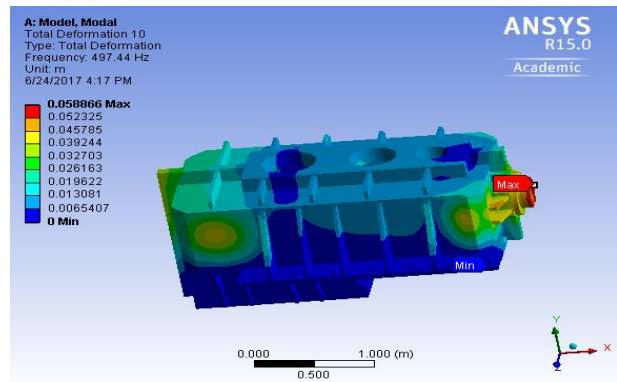


Fig.17 10th Frequency mode range at 497.44 Hz

VII. DYNAMIC ANALYSIS OF MODIFIED GEARBOX CASING

The FEM numerical simulation presents the first 10 mode shapes and corresponding natural frequencies for modified gear box casing shown in below figures from fig.18 to fig.27

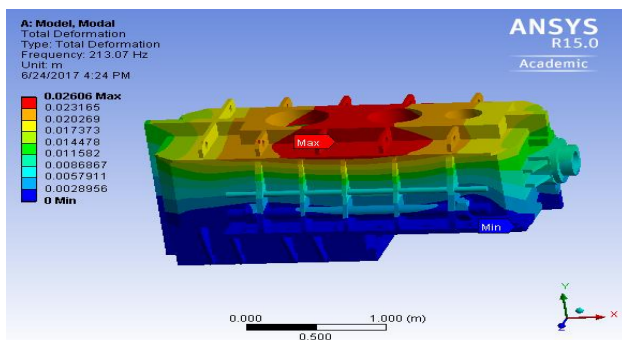


Fig.18 1st Frequency mode range at 213.07 Hz

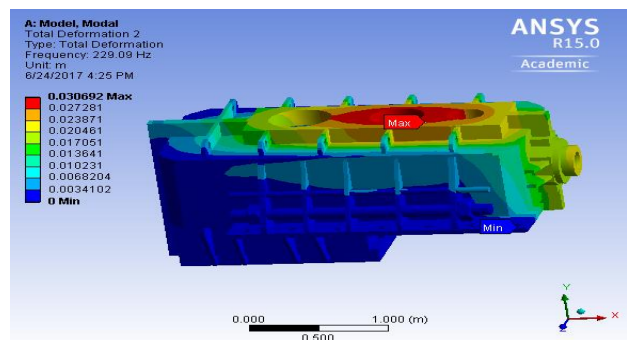


Fig.19 2nd Frequency mode range at 229.09 Hz

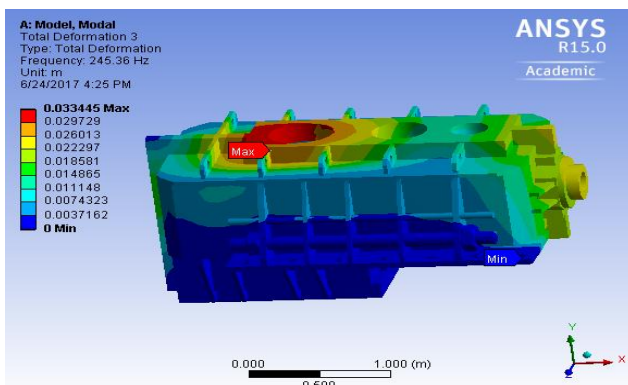


Fig.20 3rd Frequency mode range at 245.36 Hz

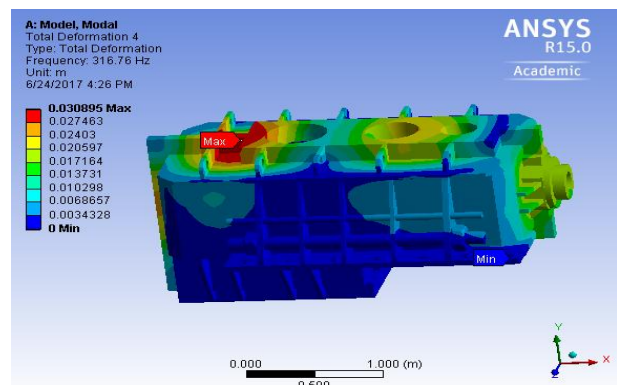


Fig.21 4th Frequency mode range at 316.76 Hz

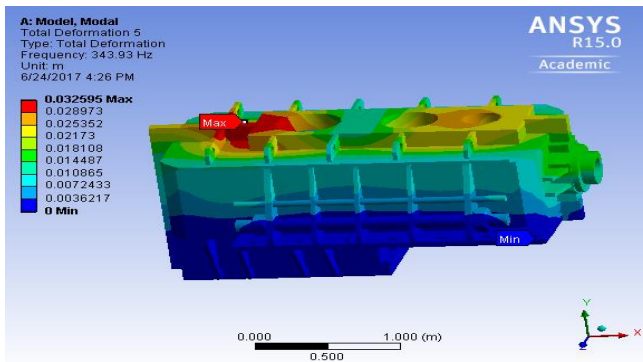


Fig.22 5th Frequency mode range at 343.93 Hz

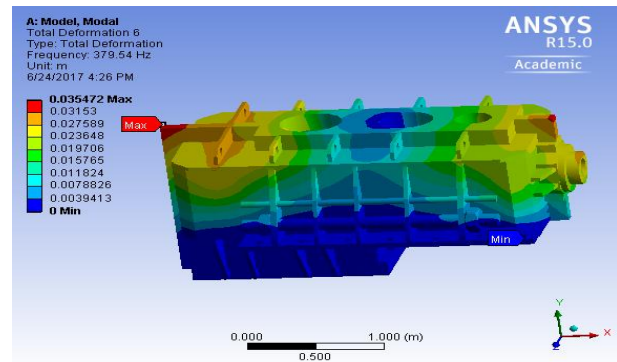


Fig.23 6th Frequency mode range at 379.54 Hz

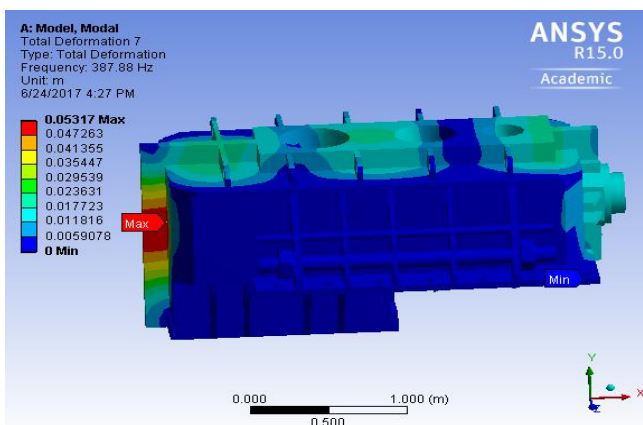


Fig.24 7th Frequency mode range at 387.88 Hz

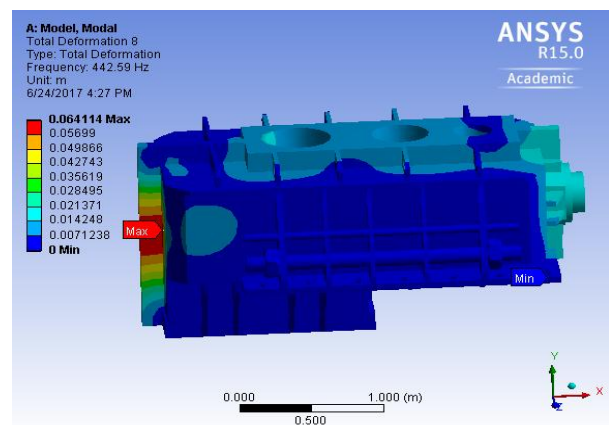


Fig.25 8th Frequency mode range at 442.59 Hz

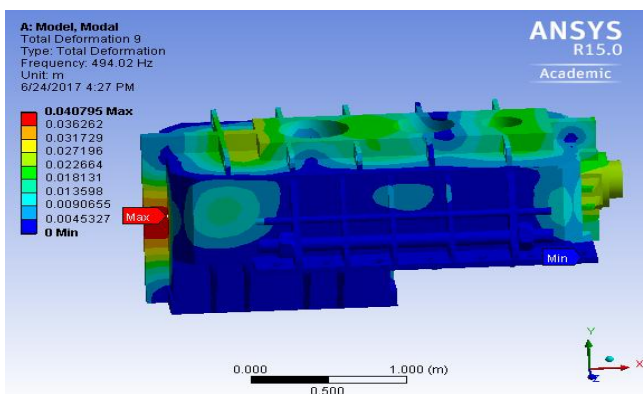


Fig.26 9th Frequency mode range at 494.02 Hz

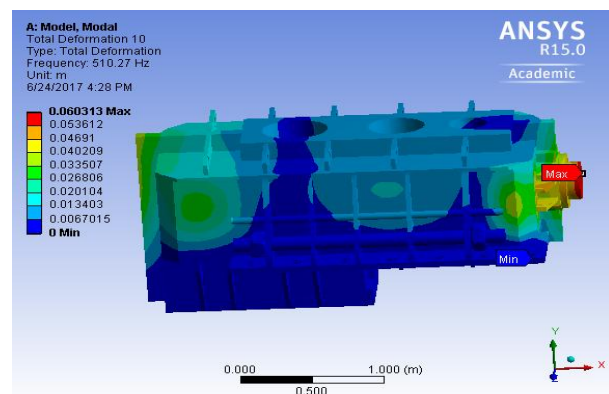


Fig.27 10th Frequency mode range at 510.27 Hz

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Table 2: Comparison of natural frequencies of existing and modified gearbox casing

Mode No.	Natural Frequency in Hz Existing	Natural Frequency in Hz Modified
1	205.45	213.07
2	209.74	229.09
3	228.18	245.36
4	294.97	316.76
5	314.28	343.93
6	361.43	379.54
7	382.74	387.88
8	438.31	442.59
9	489.61	494.02
10	497.44	510.27

VIII. CONCLUSION

The following solution is recommended, after the detailed dynamic analysis conducted on the gear box casing. Gearbox casing was operating dangerously close to resonance, so dynamic analysis was carried to shift the natural frequencies of the gear box casing. Different modification was tried and the best feasible modification is suggested to shift the natural frequencies of the gearbox casing. The gearbox casing natural frequency of 4th gear meshing frequency 294.97 Hz is shifted to 316.76 Hz by giving external stiffness. As a result of this modification the stiffness of the gear box casing is increased and the natural frequency is shifted away from the resonance band.

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