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Design Manufacturing and Vibration Analysis of Worm and Worm Wheel Gear Box

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Abstract: Gears are important element in a variety of industrial applications such as machine tool and gearboxes. An unexpected failure of the gear may cause significant economic losses. For that reason, fault diagnosis in gears has been the subject of intensive research. Vibration signal analysis has been widely used in the fault detection of rotation machinery. In this dissertation vibration analysis of worm and worm wheel gear box is done by FEA and experimental method. Design of worm and worm wheel gear box is done on basis of given working parameters using SI units and design data book and same design parameters is used for fabrication. The performance of gear box is tested at 0 kg, 3kg, 6kg, 9kg and speed for 1425 rpm. Frequency measurement at working loading condition is performed using FFT analyzer. Natural frequencies at different loading condition are determined by using FFT analyzer. The experimental results obtained by above testing is validated with finite element analysis and the results found satisfactory and within the range.
Keywords: Vibration, fault diagnosis, condition monitoring, gearbox.

I. INTRODUCTION

Gears are critical components of industrial gearbox and are critical to running the company. It is vital that they work as intended or entire operation could come to a halt. Gearboxes, while tough, are sensitive machines prone to failure if not properly maintained. These machines are constantly under extreme stress and high temperatures. Accordingly, even the smallest misalignment caused by vibration issues could be catastrophic. Vibration analysis has grown in importance recently when it comes to industrial gearboxes. This type of maintenance is one of the most widely used gear fault analysis techniques. It aids in early fault detection, enabling users to prevent breakdowns. Vibration analysis involves listening to the vibration in the gearbox. An industrial gearbox is composed of a variety of components, and each of them vibrates on a unique frequency. If your gearbox has suffered damage, the noise patterns will change. The sound you hear can help you diagnose the type of the damage, and even its source. Vibration analysis is a process of looking for anomalies and monitoring change from the established vibration signature of a system. The vibration of any object in motion is characterized by variations of amplitude, intensity, and frequency.

These can correlate to physical phenomena, making it possible to use vibration data to gain insights into the health of equipment. Vibration analysis can be used to:

1) Find a developing problem that can be repaired to increase machine lifetime.
2) Detect and monitor a chronic problem that cannot be repaired and will only get worse
3) Establish acceptance testing criteria to ensure that installation/repairs are properly conducted.

II. LITERATURE SURVEY

Elasha, F. , Ruiz-Cárcel, C. , Mba, D. , Kiat, G. , Nze, I. and Yebra, G., Engineering Failure Analysis, volume 42 : 366-376. (2015) in paper entitled, “Pitting detection in worm gearboxes with vibration analysis”, this paper aimed to apply various vibration analysis techniques to diagnose the presence of naturally developed faults within worm gearboxes. The condition of three different worm gearboxes was assessed using various vibration signal analysis techniques including a few statistical measures, Spectral Kurtosis and enveloping. This was undertaken in an attempt to identify the presence of defects within the worm gearboxes. [1]

Vikram A. Jagtap, Prof. Pavankumar R. Sonawane (2017), in International Journal of Innovative Research in Science, Engineering and Technology, paper entitled “A Review on Fault Detection of Gearbox by using Vibration Analysis” reviewed on various techniques used for analyzing the faults of gearbox based on vibration analysis method with small insight on new approach used for diagnosis of gearbox such as Artificial Neural Network, fuzzy sets and some emerging technology in gear fault analysis. [2]

G.S. Lamani1 , Prashant S.Pawar2,Nikhil G.Ranalkar3,Omkar P.Pawar4,Suyog V.Patil in IOSR Journal of Mechanical and Civil Engineering(2018) in paper entitled, “Vibration analysis of worm and worm wheel gear box” Reviewed is made of some current vibration analysis techniques used for condition monitoring in gear fault. Each unit of mechanical equipment has a different signature in the frequency spectrum.The vibration spectrum shows the areas of stress and undue energy. Vibration measurements trend changes at different locations along the units to predict the problems. [3]

Ganesh Survase1, Suraj Sutar2, Tushar Pawar 3, Akshay Rajmane4 in International Journal of Mechanical, Robotics and Production Engineering in paper (2018), "Study & Vibration analysis of worm and worm wheel gear box by using FFT Analyzer" Reviewed some of current vibration analysis techniques used for condition monitoring in gear fault. Each unit of mechanical equipment has a different signature in the frequency spectrum. The vibration spectrum shows the areas of stress and undue energy.. The key benefits include: - Monitoring equipment life, increasing equipment uptime, managing and scheduling maintainace work. Vibration analysis can determine misalignment unbalanced, mechanical losses, eccentric shafts, gear wear, broken teeth & bearing wear. As load increase there is initial decrease in acceleration to its minimum and then again starts increasing with same behaviors in trends of corresponding maximum frequency value. [4]

Miss. Radhika Laxman Patil1 Mr. Ravindra D. Patil2 Mr. Sandesh S. Awati3 Mr. Suhas N. Ankalkhope4, (2017) International Journal for Scientific Research & Development in paper entitled "A Review Paper on Design, Optimization and Testing of Special Purpose Worm and Worm Wheel Gearbox for Butterfly Valve Operation" used higher standard output torque gearboxes which are uneconomical, heavy as well as large in size. Also quarter turn worm and worm wheel gearboxes for opening and closing of butterfly valves gives better performance, because butterfly valves rotate only in 90°. This paper represents design, optimization and testing of special purpose worm and worm wheel gearbox for butterfly valve operation [5]

III.PROBLEM STATEMENT

As the companies profile, company manufactures gears & gear box as per customer's requirement. The one customer wants a worm & worm wheel gear box for 0.5HP motor. Then after the design & manufacturing of gear box. Company should check the vibration occurs in the gear box, it should be as minimum as, It is very important as per the quality aspect. Therefore to find the vibration occurs in the gear box we are using the FFT analyser and validate with the help of finite element analysis.

A. Objectives

1) To design worm and worm wheel gear box.
a) To understand design of worm and worm wheel gear box.
2) To evaluate the performance of gear box for various loading and speed conditions.
a) Evaluate the performance of worm and worm wheel gear box for different loading conditions.
b) Evaluate the performance of worm and worm wheel gear box for different speed conditions
c) Calculate both the values.
3) To determine natural frequencies at different loading condition.
4) To validate the design experimentally and by FEA.
a) Calculate the results experimentally by FFT analyser.
b) Calculate the results by using Finite element analysis.
c) Validate the design by comparing the FFT and FEA results.

B. Scope

1) Similar work can be performed on different types of other gear and gear boxes for reduction in vibration caused by rotating machinery parts.
2) Observation results obtained by FFT can be validated with mode shape analysis using various Finite element software like ANSYS to get more accurate results.
3) This kind of project work proves to best suited method in field of NVH Analysis in various automobile sectors

C. Methodology

1) Design of worm and worm wheel gear box
2) Manufacturing of worm and worm wheel gear box.
3) Selecting Vibration techniques to determine the fault in worm and worm wheel gear box.
4) Vibration analysis using Fast Fourier Transform (FFT) analyser.
5) Vibration analysis at different load and different speed conditions.
6) Finite Element analysis for results obtained by FFT analyser.

7) Results and Discussion.
8) Validation of design using FEA.
9) Conclusion

IV. DESIGN

Computer Aided Design software uses either vector-based graphics to represent the objects of traditional drafting, or may also produce raster graphics which show the overall appearance of designed models for mechanical design. Similar to the manual drafting of the engineering and technical drawings, the CAD output must convey information, such as materials taken, processes, dimensions of the component, and tolerances, according to the application-specific conventions.

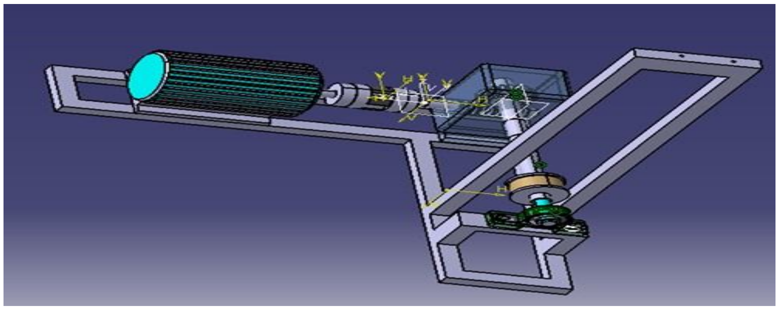

Fig. No. 1: CAD model of assembly.

A. Worm Wheel

1) No. of teeth (Z2) = 21
2) Module (m) = 3mm
3) PCD (d2) = 63mm
4) Outer Dia. = 72mm

B. Worm

1) No. of threads = 6
2) PCD (d1) = 26.6mm
3) Outer Dia. = 32.6mm
4) Centre Distance = 44.45m
5) Worm Wheel Bearing = 30205×2
6) Worm Bearing = 30204×2
7) A pair of worm gears is specified and designated by four quantities in the following Manner,
   z1 / z2 / q / m
8) Dimensions of worm and worm wheel
9) l = 3.14× no. of threads in worm diametric pitch
   l = 3.14×6 = 18.84mm
10) Px =p×m
    = p×3
    =9.425mm
11) l = Px × Z1 = 18.84
    Z1 = 1.99 = 2
12) Lead angle of worm:
    Tan g = l/(p*d1)
13) g = 12.71° g + y = 90°
14) y = 77.30°
    = helix angle of worm tang = Z1/q
    q = 8.86
15) Speed Ratio = Z2/Z1 = 21/2 = 10.5

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V. MANUFACTURING OF WORM AND WORM WHEEL GEAR BOX

Sr. No.	Part Name	Material	Machine	Operation	Quantity
1	Worm Gear	SS	Hobbing &Shaping Mc	Hobbing & Shaping	1
2	Worm Wheel	SS	Sawing	Sawing	1
3	casing	MS	Casting	Casting	1
4	Stand	MS	Welding	Cutting Mc/welding	1
5	AC Motor				1
6	Shaft	MS	Lathe Mc	Turning/Facing	1
7	coupling	MS			1
8	key	MS			2
9	Pulley	MS	Lathe Mc	Turning/Facing	1
10	Bearing				1
11	Rope	Resin			1

A. *Vibration Analysis USING FFT Analyser.*

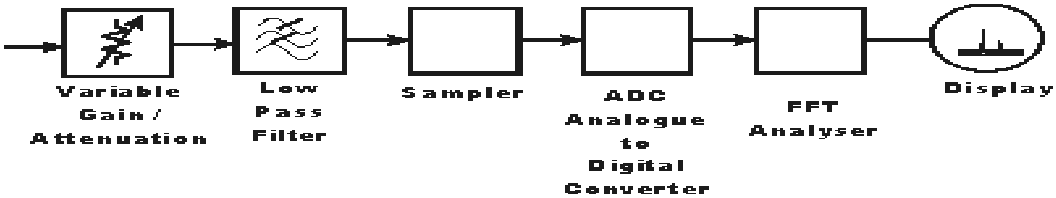

Fig. No. 2: FFT Analyser.

Node Description


Experimental set up

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VI. RESULTS OBTAINED BY FFT ANALYSER.

A. 0 Kg load

1) *Axial:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at 5439.45Hz with value of 0.74g.

Graph1

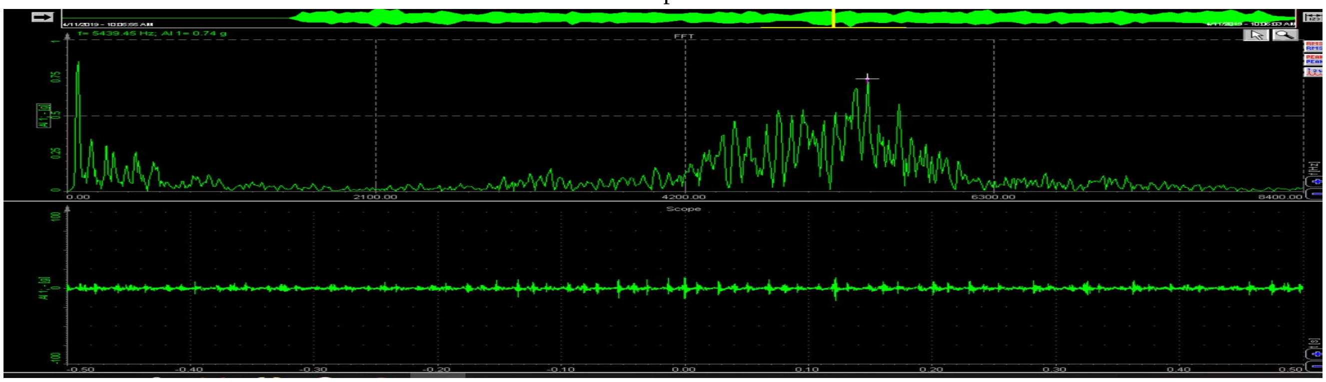

Fig. No. 3

2) *Horizontal:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at 4292.88Hz with value of 0.96g.

Graph2

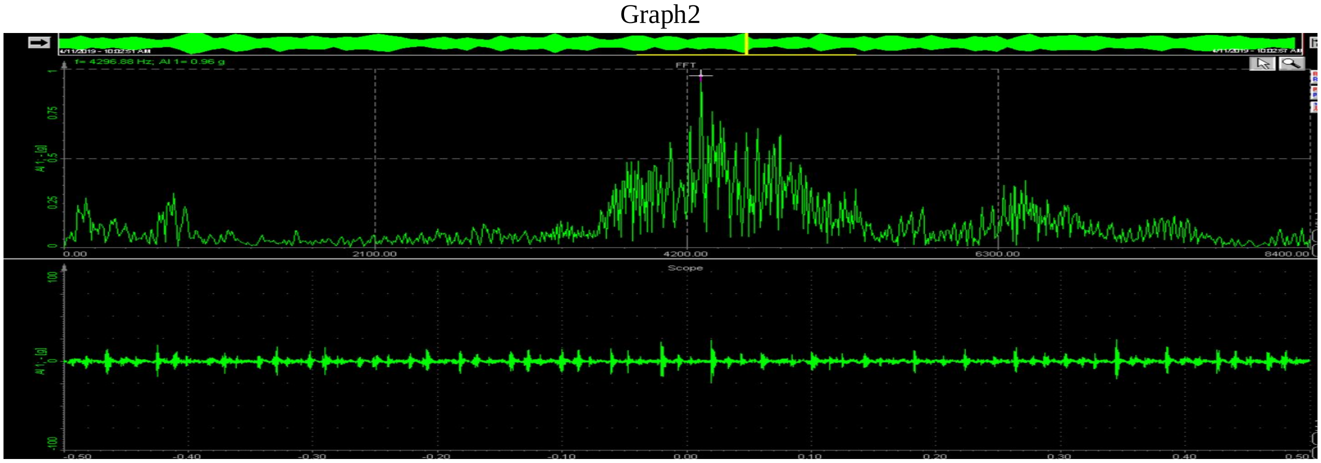

Fig. No. 4

3) *Vertical:* Maximum deviation is in range of 4500-6300Hz and maximum value of deviation is at 5429.69Hz with value of 1.05g. (g=9.81m/s2)

Graph3

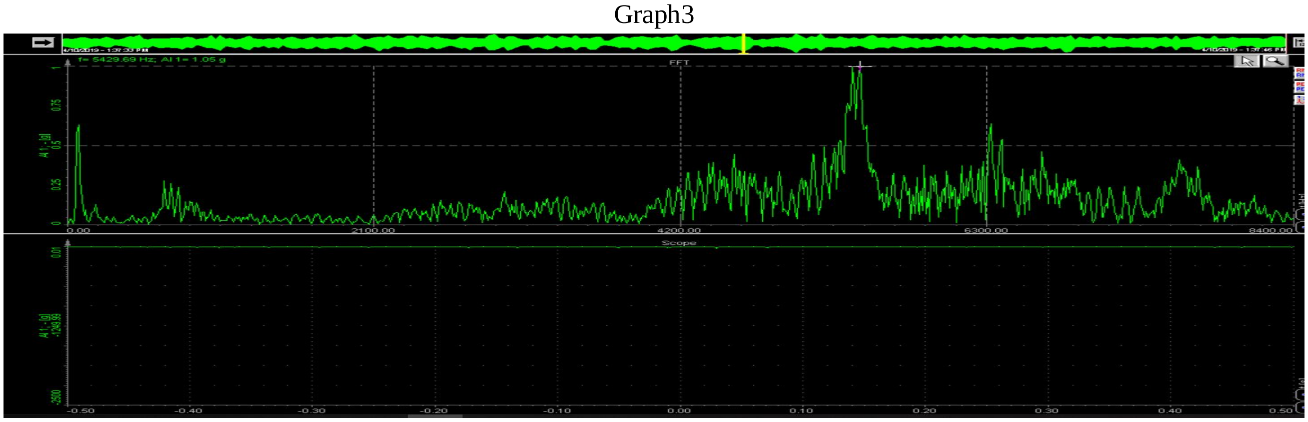

Fig. No. 5

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B. 3 Kg Load

1) *Axial:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at 5410.16Hz with value of 055g. (g=9.81m/s2)

Graph4

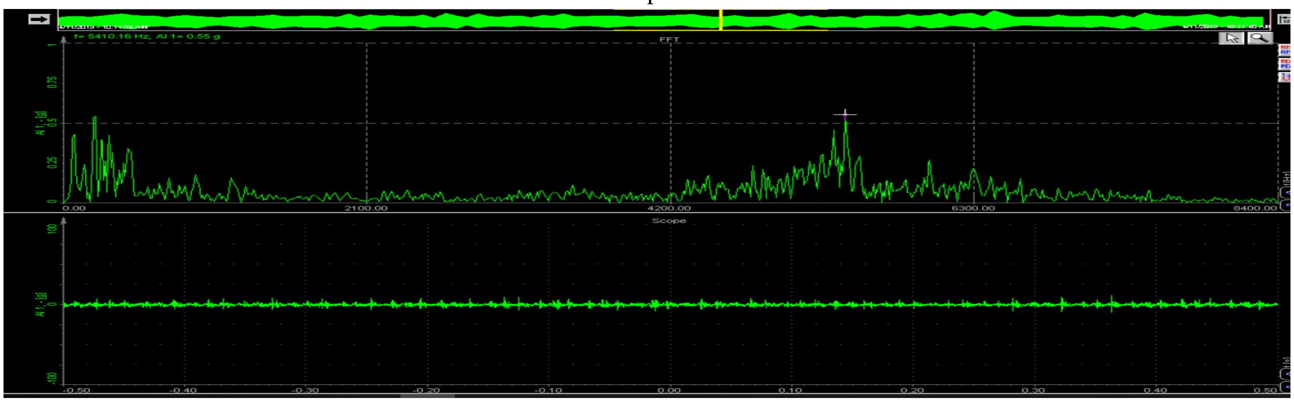

Fig. No. 6

2) *Horizontal:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at5312.50Hz with value of 0.80g. (g=9.81m/s2)

Graph5

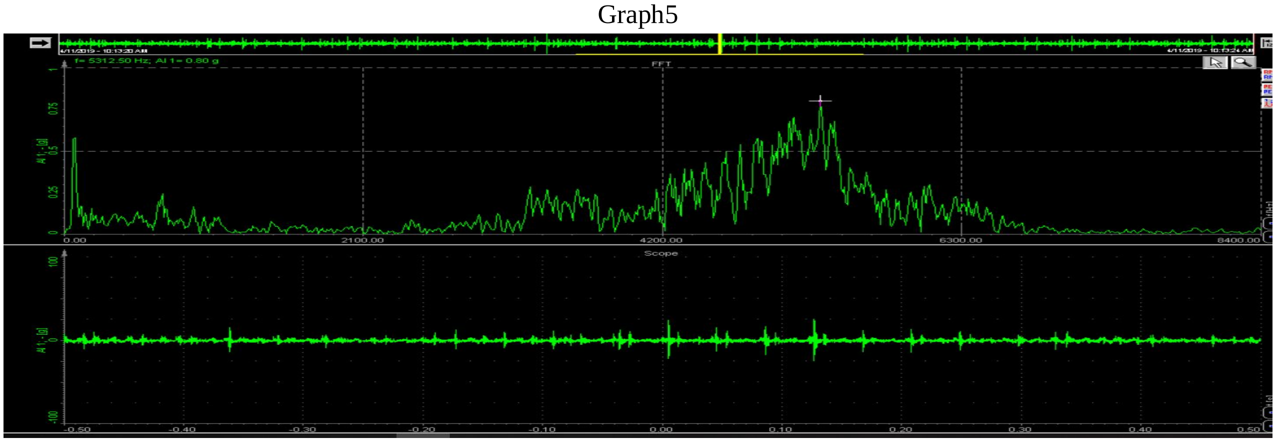

Fig. No. 7

3) *Vertical:* Maximum deviation is in range of 5000-7500Hz and maximum value of deviation is at 5332.03Hz with value of 0.92g. (g=9.81m/s2)

Graph6

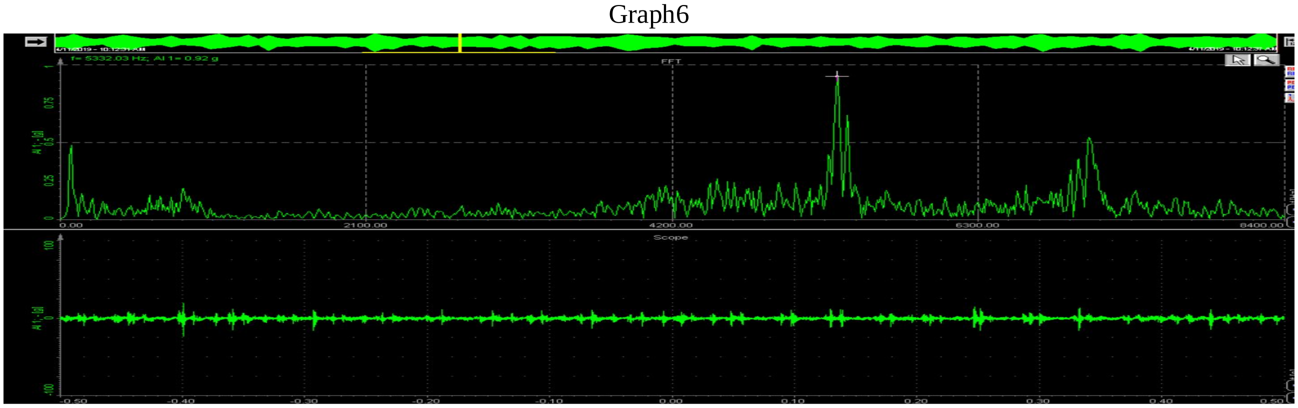

Fig. No. 8

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C. 6 kg Load

1) *Axial:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at 4521.48Hz with value of 1.03g. (g=9.81m/s2)

Graph7

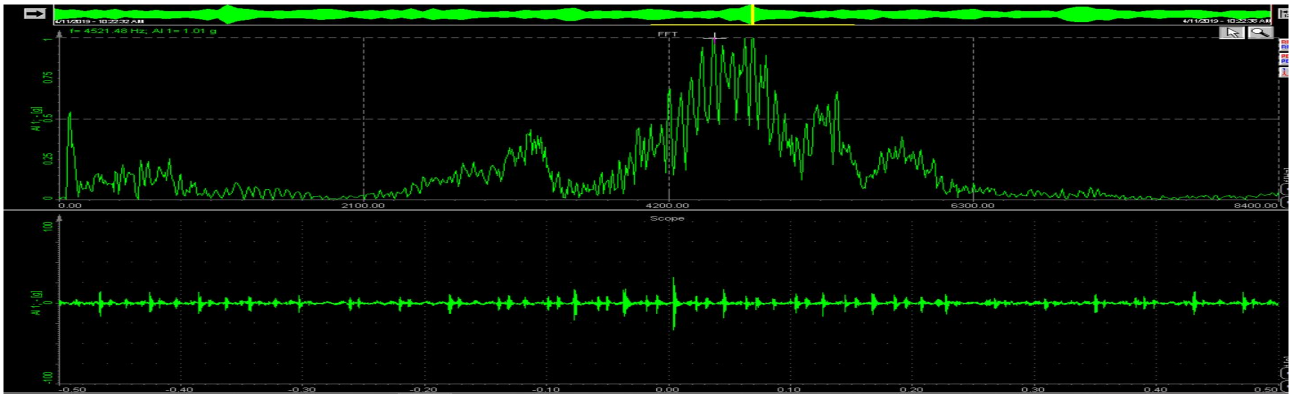

Fig. No. 9

2) *Horizontal:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at 4824.22Hz with value of 1.10g. (g=9.81m/s2)

Graph8

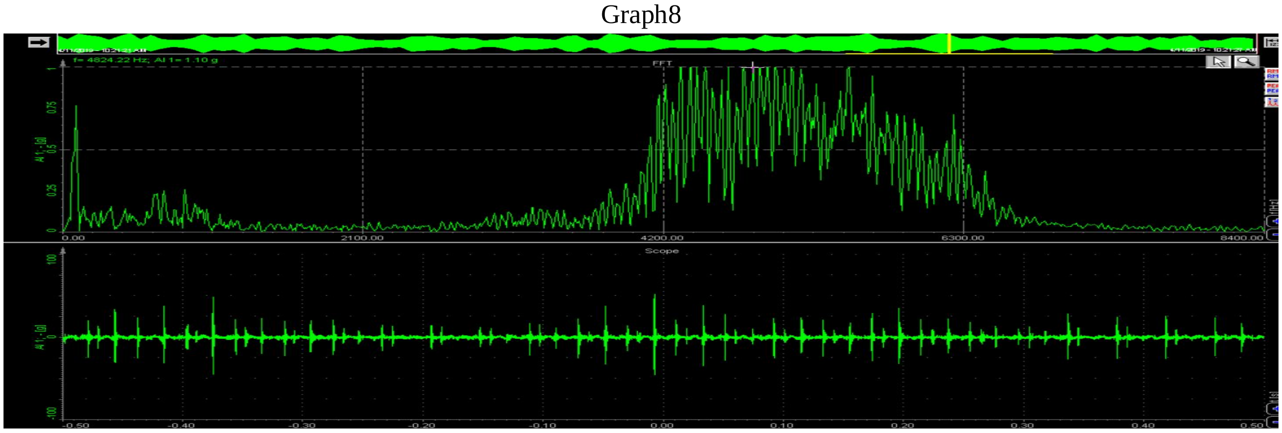

Fig. No. 10

3) *Vertical:* Maximum deviation is in range of 4200-6000Hz and maximum value of deviation is at 4492.19Hz with value of 0.80g. (g=9.81m/s2)

Graph9

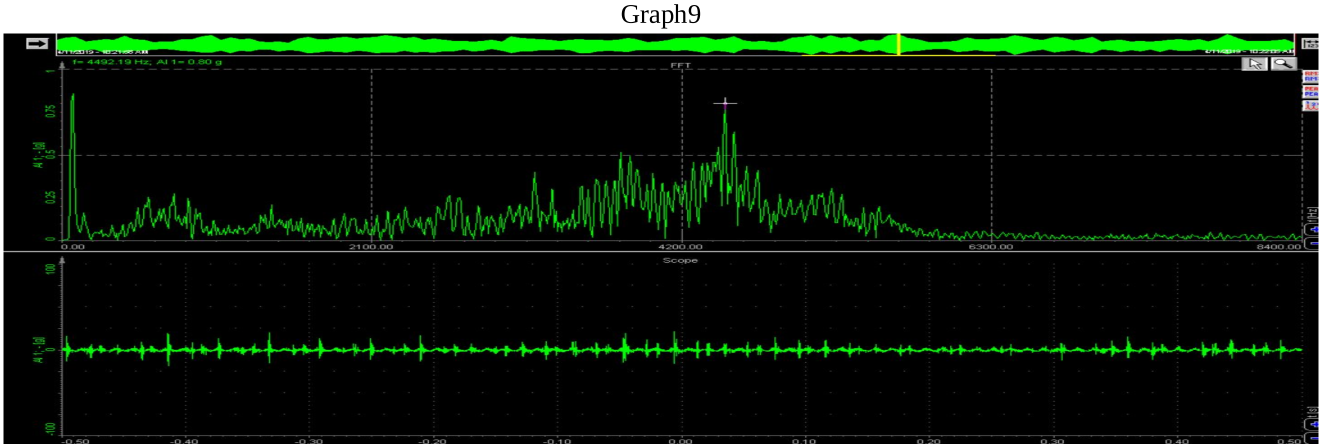

Fig. No. 11

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D. 9 Kg load

1) *Axial:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at 5322.27Hz with value of 1.42g. (g=9.81m/s2)

Graph10

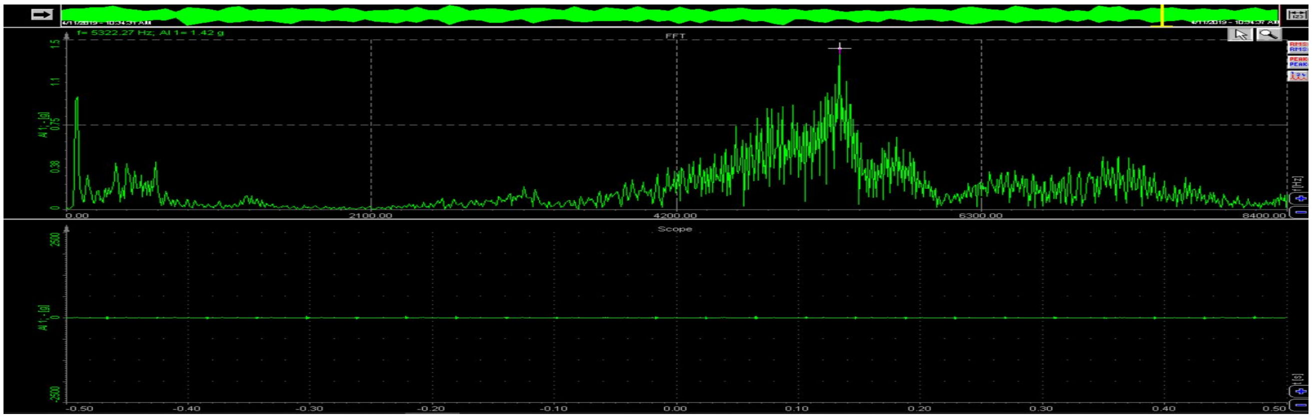

Fig. No. 12

2) *Horizontal:* Maximum deviation is in range of 2100-4200Hz and maximum value of deviation is at 2382.8Hz with value of 0.253g. (g=9.81m/s2)

Graph11

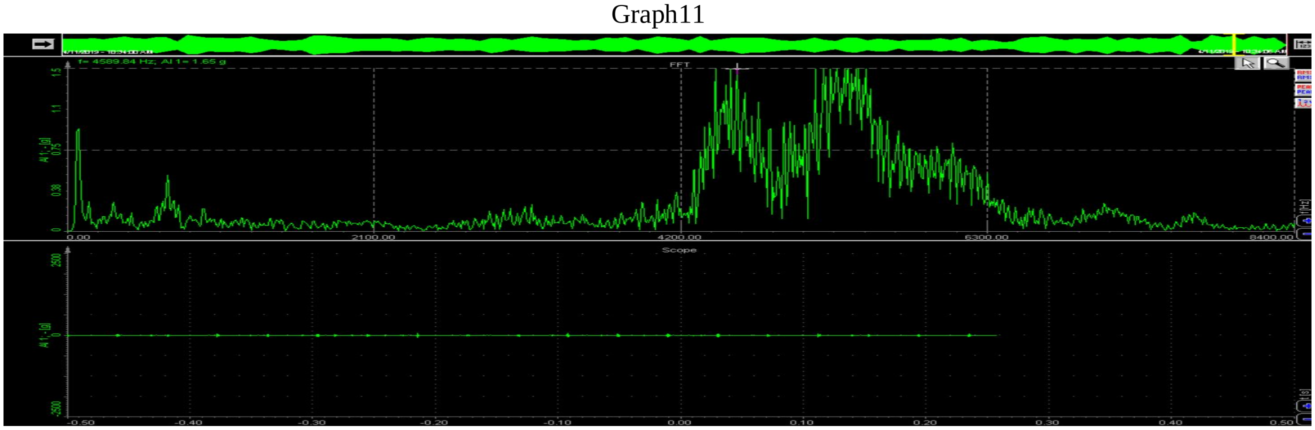

Fig. No. 13

3) *Vertical:* Maximum deviation is in range of 4200-6300Hz and maximum value of deviation is at 5332.03Hz with value of 1.52g. (g=9.81m/s2)

Graph12

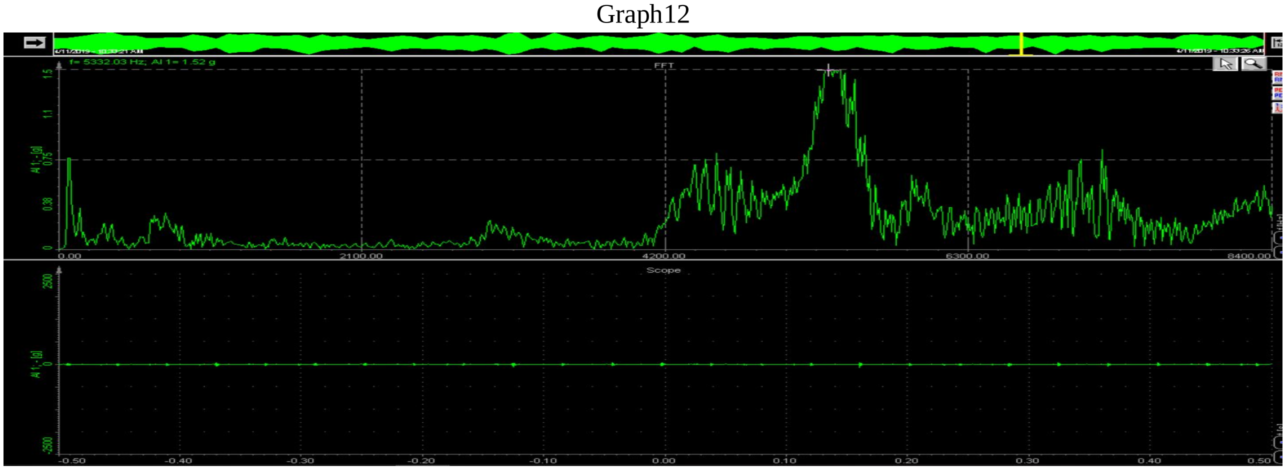

Fig. No. 14

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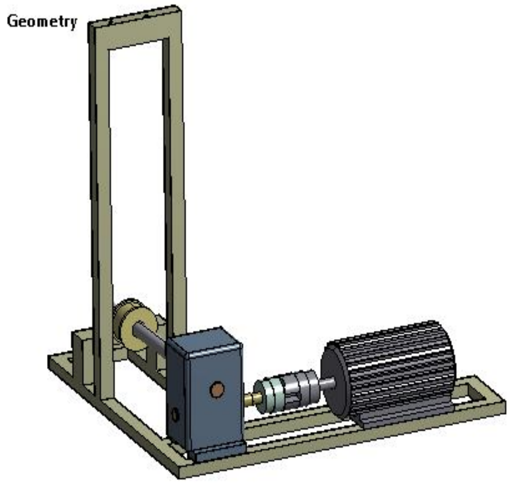
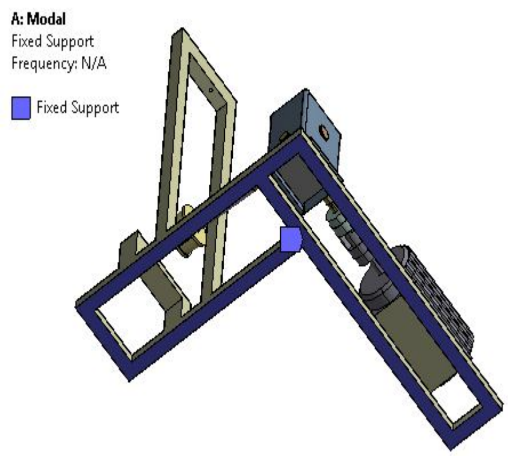
VII. FINITE ELEMENT ANALYSIS

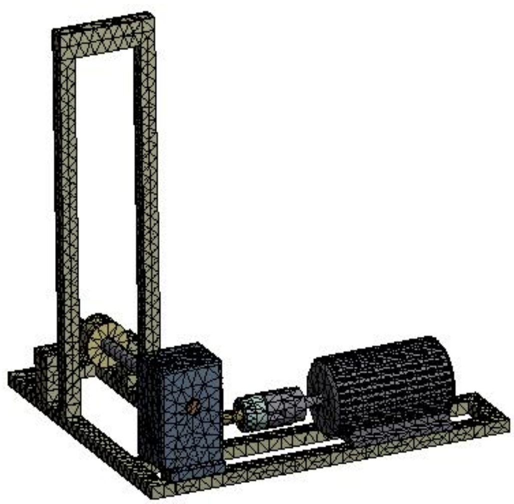
A. Results Obtained by Using Fea.



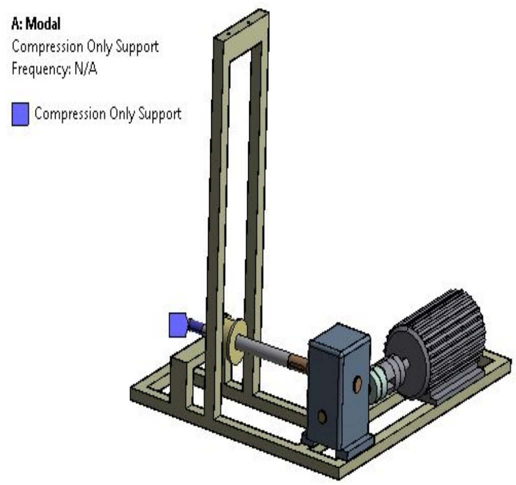
Geometry for analysis



Boundary condition 1



Meshing



Boundary condition 2

Details of "Analysis Settings"	
Options	
Max Modes to Find	30
Limit Search to Range	Yes
Range Minimum	4000. Hz
Range Maximum	6000. Hz
Solver Controls	
Damped	No
Solver Type	Program Controlled
Rotordynamics Controls	
Output Controls	
Analysis Data Management	

Fig. No. 15

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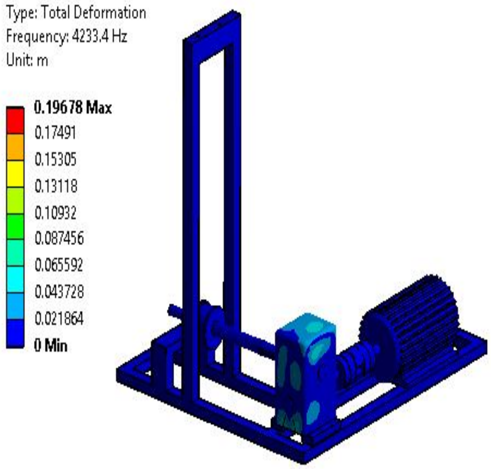
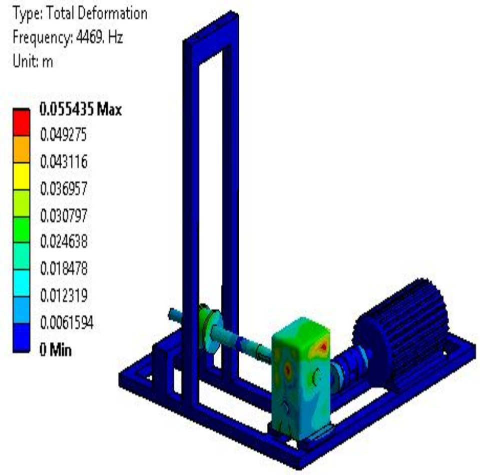
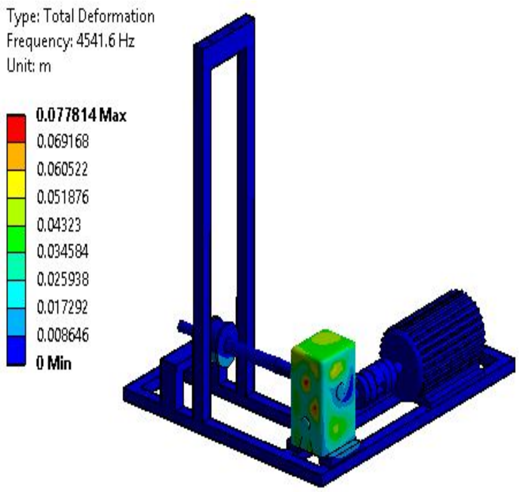
B. 30 Natural frequencies were extracted in range between 4000Hz to 6000Hz
C. Above frequency range was chosen from testing frequency values



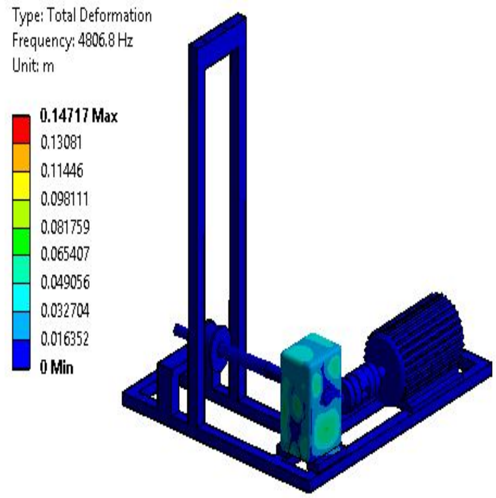
FEA result at 4233.4Hz



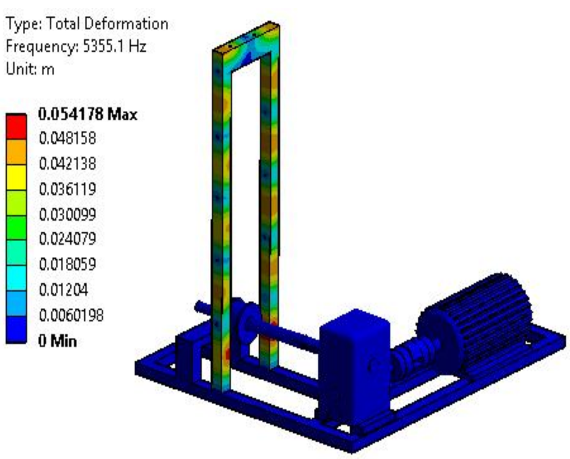
FEA result at 4469 Hz



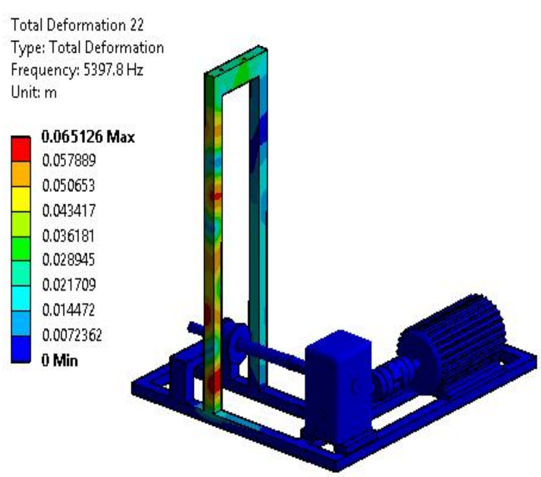
FEA result at 4541.6Hz



FEA result at 4807.8 Hz



FEA result at 5355.1 Hz



FEA result at 5397.8 Hz

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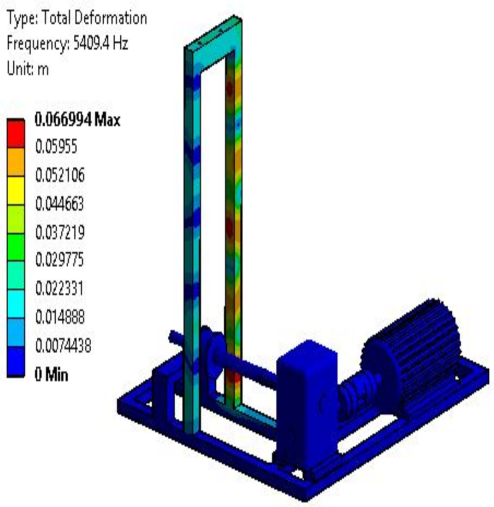
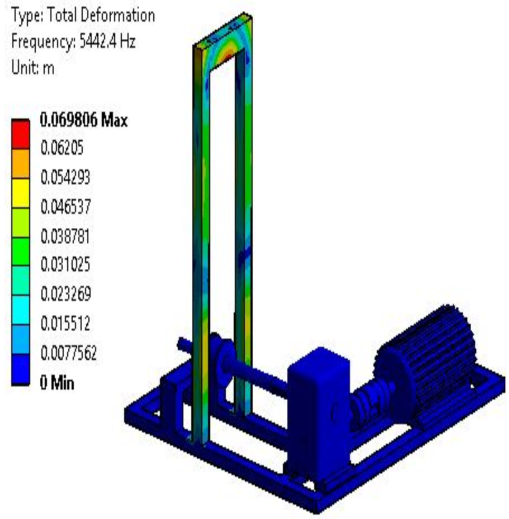


FEA result at 5409.4 Hz

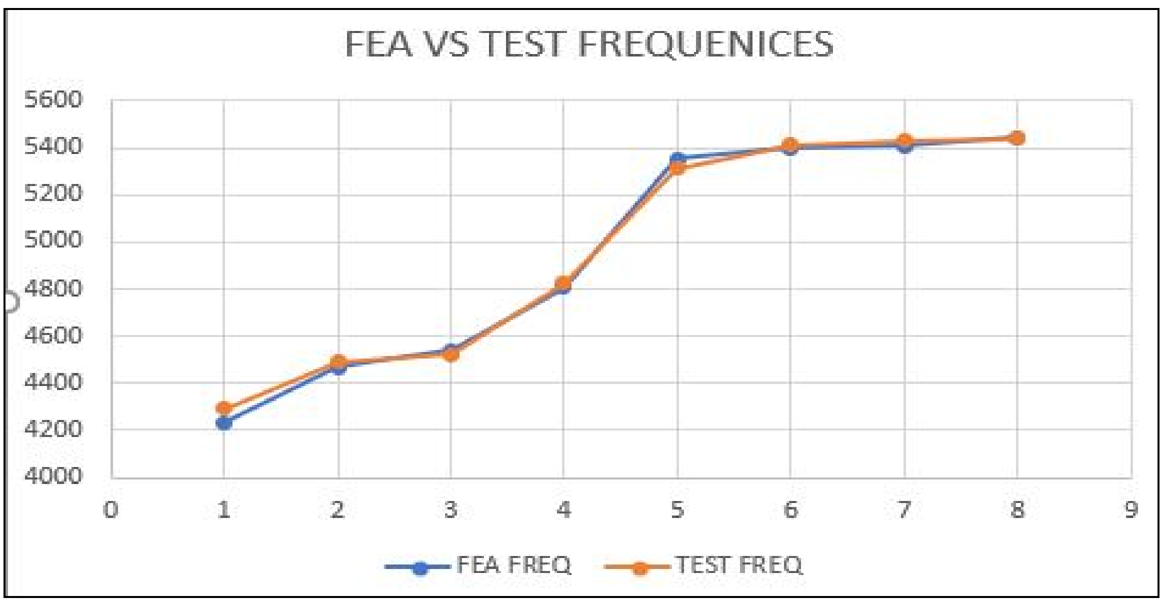


FEA result at 5442.4 Hz

VIII. OBERVATIONS

Comparative Analysis of FEA and Test Results.

MODE NO	FEA Frequency (Hz)	TEST Frequency (Hz)	Error %
1	4233.4	4292.88	-0.5948
2	4469	4492.19	-0.2319
3	4541.6	4521.48	0.2021
4	4806.8	4824.22	-0.1742
5	5355.1	5312.5	0.426
6	5397.8	5410.16	-0.1236
7	5409.4	5429.69	-0.2069
8	5442.4	5439.45	0.0295



Graph of Test frequencies vs FEA results.

VIII. CONCLUSION

A. Axial Direction: For node 1,2,3,4 as load increases there is decrease in acceleration with decrease in value if maximum frequency attainted for corresponding Maximum acceleration.
B. Horizontal Direction: For node 1,2,3,4 as load increase there is initial decrease in Acceleration to its minimum and then again starts increasing with same behaviours in trends of corresponding maximum frequency value.
C. Vertical Direction: For node 1,2,3,4 as load increase there is initial decrease in Acceleration to its minimum and then again starts increasing with same behaviours in trends of corresponding maximum frequency value.
D. Vertical Direction: For node 5, 6 as load increase there is initial decrease in acceleration to its minimum and then again starts increasing with same behaviours in trends of corresponding maximum frequency value.
E. From the test result and FEA results it is observed that the results are found satisfactory and within the range.

IX. FUTURE SCOPE

A. Similar work can be performed on different types of other gear and gear boxes for reduction in vibration caused by rotating machinery parts.
B. Observation results obtained by FFT can be validated with mode shape analysis using various Finite element software like ANSYS to get more accurate results.
C. Various metrological methods can be implemented for online inspection of rotating machines on basis of results obtained by above experimental work, for suitability to low skilled workers.
D. This kind of project work proves to best suited method in field of NVH Analysis in various automobile sectors

X. ACKNOWLEDGMENT

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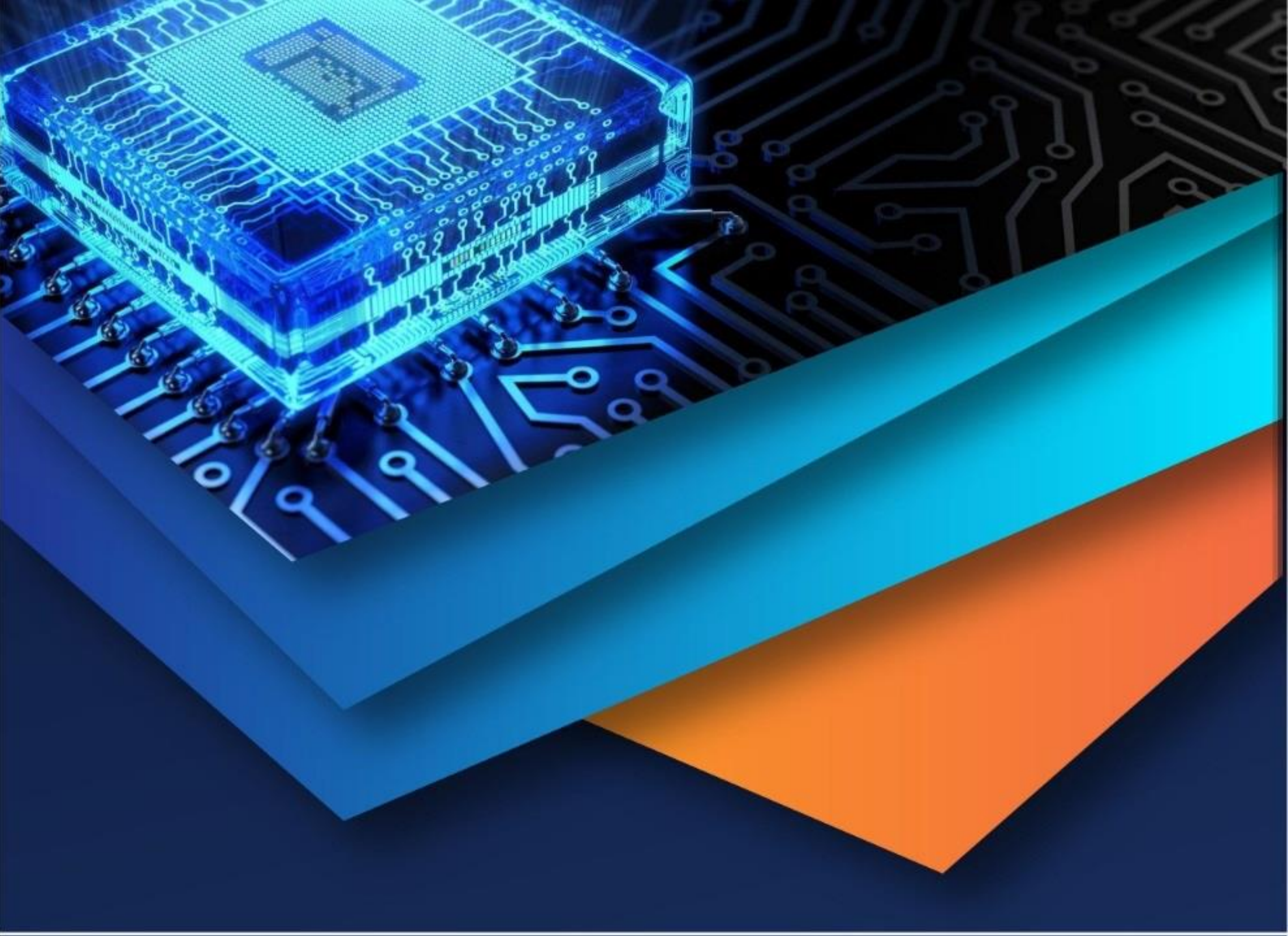

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