A simplified approach to model damping behavior of metal frame motor using composite material

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Abstract: - In this advanced technological era, lightweight design for fuel efficiency and environmental friendliness is essential for both conventional and hybrid electric vehicles (HEVs), without sacrificing the durability which is an important design factor for vehicle safety. The scope of this project is to describe design methodologies for the vehicle differential case applied to achieve light weight and to ensure product life. Three-dimensional CAD model of 4-wheeler differential case is designed using CATIA V5R20. Finite Element Analysis (FEA) software ANSYS Version 19.0 is used to determine the total deformation and equivalent stresses, strain in 4-wheeler differential case for weight optimization of 4-wheeler differential case topology optimization module will use. Experimental investigation will be done by strain gauge technique and UTM. Comparative analysis of FEA and Experimental will be done for validation of work. Conclusion and future scope will be suggested.

Index terms: Doors, ANSYS, differential case, Optimization, UTM.

I. INTRODUCTION

The motor is widely used for power source. The vibration reduction motor has important application value for reducing the vibration of the equipment system. Motor vibration involves many disciplines and fields. Some scholars have studied the vibration characteristics of the motor structure. Mendon et al. has studied the dynamic characteristics of the composite rotor. It is found that different laminate composite can obtain a rotor with different critical speed of rotation, instability threshold, and frequency response characteristics. Druesne et al. used the structural dynamic finite element coupling model to analyze the dynamic characteristics of the motor stator under electromagnetic vibration and mechanical vibration. It is found that Young's modulus and density of stator material have a great influence on the natural frequency and vibration response signal. Induction motors are highly nonlinear and electric rotor variables are not measurable. The skin effect in the rotor winding and iron core saturation lead to even bigger complications in the modeling process of the Machine.

Traditionally dynamic parameters are estimated by performing no-load test and locked-rotor test. Due to the complication of dynamic behaviors of induction motors, inaccuracy of transient characteristics may obtain while using these dynamic parameters. These tests are not convenient because they require human electrical measurements and intervention on the machine. The locked rotor test results in very high slip frequency, and increasing skin effect influence on the rotor resistance. This leads to incorrect operating conditions and inaccurate parameter estimation

Fig. Motor frame

In this research work synchronously rotating reference frame dynamic modeling of the induction motor is used. The induction machine is represented mathematically using the two-axis theory of electric machines. The two-phase signal representation is often used to reduce the complexity of the differential equations that describes the induction machine. Complexity of these equations can also be reduced by eliminating all time varying inductances, due to electric circuits in relative motion, from the voltage equations of the machine. The time varying voltage and torque equations describe the dynamic behavior of the induction motor.

II. LITERATURE REVIEW

Heng Lin, Yiqian, Xiang, Ying Yang. et.al [1], In this writing writer clarify about vibration investigation of CFRP link tube. Carbon fiber supported polymer (CFRP) enjoys benefits of light weight, incredible strength, impressive adaptability and protection from consumption and weariness. In this paper, the lowered skimming burrow (SFT) with CFRP link is proposed. The coupled vibration model of CFRP link tube framework is set up and the unique reaction is exhaustively broke down under parametric excitation. The mathematical models are given to tackle movement differential condition by utilizing the fourth-request Runge-Kutta technique. The outcomes show that SFT with CFRP link is all the more effectively wavering at free vibration, yet the sufficiency of removal reaction for link is diminished pointedly while considering the water and materials damping of the framework. The impact of vibration is essential issue for seaward design in the marine climate. Carbon Fiber supported polymer (CFRP) material has been generally utilized in structural designing. Since its mechanical and substance properties are better than conventional materials somely, they are utilized to supplant steel links as of late.

CFRP is all the more effectively swaying at free vibration, however the adequacy of dislodging reaction is diminished forcefully when the framework considers the water and materials damping. The material of CFRP has a lot more modest scope of reverberation recurrence proportion than the material steel. The regular recurrence of CFRP link is higher than steel strand in SFT. Albeit the material of CFRP has extraordinary enemy of weakness execution, the weariness of materials ought to be additionally contemplated.

Willy roger de Paula mendonça, et.al [2], In this article the powerful investigation of rotors mounted on composite Shaft. The shafts are made of composite materials, which show viscoelastic conduct. The conditions of movement for these rotors address the impact of inner damping on the powerful conduct of the rotor framework. Composite materials can be made utilizing various layups. This investigation audits the strategy that can be utilized to foresee the same mechanical properties of composite shafts. The point of this examination is to work on the comprehension of the elements of rotors with composite shafts through reenactments dependent on existing approaches, hence showing the constraints of innovation and empowering the advancement of procedures to work on the choice of composite layups utilizing enhancement algorithms.Viscoelastic materials, for example, the rotors utilized in this investigation, experience high inward damping contrasted with metallic materials. This conduct is because of the composite constituents: carbon fiber displays versatile conduct and epoxy tar has thick conduct. Recreations were performed to exhibit the impact of the layup on the shaft identical mechanical properties and subsequently the consequences for the rotor dynamic conduct. The outcomes show the capability of the strategies applied and the adaptability in the utilization of composite materials, which empowers the streamlining of the mechanical properties and further develops the rotor dynamic conduct. C. Elanchezhian, B. Vijaya Ramnath, J. Hemalatha. et.al [3], In this survey paper, Author C. Elanchezhian find out about Mechanical conduct of glass and carbon fiber built up composites at different strain rates and temperatures. The utilization of elite polymeric composites is an important option in contrast to traditional materials because of their high mechanical properties, firmness to weight proportion and harm resilience. The Mechanical property of epoxy frameworks can be affected by altering the atomic design and construction, along these lines expanding the crosslink thickness to produce high firmness and strength.Fibres, for example, glass and carbon are plentiful and sustainable, lightweight, with low thickness and high durability. Strands, for example, glass and carbon can possibly be utilized as a swap for customary support materials in composites for applications which requires high solidarity to weight proportion and further weight reduction. In this work, fiber composites are manufactured with filaments like CFRP and GFRP. Their mechanical properties like rigidity (at different strain rates and temperatures), flexural strength (at different strain rates) and effect strength are researched and from the outcomes acquired, the accompanying ends were drawn. The impact of the various tests is considered and the inner designs of composites have been explored utilizing SEM (Scanning Electron Microscope) and it is tracked down that the direction points of strands assume a significant part in the mechanical conduct of CFRP and GFRP composite. SEM micrographs of the tractable and flexural tried examples help to anticipate fiber disappointment, reason for voids and fiber pull out during stacking condition. It's anything but a thought regarding the break proliferation in the composite.

R. Capozucca and B. Bonci, et.al [4], In this article exploratory and hypothetical investigation of harmed and unharmed Carbon Fiber Reinforced Polymer (CFRP) cover components under free vibration. Somewhat recently, structures utilizing composite materials have gotten essentially normal in many designing applications, for example, aviation structures and mechanical and common constructions because of their high strength and firmness in regard to their weight. Carbon Fiber Reinforced Polymer (CFRP) overlays commonly comprising of supporting strands in a pitch grid (epoxy tar) have been utilized broadly. In this paper, the trial dynamic conduct of composite CFRP overlays with harm due to rectangular notches is researched considering basically upheld radiates as specimens. A satisfactory mechanical device for mimicking pivot conditions at the edges was received to analyse the free vibration of CFRP laminate elements. Test vibration tests on whole CFRP covers and on overlays harmed by twofold rectangular scores at various positions were done in research center on just upheld examples. The exploratory consequences of recurrence esteems were contrasted and information acquired from both limited components and from the insightful demonstrating of CFRP cover. The hypothetical model embraced depends with the understanding that decrease of solidness because of scores might be portrayed utilizing a pivot situated at the hub of the indent. Sabin Sathyan, Anouar Belahcen, Antti Lehikoinen, et.al [5], In this article writer clarify about vibration of a high speed strong rotor enlistment engine. This paper examines the reasons for vibrations in a strong rotor acceptance engine (SRIM) through electromagnetic Finite Element (FE) reproductions and research facility estimations. The registered outcomes are contrasted and vibration estimations, and the electromagnetic reasons for vibrations were found, including the shortcoming related reasons. The machine being scrutinized is a 300 kW, 60 000 rpm, three-stage SRIM.The vibrations in electrical machines cause undesirable commotion in adjoining conditions and it can likewise prompt reduced execution and life expectancy of machines. Mathematical reproductions to investigate and anticipate these vibrations are henceforth significant in machine plan. In modern hardware, the commotion examination is an unpredictable method, in light of the fact that there are mechanical wellsprings of vibrations separated from electromagnetic reasons, and impedance from close by electrical and mechanical establishments makes the circumstance really testing. This examination inspects the subject of vibration investigation overwhelmingly from an electromagnetic angle and corresponded the discoveries with unbalances in the engine framework. The investigation of vibrations and clamor has been a conspicuous subject in electrical machines and electromechanics for quite a long time. Attractive powers and magnetostriction (MS) were discovered to be the major electromagnetic reasons for vibration. An broad investigation on the electromagnetic reasons for vibrations in a high velocity acceptance engine is completed for this paper. On account of the explored machine, while the principal supply recurrence segments and its products cause vibrations, the presence of dynamic unusualness contribute extra recurrence parts and consequently strengthened the vibrations. The recurrence segments and their sidebands actuated by the capriciousness condition were discovered to be something similar in both reproduced and estimated spectra.

Rameshwar Kendre. et.al [6], In this paper creator depict about starter engine examination which utilized in three-wheeler automobile. Automobile enterprises have prime significance to vibration testing. Sine vibration testing is performed when we have been given with just a single recurrence at given time moment. Pattern to perform arbitrary vibration testing has been expanded lately. As arbitrary vibration considers all energized frequencies in characterized range at known time period, it gives constant information of vibration severities. Manual turning over of a motor has an issue of making jerk or a physical issue the working individual. The coming of Starter Motor (SM) made it simple to turn over a motor by electrical methods and tackled the issue of hand-wrenching the motor physically. Fundamentally, engine draws in with flywheel for 0.01 to 1 second. First numerical investigation on the development of particles suspended in a fluid medium is performed by Einstein. The finish of his examination was the development of molecule is an element of mass and calculation of molecule and furthermore it relies upon actual property of fluid medium. As this arrangement yielded probabilistic conduct of mass and damper of mechanical framework, his work could be considered as first starting answer for irregular vibration issues

A. Martone, V. Antonucci, M. Zarrelli, M. Giordano. et.al [7], Interleaving a viscoelastic layer inside an overlay has been individuated as a productive design for expanding damping execution of plane constructions. A semi-insightful model dependent on the principal request shear disfigurement hypothesis representing the out of plane strain commitments to the energy scattering in composite covers with interleaved engineering is proposed. Two distinct designs for the interleaved composite overlay engineering have been produced and tried in bowing. The versatile and dissipative material capacities for the elongation and shear modes have been tentatively portrayed for the constituents of the interleaved overlays: the unidirectional lamina and the damping layer material. These constitutive material practices have been utilized for the model computations. An agreeably arrangement between the test information and anticipated outcomes has been found for the bowing conduct of the various models. Progressed fiber built up composites are ordinarily utilized in weight delicate underlying applications because of their high firmness to weight proportion. In any case, because of the weight decrease itself the polymer lattice composite designs shows a low vibroacoustic damping in regard to standard metallic constructions. The current planning practice is described by a successive strategy, where structure advancement is fundamentally performed as for the firmness and the strength. The satisfaction of applicable useful necessities, for example, the warm and the acoustical protection is subsequently tended to with weight punishments for the construction. A far reaching way to deal with configuration damping conduct of interleaved cover structures has been proposed.

III. PROBLEM STATEMENT

starting from the improvement of the damping of the material of the motor frame, a three-phase asynchronous motor of a certain type, the structure design of the Carbon Fibre Reinforced Polymer (CFRP) and Glass Fibre Reinforced Polymer (GFRP) motor frame is carried out based on the excellent damping performance and establishes a damping prediction model based on the strain energy loss.

IV. OBJECTIVES

The fiber reinforced composites structures are usually subject to dynamic external loads during service. Vibration analysis of these structures plays a significant role in tailoring the parameters like damping, modal frequencies, and shapes.

- Modelling of Carbon Fibre Reinforced Polymer (CFRP) and Glass Fibre Reinforced Polymer (GFRP) motor frame in CATIA V5 software.
- Analyzing for stresses and deformation in both metal frame motor and composite frame motor specimen using ANSYS software.
- To perform modal analysis of Carbon Fibre Reinforced Polymer (CFRP) and Glass Fibre Reinforced Polymer (GFRP) motor frame using ANSYS 19.
- Selection of composite material depending upon cost estimation and analysis results.
- Manufacturing of new composite motor frame using hand lay-up method.
- Experimental testing will be done using FFT analyzer and impact hammer for finding natural frequency.

EXISTING CAD 4-WHEELER DIFFERENTIAL CASE

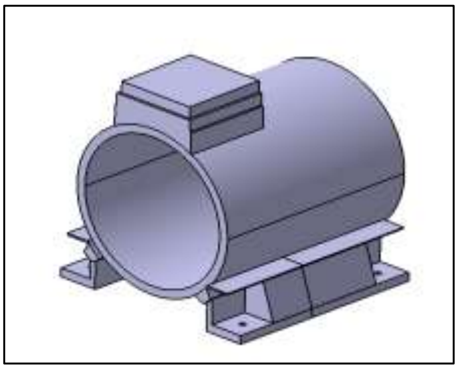


Fig.1 CATIA model of motor casing

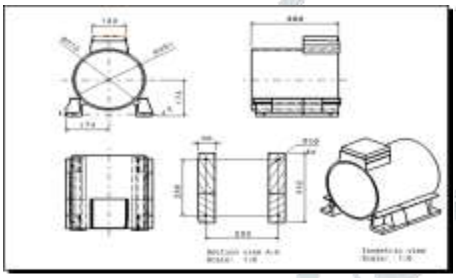


Fig Drafting of motor casing

ANALYSIS OF MOTOR FRAME

FINITE ELEMENT METHOD

STATIC ANALYSIS OF EXISTING DIFFERENTIAL CASING:

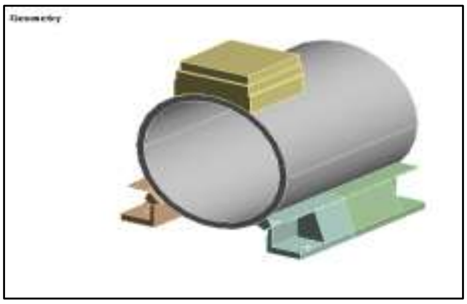
- Material properties of Casing:

Properties of Outline Row 3: Aluminum Alloy

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	2770	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	2.3E-05	C^-1
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and...	
8	Young's Modulus	7.1E+10	Pa
9	Poisson's Ratio	0.33	
10	Bulk Modulus	6.9608E+10	Pa
11	Shear Modulus	2.6692E+10	Pa

Table. Material properties

GEOMETRY:



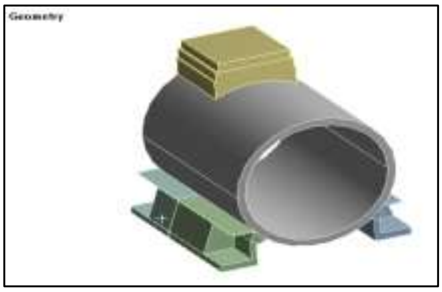
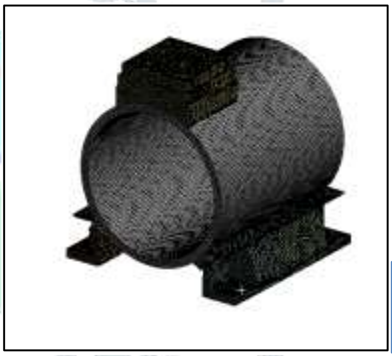


Fig Geometry of motor casing

MESHING:

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Metaphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.



Statistics	
Nodes	583905
Elements	311844

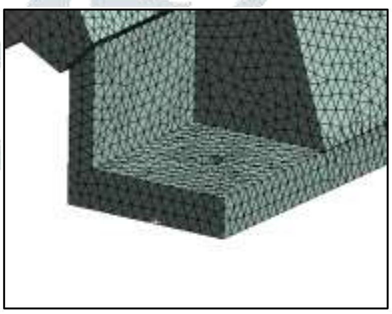


Fig. Meshing details

Boundary Condition

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both.

The main types of loading available in FEA include force, pressure and temperature. These can be applied to points, surfaces, edges, nodes and elements or remotely offset from a feature. The way that the model is constrained can significantly affect the results and requires special consideration. Over or under constrained models can give stress that is so inaccurate that it is worthless to the engineer. In an ideal world we could have massive assemblies of components all connected to each other with contact elements but this is beyond the budget and resource of most people. We can however, use the computing hardware we have available to its full potential and this means understanding how to apply realistic boundary conditions.

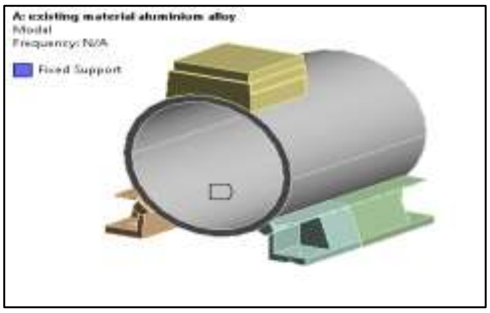


Fig. Boundary condition

Fixed support applied at 4mounting holes

MODAL ANALYSIS:

Every object has an internal frequency (or resonant frequency) at which the object can naturally vibrate. It is also the frequency where the object will allow a transfer of energy from one form to another with minimal loss. As the frequency increases towards the "resonant frequency," the amplitude of response asymptotically increases to infinity. In other words, the results of the modal analysis are these frequencies at which the amplitude increases to infinity.

Every system can be described in terms of a stiffness matrix that connects the displacements and forces. These frequencies are known as natural frequencies of the system and are provided by the eigenvectors of the stiffness matrix. These frequencies are also known as the resonant frequencies.

	Mode	Frequency [Hz]
1	1.	175.75
2	2.	336.67
3	3.	551.
4	4.	961.09
5	5.	1141.3
6	6.	1554.9

Fig. Natural frequencies at 1 to 6 mode shape

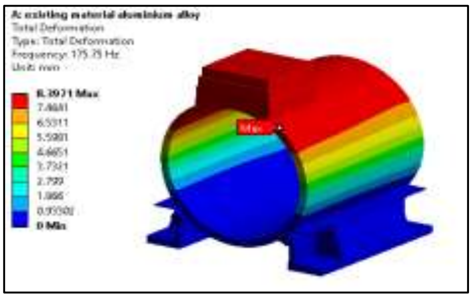


Fig. Mode shape 1 with fundamental frequency 175.75Hz

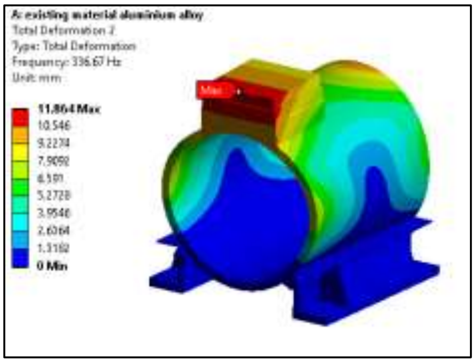


Fig. Mode shape 2 with fundamental frequency 336.67Hz

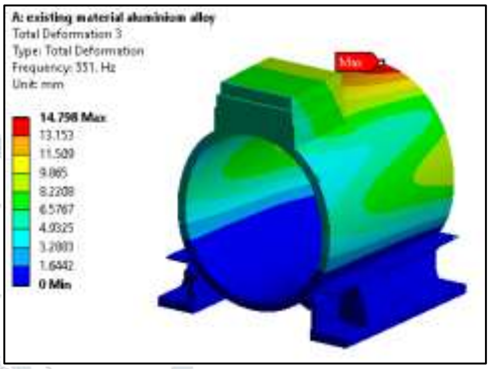


Fig. Mode shape 3 with fundamental frequency 551 Hz

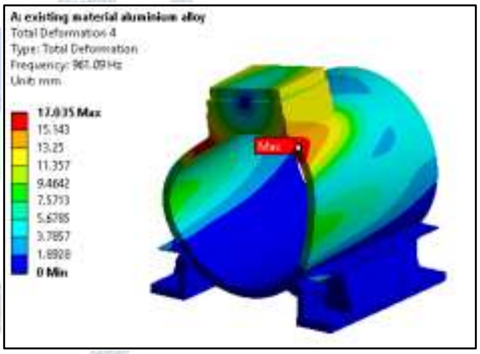


Fig. Mode shape 4 with fundamental frequency 961.09 Hz

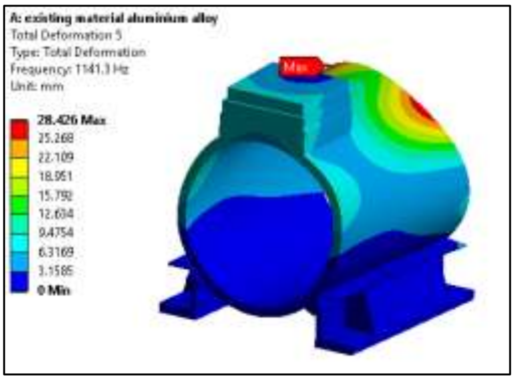


Fig. Mode shape 5 with fundamental frequency 1141.3 Hz

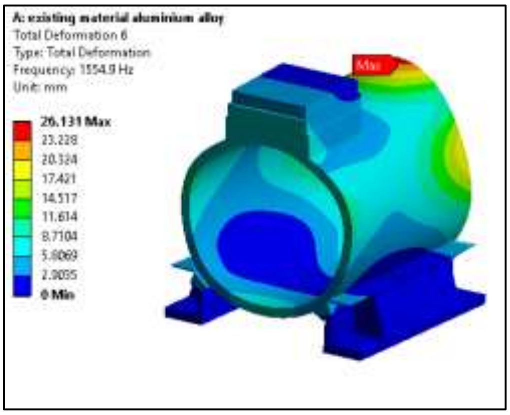


Fig. Mode shape 5 with fundamental frequency 1554.9 Hz

ANALYSIS OF MOTOR CASING USING REVERSE ENGINEERING METHOD

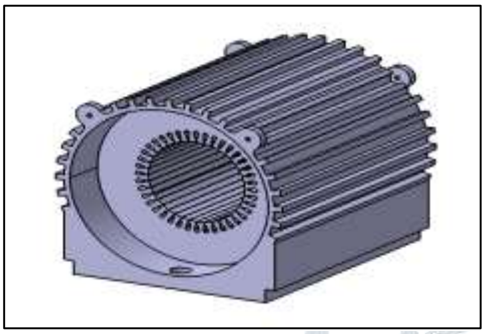


Fig. CATIA model

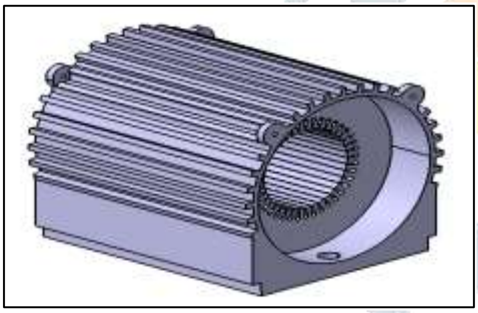


Fig. Motor bracket cad model

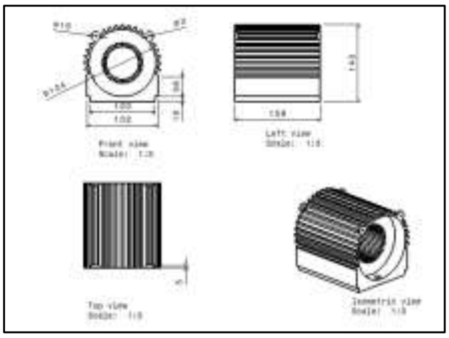


Fig. Drafting of motor casing

ANALYSIS OF EXISTING MOTOR HOUSING USING MODAL ANALYSIS

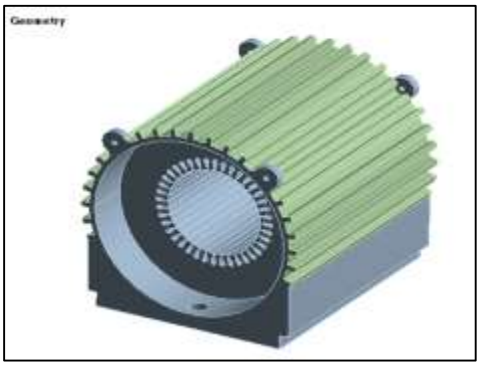


Fig. Geometry import in ANSYS

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	1.2E-05	C^-1
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa

Fig. Material properties

Details of "Body Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	2 Bodies
Definition	
Suppressed	No
Type	Element Size
Element Size	10.0 mm
Advanced	
Defeature Size	Default
Behavior	Soft

Statistics	
Nodes	63525
Elements	36314

Fig. Meshing details

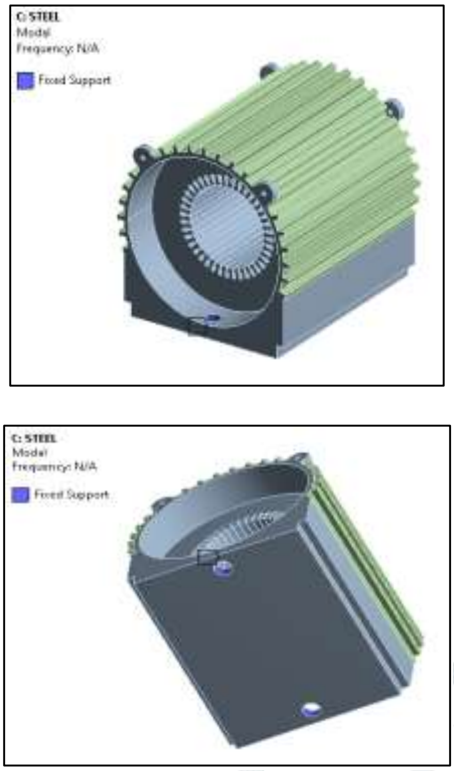


Fig. Boundary condition

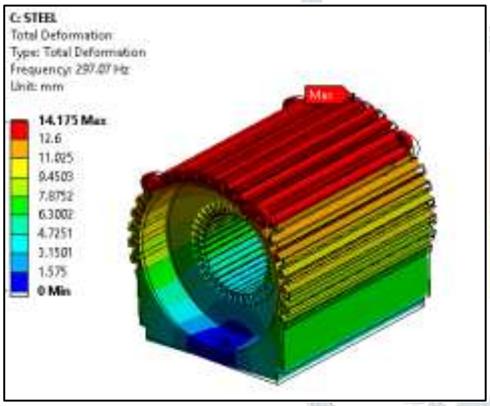


Fig. Mode shape 1 with fundamental frequency of 297.07 Hz

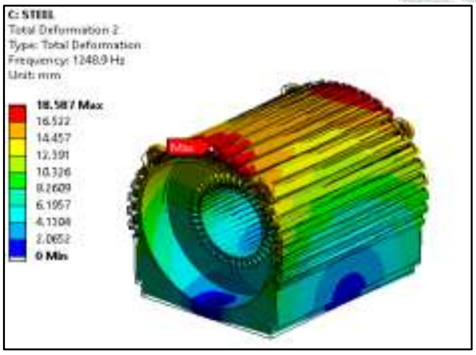


Fig. Mode shape 2 with natural frequency of 1248.9 Hz

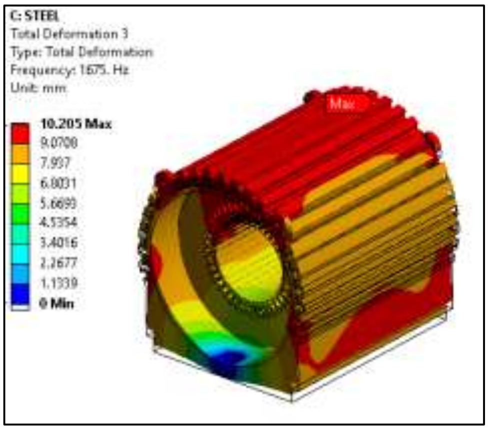


Fig. Mode shape 3 with natural frequency of 1675 Hz

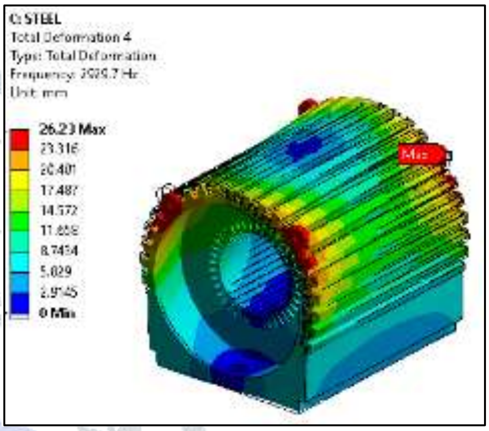


Fig. Mode shape 4 with natural frequency of 2929.7 Hz

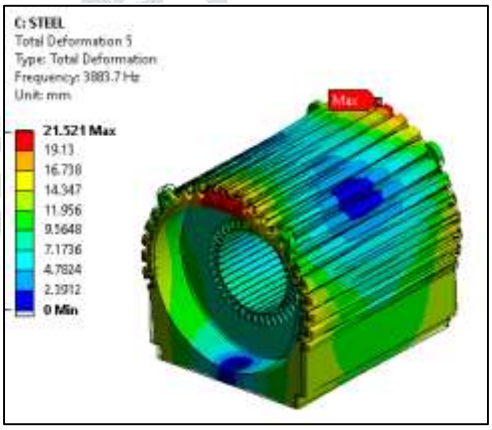


Fig. Mode shape 5 with natural frequency of 3883.7 Hz

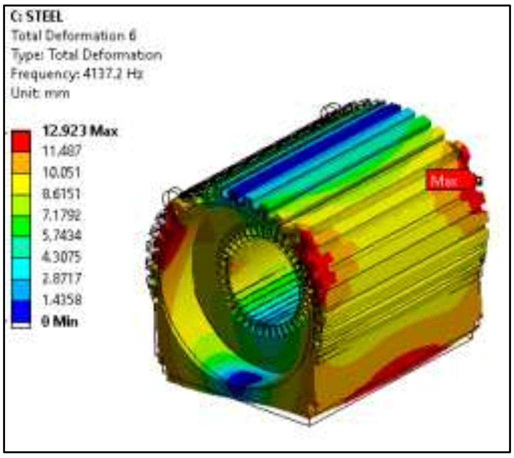


Fig. Mode shape 6 with natural frequency of 4137.2 Hz

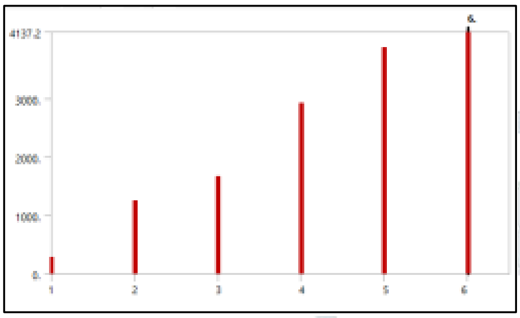
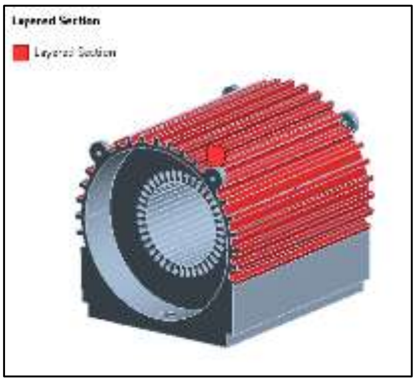


Fig. Modal analysis result in graphical format

	Mode	Frequency [Hz]
1	1.	297.07
2	2.	1248.9
3	3.	1675.
4	4.	2929.7
5	5.	3883.7
6	6.	4137.2

Fig. Modal shape result in tabular format

ANALYSIS OF MOTOR HOUSING USING LAYER OF COMPOSITE MATERIAL CARBON FIBRE



Layer	Material	Thickness (mm)	Angle (°)
(+Z)			
2	Epoxy Carbon UD (395 GPa) Prepreg	1	0
1	Epoxy Carbon UD (395 GPa) Prepreg	1	0
(-Z)			

Fig. Layered section applied on red region

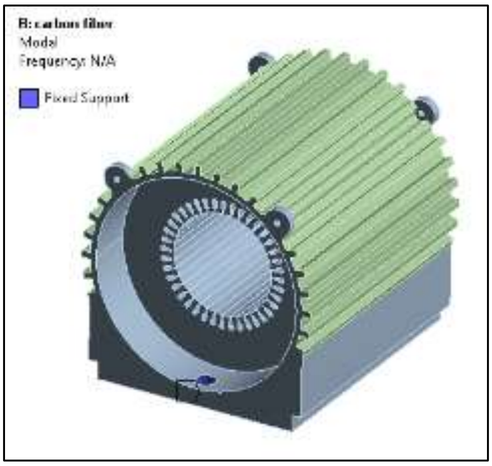


Fig. Fixed support

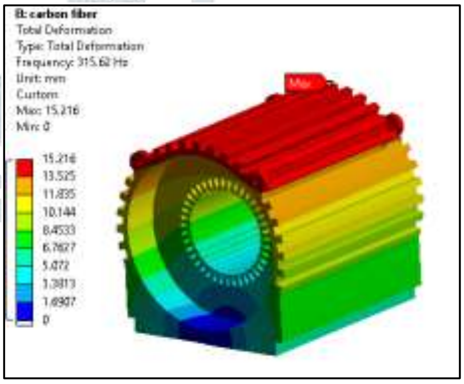


Fig. Mode shape 1 with fundamental frequency 315.62 Hz

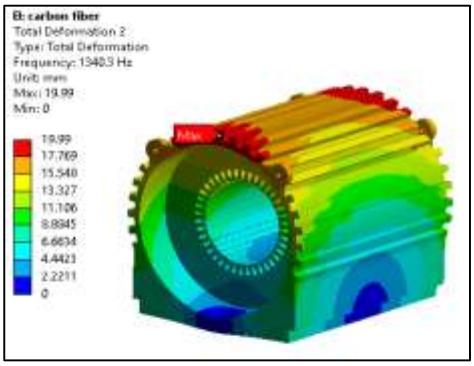


Fig. Mode shape 2 with natural frequency 1340.3 Hz

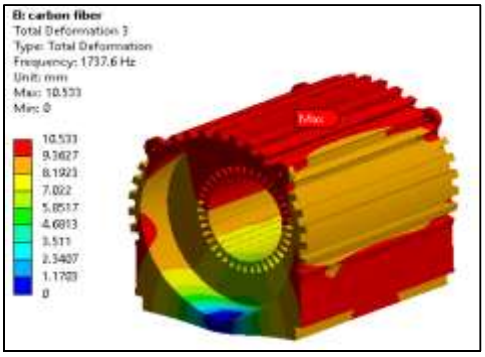


Fig. Mode shape 3 with natural frequency 1737.6 Hz

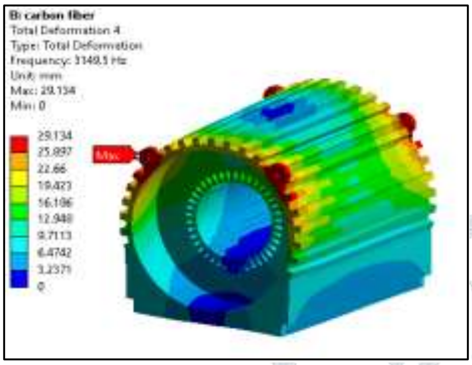


Fig. Mode shape 4 with natural frequency 3149.5 Hz

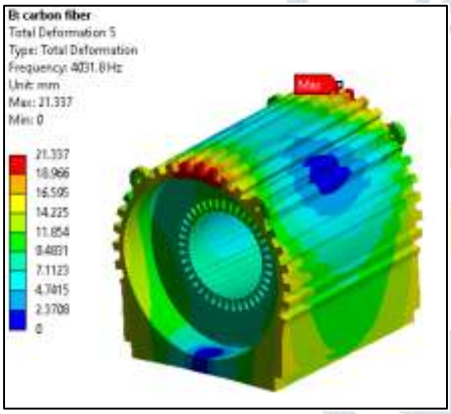


Fig. Mode shape 5 with natural frequency 4031.8 Hz

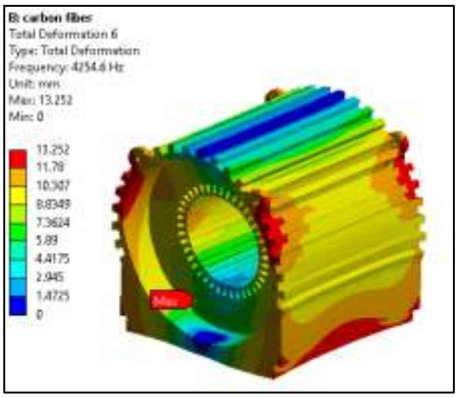
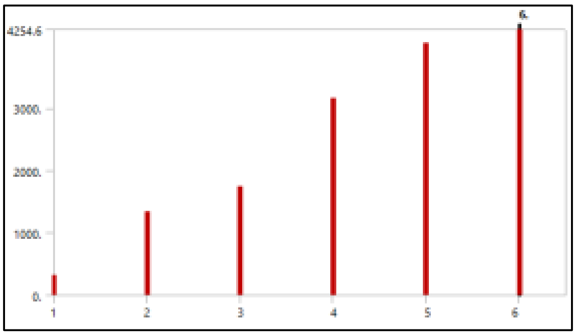


Fig. Mode shape 6 with natural frequency 4254.6 Hz



	Mode	Frequency [Hz]
1	1.	315.62
2	2.	1340.3
3	3.	1737.6
4	4.	3149.5
5	5.	4031.8
6	6.	4254.6

Fig. Mode shape result for carbon fiber composite material

MANUFACTURING PROCESS

Fig. Sheet of carbon fiber

Fig. Motor housing with carbon fiber

Fig. Motor housing with carbon fiber

EXPERIMENTAL TESTING USING FFT

FFT analysis

FFT is one principle property in any succession being utilized as a rule. To discover this property of FFT for some random succession, many changes are being utilized. The significant issues to be seen in discovering this property are the time and memory the board. Two unique calculations are composed for figuring FFT and Autocorrelation of some random succession. Correlation is done between the two calculations concerning the memory and time administrations and the better one is pointed. Examination is between the two calculations composed, thinking about the time and memory as the main fundamental limitations. Time taken by the two changes in finding the basic recurrence is taken. Simultaneously the memory expended while utilizing the two calculations is additionally checked.

DEWE-43 Universal Data Acquisition Instrument

At the point when associated with the rapid USB 2.0 interface of any PC the DEWE-43 turns into an amazing estimation instrument for simple, computerized, counter and CAN-transport information catch. Eight concurrent simple sources of info test information at up to 204.8 kS/s and in blend with DEWETRON Modal Smart Interface modules (MSI) a wide scope of sensors are upheld Voltage Acceleration Pressure Force Temperature Sound Position RPM Torque Frequency

Velocity and more The included DEWESoft application programming includes incredible estimation and examination capacity, transforming the DEWE-43 into a committed recorder, extension or FFT analyzer.

Fig. Experimental setup

Fig. Experimental testing

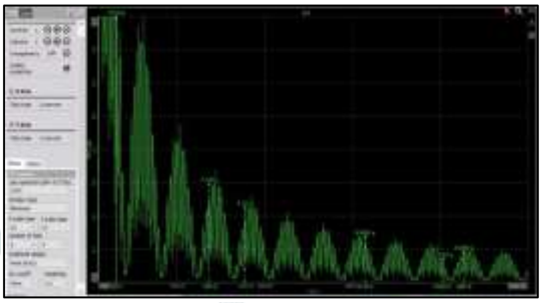


Fig. Experimental testing result

SR NO	MODA SHAPES	RESULTS (Hz)
1	NATURAL FREQUENCY 1	302.7
2	NATURAL FREQUENCY 2	1367.2
3	NATURAL FREQUENCY 3	1777.3
4	NATURAL FREQUENCY 4	3144.5
5	NATURAL FREQUENCY 5	4033.2
6	NATURAL FREQUENCY 6	4267.6

V. RESULT AND DISCUSSION

The motor housing is the made up of steel material and have to sustain vibration created by own mechanism. The vibration analysis on existing motor housing completed using ANSYS software and find out fundamental frequency of the existing model. To increase the fundamental frequency of the housing applied 2 mm carbon fiber layer replacing steel. As per analysis result the fundamental frequency of the optimized model is increased.

SR NO	MODE SHAPES	EXISTING MODEL (Hz)	OPTIMIZED MODEL (Hz)
1	MODE SHAPE 1	297.07	315.62
2	MODE SHAPE 2	1248.9	1340.3
3	MODE SHAPE 3	1675	1737.6
4	MODE SHAPE 4	2929.7	3149.5
5	MODE SHAPE 5	3883.7	4031.8
6	MODE SHAPE 6	4137.2	4254.6

SR NO	MODE SHAPES	OPTIMIZED MODEL (Hz)	EXPERIMENTAL RESULTS (Hz)
1	MODE SHAPE 1	315.62	302.7
2	MODE SHAPE 2	1340.3	1367.2
3	MODE SHAPE 3	1737.6	1777.3
4	MODE SHAPE 4	3149.5	3144.5
5	MODE SHAPE 5	4031.8	4033.2
6	MODE SHAPE 6	4254.6	4267.6

VI. CONCLUSION

CASE STUDY

- In present research we develop 3D cad model of motor casing using research papers and reverse engineering method with the help of CATIA software.
- Perform vibration analysis of existing motor casing bracket using ANSYS software.
- It is observed that natural frequency of existing model is between 175.75 Hz to 1554.9 Hz.

PROJECT

- Perform vibration analysis of existing motor housing using ANSYS software and find out fundamental frequency of the structure. The natural frequency of the existing model is 297.07 Hz.
- To optimized the structure of motor housing bracket applied the layer of unidirectional carbon fiber and reanalysis using modal analysis tool. The optimized fundamental frequency of motor housing is 315.62 Hz.
- The experimental testing is performed to validate the frequencies result. FFT analyzer machine and impact hammer test use to find out natural frequency of the motor housing.

VII. REFERENCES

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