Modal Analysis and Stiffness Optimization of Glass Fibre Reinforced Mudguard using Fast Fourier Transform and Finite Element

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Abstract— **Mudguards of two wheelers are subjected to harmonic and random vibration due to various road conditions. They are made up of Plastic or sheet metal structures which undergo failure at joints or cantilever ends. Reinforcement of these existing structures with epoxy and glass fiber will strengthen it in its dynamic characteristics. Modal analysis will be carried out to investigate stiffness of existing and reinforced structure. Modes shapes and resonant frequencies will be checked for both models. FFT analyzer and Impact hammer will be used to perform experimental modal analysis. Validation will be done by comparing both experimental and FEA results. Suitable conclusions will be drawn and future scope will be suggested.**

Keywords— Glass Fiber Reinforcement, FFT analyzer, FEA, Mudguard.

INTRODUCTION

The automotive companies has been in process to make the light Two-wheeler mudguards are subjected to harmonic and random vibration due to various road conditions. They undergo structural failures due to vibration excitations. To enhance dynamic characteristics of existing mudguard by composite reinforcement Composite reinforcement of epoxy resin and glass fibre will be done on existing structure To measure natural frequencies and mode shapes using FEA and Experimental approach. To validate results and propose further future scope weight structure bodies to get the cost and weight benefit along with customer satisfaction. So main focus is given on the thickness reduction of frame/body panels and use of alterative materials. In recent years, the use of simulation software in metal forming processes has increased significantly as the benefit of trouble shooting and process optimization on the computer has been realized rather than through extensive shop floor testing. The rapid development of software technology, together with faster and lower cost computer hardware, has allowed many manufacturing operations to take place recently. Modeling cost-effectively that would have been deemed impractical only a few years ago. Many of these advances were made possible by tailoring and optimizing programs for specific applications, resulting in the general terms "sheet forming" and "bulk forming" being applied to various process modeling software types. The software choice for an uninitiated company, however, is this classification is not always as simple as that. For example, sheet metal forming is developing a great deal of interest in the globe as a means of reducing both the development cost of stamping a new part as well as the production lead time. These costs are accumulated from the initial part design to the final production tool throughout the entire development process. The correct software tool will depend on both the application and the stage of product development. Traditionally, sheet metal forming design relies on the experience accumulated by tool design engineers through long and expensive experiments with testing and error. Simple empirical methods provide guidance for similar cases to those on which these methods have been developed. Experiments are being used extensively in increasing numbers of cases with complex geometry and thinner, stronger materials.

I. LITERATURE REVIEW

S.M.Chavan The demand for higher quality exterior panels is increasing in the automotive industry. Better and lower weight functional properties. Weight reduction demand has resulted in thinner sheets, increased use of high-strength steels, and a shift from steel to aluminum grades. This reduction in thickness, which reduces the resistance of the dent, promoted the examination of the resistance of the dent resistance of static and dynamic loads K. Bhoyar et al. Pankaj.

Super plastic forming (SPF) is a near- net forming process that offers many conventional forming operations including low forming pressure under low flow stress, low die cost, more flexibility in design, and the ability to shape hard metals into complex shapes. Low production rate, however, due to slow process formation and limited predictive capabilities provides a lack of precise constitutive models for super plastic deformation, treated as a barrier to the widespread use of SPF. Recent progress in finite element tools has been demonstrated while analyzing the complex operations of super plastic forming. These tools can be utilized successfully in order to develop optimized super plastic forming techniques to develop the future materials[6]. Mehmet C and others. The parametric model of the body "s computer-aided design (CAD)' was prepared primarily for some static analyzes in this optimization study. In the following step, some critical dimensions of the structure parts were defined as design parameters. The optimization study's objective is to minimize the value of critical equivalent stress below the yield limit. In addition, a sensitivity study has been made on the body model with stress measures for an in- depth analysis. In various steps, Pro/Engineer CAD and Pro/MECHANICAL computer aided engineering (CAE) software has been used. Finally, the obtained results have been presented as both visually and in diagrams or tables. In other words, this study can be defined as a computer-aided design and optimization application of a sophisticated three-dimensional (3D) sheet-metal structural model. Consequently, in order to solve a sophisticated structural design problem, integrated CAD/ CAE programs supported optimization techniques are vital in providing time, error and cost reduction compared to conventional design processes Jesús M. Blanco and others. Double-skin perforated sheet facades, are enclosures composed of a perforated metal sheet, air chamber and glass, show a growing trend in modern construction design. Their thermal behavior has been addressed in previous research, taking into account several physical parameters such as perforation rates, colors and materials, as well as the influence of wind penetration through a Matlab® model, validated through a fully experimental test campaign, monitoring metal sheets for different configurations for 1 year, within a range of 0–35% (perforation rates)Galvanized steel aluminum (materials) and black-white (colours). Through a complete Energy plus ® model (design builder) validated by the Matlab ® model and experimental outputs mentioned above. The relevant contribution shows a new parametric energy evaluation taking into account additional variables such as air gap and location (defined according to the different climate zones).Finally, the influence of various enclosures on the entire building's cooling, heating and lighting loads (energy consumption) was obtained, demonstrating the suitability of the previously optimized configurations with respect to relative energy savings[7]. This leads to the establishment of a new methodology to optimize sustainability of design based on minimum energy consumption Baskaran and others. The focus of the current automotive scenario is to increase the strength and reduce the weight of body parts. Mudguard is provided in two wheelers to prevent other parts from entering and damaging the dirt and sand particles in the tire[8]. Most of which are currently made from plastics made from ABS / Polypropylene. They are expensive and not entirely degradable. An attempt in my work strong and abundantly available sisal plant fibers have been used to reinforce epoxy resin to replace mudguards with low cost, high strength and less weight. In a number of aerospace and non-aerospace applications, glass fiber strengthened epoxy composites are commonly used. In structural design of the composite product for particular applications, the selection of reinforcements and matrix structures as well as the nano clay fraction is crucial[1].The composites ' long-term performance capacities are governed by thermal stability and mechanical characteristics. Fibre reinforced composite materials have been reported to have attracted many applications in view of its low weight and superior strength when compared with the metal matrix composite. While researches have established the weight reduction of fibre reinforced polymer material, few works have reported the impact of orientation on the manufacturing of polymer composite. In this study, series of experimental works were done to demonstrate the manufacturing of glass-fibre reinforced epoxy resin with special attention on the influence of oriented reinforced composite material[2]. The composites were manufactured using hand-lay technique. Currently the glass fiber is manufactured with other resins such as epoxy, vinyl ester and polypropylene. These composites are used as sports goods, automobile bodies[3]. The present study is an attempt to take an overview of the work done in the area of characterization of Glass Fiber/Epoxy composite material. Different manufacturing processes are used for making Glass Fiber/Epoxy composite. Based on comprehensive literature review of various aspects in developing Glass Fiber/epoxy composite material, it is observed that extensive work has been done related to manufacturing and mechanical characterization of current material composites are most promising materials for components of current and future engineering structures, with a significant demand at present in aircraft and aerospace industries[4]. Modal analysis is the study of the natural characteristics of structures. Understanding both the natural frequency and mode shape helps to design any structural system for noise and vibration applications. In this paper analysis of free vibration of cantilever beam for the composite as well as steel material are carried out. Natural frequency and mode shape of the plates has been determined using FFT analyzer. Also comparative study of Steel, E glass epoxy and FRP is done for stress analysis with the help of UTM. These materials are used for vibration analysis to observe the effect of a modal parameters of cantilever beam subjected to free vibration is analyzed with the help of FFT analyzer in experimental setup[5].

II. METHODOLOGY

CAD modeling of existing structure using CATIA.
Finite Element Discretization using AnsysWorkbench.FEA of existing mudguard to obtain Natural frequencies and mode shapes FEA of composite mudguard to obtain Natural frequencies and mode shapes. Experimental Modal analysis of existing and reinforced structure using FFT analyzer and Impact hammer Comparative analysis between FEA & Experimental results. Conclusion & Future scope

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A. *PREPARATION OF GLASS FIBRE EPOXY RESIN MUDGUARD*

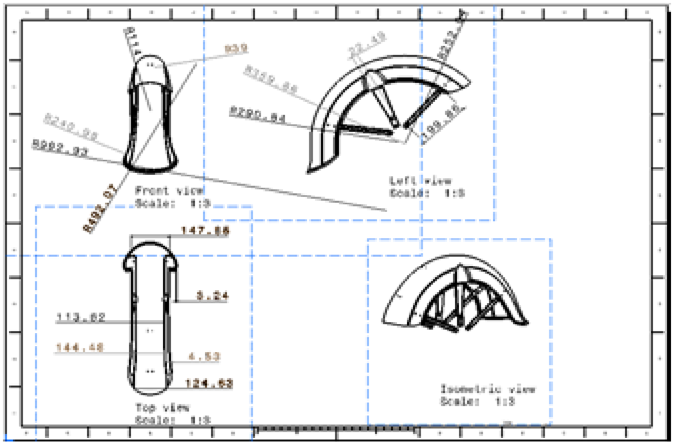


Fig 2 Layout of Jawa Mudguard

Epoxy resins are mostly used for large performance applications such as airspace objects and Submarine Epoxies have excellent mechanical properties than polyester resins. Epoxies also have better adhesion properties. Glass fiber is obtained from waste of industries after they are decomposed. Glass fiber and epoxy resin are mixed in ratio of 50:50, casting is done by "Hand layup method".

For manufacturing wooden pattern mould is firstly made and then on it thick layer of wax (Goat Gel) is applied on it then by brush Glass fiber and epoxy mixture is sprayed by hand with brush. Thickness of wax decides the flexibility of removal from the mould. Resin is applied on it and left for drying. Hair drier is used to dry the resin and resin is again applied on it. The drying period is around 24-36 hours then the mudguard was carefully removed from the mould[10].

For developing the mudguard following assumptions should be considered

- Dimension is specified as(width*diameter)
- The clearance between tyre and mudguard must be around 25cm.

Fig 3 Reinforced Epoxy Resin Glass Fiber Mudguard

B. *B.STATIC ANALYSIS*

1. Material Properties for Steel

Properties of Outline Row 3: Structural Steel

	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 Modulu...	
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

2. Material Properties for Epoxy Resin

Properties of Outline Row 3: Epoxy E-Glass Wet

	A	B	C
1	Property	Value	Unit
2	Density	1.85E-09	mm^-3 t
3	Orthotropic Secant Coefficient of Thermal Expansion		
8	Orthotropic Elasticity		
9	Young's Modulus X direction	35000	MPa
10	Young's Modulus Y direction	9000	MPa
11	Young's Modulus Z direction	9000	MPa
12	Poisson's Ratio XY	0.28	
13	Poisson's Ratio YZ	0.4	
14	Poisson's Ratio XZ	0.28	
15	Shear Modulus XY	4700	MPa
16	Shear Modulus YZ	3500	MPa
17	Shear Modulus XZ	4700	MPa

- **Mass of Steel Mudguard =3.77 kg**
- **Mass of Epoxy resin Glass Fiber Mudguard=1.58kg**

Fig 4 Epoxy resin Glass Fiber and Steel Mudguard

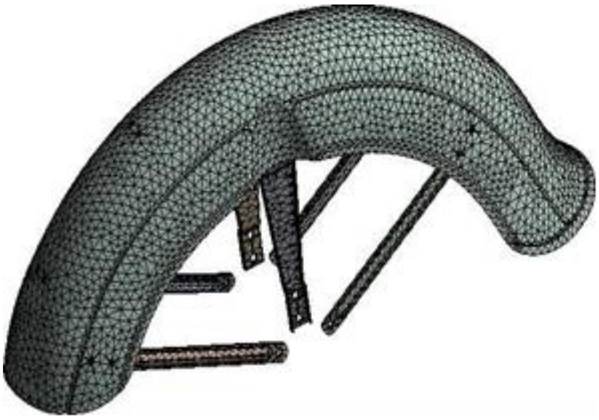
1. **Finite Element Analysis:**

- Design of existing mudguard is done by using CAD package CATIA V5 as per following

Fig. 5 CATIA model of Mudguard

Mesh

ANSYS Meshing is a high-performance general-purpose, smart, automated product. It produces the most appropriate mesh for Multi Physics solutions that are accurate and efficient. For all parts of a model, a mesh well suited for a particular analysis can be generated with a single mouse click. Full controls are available for the expert user who wants to fine tune it to the options used to generate the mesh. Parallel processing power is used automatically to reduce the amount of time you need to wait for mesh generation.



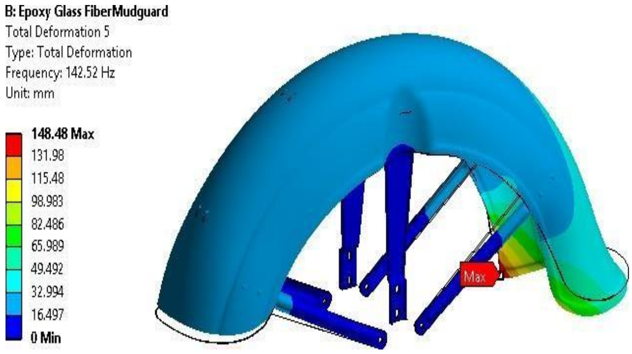
Statistics	
Nodes	74180
Elements	37117

Fig.No.6 Solid Mesh

Tabular Data

	Mode	Frequency [Hz]
1	1.	37.461
2	2.	45.272
3	3.	89.738
4	4.	127.87
5	5.	152.17

Fig. 7 Modal Analysis



Tabular Data

	Mode	Frequency [Hz]
1	1.	46.197
2	2.	54.798
3	3.	84.545
4	4.	115.07
5	5.	142.52

Fig.8 Modal Analysis of Composite Mudguard

C.EXPERIMENTAL TESTING

The experimental validation operation is done by using FFT Operation testing (Fast Fourier Transform) analyzer. The FFT spectrum analyzer samples the input signal, computes the magnitude of its sine and cosine components, and displays the spectrum of these measured frequency components. The advantage of this technique is its speed. Because System operation FFT spectrum analyzers measure all frequency components at the same time, the technique offers the possibility of being hundreds of times faster than traditional analog spectrum analyzer. Fourier analysis of a periodic function refers to the removal of the series of sines and cosines that will reproduce the function when superimposed. This analysis can be expressed as an operation of the Fourier series. The rapid transformation of Fourier is a method of mathematical operation to transform a function of time into a frequency function. It is sometimes described as a system that transforms the frequency domain from the time domain. It is very useful to analyze all methods of time-dependent phenomena

Fig 9 Testing and Validation by Impact Hammer & FFT Analyzer

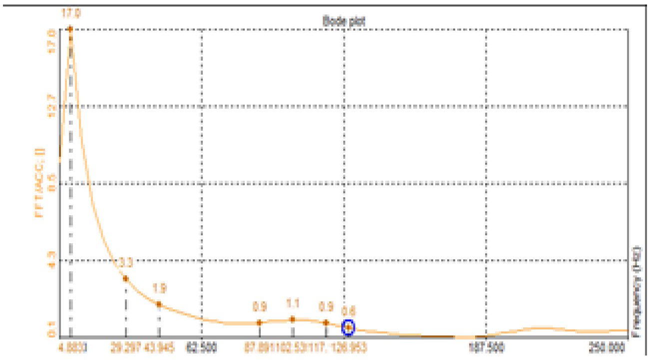


Fig.10 Experimental Result of Steel Mudguard

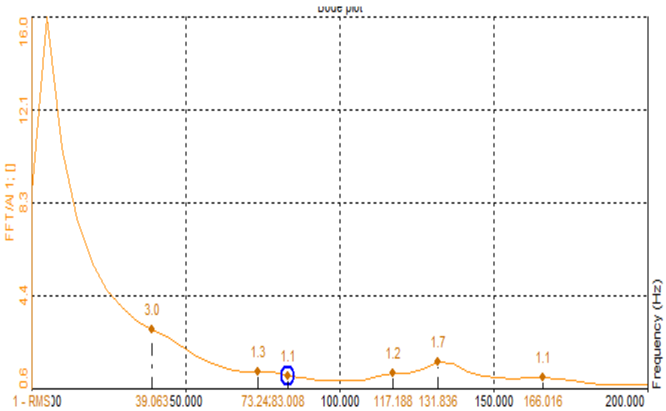


Fig .11 Experimental Result of Composite Mudguard

D. RESULTS & VALIDATION OF STEEL AND GLASS FIBER

MODE NO	STEEL MUDGUARD (Hertz)FEA	EPOXY GLASS FIBER MUDGUARD(Hertz) FEA	STEEL MUDGUARD EXP(Hertz)	EPOXY RESIN MUDGUARD EXP(Hertz)
1	37.461	46.197	29.29	39.03
2	45.272	54.798	43.94	73.24
3	89.738	84.545	87.89	83
4	127.87	115.07	102.23	117.18
5	152.17	142.52	126.95	131.83

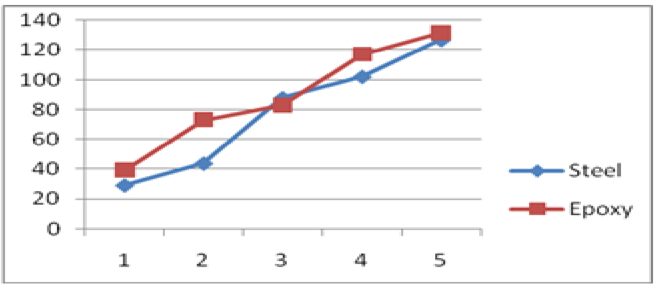


Fig 12 Mode no Vs Natural Frequency (Test)

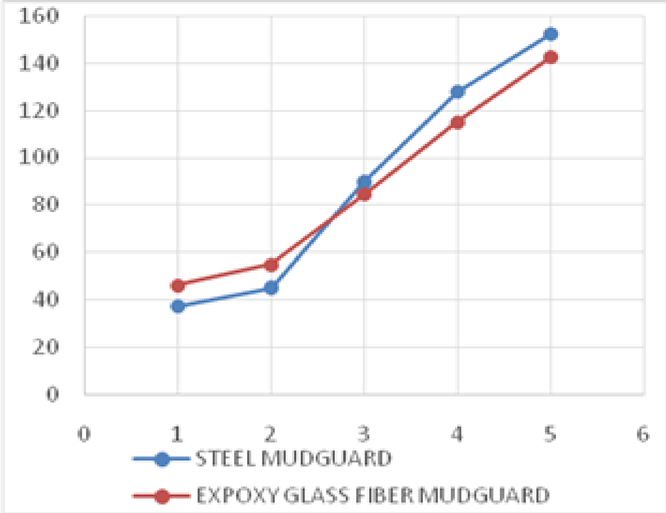


Fig 13 Mode no Vs Natural Frequency (FEA)

From above graph it is clear that Natural frequency is higher at initial model for Epoxy mudguard and slightly less at higher order frequencies. The Natural Frequencies obtained in the Analysis & Testing results are almost same so, the validation of the result is done. Steel Mudguard has mass of 3.77kg and Epoxy Glass Fibre Mudguard mass is 1.58 kg. Hence 58% reduction in mass is achieved which finally helps in increasing mechanical efficiency of vehicle as it's controlled by mass of components. The table shown above give the values of Glass Fiber epoxy resin and Steel Mudguard. Both by experimental and analytical, it indicates that the natural frequency values for Glass Fiber is lesser than Steel Mudguard values for both analytically and practically. For epoxy resin the values for second and third mode are slightly high, but overall the values are less compared to the other one.

IV. CONCLUSION

1. From above graphs it is clear that Natural frequency is higher at initial model for Epoxy mudguard and slightly less at higher order frequencies.
2. The values obtained in the mode shape results indicates that there is less deflection in Glass Epoxy fibre than Steel Mudguard and the frequency values obtained in experimental results have Epoxy Glass Fibre values higher than steel mudguard and so the stiffness is maximum in Epoxy Glass Fibre as the natural frequency is directly proportional to the stiffness of material.
3. The Natural Frequencies obtained in the Analysis & Testing results are almost same so, the validation of the result is done.
4. Steel Mudguard has mass of 3.77 kg and Epoxy glass fibre Mudguard mass is 1.58 kg, Hence 58% reduction in mass is achieved which finally helps in increasing mechanical efficiency of vehicle as it's controlled by mass of components.

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