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Design And Vibration Characteristics Improvement of Conventional 2-Wheeler Front Mudguard Using Synthetic Fiber

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Abstract - The front mudguard of a conventional two-wheeler is essential for protecting the rider and vehicle from road debris and water splashes. Traditional mudguards made from metal or plastic often have poor vibration characteristics and durability. This research explores using synthetic fibers like carbon fiber, glass fiber, and Kevlar to improve these aspects. We design and fabricate prototype mudguards with these materials and analyse their performance using finite element analysis (FEA) and experimental modal analysis. Results show that synthetic fiber mudguards significantly reduce vibration amplitudes and improve resonance frequencies compared to conventional ones. The enhanced durability and lightweight nature of these materials also contribute to better handling and fuel efficiency. This study demonstrates the potential of synthetic fiber composites in automotive components, offering a path toward more robust and high-performance vehicle designs

Keywords: Synthetic Fiber, Composite Materials, Two-Wheeler Front Mudguard, Vibration Dampening, Finite Element Analysis (FEA), Modal Analysis, Structural Integrity, Lightweight Design, Durability, Fuel Efficiency

1. Introduction

The front mudguard of a two-wheeler is a vital component that protects both the rider and the vehicle from road debris, water splashes, and other environmental hazards. Traditionally, these mudguards are made from metal or conventional plastics, materials that often suffer from limitations such as inadequate vibration dampening and reduced durability. These shortcomings can lead to compromised ride quality, increased wear and tear, and potential safety concerns. Advancements in material science have introduced synthetic fibers such as carbon fiber, glass fiber, and Kevlar, which possess superior mechanical properties. These materials are renowned for their high strength-to-weight ratios, excellent vibration dampening capabilities, and enhanced durability. The integration of synthetic fiber composites into automotive components presents an opportunity to overcome the limitations of traditional materials. This research focuses on redesigning the front mudguard of a two-wheeler using synthetic fiber composites. By employing advanced design techniques and leveraging the mechanical advantages of synthetic fibers, we aim to enhance the vibration characteristics, structural integrity, and overall performance of the mudguard. Through finite element analysis (FEA) and experimental validation, this study seeks to demonstrate the potential benefits and feasibility of using synthetic fiber composites in automotive applications, ultimately contributing to the development of more robust and high-performance vehicle components.

2. Literature Review

In automotive industry there is increasing demand for higher quality exterior panels. Better functional properties and lower weight. The demand for weight reduction has led to thinner sheets, greater use of high strength steels and a change from steel to aluminium grades.[1] Super plastic forming (SPF) is a near net-shape forming process which offers many advantages over conventional forming operations including low forming pressure under low flow stress, low die cost, more design flexibility, and the ability to shape hard metals to form complex shapes.[2] The aim of this study is to increase power/weight ratio of a steel-alloyed vehicle body without any structural weakness and to use an integrated engineering solution of "computer-aided design, engineering (CADO)". and optimization.[3] Double-skin perforated sheet facades, are enclosures composed of a perforated metallic sheet, air chamber and carbon, is showing an increasing tendency in modern building design.[4] In the current scenario automobile industries focuses on enhancing the strength and reducing the weight of body parts. In two wheelers mudguard is provided to prevent the dirt's and sand particles in tire from entering and damaging other parts.[5]

3. Flow Chart

CAD modelling of existing Structure using CATIA
↓
Finite Element Discretization using Ansys Workbench
↓
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
↓
Comparative analysis between FEA & Experimental results
↓
Conclusion & Future scope

4. Design of Front Mudguard

4.1 Computer-Aided Design (CAD)

Computer-aided design (CAD) revolutionizes design processes by leveraging computers for precision, efficiency, and collaboration. CAD software enables designers to create, modify, and optimize two or three-dimensional models with accuracy.

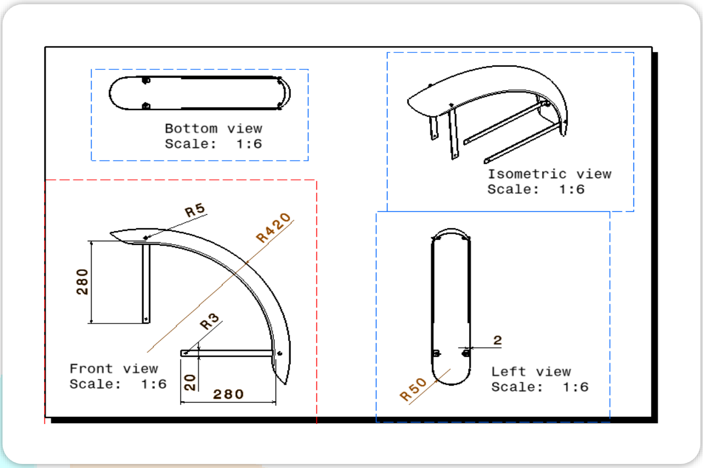


Fig 1 - Design of Front Mudguard (Drafting)

Benefits of CAD:

Precision: Ensures accurate design representation.

Efficiency: Streamlines design iteration and testing processes.

Collaboration: Facilitates communication and sharing of electronic files.

Versatility: Supports both 2D and 3D modeling for diverse applications.

CAD in Mechanical Design:

Vector based or raster graphics depict objects with clarity.

Conveys crucial information such as materials, dimensions, and tolerances.

Used in various industries including automotive, aerospace, and industrial design.

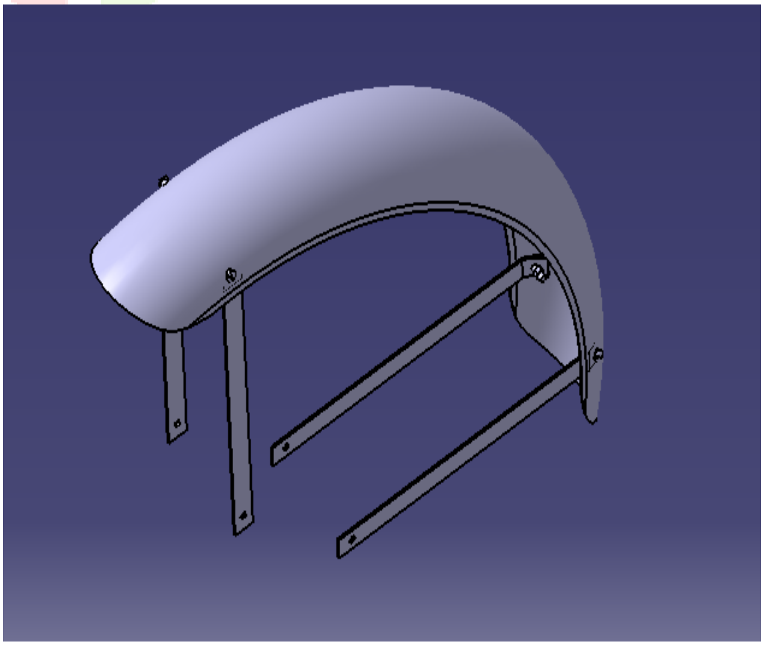


Fig 2 - Design of Front Mudguard (3D)

Impact of CAD:

Drives innovation in computational geometry and computer graphics. Widely used in digital content creation for movies, advertising, and technical manuals. Shapes design practices across industries, from complex engineering structures to everyday products.

Fig 3 – Composite Mudguard

5. Finite Element Analysis (FEA)

5.1 Introduction to FEA

Recognizing FEA as a problem-solving approach, we delved into its theoretical foundation, converting practical engineering problems into matrix and partial differential equation forms. We acknowledged the indispensability of computers in tackling these complex equations and explored various FEA packages available, such as Pro Mechanical, ANSYS, NASTRAN, and Gambit.

5.2 Steps of FEA

Pre-processing: We initiated the FEA process by meticulously modeling the structure using CAD software. This involved defining constraints, loads, and material properties, followed by the critical step of meshing or discretization to break down the structure into finite elements.

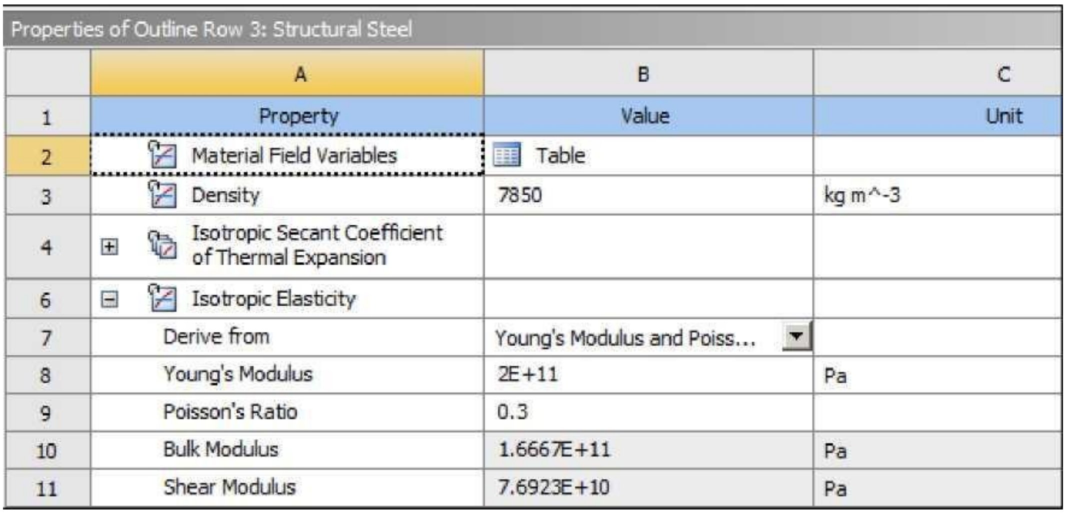
Solution: Armed with the geometry, constraints, and loads, we applied them to generate matrix equations, which we diligently solved to obtain crucial parameters like deflections, strains, stresses, and reactions.

Post-processing: With the solution in hand, we turned to post-processing, leveraging CAD software to manipulate the data and generate insightful graphical representations such as deflected shapes and stress plots, aiding our understanding of the structural behaviour.

5.3 FEA of Existing Royal Enfield Classic 500 Front Mudguard:

5.3.1 Material Properties

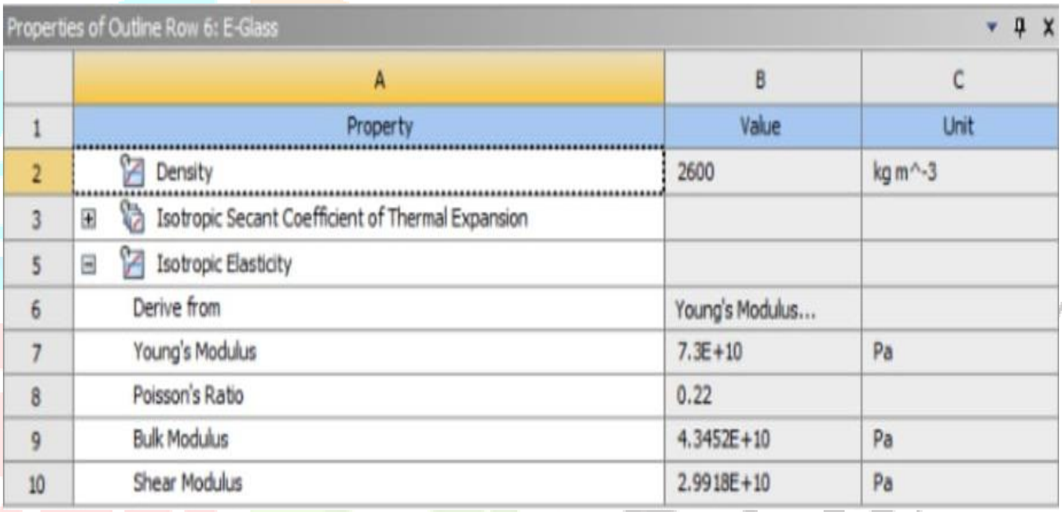
The project involves performing Finite Element Analysis (FEA) on the front mudguard of a Royal Enfield Classic 500 using structural steel and composite fiber. The aim is to compare stress distribution, deformation, and weight differences between the two materials. Structural steel offers high strength but is heavier, whereas composite fiber provides a higher strength-to-weight ratio and corrosion resistance. The analysis includes preparing the CAD model, applying appropriate material properties, generating a refined mesh, and applying realistic boundary conditions and loads. The results will highlight the potential advantages and disadvantages of each material in terms of performance and durability.



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		
6	⊟ Isotropic Elasticity		
7	Derive from	Young's Modulus and Poiss... ▼	
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 4 – Material Properties of Structural Steel



Properties of Outline Row 6: E-Glass

	A	B	C
1	Property	Value	Unit
2	Density	2600	kg m^-3
3	⊞ Isotropic Secant Coefficient of Thermal Expansion		
5	⊟ Isotropic Elasticity		
6	Derive from	Young's Modulus...	
7	Young's Modulus	7.3E+10	Pa
8	Poisson's Ratio	0.22	
9	Bulk Modulus	4.3452E+10	Pa
10	Shear Modulus	2.9918E+10	Pa

Fig 5 - Material Properties of composite fiber

5.3.2 Meshing

Employing advanced meshing technologies from ANSYS, we meticulously divided the structure into finite elements, ensuring accuracy and convergence critical for simulation.

5.3.3 Boundary Condition

Applying boundary conditions to the model, we set known values for displacement or associated loads, crucial for capturing the real-world behaviour of the structure

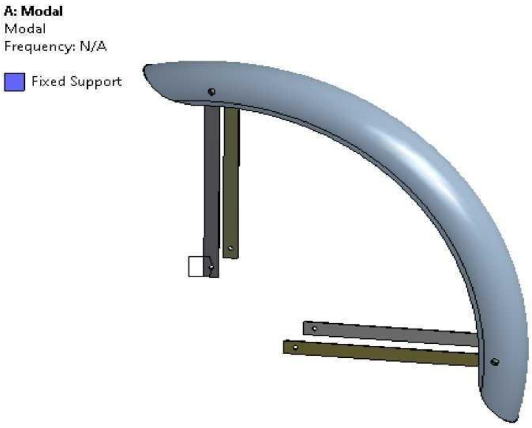
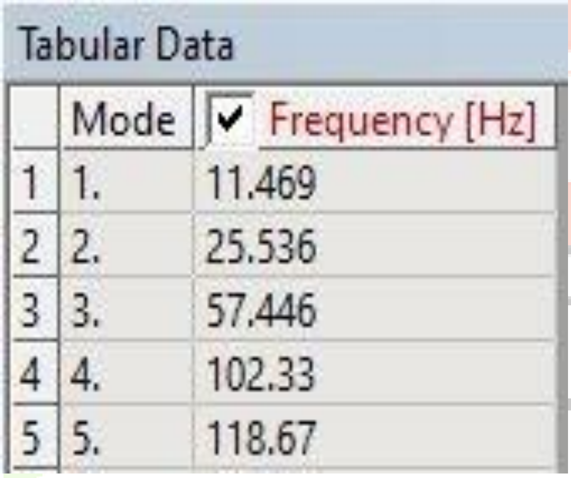


Fig 6 – Boundary Condition

5.3.4 Modal Analysis

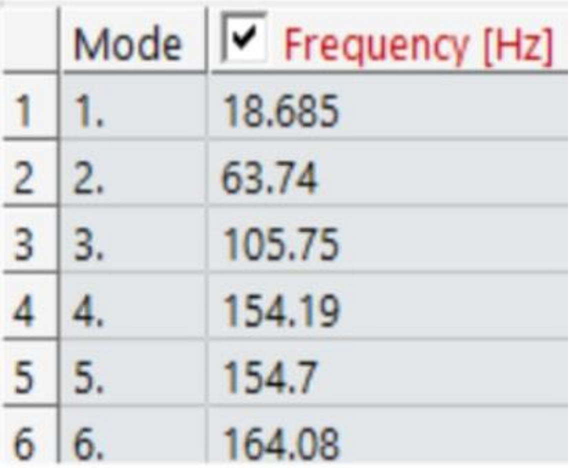
Engaging in modal analysis, we explored the dynamic properties of the Royal Enfield Classic 500 front mudguard in the frequency domain. Sensors measured vibration patterns, and excitation signals were analyzed to identify resonances and mode shapes. Both structural steel and composite fiber materials were evaluated.


Tabular Data

	Mode	☑ Frequency [Hz]
1	1.	11.469
2	2.	25.536
3	3.	57.446
4	4.	102.33
5	5.	118.67

Fig 7 – Modal Analysis of Structural Steel

Our meticulous analysis identified key resonant frequencies and mode shapes for each material, which were tabulated for further scrutiny. This comprehensive modal analysis provided insights into the dynamic behaviour and potential performance benefits of using composite fiber over structural steel, highlighting differences in vibration response and durability under operational conditions.



	Mode	☑ Frequency [Hz]
1	1.	18.685
2	2.	63.74
3	3.	105.75
4	4.	154.19
5	5.	154.7
6	6.	164.08

Fig 8 – Modal Analysis of composite fiber

6. Experimental Testing

6.1 Fast Fourier Transform (FFT)

The Fast Fourier Transform (FFT) is a computational method essential for analysing signals in various fields. Originally described by Cooley and Tukey (1965), it efficiently computes the discrete Fourier transform, particularly when the number of points is a power of two. For non-power-of-two cases, it utilizes prime factorization but slightly compromises speed. Base-4 and base-8 FFTs offer optimized code, enhancing speed by up to 30%. In experimental validation, FFT spectrum analyser's rapidly sample and analyse input signals, providing an overview of frequency components hundreds of times faster than analogy methods. This technique is invaluable for analysing time-dependent phenomena.

6.2 Impact Hammer Test

Impact excitation, commonly conducted through hammer impacts, is a versatile and efficient method for experimental modal testing. Despite challenges such as truncation errors and double hits, impact testing remains widely utilized due to its reliability and minimal equipment requirements. Truncation errors, caused by finite sample durations, can be mitigated with techniques like exponential windowing. Double hits, where two impulses are applied to the structure, pose unique challenges in spectral analysis. Understanding these phenomena is crucial for accurate data acquisition in structural impact testing.

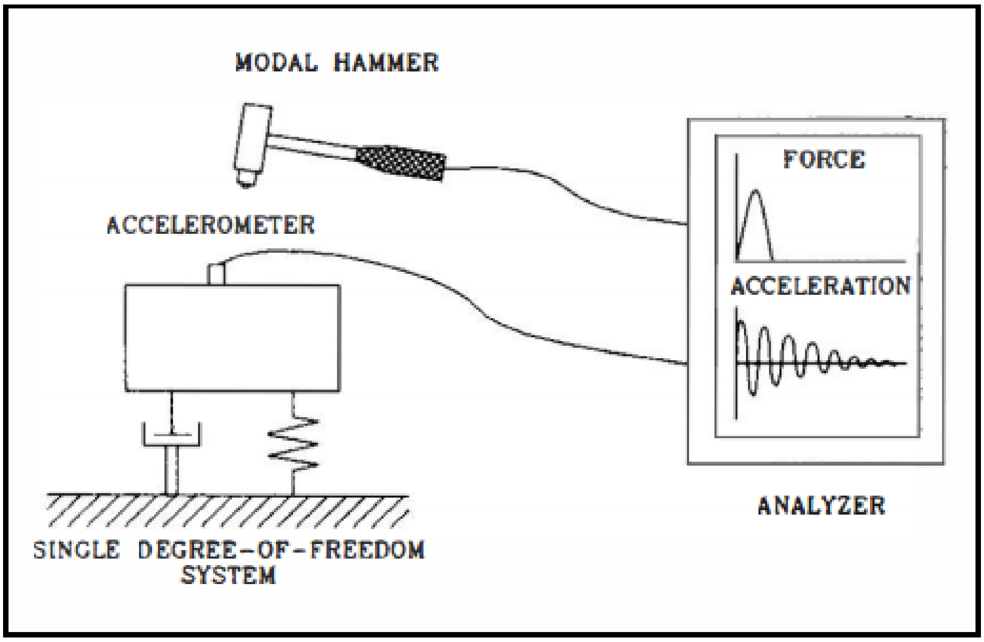


Fig 3 - FFT construction

Fig 10 – FFT Experimental Setup

6.4 Experimental Procedure.

Initially optimized 2-wheeler mudguard is designed according to existing boundary condition as per FEA results. FFT consists of impact hammer, accelerometer, data acquisition system in which each supply is applied to DAS and laptop with DEWSOFT software to view FFT plot. Accelerometer is mounted at edge as per high deformation observed in FEA results along with initial impact of hammer are placed for certain excitation to determine frequency of respective mode shapes. After impact FFT plot are observed on laptop and comparison of FEA and experimental results are analysed.

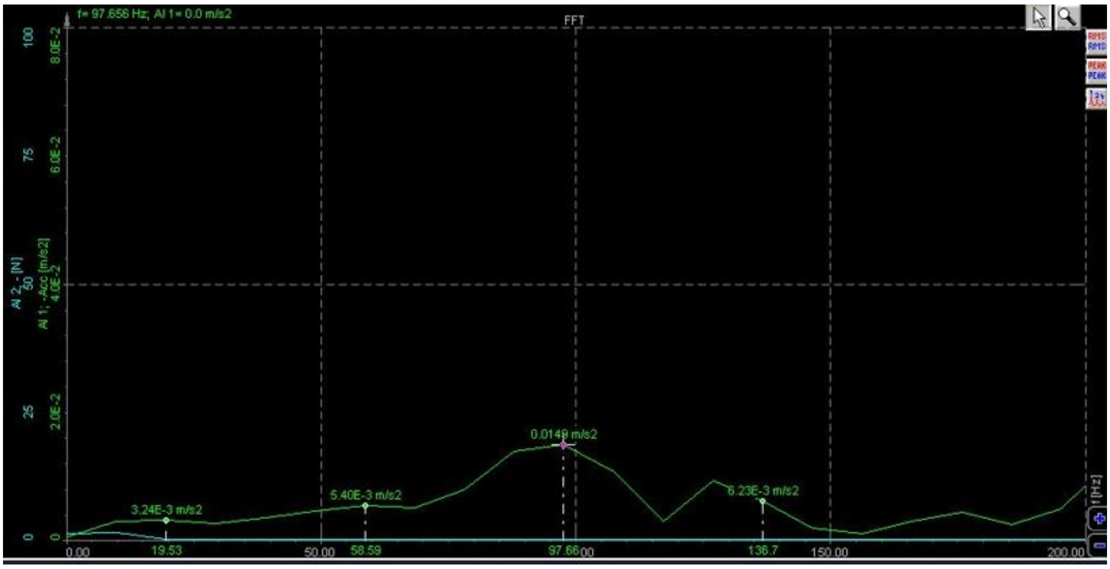


Fig 11 - FFT plot

6.3 Comparison of FEA Result

Table 1 – Comparison of FEA and FFT

Optimize model (FEA)	Optimize model (FFT)
17.846	**19.53**
42.843	**58.69**
89.484	**97.66**
143.88	**136.7**
144.88	**136.7**
149.95	**136.7**

7. Conclusion

The natural frequency of structural steel, determined to be 11.469 Hz, serves as a benchmark for comparing materials in our study. This comparative analysis will help us assess the performance of conventional material, such as structural steel used in the Royal Enfield Classic 500 model, against synthetic fiber, the proposed material for our upcoming project stages.

Having successfully developed a comprehensive design for the synthetic fiber mudguard, our project team has meticulously crafted specifications encompassing dimensions, shape, and additional features. These specifications are intricately tailored to align with project objectives and adhere to industry standards, ensuring optimal performance and reliability.

Furthermore, our proactive approach to risk management has allowed us to identify potential challenges stemming from design flaws or material limitations. By addressing these issues at an early stage, we mitigate the likelihood of setbacks, thereby safeguarding the project's progress and success.

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