STATIC AND DYNAMIC ANALYSIS AND OPTIMIZATION OF PULSER180 BIKE CHASSIS

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***Abstract*- A man-made object is supported by an interior framework called a chassis. It's like the skeleton of an animal. The chassis, which includes the wheels, equipment, and frame on which the body is placed, is an example of the underneath of a car. A vehicle's "chassis" includes its running gear, which includes the engine, transmission, driveshaft, differential, and suspension, as well as the vehicle's overall frame. To complete the vehicle, a body—which is typically not required for structural integrity—is constructed on top of the chassis. All of the parts of an automobile must be held together when driving, and the suspension and wheels must transfer lateral and vertical loads brought on by accelerations to the chassis. Because it holds all the elements and components together, The vehicle's chassis is seen to be its most important part. Usually, it is made comprised of a steel frame that holds up the body and engine of an automobile.**

Keywords- Chassis, Vehicle Structure, Framework, Suspension, Wheels, Powertrain, Steel Frame

I. INTRODUCTION

A manufactured object's internal framework is called a chassis. It resembles the skeleton of an animal. The chassis is an automobile's underbelly, which includes the wheels, gearbox, and frame that the body is fastened to. The running gear, which consists of the engine, transmission, driveshaft, differential, and suspension, as well as the vehicle's general frame, make up a vehicle's "chassis." To complete the vehicle, a body which is typically not required for structural integrity is constructed on top of the chassis. All of the parts of an automobile must be held together when driving, and the suspension and wheels must transfer lateral and vertical loads brought on by accelerations to the chassis. Because it holds all the elements and components together, The vehicle's chassis is seen to be its most important part. Usually, it is made comprised of a steel frame that holds up the body and engine of an automobile.

II. LITERATURE REVIEW

CH.Neeraja et al. [1] The study focused on the structural analysis and weight optimization of a two-wheeler suspension frame. A two-wheeler chassis includes key components such as the frame, suspension, wheels, and brakes, with the frame playing a crucial role in defining the vehicle's overall style. Functioning like a skeleton, the frame supports major components like the engine and gearbox. Common materials for frame construction include steel, Aluminum, and alloys. To ensure durability, especially on uneven terrains, the frame must be torsion-resistant and capable of absorbing distortions without transferring them to the vehicle body.

Using 3D modeling software (Pro/Engineer), a suspension frame was created, and wheel loads were applied to verify its structural integrity. The design's maximum stress limit was determined by the analysis. To find the best material for the frame, simulations were conducted using four potential materials: magnesium, carbon fiber reinforced polymer (CFRP), alloy steel, and aluminum alloy A360.

Modal analysis was also conducted to examine the vibrational behavior and mode shapes across several modes. All simulations were carried out using

ANSYS software. The results indicated that the stress levels in all four materials were below their respective yield limits, confirming the design's safety. Among them, CFRP showed the least displacement under load and had significantly lower density, making it ideal for chassis manufacturing. The study concludes that CFRP, due to its lightweight, high strength, and manufacturability, is the most efficient material, and with its increased usage, manufacturing costs may decrease in the future.

M.Ravi Chandra et al. [2] The work focused on modeling and structural characterization of a large vehicle chassis composed of polymeric composite materials in order to minimize weight. The primary purpose of the chassis frame, the basic structural element of a heavy vehicle, is to safely support the maximum load in all operating conditions. This paper presents the design and analysis of a chassis optimized for reduced weight, an increasingly significant concern in the automobile industry. Three distinct composite material types—carbon/epoxy, e-glass/epoxy, and s-glass/epoxy—were used to model the chassis. Each of these materials has three distinct cross-sectional profiles: C-, I-, and Box-sections. Applying vertical loads over the various cross-sections allowed for the validation of the models' structural integrity. The results demonstrated that using polymeric composites for the chassis resulted in a weight reduction of 73–80% compared to traditional steel chassis. Additionally, the natural frequencies of the composite chassis were found to be 32–54% higher, and the stiffness was 66–78% greater than that of the steel counterpart. Among the materials studied, Carbon/Epoxy showed the best performance, offering superior strength, higher stiffness, and significantly lower weight than both steel and the other composites. The findings indicate that a polymeric composite chassis, particularly with Carbon/Epoxy, provides a lighter, stiffer, and more cost-effective alternative to conventional steel chassis while maintaining equivalent load-bearing capacity.

D.Nagarjuna et al. [3] The study focused on weight optimization of an all-terrain vehicle (ATV) chassis. An ATV, often referred to as a quad, quad bike, three-wheeler, or four-wheeler, is defined by the American National Standards Institute (ANSI) as a vehicle equipped with low-pressure tires, a straddle seat for the rider, and handlebars for steering. Designed for operation over a wide range of terrain, ATVs require a robust yet lightweight chassis for optimal performance.This research involved the design and structural optimization of an ATV chassis frame. To ensure safety and durability, the chassis was subjected to various load tests, including front impact, rear impact, side impact, and rollover tests. The design was optimized by strategically reducing weight, while maintaining structural integrity. Material IS3074 was used for the frame, and optimization was achieved by reducing the diameter of the chassis tubes in areas experiencing minimal stress and deformation. As a result, the chassis weight was successfully reduced from 84 kg to 64 kg, enhancing the vehicle's performance and speed without compromising safety.

K.S.Sunil et al. [4] This study focused on the integration of reverse engineering and 3D printing techniques for the development and optimization of a bike chassis. Recognizing the chassis as the structural backbone of a two-wheeler, a 3D model was created using reverse engineering methods in CATIA V5 R20. The model was further analyzed and optimized through Finite Element Method (FEM) simulations in ANSYS. The simulation process provided key insights into stress distribution, displacement, and natural frequencies of the chassis under load conditions. Particular attention was given to optimizing the chassis plate, which serves as the engine mounting component. Through optimization, a 10.28% weight reduction of the chassis plate was achieved. Results from the static analysis indicated a maximum stress of 217.029 MPa and a displacement of 0.07 mm under a maximum load of 250 kg. The modal analysis revealed the chassis could endure vibrations up to a maximum natural frequency of 236.697 Hz. For physical validation and visualization, Fused Deposition Modeling (FDM)—a rapid prototyping technique—was used to produce a prototype of the chassis.

Wang Li-rui et al. [5] This study focused on the simulation and enhancement of a vehicle frame design using Finite Element Method (FEM). To develop and improve the frame, 3D modeling was performed using UG NX6.0, and simulation was carried out in ANSYS 12.0. In an effort to reduce the overall weight of the frame, 6061 aluminum alloy—which contains magnesium and silicon—was selected as the base material. Additionally, carbon fiber was used in the construction of the seat and various accessories to further minimize weight. Following simulation analysis, structural reinforcements were incorporated into the frame to improve strength. The enhanced design was then validated using Hyperworks, which applied a different shell element algorithm. The validation revealed only minor differences in displacement across the three axes. Since the vehicle using this frame was intended to compete in a low fuel consumption contest, the analysis suggested that the frame was still slightly heavy, indicating potential for further optimization using even more suitable materials. Nevertheless, simulations in both static and dynamic conditions confirmed the frame's integrity, with stress, displacement, and load distribution all remaining within the material's permissible limits. Overall, the final model was deemed fit for competition, having met safety and performance criteria through successive design improvements.

Dr.R.Rajappan et al. [6] The Finite Element Method (FEM) was utilized in this study to do both static and modal analysis of a truck chassis. The truck chassis is a crucial structural element that can fail in a number of ways under both static and dynamic loading circumstances. FE modeling was used in this study to assess how the chassis would behave in these circumstances. Finding natural frequencies, analyzing mode forms, studying vibration properties, and identifying high-stress zones were the objectives of the investigation. component mounting positions. Modal update was done by adjusting material characteristics like mass density and Poisson's ratio in order to increase accuracy. Then, by contrasting with previously released data, the anticipated natural frequencies and mode shapes were confirmed. In order to improve the chassis by decreasing vibrations, boosting structural strength, and optimizing weight, design changes were suggested based on the investigation. PRO-E 5.0 was utilized for modeling, and ANSYS 12.0 was used for analysis. The AISI 4130 alloy, which was quenched and tempered, was the material under consideration. The study evaluated the impact of component mounting locations in addition to examining dynamic properties, such as mode shapes and natural frequencies. The chassis's behavior under static conditions was analyzed for two scenarios: component load and asymmetrical load. The results revealed that maximum stress occurred near the suspension mounting brackets, while maximum deformation (2.013 mm) was observed in areas subjected to both symmetric and asymmetric loading. The peak stress value of 16 kN was found to be well within the yield strength and allowable tolerance of the chassis material, indicating the structural safety and integrity of the design.

Jakub Smiraus et al. [7] This work focused on the design of an active motorcycle chassis geometry, marking a significant advancement in motorcycle engineering. A major innovation in motorcycle chassis development emerged in the late 1990s with the adoption of advanced materials such as aluminum alloys and composite materials. These materials provided enhanced strength while maintaining or even reducing the weight of individual components. This technological shift enabled the production of motorcycles that were not only faster but also more stable and safer to handle. Today's motorcycles often rely on electronic systems to enhance riding stability. However, this research explores a novel concept: improving stability through adjustable mechanical parameters like wheelbase and trail, which traditionally remained fixed. The study presents an innovative suspension design with geometry that adapts in real time based on riding conditions—an approach that could revolutionize motorcycle chassis construction in the 21st century. By enabling dynamic adjustments to critical parameters such as steering axis angle, wheelbase, trail, and ground clearance, the proposed system helps counteract adverse effects caused by the dynamic behavior of the motorcycle. The integration of modern composite materials and aluminum alloys opens new avenues for developing adjustable suspension systems that fine-tune the chassis geometry while the vehicle is in motion. The core objective is to allow seamless, real-time changes to chassis parameters, thereby enhancing both performance and safety during the ride

Chien-Ping Chung et al. [8] This research focused on determining the optimal design parameters for a bike frame, with the objective of reducing costs and improving quality—key factors in maintaining product competitiveness. The study utilized statistical techniques and ANSYS simulation software to gather experimental data related to bike frame performance. To analyze this data, the Response Surface Methodology (RSM) was employed, allowing for the modeling and optimization of the design space.By simulating the product's assembly functions and conducting a structured experimental design, the researchers were able to identify suitable design parameters. Specifically, the Box–Behnken Design (BBD) matrix within RSM was used for its efficient experiment setup. To further refine the results, mathematical programming tools were applied to develop an optimal solution model.The integration of RSM and mathematical programming provided the dual benefits of statistical accuracy and optimization capabilities. The study introduced a novel approach to product parameter selection, aiming to minimize unnecessary costs and boost production efficiency. Ultimately, this method enhances manufacturer competitiveness and contributes to increased profitability.

III METHODOLOGY

- **CAD Model Generation:**
1. Collect dimensional data of existing two-wheeler chassis designs from market sources.
2. Develop a precise 3D CAD model of the chassis using CATIA software.
- **Load Determination:**
1. Analyze the sources of vibrations and dynamic effects encountered during vehicle operation.
2. Calculate the loads acting on the chassis during motion using principles of vehicle dynamics.
- **Testing and Structural Analysis:**
1. Perform meshing of the CAD model and apply appropriate boundary conditions.
2. Conduct Finite Element Analysis (FEA) using ANSYS to determine stress distribution, deformation, and safety margins.
- **Redesign and Material Optimization:**
1. Research and evaluate a range of alternative materials for chassis construction.
2. Re-analyze the chassis model using the selected materials to identify the most suitable option based on strength, weight, and cost considerations.
3. Ensure the design stays within safety limits under expected loading conditions.
- **Fabrication and Experimental Validation:**
1. Fabricate a prototype of the optimized chassis using the best-performing alternative material.
2. Perform experimental tests under real-world conditions and compare the results with those from the original chassis.
3. Validate the simulation results by comparing experimental data with ANSYS outcomes to ensure accuracy and reliability.

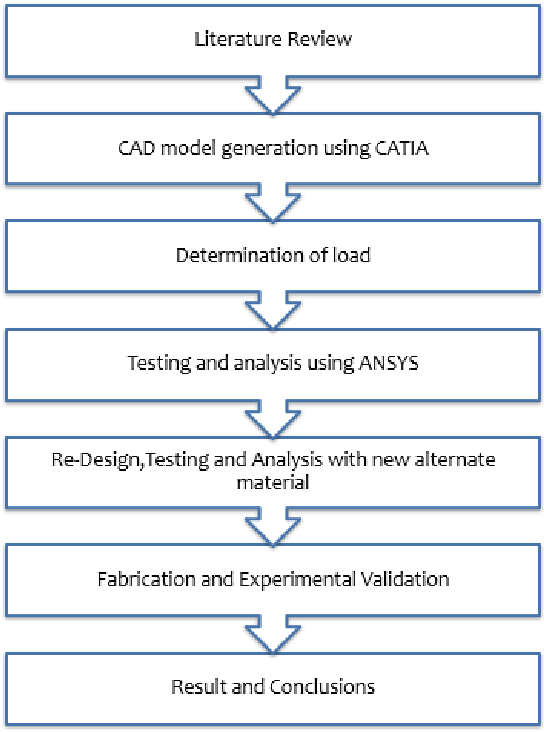

Figure 3.1 Flowchart

IV OVERVIEW OF BIKE CHASSIS

Chassis Components:

- **Frame:** Acts as the main structural skeleton, typically made from steel, aluminum, or alloy tubes.
- **Suspension:** Absorbs road shocks and ensures tire contact with the ground.
- **Wheels:** Made from aluminum or steel; modern bikes often use cast wheels for tubeless tires.
- **Brakes:** Modern motorcycles use disc brakes on both wheels for improved stopping power.

Types of Motorcycle Chassis Frames:

- **Backbone Frame:** Simple and cost-effective; engine is suspended below the main beam.
- **Diamond Frame:** Popular in Indian bikes; resembles a diamond shape, offers decent rigidity.
- **Single Cradle Frame:** Basic steel tube design; used in lightweight or off-road bikes.
- **Double Cradle Frame:** Offers better strength; commonly used in commuter and sport bikes.

- **Perimeter Frame:** Rigid and performance-focused; connects steering head and swing arm directly.
- **Monocoque Frame:** Rare and used mainly in race bikes; integrates multiple functions into one structure.
- **Trellis Frame:** Cage-like welded pipe design; lightweight and sporty but complex and expensive.

This chapter establishes the foundation for selecting an appropriate frame design and material, forming the basis for optimization, fabrication, and testing in later stages of the project.

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V. STATIC ANALYSIS RESULTS

Displacement

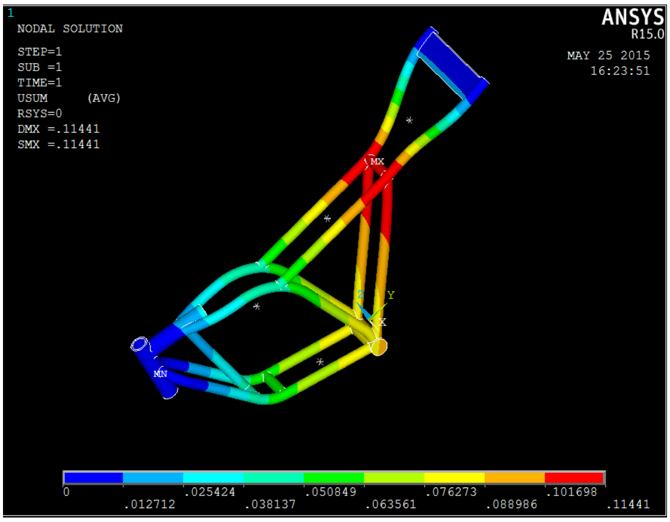

Figure 5.1 Displacement pattern for steel chassis

The greatest displacement, which is quite small, is 0.11441mm.

Stress

The highest stress, which is 43.44 N/mm2 and is below the safety limit, is found at joint sites.

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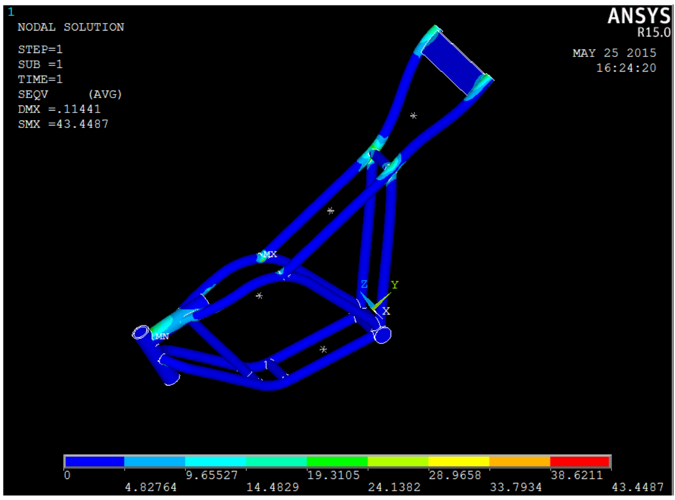

Figure 5.2 - Stress distribution for steel chassis

VI. MODAL ANALYSIS

Modal analysis is the study of a structure's dynamic properties specifically its natural frequencies, mode shapes, and damping characteristics under vibrational excitation. It helps determine the frequencies at which a structure naturally resonates, which is crucial for avoiding resonance-induced failure in machines and components. Using the Finite Element Method (FEM), engineers can accurately simulate and analyze complex geometries to determine how a structure vibrates during free vibration. Each mode shape represents a unique deformation pattern at a specific frequency. These shapes are influenced by material properties, geometry, and boundary conditions. Understanding modal behavior is essential in designing components for noise and vibration control. Modal analysis is widely applied across industries, including automotive, aerospace, consumer electronics, and sporting equipment, to enhance structural performance, safety, and comfort

VII. RESULTS FOR MODAL ANALYSIS

Mode 1:

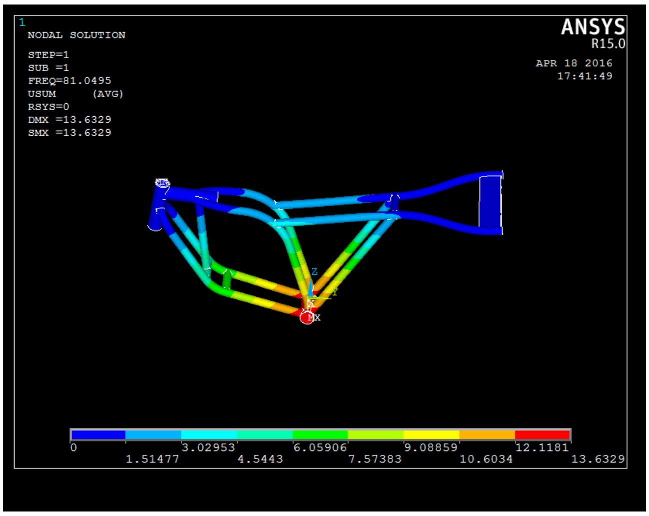

Fig: The bike chassis's first mode frequency (MS)

The first mode's frequency is 81.04 Hz.

Mode 2:

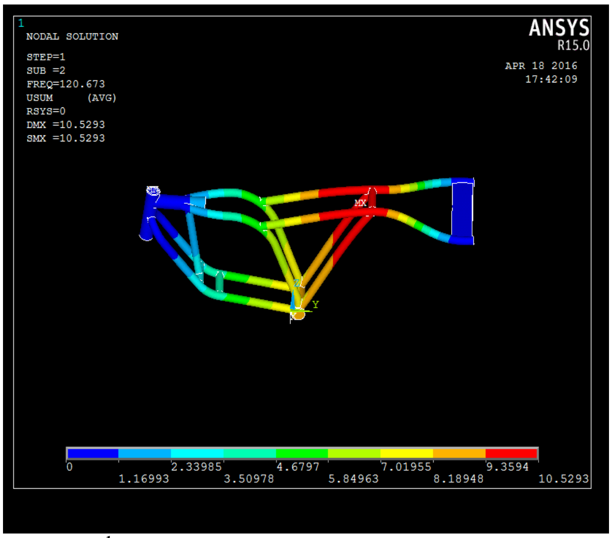

Fig: 2nd mode frequency of bike chassis (MS)
The second mode's frequency is 120.67 Hz

Mode 3:

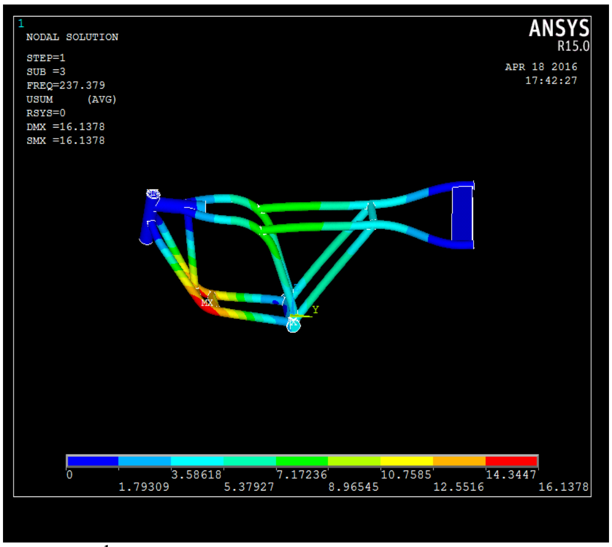

Fig: 3rd mode frequency of bike chassis (MS)
The third mode's frequency is 237.37 Hz.

Mode 4:

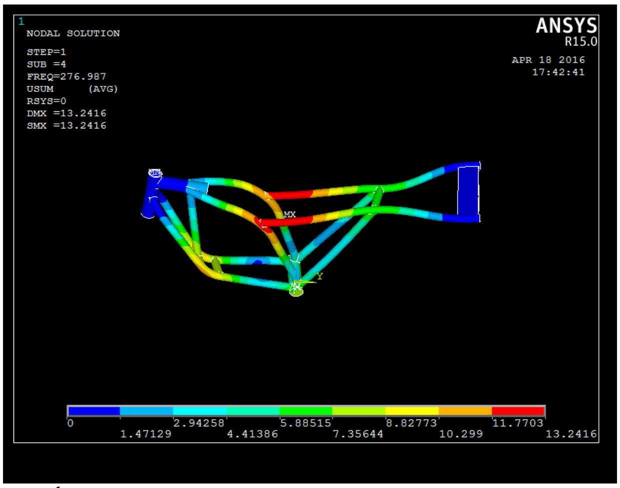

Fig: 4th mode frequency of bike chassis (MS)
The fourth mode's frequency is 276.98 Hz.

Mode 5:

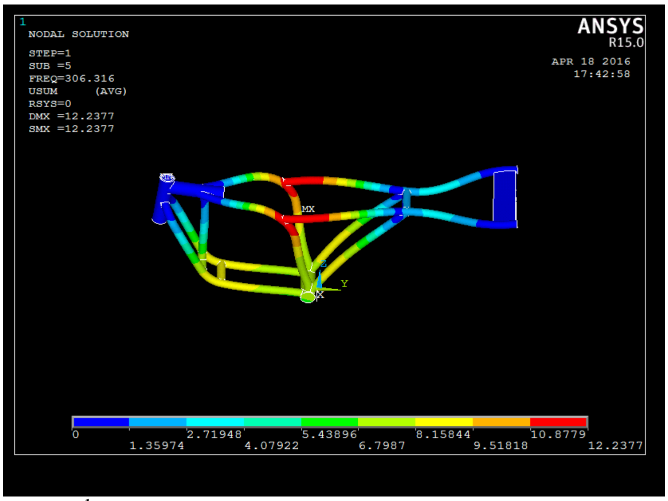

Fig: 5th mode frequency of bike chassis (MS)
The fifth mode's frequency is 306.31 Hz.

Mode 6:

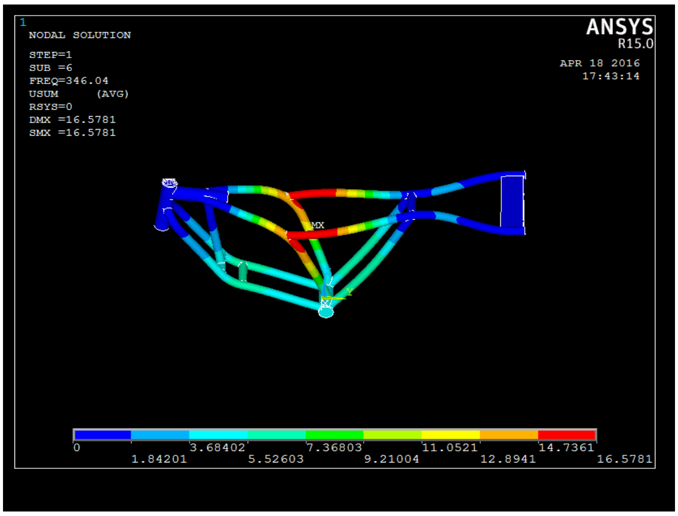

Fig: 6th mode frequency of bike chassis (MS)
The sixth mode's frequency is 346.04 Hz

VIII. FINITE ELEMENT ANALYSIS (FEA)

The three primary stages of finite element analysis are pre-processing, solution (processing), and post-processing.
A finite element model is produced during the pre-processing stage, usually beginning with an already-existing CAD model (as in this project). After that, material attributes are assigned, the model is meshing, and suitable boundary conditions are used. In the solution phase, a FEA solver is used to solve the specified issue and compute outcomes like displacement, stress, and strain. Lastly, the utcomes are examined and visualized during the post-processing stage to evaluate the structure's functionality.

In this project, ANSYS is utilized for post-processing and problem solution, and Hypermesh is used for pre-processing (meshing, material assignment, and boundary conditions).

First, a thorough FEA model was created for the current mild steel bike frame. Alternate materials were studied using the same model after mesh optimization and element quality verification. The only material properties that were updated in Hypermesh were density (ρ), Poisson's ratio (v), and young's modulus (E).

The analysis was repeated for the following alternate materials:

- **Aluminium Alloy 6063**
- **Carbon Fibre**
- **Titanium**

The **same boundary conditions** were maintained as in the steel chassis case to ensure consistency in comparison. The simulations were solved using the **ANSYS solver**, and the results were used to evaluate and compare the structural performance of each material.

IX. RESULTS FOR MODAL ANALYSIS

Mode 1:

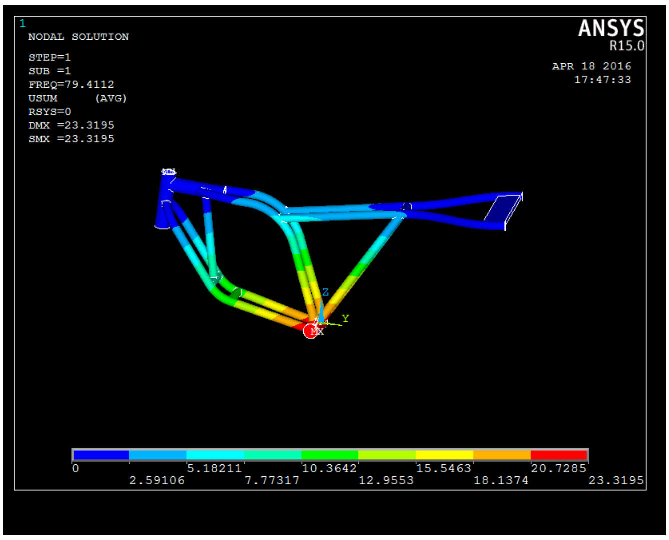

Fig: 1st mode frequency of bike chassis (Al)

The first mode's frequency is 79.41 Hz.

Mode 2:

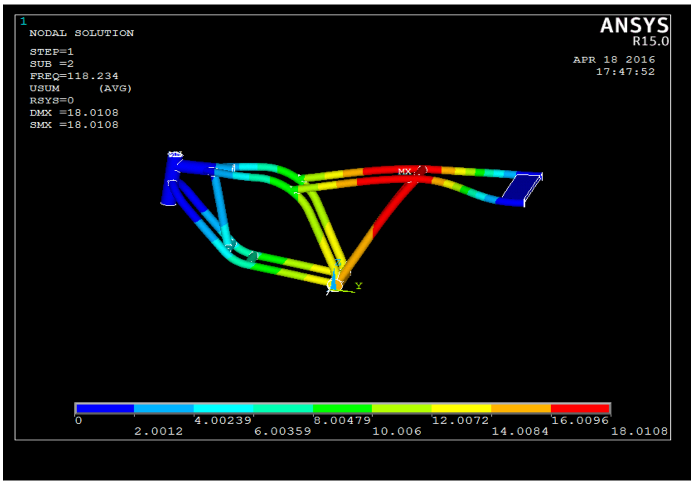

Fig: 2nd mode frequency of bike chassis (Al)

The second mode's frequency is 118.23 Hz.

Mode 3:

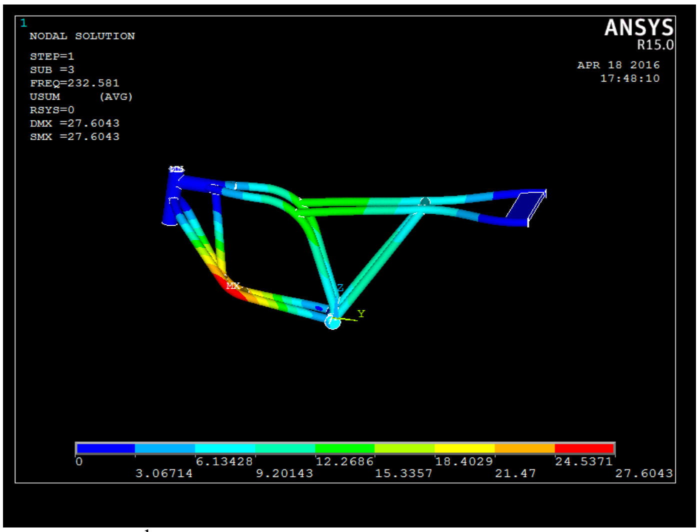

Fig: 3rd mode frequency of bike chassis (Al)

232.58 Hz is the frequency of the third mode.

Mode 4:

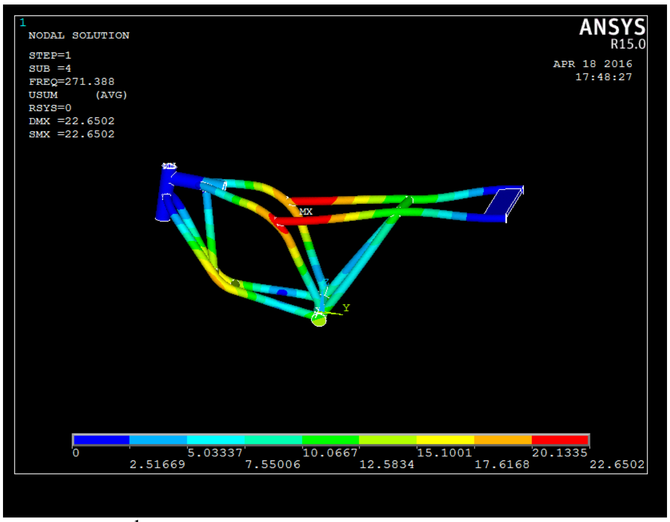

Fig: 4th mode frequency of bike chassis (Al)

The fourth mode's frequency is 271.38 Hz.

Mode 5:

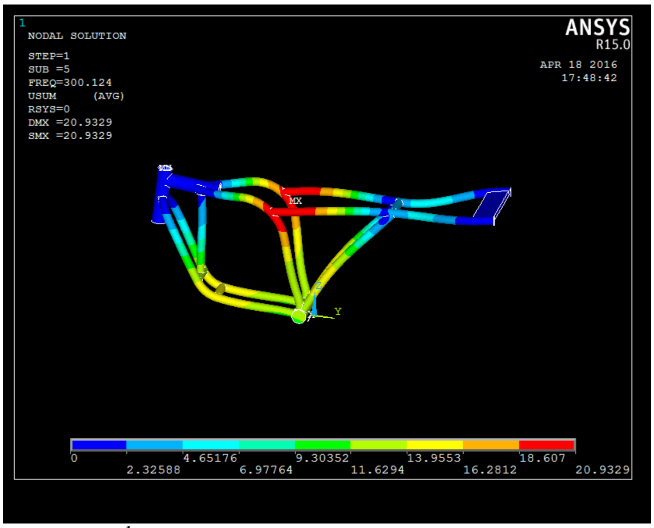

Fig: 5th mode frequency of bike chassis (Al)

The fifth mode's frequency is 300.12 Hz.

Mode 6:

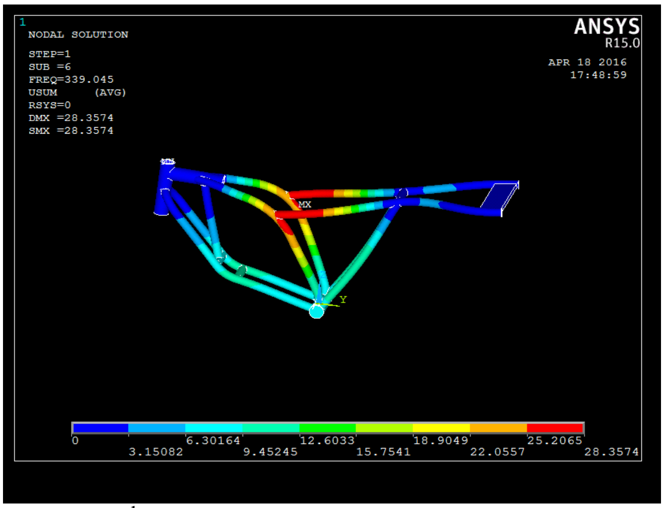

Fig: 6th mode frequency of bike chassis (Al)

The sixth mode's frequency is 339.04 Hz.

X. CONCLUSION

The design and optimization of a two-wheeler chassis frame is essential for enhancing vehicle performance, stability, and safety. By analyzing various static and dynamic loading conditions, the chassis structure can be improved to withstand real-world stresses while minimizing weight. The optimized design not only contributes to better handling and fuel efficiency but also ensures durability and cost-effectiveness. This project demonstrates that careful material selection and structural analysis can lead to an efficient and reliable chassis suitable for modern two-wheeler applications.

REFERENCES

1. Ch. Neeraja, C.R. Sireesha, and D. Jawaharlal, *Structural Analysis of Two-Wheeler Suspension Frame*, International Journal of Engineering Research and Technology, August 2012.

2. M. Ravi Chandra, S. Sreenivasulu, and Syed Altaf Hussain, *Modeling and Structural Analysis of a Heavy Vehicle Chassis Made of Polymeric Composite Material with Three Different Cross Sections*, International Journal of Modern Engineering Research, August 2012, pp. 2594–2600.

3. D. Nagarjuna, Junaid Mohammed Farooq, A. S. N. Saiteja, and P. Siddhartha Sri Teja, *Optimization of an All-Terrain Vehicle Chassis*, International Journal of Innovative Technology and Exploring Engineering, January 2013, pp. 55–57.

4. K. S. Sunil and Jaya Christiyan, *Reverse Engineering and 3D Printing Integration for Bike Chassis Development*, Journal of Mechanical Engineering Research and Technology, 2014, pp. 405–411.

5. Wang Li-rui and Yang Xiao-long, *Finite Element Simulation and Enhancement of Vehicle Frame*, Proceedings of the International Conference on Mechanical Engineering and Material Science, 2012, pp. 627–629.

6. R. Rajappan and M. Vivekanandhan, *Static and Modal Analysis of a Chassis Using Finite Element Analysis*, International Journal of Engineering and Science, 2013, pp. 63–73.

7. Jakub Smiraus and Michal Richtar, *Design of a Motorcycle Active Chassis Geometry Modification System*, Technical University of Ostrava, Vol. VI, No. 5, December 2011, pp. 279–288.

8. Chien-Ping Chung and Ching-Fang Lee, *Decision Parameters Influencing Product Characteristics of a Bike Frame*, Asia Pacific Business Innovation and Technology Management Society, 2012, pp. 107–115.