Theoretical And Experimental Validation Of Bike Chassis For Weight Reduction

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Abstract: It is important to recognize that the design of any machine is an interdisciplinary process, involving aerodynamics, thermodynamics, fluid dynamics, stress analysis, vibration analysis, the selection of materials, and the requirements for manufacturing. The operation of any mechanical system will always produce some vibration. Our goal is to minimize the effect of these vibrations, because while it is undesirable, vibration is unavoidable. The result of excess vibration can vary from nuisance disturbance to a catastrophic failure. Bike chassis is a major component in a vehicle system. This work involves vibration analysis to determine the key characteristics of a bike chassis. The dynamic characteristics of bike chassis such as the natural frequency and mode shape were determined by using finite element (FE) method. Al material will replace the conventional MS material. Experimental modal analysis was carried out to validate the FE models. Predicted natural frequency and mode shape were validated against the experimental results. Finally, the modification of the updated FE bike chassis model was proposed to reduce the vibration, improve the strength and optimize the weight of the bike chassis. Tools used are catiaV5 for 3D modelling, Hypermesh for meshing, and Ansys for post processing.

Index Terms: Ansys, Catia v5, Chassis, Finite Element Method, Hypermesh, Modal Analysis, Stress Analysis, Vibrational Analysis.

1 INTRODUCTION

A chassis consists of an internal framework that supports a man-made object. It is analogous to an animal's skeleton. An example of a chassis is the under part of a motor vehicle, consisting of the frame (on which the body is mounted) with the wheels and machinery. In the case of vehicles, the term chassis means the frame plus the running gear like engine, transmission, driveshaft, differential, and suspension. A body, which is usually not necessary for integrity of the structure, is built on the chassis to complete the vehicle. The automotive chassis is tasked with holding all the components together while driving and transferring vertical and lateral loads, caused by accelerations, on the chassis through the suspension and the wheels. Therefore the chassis is considered as the most important element of the vehicle as it holds all the parts and components together. It is usually made of a steel frame, which holds the body and motor of an automotive vehicle. In fact only using a FE-description of the frame and of other components with distributed stiffness and mass it has been possible not only to take into account the vibrations of the frame due to its complex mode shapes but also the influence of local elasticity at the attachment points. The validation of this model has lead to good behaviour coupling with the real one, due to an accurate phase of model up-dating.

2 Design and analysis of bike chassis

2.1 CAD Model Generation

- **Specifications of Chassis**

The Bajaj Pulsar 180 DTS-i chassis have been used in the project.

SPECIFICATIONS OF BAJAJ PULSAR 180 DTS- i

ENGINE	
Displacement (cc)	178
Cylinders	1
Max Power	17 bhp @ 8500 rpm
Maximum Torque	14 Nm @ 6500 rpm
Bore (mm)	63
Stroke (mm)	56
Valves Per Cylinder	4
Fuel Delivery System	Carburetor
Fuel Type	Petrol
Ignition	Digital Twin Spark Ignition
Spark Plugs (Per Cylinder)	2
Cooling System	Air Cooled
TRANSMISSION	
Gearbox Type	Manual
No Of Gears	5
Transmission Type	Chain Drive
Clutch	Wet multi-plate
DIMENSIONS AND WEIGHT	
Kerb Weight (Kg)	147
Overall Length (mm)	2035
Overall Width (mm)	765
Overall Height (mm)	1165
Wheelbase (mm)	1350
Ground Clearance (mm)	150
Seat Height (mm)	790
FUEL EFFICIENCY AND RANGE	
Fuel Tank Capacity (Litres)	15
ReserveFuel Capacity (Litres)	3.2
Fuel Efficiency Overall (Kmpl)	45
Fuel Efficiency Range (Km)	675
CHASSIS AND SUSPENSION	
Chassis Type	Double Cradle
Front Suspension	Telescopic, Anti-friction bush
Rear Suspension	5 way adjustable, Nitrox shock absorber
Chassis Weight	25.2 kg
BRAKING	
Brake Type	Disc
Front Disc	Yes
Front Disc/Drum Size (mm)	260
Rear Disc	No
Rear Disc/Drum Size (mm)	130
Calliper Type	--

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WHEELS AND TYRES	
Wheel Size (inches)	17
Front Tyre	90/90 x 17
Rear Tyre	120/80 x 17
Tubeless Tyres	Yes
Radial Tyres	No
Alloy Wheels	Yes
ELECTRICALS	
Electric System	--
Battery	12 V (Low Maintenance Battery)
Headlight Type	Pilot Lamps Type
Headlight Bulb Type	35/35 W with 2 pilot lamps
Brake/Tail Light	Pilot Lamps
Turn Signal	Yes
Pass Light	Yes

- **Dimensions of Chassis**

The dimensions of chassis have been extracted from existing one by using reverse engineering. Dimensions for chassis were measeured from site. These dimensions taken from the actual model of Pulsar180 were used for 3D modeling. Below are some of the images taken at site. A rough hand sketch was drawn showing all the dimensions of chassis. Dimensions are required for calculating of boundary conditions. Hence its CAD model is necessary. CAD model then is made by the commands in CATIA of Pad, pocket, fillet, and geometrical selections in part design module. By using Vernier caliper measurements are done.

Fig. 1. *Reverse Engineering Of Bike Chassis*

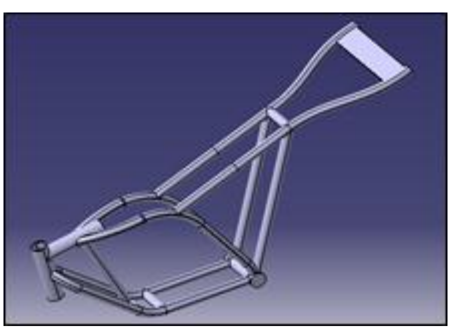

Fig. 2. *CAD Model of Chassis In Catia V5*

- **Main Commands Used**

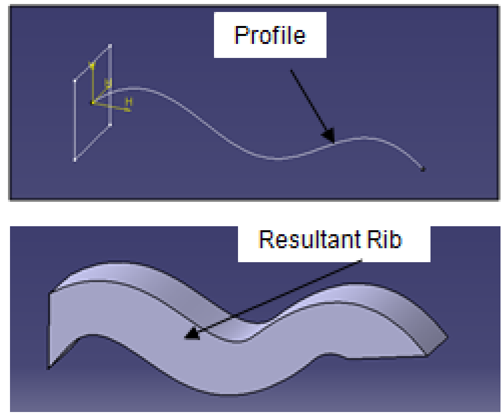

Fig. 3. *Rib Command*

Rib tool is used to sweep an open or a closed profile along an open or a closed centre curve. A profile is the cross-section for the rib feature and the centre curve is the course taken by the profile while creating rib feature.

Multi-Section Solid

The multi-section solid tool is used to create a feature by blending more than one similar or dissimilar geometries together to get a free form shape. These similar or dissimilar geometries may or may not be parallel to each other.

2.2 Finite Element Method

Meshing

For finite element analysis quality criterion was prepared as listed above and is maintained throughout the meshing process.

Quality Parameter Allowable

- Maximum Aspect Ratio: 5
- Maximum Warpage Angle: 15
- Minimum Quads Internal Angle: 45
- Maximum Quads Internal Angle: 135
- Minimum Tria Internal Angle: 15
- Maximum Tria Internal Angle: 120
- Percentage of Triangular Elements: 5

Meshing Details

- No. of element = 79146
- No. of nodes = 254913

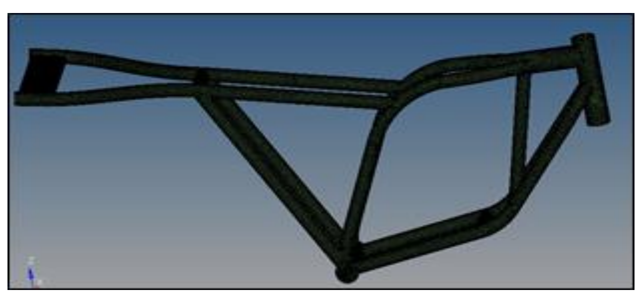

Fig. 4. *Meshed Model of Bike Chassis The properties of mild steel are listed below:*

TABLE 2

MATERIAL PROPERTIES OF BIKE CHASSIS

Property	Value
Young's Modulus, E	2.1x105 MPa
Poisson's Ratio ,v	0.3
Density, ρ	7850kg/m3
Yield Stress, σ_{yield}	350 MPa
Ultimate Tensile Stress, σ_{uts}	490 MPa

2.3 Applied Boundary Conditions

- The rear end portion and portion of handle in front is made fixed (as shown in figure by whitish portion) and then various loads are applied and analysis was done.

Various load applied are as follow-

TABLE 3
LOAD CONDITIONS APPLIED IN MESHED MODEL

Rider Weight	70 kg
Pillion Weight	70 kg
Fuel Tank Weight	20 kg
Engine Weight	40 kg

- In the below figure we see that all 6 DOF are constrained.
- The figure shows the portions that were made fixed during the analysis.

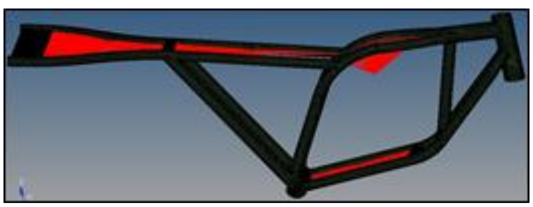

Fig. 5. *Loads Applied On Chassis In Hypermesh*

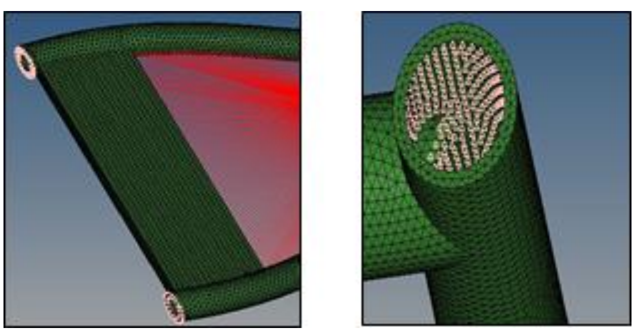

Fig. 6. *Constraints Applied In Hypermesh*

- After creating deck/hierarchy in hypermesh, it is exported into .cdb format and saved at a location.

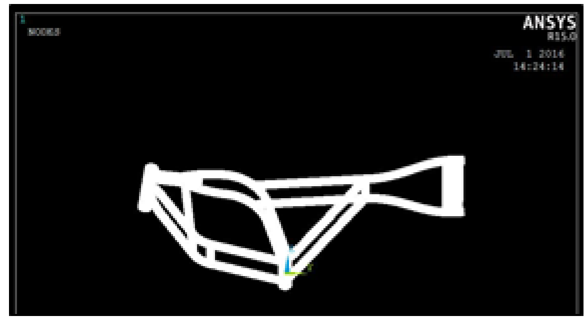

Fig. 7. *Chassis After Importing Into Ansys*

2.4 Static Analysis Results

- **Displacement**

The maximum displacement is coming out to be 0.11441 mm which is very less.

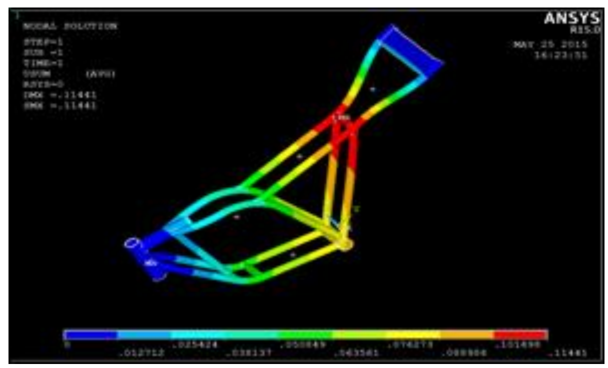

Fig. 8. *Displacement Pattern For Steel Chassis*

- **Stress**

The maximum stress occurs at joint locations and is coming out to be 43.44 N/mm2 which is within the safety limit.

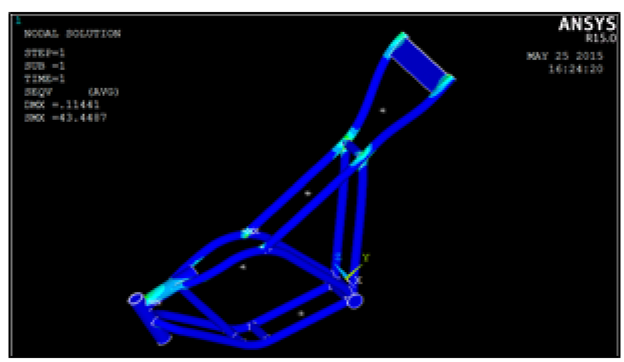

Fig. 9. *Stress Distribution For Steel Chassis*

2.5 Modal Analysis of bike chassis made of MS material

- Mode 1: The frequency of 1st mode is 81.04hz

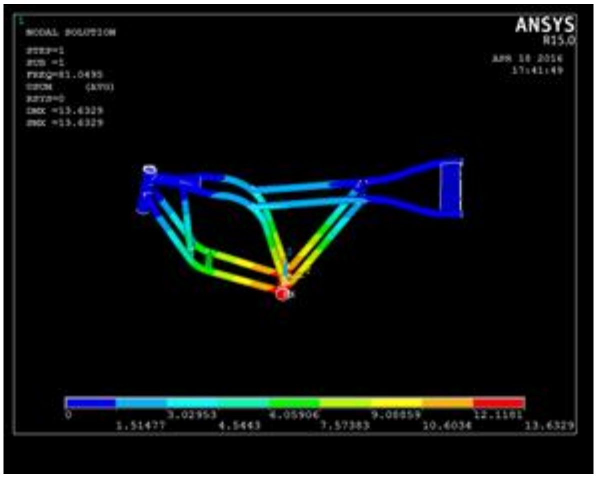

Fig. 10. *Frequency of 1st Mode(MS)*

- Mode 2: The frequency of 2nd mode is 120.67 hz.

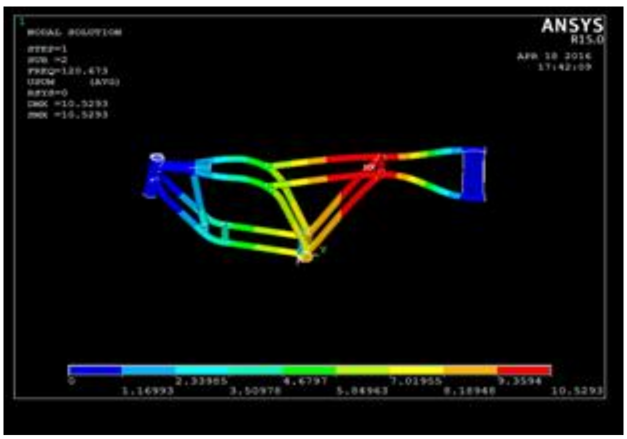

Fig. 11. *Frequency of 2nd Mode(MS)*

- Mode 3: The frequency of 3rd mode is 237.37 hz

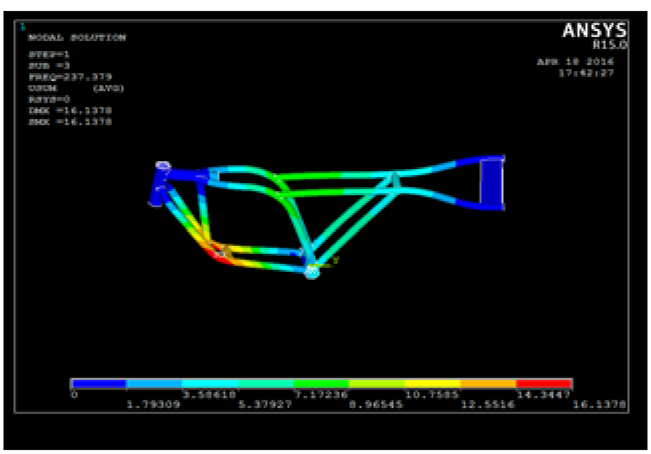

Fig. 12. *Frequency of 3rd Mode(MS)*

- Mode 4: The frequency of 4th mode is 276.98 hz.

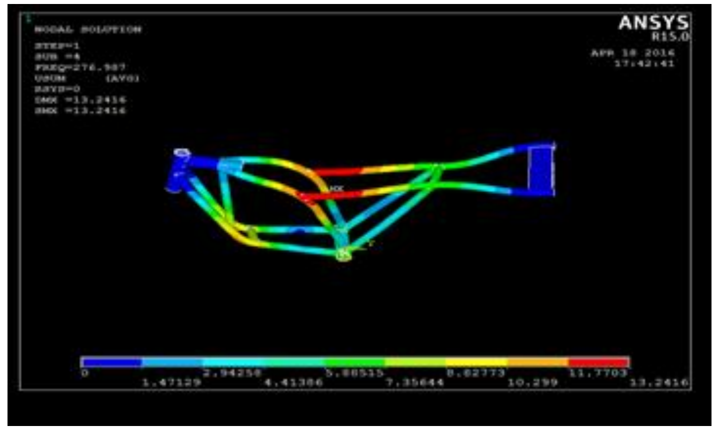

Fig. 13. *Frequency of 4th Mode(MS)*

- Mode 5: The frequency of 5th mode is 306.31 hz.

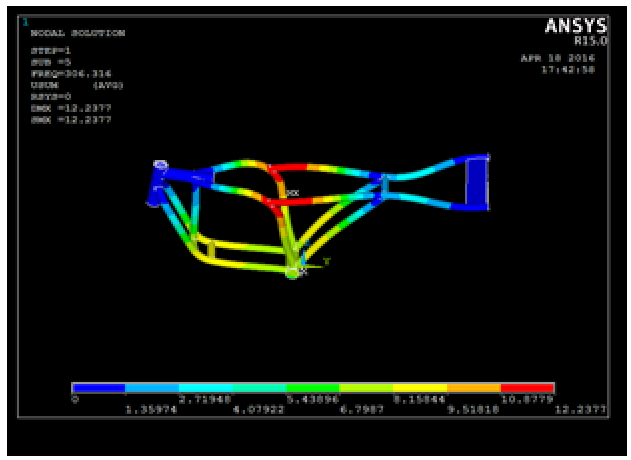

Fig. 14. *Frequency of 5th Mode(MS)*

- Mode 6: The frequency of 6th mode is 346.04 hz.

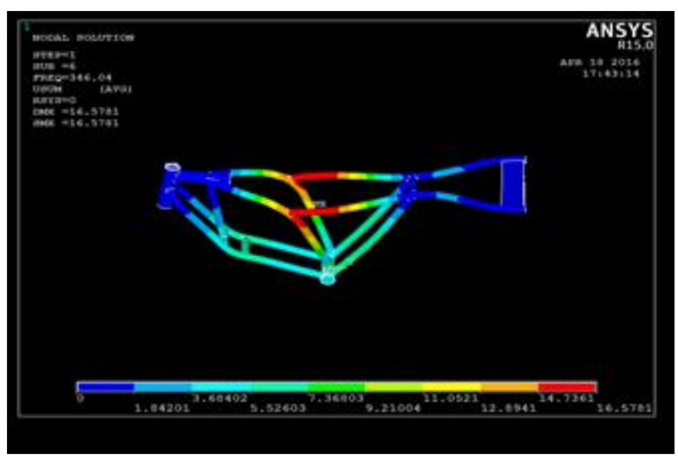

Fig. 15. *Frequency of 6th Mode(MS)*

TABLE 3
MATERIAL PROPERTIES OF ALUMINIUM ALLOY 6063

Property	Value
Young's Modulus, E	68.9 GPa
Poisson's Ratio ,v	0.33
Density, ρ	2700 kg/m3
Yield Stress, σ_{yield}	214 MPa
Ultimate Tensile Stress, σ_{uts}	241 MPa

2.6 Simulation Results for Chassis: Aluminum Alloy 6063

- **Displacement**

The maximum displacement is coming out to be 0.34746 mm which is very less

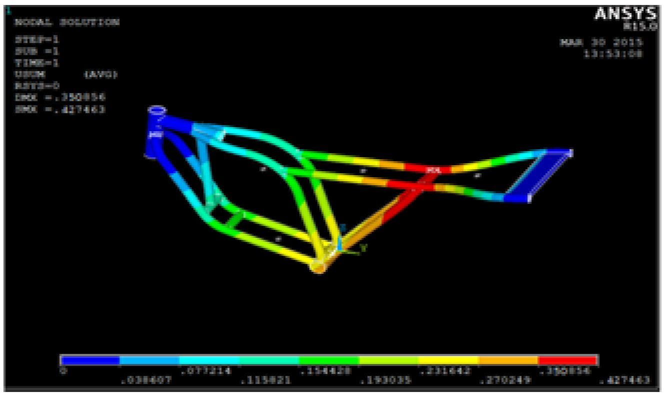

Fig. 16. *Displacement Pattern For Al Chassis*

- **Stress**

The maximum stress occurs at joint locations and is coming out to be 43.70 N/mm2 which is within the safety limit.

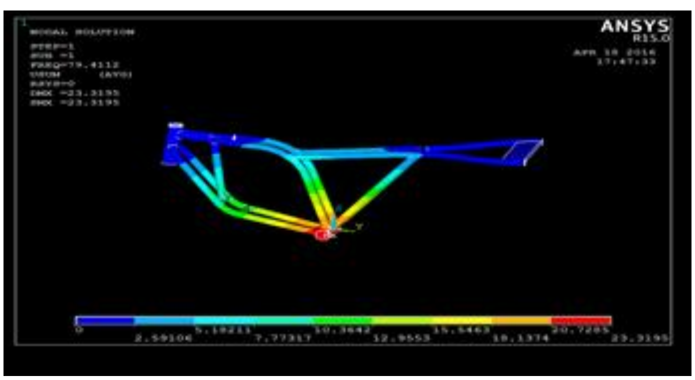

Fig. 17. *Stress Distribution For Al Chassis*

2.7 Results For Modal Analysis of Al

- Mode 1: The frequency of 1st mode is 79.41 hz

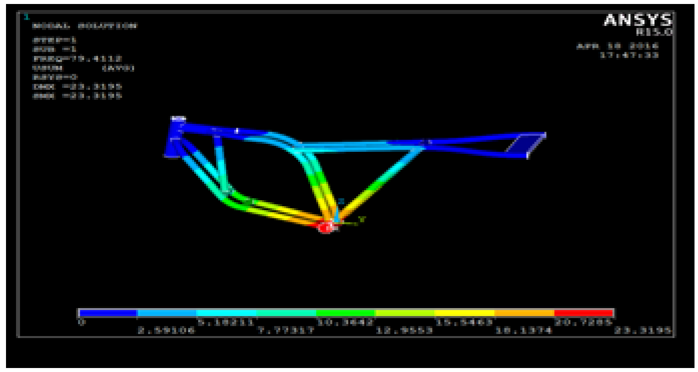

Fig. 18. *Frequency of 1st Mode(Al)*

- Mode 2: The frequency of 2nd mode is 118.23hz.

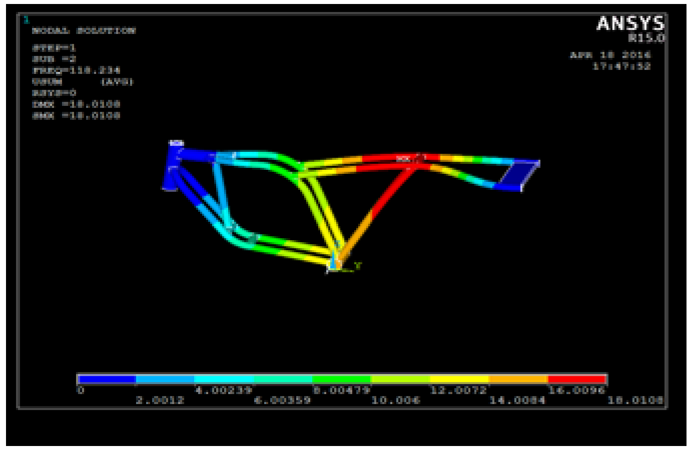

Fig. 19. *Frequency of 2nd Mode(Al)*

- Mode 3: The frequency of 3rd mode is 232.58hz

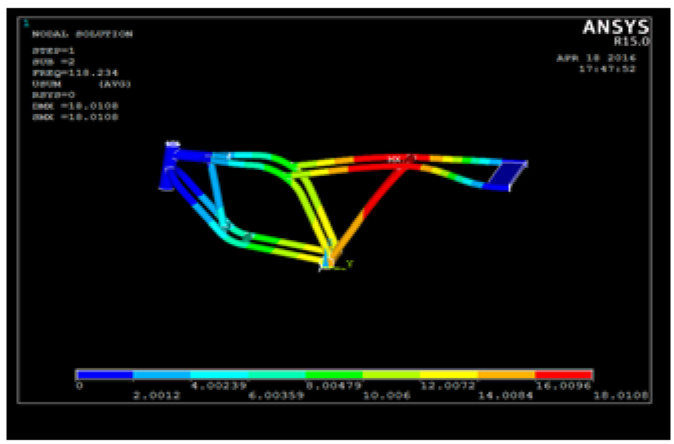

Fig. 20. *Frequency of 3rd Mode(Al)*

- Mode 4: The frequency of 4th mode is 271.38 hz.

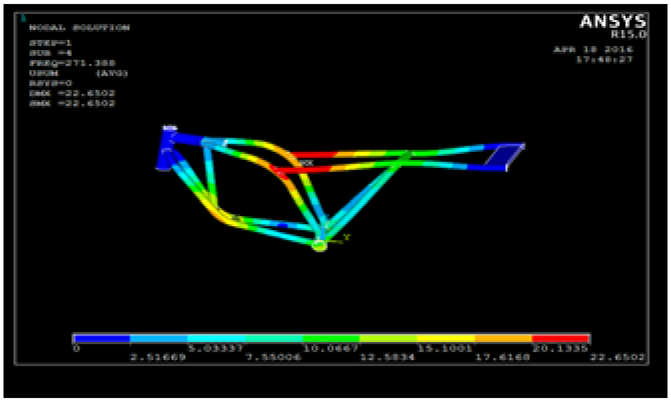

Fig. 21. *Frequency of 3rd Mode(Al)*

- Mode 5: The frequency of 5th mode is 300.12 hz.

Fig. 22. *Frequency of 5th Mode(Al)*

- Mode 6: The frequency of 6th mode is 339.04 hz.

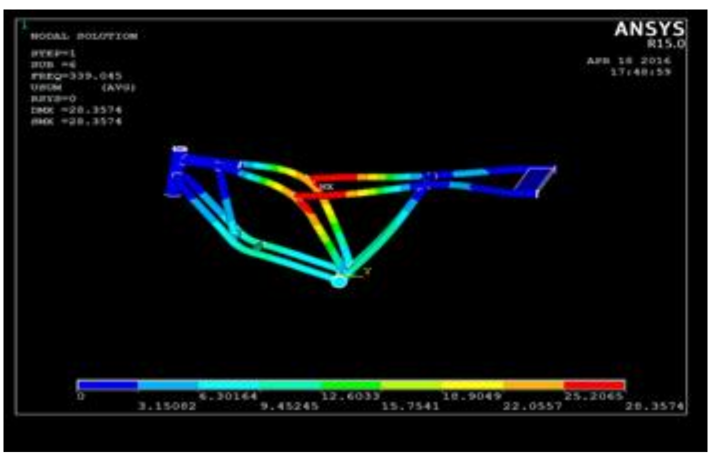

Fig. 23. *Frequency of 6th Mode(Al)*

3 Comparison of Analysis Results

The analysis of chassis has been done for all the four materials viz. steel, aluminum alloy 6063, carbon fiber and titanium. The comparison of properties and analysis results is shown in table 4 & 5 respectively.

Table 4
Comparison of Stress and Displacement

Material	Max. Stress	Max. Displacement
Steel	43.44 MPa	0.11441 mm
Aluminum Alloy 6063	43.70 MPa	0.34746 mm

Table 5
Comparison of Mode shapes

Mode shapes of Chassis (MS)	Mode shapes of Chassis (Al)
81.04	79.41
120.67	118.23
237.37	232.58
276.98	271.38
306.31	300.12
346.04	339.04

3.1 Fabrication of Prototype

A prototype is fabricated using aluminium alloy 6063 for testing purpose. The prototype is fabricated in KK Engineering, Katraj, Pune, India. The general fabrication process includes following steps,

- Selection of tube types
- Tube profiling
- Jigging
- Welding
- Frame finishing

3.2 Final Prototype Produced

The final prototype produced after following the above procedure is shown in figure. This prototype is further used for experimentation and validation of research.

Fig. 24. *Chassis After Importing Into Ansys*

4 Results and Discussion

4.1 Test Setup

Bike chassis is mounted by using clamps on the bench to perform the testing. The hammering test is carried out as stated above. The FFT analyzer is connected to a sensor which reads the vibrations on the component. The Bike chassis is hammered to give the vibrations by external means. As the vibrations flow in the bike chassis there will be peak amplitude which is the natural frequency of the component. Likewise the component is tested at three different points. Which the sensor is made to read and the readings are recorded in the FFT analyzer. Then the FFT analyzer is connected to data acquisition system and here the software is synced with FFT and the respective graphs are plotted.

Fig. 25. *Test Setup For Recording Readings*

4.2 Experimental results

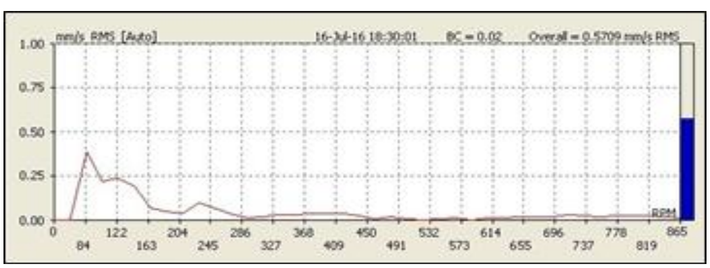

Fig. 26. *Readings At Point 1- 84Hz*

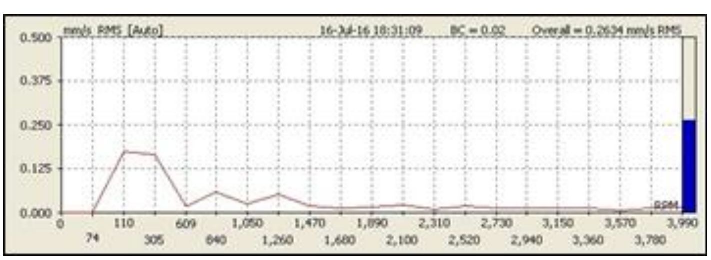

Fig. 27. *Readings At Point 2 - 110Hz*

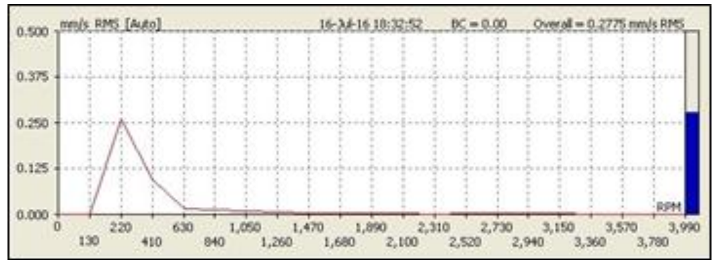

Fig. 28. *Readings At Point 3 - 220Hz*

4.3 Validation

TABLE 6
COMPARISON OF FEA

Natural Frequency of Bike Chassis FEA results(Hz)	Natural Frequency of Bike Chassis Experimental results(Hz)
79.41	84
118.23	110
232.58	220

5 END SECTIONS

5.1 Acknowledgments

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5.2 Conclusion

CAD model of bike chassis is modeled by using reverse engineering. The forces are calculated and the FEA analysis of conventional model is performed. Natural frequency of the bike chassis is extracted. Bike chassis is analyzed for aluminum material and results are interpreted for design safety. Natural frequency of the same are extracted. Aluminum bike chassis is fabricated and tested using FFT analyzer. The results of the analytical and the experimental values are compared and validated. The comparative study of both conventional and aluminum model is made.

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