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Design Optimization of Two Wheeler (Bike) Chassis

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ABSTRACT

The chassis frame forms the backbone of a vehicle; its principle function is to safely carry the maximum load for all designed operating conditions. Automotive chassis is the main carriage system of a vehicle. The chassis serves as a skeleton upon which parts like gearbox and engine are mounted.The two-wheeler chassis consists of a frame, suspension, wheels and brakes.The chassis is what truly sets the overall style of the two-wheeler. Commonly used material for two-wheeler chassis is steel which is heavy in weight or more accurately in density. There are various alternate materials like aluminium alloys, titanium, carbon fiber, magnesium, etc. which are lesser in weight and provide high strength and thus can be used for chassis. This paper deals with design of two wheeler chassis frame and its weight optimization. Various loading conditions like static and dynamic loadings were carried out on the chassis and the design is optimized by reducing the weight of the chassis by using alternate material while maintaining the strength.

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I. 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.

Chassis frame forms the backbone of a heavy vehicle, its principle function is to safely carry the maximum load for all designed operating conditions. It is essential that the frame should not buckle on uneven road surfaces and that any distortions which may occur should not be transmitted to the body. The frame must therefore be torsion resistant [2].

Weight optimization is now the main issue in automobile industries. Weight optimization will give substantial impact to fuel economy, efforts to reduce emissions and therefore, save environment [3].Steel is commonly used chassis material at present. Optimization process involves preparation of a CAD model of existing component with help of 3D modelling software like CATIA V5, Pro-E. Analysis is done on this model with the help of analysis software like ANSYS which helps in determining the maximum stress, and displacement values of existing model. Further the analysis is done with alternate materials to verify the best material. Simulation using softwares like ANSYS and Hyperworks can successfully validate the model in static conditions and dynamic conditions with the safety index against previous results. Validation can also be done with the help of experimentation, a prototype of proposed material can be produced and maximum stress and displacement values can be found out through UTM testing. Utilization of new materials, e.g. aluminium alloy or various composite, can bring about an unprecedented strength while sustaining or even decreasing weight of parts. There are various alternate materials like composites, aluminium alloys, titanium, carbon fibre, magnesium, etc. which are lesser in weight and provide high strength and thus can be used for chassis. Various compositions can be tested and experimented so that the overall weight of the vehicle can be reduced for better fuel efficiency [6], [7], [8].

II. MODEL OF FRAME

Fig. 1 Bajaj Pulsar Chassis

With the use of strong design and simulation tools like CATIA, Hyper-Mesh and ANSYS optimization of existing Bajaj Pulsar 180 DTS-i chassis is done. The optimization process consists of CAD model generation of existing chassis in CATIA, its analysis using Hyper-Mesh and ANSYS. An alternate material is used for the redesign and analysis of model. Experimentation is also done for validation of proposed model.

A. Specifications of Bajaj Pulsar 180 DTS-i

TABLE I

DIMENSIONS AND WEIGHT OF BAJAJ PULSAR

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*

TABLE II

CHASSIS AND SUSPENSION OF BAJAJ PULSAR

Chassis Type	*Double Cradle*
Front Suspension	*Telescopic, Anti-friction bush*
Rear Suspension	*5 way adjustable, Nitrox shock absorber*

B. CAD Model

CAD model of existing chassis has been prepared in CATIA V5 as shown in figure 2. The dimensions were measured from existing chassis by reverse engineering.

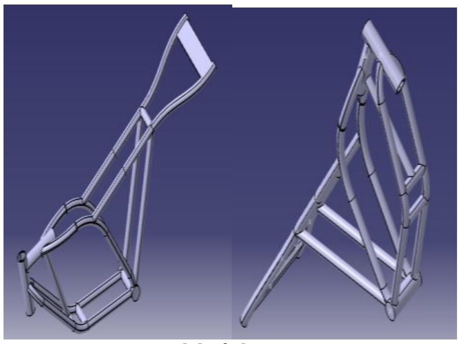

Fig. 2 CAD model of chassis in CATIA V5

III. STRUCTURAL ANALYSIS OF BIKE CHASSIS

A general-purpose commercial finite element code, Hyper-Mesh and ANSYS is applied to conduct the static simulations. A full 3-D solid model is constructed for the static test simulation. The schematic of proposed FEA model used in static test simulations is shown in figure 3. Mixed type of elements which contain quadrilateral as well as triangular elements, have been used in analysis. These 2D elements are converted into 3D tetra elements. The sensitive regions have been re-meshed manually considering the shape and size of the parts.

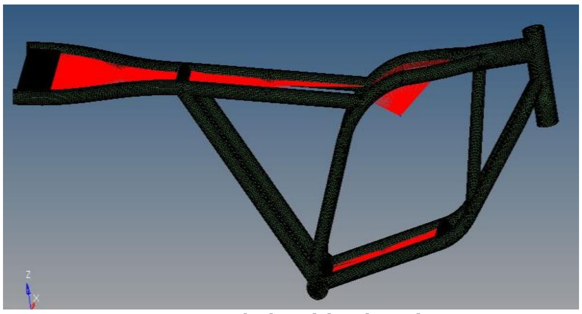

Fig. 3 Meshed model with rigids

The finite element analysis is carried out on steel chassis as well as on three other alternate materials viz. aluminium alloy 6063, carbon fibre and titanium. From the analysis the equivalent stress (Von-mises stress) and displacements were determined and are shown in figure 5-12. Table III shows the comparative analysis of propertiesof steel and other three materials while Table V shows comparison of result of all the chassis materials

TABLE III

MATERIAL PROPETIES

S.No.	***Material***	***Young's Modulus E***	***Poisson's Ratio υ***	***Density ρ***	***Yield Stress σ_{yield}***	***Ultimate Tensile Stress σ_{uts}***
1.	***Steel***	*210 GPa*	*0.3*	*7850 kg/m^3*	*350 MPa*	*490 MPa*
2.	***Aluminium Alloy 6063***	*68.9 GPa*	*0.33*	*2700 kg/m^3*	*214 MPa*	*241 MPa*
3.	***Carbon Fibre***	*73.1 GPa*	*0.33*	*2780 kg/m^3*	*324 MPa*	*469 MPa*
4.	***Titanium***	*119 GPa*	*0.34*	*4430 kg/m^3*	*880 MPa*	*900 MPa*

A. Applied Boundary Conditions

The rear end portion and portion of handle in front is made fixed (as shown in figure 4 by whitish portion) and then various loads are applied and the analysis was done.

TABLE IV

LOAD CONDITIONS APPLIED

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

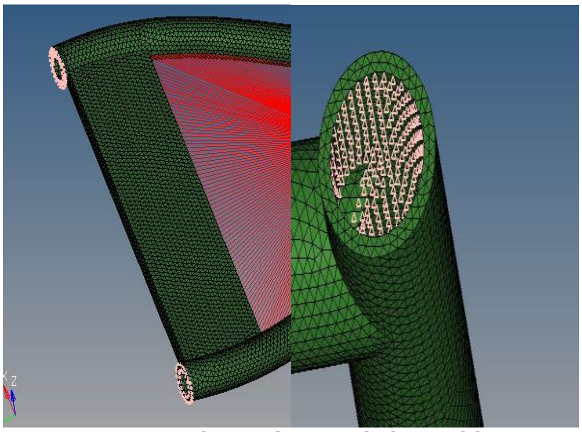

Fig.4 Boundary conditions applied on model

B. Meshing Details

No. of element = 79146

No. of nodes = 254913

C. Analysis Results

Steel

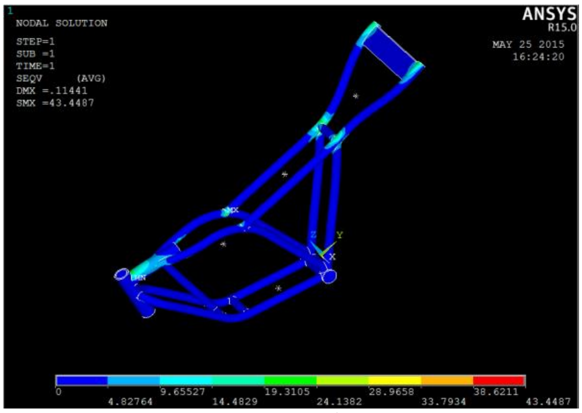

Fig. 5 Stress distribution for steel chassis

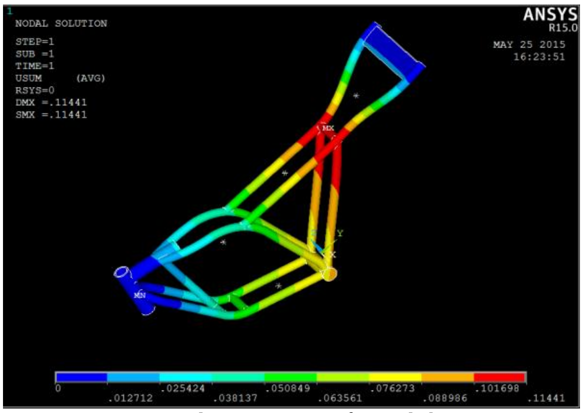

Fig. 6 Displacement pattern for steel chassis

Aluminium Alloy 6063

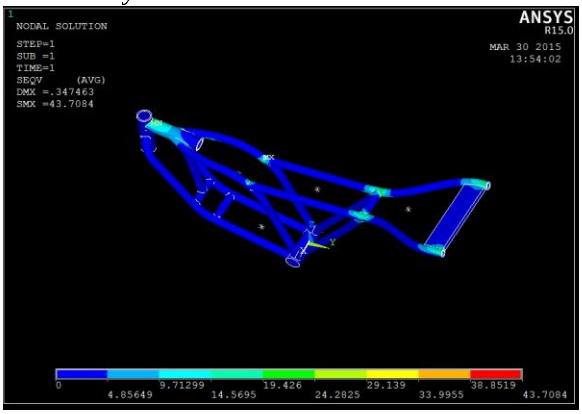

Fig. 7 Stress distribution of aluminium chassis

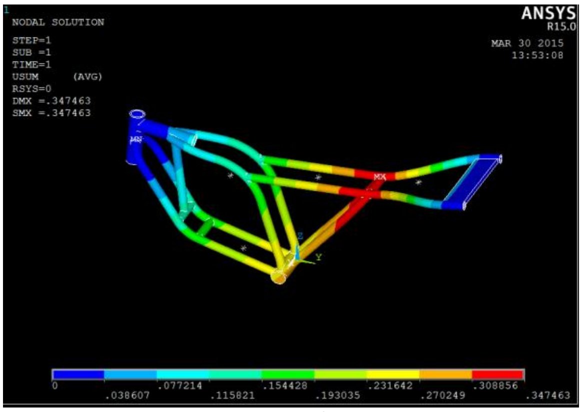

Fig. 8 Displacement pattern for aluminium chassis

Carbon Fibre

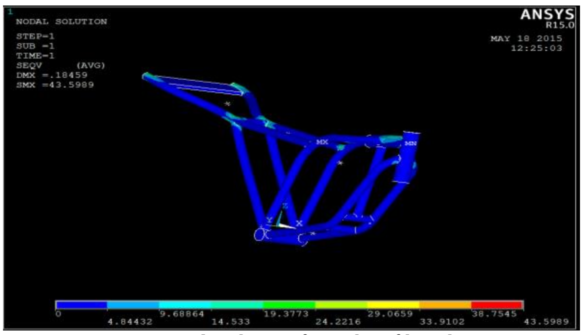

Fig. 9 Stress distribution for carbon fibre chassis

Fig. 10 Displacement pattern for carbon fibre chassis

Titanium

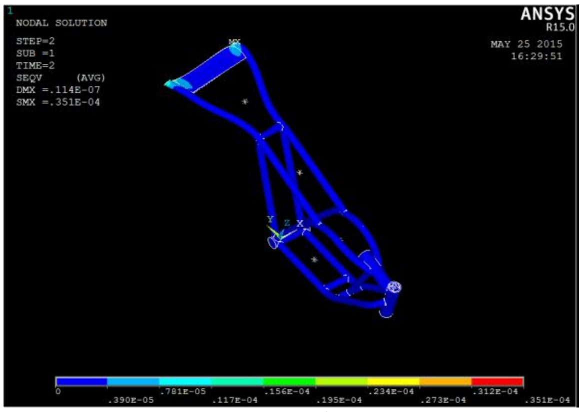

Fig. 11 Stress distribution for titanium chassis

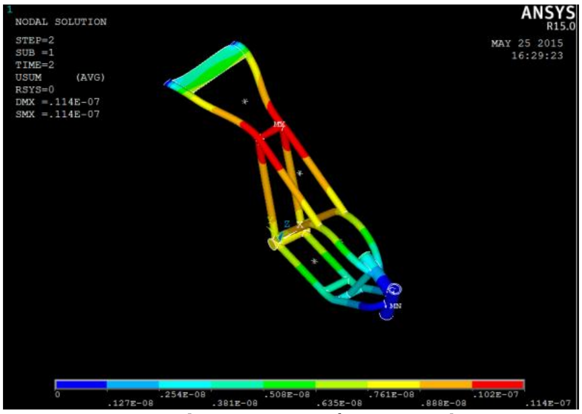

Fig. 12 Displacement pattern for titanium chassis

TABLE V

COMPARATIVE ANALYSIS OF STEEL CHASSIS WITH OTHER TYPES

S.No.	***Material***	***Max. Stress***	***Max. Displacement***
1.	***Steel***	*43.44 MPa*	*0.11441 mm*
2.	***Aluminium Alloy 6063***	*43.70 MPa*	*0.34746 mm*
3.	***Carbon Fibre***	*43.59 MPa*	*0.18459 mm*
4.	***Titanium***	*35.14 MPa*	*0.11400 mm*

From results of finite element analysis of chassis it is observed that stresses are maximum at joint locations. It is also observed that all the materials have stress values less than their respective permissible yield stress values. So the design is safe.

IV. PROPOSED EXPERIMENTATION AND VALIDATION

A prototype for experimentation is produced by using aluminium alloy 6063 for testing as shown in figure 13. The input conditions will be recreated in the lab while the component testing. The loading and the boundary conditions will be matching the practical working conditions in which the chassis is expected to perform. For simplicity, a Universal Testing Machine along with a suitable fixture for the component shall be engaged for testing purpose.The measured values will be compared with the results from software and will be validated accordingly.


Fig. 13 Prototype model produced

The proposed setup is expected to be performing better with a satisfying amount of weight reduction. The weight reduction will hence lead to better fuel efficiency of the vehicle.

V. CONCLUSION

Structural analysis has been done on chassis by using four materials viz. steel, aluminium alloy 6063, carbon fibre and titanium. The maximum stress values are coming out to be 43.44 MPa, 43.70 MPa, 43.59 MPa, 35.14 MPa respectively. From the results it is observed that the stresses are maximum at joint locations and also for all the materials the stress values are less than their permissible yield stress values. So the design is safe.

By using aluminium alloy 6063, a prototype is prepared for experimentation.As the material has less density compared to other materials used and is also cheap in cost, this isthe best suited alternate material for the chassis and is expected to perform better with satisfying amount of weight reduction.

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