Topology Optimization Of Two Wheeler Frame By Using Fea

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Abstract- *Manufacturers have been concentrating their interests on lightweight bodies. The fabrication of lightweight body is limited by constraints such as stiffness, weight. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing process. Frames used in the mechanical design, which is still designed on the rule of thumb, are one of the potential areas for design optimizations for better stiffness. Frame especially two wheeler frame due to its geometrical construction, assemblies and complex loading conditions cannot be analyzed by a theoretical model and hence need a power full numerical approach for analysis. The two-wheeler chassis consists of the frame, suspension, wheels and brakes. The frame serves as a skeleton upon which parts like gearbox and engine are mounted. It can be made of steel, aluminium or an alloy. In this present project design and analysis of two wheeler frame is done using four materials alloy steel, aluminium alloy A360, magnesium and carbon fiber reinforced polymer to verify the best material for the frame. In the present work, the dimensions of an existing vehicle chassis are taken for modelling and analysis of a two wheeler vehicle chassis. Finally, modal analysis is performed to find natural frequencies, and from the study results stresses and deflections are plotted, and the alternative material is documented. This project extended to shock analysis by considering three bumps per second with the peak acceleration as per the standard road tests. Software used in this work is NX-CAD for modelling and ANSYS for analysis.*

I. INTRODUCTION

A chassis consists of an internal framework that supports a human-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 with the wheels and machinery. In the case of vehicles, the term chassis means the frame plus the running gear like engine, transmission, differential, driveshaft, and suspension. A body, which is not necessary for the integrity of the structure, is built on the chassis to complete the vehicle. The automotive chassis is tasked to perform holding all the components together while driving and transferring lateral and vertical loads, caused by accelerations, on the chassis through the suspension and the wheels. Therefore the chassis is considered as one of the important elements 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 principal function is to carry the maximum load for all designed operating conditions safely. It is necessary 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.

II. LITERATURE REVIE

A Review on ‘Design and Analysis of Two Wheeler Chassis’ by Gaurav Vasantrao Bhunte1 and Dr Tushar R. Deshmukh. In this paper, the effort is made to review the investigations that have been made on the different analysis techniques of automobile frames. That analysis can be, static analysis or dynamic analysis. Some analytical and experimental methods are available for the discussion of the automobile frames. Determination of the different analysis around different conditions in an automobile frames has been reported in the literature. An attempt has been made in the article to present an overview of various techniques developed for the analysis of automobile frames and results of that analysis due to which further study on the chassis will become accessible".

Structural analysis of two wheeler suspension frame by CH.Neeraja, C.R.Sireesha and D.Jawaharlal. In this project "The two-wheeler chassis consists of the frame, suspension, wheels and brakes. The chassis indeed set the overall style of the two-wheeler. Automotive chassis is the important carriage systems of a vehicle. The frame serves as a skeleton upon which parts like gearbox and engine are mounted. It can be made of steel, aluminium or an alloy. It is essential that the frame should not buckle on uneven road surfaces and that any alterations which may occur should never transmit to the body. The frame should, therefore, be a torsion resistant. The aim of the project is to model a frame using 3D modelling software Pro/Engineer. To validate the strength of a frame, the Structural analysis is done by applying the wheel forces. In this analysis ultimate stress limit for the model is determined.

The analysis is done for the frame using four materials alloy steel, aluminium alloy A360, magnesium and carbon fibre reinforced polymer to verify the best material for the frame. Model analysis is also done to determine different mode shapes for some modes. The analysis is done in ANSYS software".

Material and Design Optimization for an Aluminum Bike Frame by Forrest Dwyer, Adrian Shaw, Richard Tombarelli. Fatigue is a prominent failure mechanism for mountain bike frames and can lead to serious accidents, costly recalls, and poor product image for bicycle frame manufacturers. The team collaborated with a local bike company, in the process of developing a new 6061-T6 aluminium mountain bike, to investigate the fatigue behaviour of the new frame and optimize the material/heat treatment and frame design. The fatigue testing is done in-house using a test rig specifically built for this project according to the ASTM standard F2711-08 for horizontal loading. A solid model of the frame is created, and a finite element analysis (FEA) was conducted using the ASTM standard as a guide, with appropriate mechanical properties for various sections of the bike and the joining welds. The FEA model enabled the team to predict fatigue failure locations and cycles to failure and was further validated using the experimental fatigue testing results obtained from the prototype frames. On the physical frames tested, thorough fractographic examinations were conducted to identify the fatigue crack initiation locations and crack propagation mechanisms using optical and scanning electron microscopy. To complete the project, systematic studies were performed to optimize the frame's design, materials and heat treatment for improved fatigue resistance.

III. PROBLEM DEFINITION AND METHODOLOGY

In this present project design and analysis of two wheeler chassis is done for the frame using four materials alloy steel, aluminium alloy A360, magnesium and carbon fibre reinforced polymer to verify the best material for the frame. In the present work, the dimensions of an existing vehicle chassis are taken for modelling and analysis of a two wheeler vehicle chassis. Modal analysis is performed to find natural frequencies. From the analysis results, stresses and deflections are plotted. This project extended to shock analysis by considering three bumps per second with the peak acceleration as per the standard road tests. Software used in this work is NX-CAD for modelling and ANSYS for analysis.

3D MODELING OF BIKE FRAME CHASSIS

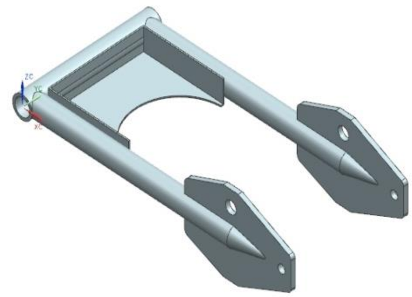

Figure 1. Isometric view -1 of bike frame chassis.

Figure 2. Isometric view -2 of bike frame chassis.

FINITE ELEMENT ANALYSIS OF BIKE FRAME CHASSIS

3D model of the bike frame chassis was developed in NX-CAD. The model was then converted into a Para solid to import into ANSYS. A Finite Element model was developed with solid elements. The elements that are used for idealizing the bike frame chassis are described below. A detailed Finite Element model was built with solid elements to idealize all the components of the chassis assembly. Modal analysis was carried out to find the natural frequencies and their mode shapes.

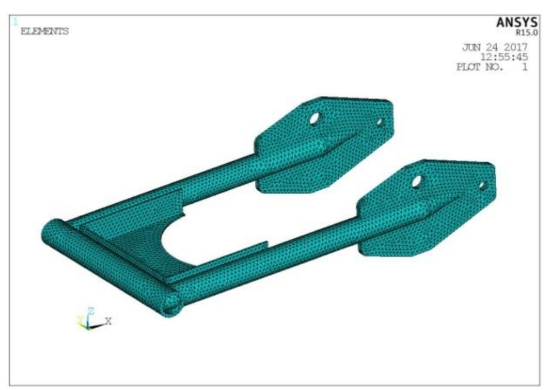

Figure 3. Meshing Model of the bike frame Chassis

Boundary Conditions

Inner tube areas of the frame are arrested in all DOF (Degrees of freedom).

A pressure of 0.3N/mm2 is applied on the areas of the hole.

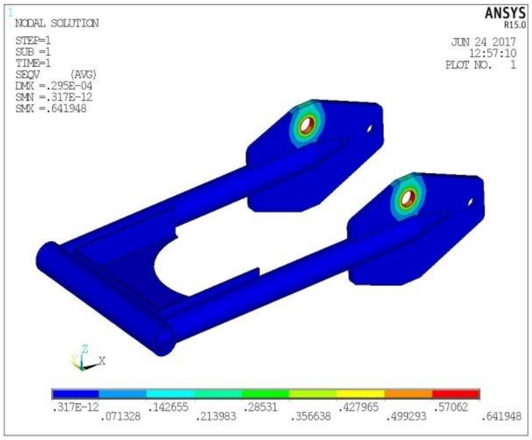

Figure 4. von misses stress developed in bike frame chassis for alloy steel

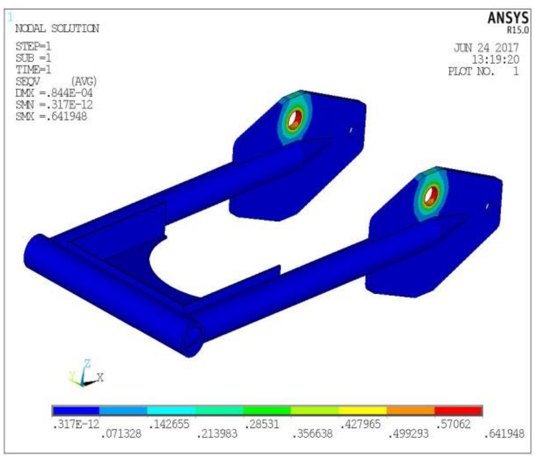

Figure 5. von misses stress developed in bike frame chassis for aluminum alloy

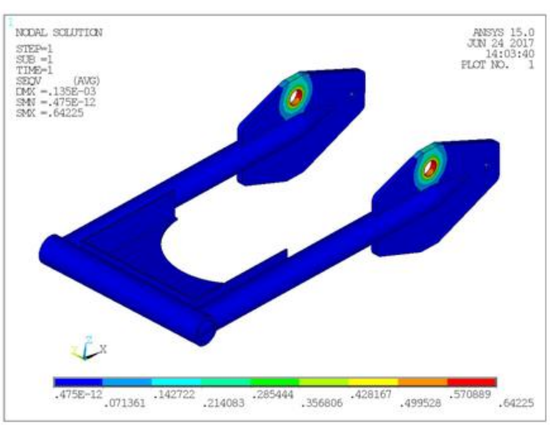

Figure 6. von misses stress developed in bike frame chassis for magnesium material

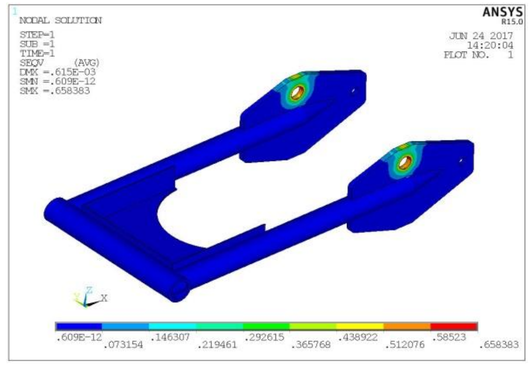

Figure 7. von misses stress developed in bike frame chassis for corban epoxy material

MODAL ANALYSIS OF BIKE FRAME CHASSIS

Modal analysis is used to find the natural frequencies

Mode shape # 1 @83.8Hz:

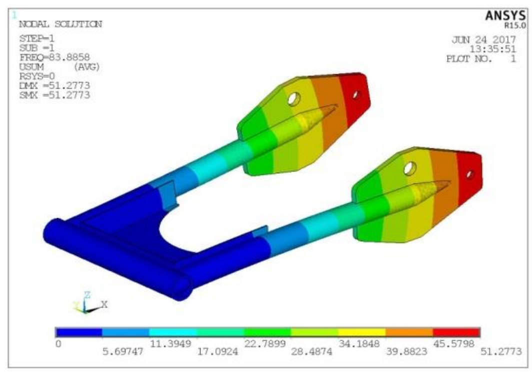

Figure 8. shows mode shape of bike frame chassis @83.8Hz

Mode shape # 2 @ 84.5Hz:

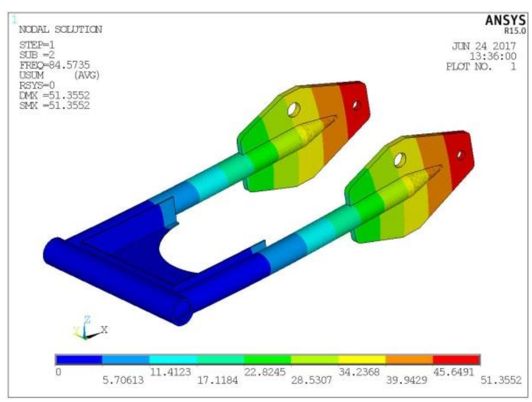

Figure 9. shows mode shape of bike frame chassis @84.5Hz

Mode shape # 3 @ 103.2Hz:

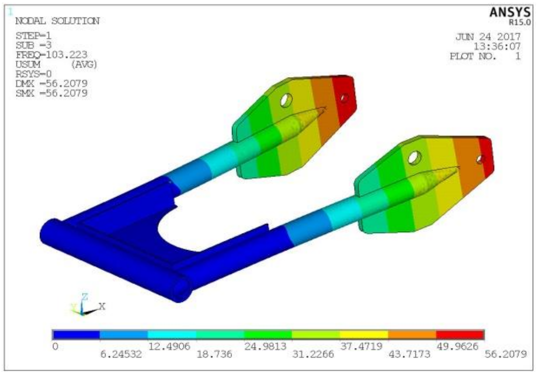

Figure 10. shows mode shape of bike frame chassis @103.2Hz

Mode shape # 4 @ 104.6Hz:

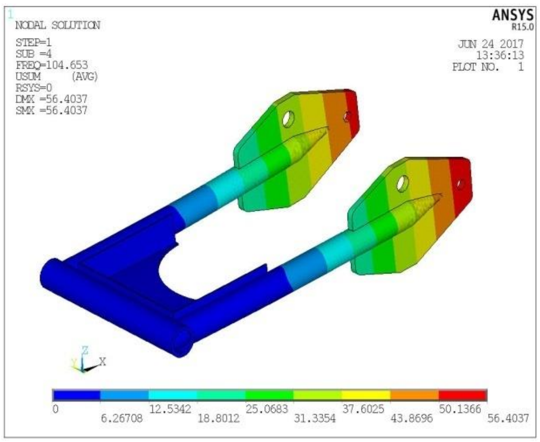

Figure 11. shows mode shape of bike frame chassis @104.6Hz

Mode shape # 5 @ 532.3Hz:

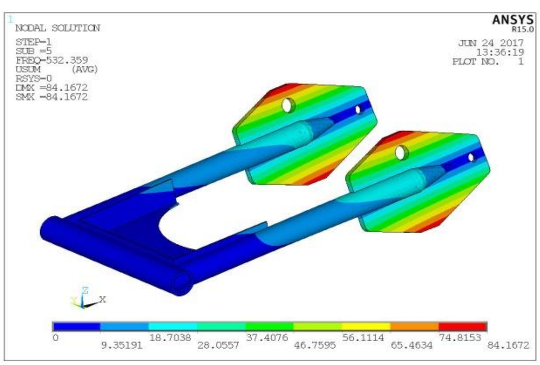

Figure 12. shows mode shape of bike frame chassis @532.3Hz

The following observations are made from the modal analysis:

The total weight of the bike frame chassis is 0.13e-2 Tons.

SHOCK ANALYSIS OF BIKE FRAME CHASSIS

Transient analysis is a technique to determine the response of a structure to arbitrary time-varying loads such as an explosion. The transient dynamic analysis is used in the design of Structures subjected to shock loads, such as automobile doors and bumpers, building frames, and suspension systems. Structures subjected to time-varying loads, such as bridges, earth moving equipment, and other machine components. Household and office equipment subjected to "bumps and bruises," such as cellular phones, laptop computers, and vacuum cleaners.

The equation of motion for a transient dynamic analysis is the same as the general equation of motion.

Mu+C{u}+K{u}={Ft}

This is the most general form of dynamic analysis. Loading may be any arbitrary function of time. Depending on the method of solution, ANSYS allows all types of nonlinearities to be included in a transient dynamic analysis - large deformation, contact, plasticity, etc.

Boundary conditions:

The bike frame chassis is subjected to 3 bumps per sec with the peak acceleration as per the standards is given in the table. Each bump can be treated as a half sine curve with a period of as per table.

Table 1.

Peak Acceleration(m/sec^2)	Pulse Duration(ms)	Number of Bumps	Application
100	16	1	General Ruggedness test.

The below analysis is carried out for a single bump. All the acceleration inputs are converted into ‘g' values, and the input loads (regarding acceleration) are calculated. The whole loading curve is divided into ten load steps (time period=1.6msec), and each load step is divided into four sub steps for better convergence. The boundary conditions applied for the shock analysis are shown below. Inner tube areas of the frame are arrested in all Dof. A pressure of 0.3N/mm2 is applied on the areas of the hole. The loading (acceleration) parameters are defined as per the below table and curve.

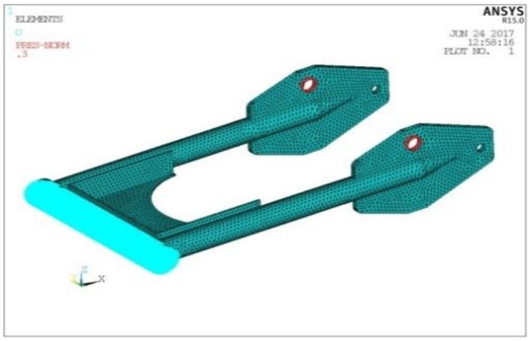

Figure 13. Shows the Load distributed on bike frame chassis

Table 2.

Sl.No.	Step	Time at end of load step(secs)	Acceleration due to Gravity(g)(mm/sec2)
1	STEP 1	0.00001	0
2	STEP 2	0.0016	30312.9
3	STEP 3	0.0032	57653
4	STEP 4	0.0048	79362
5	STEP 5	0.0064	93293
6	STEP 6	0.008	98100
7	STEP 7	0.0096	93293
8	STEP 8	0.0112	79362
9	STEP 9	0.0128	57653
10	STEP 10	0.0144	30312.9
11	STEP 11	0.016	0

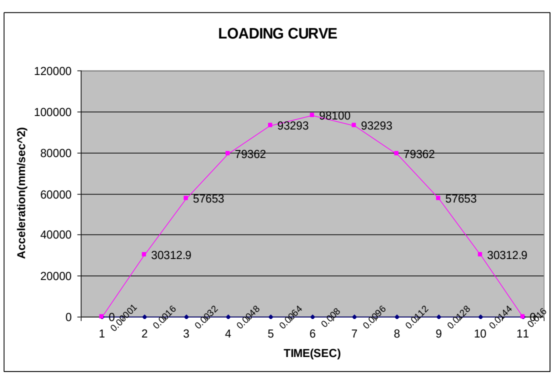

Figure 14. Loading curve for a Single Bump

IV. RESULTS AND CONCLUSION

Bike chassis frame was modelled in NX-CAD software. Bike chassis frame was analyzed for static analysis and modal analysis using different materials. Results of static and modal analysis for different materials are:

STRUCTURAL ANALYSIS OF BIKE FRAME CHASSIS FOR STEEL ALLOY MATERIAL:

From the static analysis, the maximum displacement of 0.29e-4mm was observed on bike frame chassis. The maximum Von Mises stress of 0.64MPa is observed on the chassis bike frame. The yield strength of the material is 275MPa. The Von Mises stress is less than the yield stress of the material. From the modal analysis, the total weight of the bike frame chassis is 0.3e-2Tons.

STRUCTURAL ANALYSIS OF BIKE FRAME CHASSIS FOR ALUMINIUM ALLOY MATERIAL:

From the static analysis, the maximum displacement of 0.8e-4mm was observed on bike frame chassis. The maximum Von Mises stress of 0.64MPa is found on the chassis bike frame. The yield strength of the material is 240MPa. The Von Mises stress is less than the yield stress of the material. From the modal analysis, the total weight of the bike frame chassis is 0.13e-2 Tons.

STRUCTURAL ANALYSIS OF BIKE FRAME CHASSIS FOR MAGNESIUM MATERIAL:

From the static analysis, the maximum displacement of 0.13E-3mm was observed on bike frame chassis. The maximum Von Mises stress of 0.64MPa is observed on the chassis bike frame. The yield strength of the material is 180MPa. The Von-Misses stress is less than the yield stress of the material. From the modal analysis, the total weight of the bike frame chassis is 0.86E-3Tons.

STRUCTURAL ANALYSIS OF BIKE FRAME CHASSIS FOR CARBON EPOXY MATERIAL:

From the static analysis, the maximum displacement of 0.61e-3mm was observed on bike frame chassis. The maximum 1st, 2nd and 3rd principal stresses of 0.47MPa, 0.03MPa and 0.003MPa are observed on the chassis bike frame. The 1st, 2nd and 3rd principal stresses of the material are 880MPa, 60MPa and 97MPa. The 1st, 2nd and 3rd principal stresses observed are less than the 1st, 2nd and 3rd principal stresses of the material. So, the design of bike frame chassis is safe for static loads.

From the modal analysis, the total weight of the bike frame chassis is 0.74e-3Tons.

SHOCK ANALYSIS OF BIKE FRAME CHASSIS:

Table 3.

Load step	Displacement	1st principal stress
STEP 1	0.002	0.87
STEP 2	0.04	4.44
STEP 3	0.15	13.8
STEP 4	0.22	20.7
STEP 5	0.20	18.8
STEP 6	0.14	14.2
STEP 7	0.15	14.1
STEP 8	0.17	16.4
STEP 9	0.13	12.2
STEP 10	0.01	1.33
STEP 11	0.07	6.57

From above results, bike frame chassis at every load step has 1st principal stress less than 1st principal stress of material

V. CONCLUSION

Bike chassis frame was modelled using the NX-CAD software. The bike chassis frame model was imported to ANSYS software to perform structural analysis (i.e. static and modal analysis). The analysis was done on the bike chassis frame for different materials (steel alloy, aluminium alloy, magnesium alloy and carbon epoxy material). From the static analysis, steel alloy has displacement value compare to other materials, but comparing to stresses and factor of safety, carbon epoxy material was better. From the modal analysis, the fundamental frequency of carbon epoxy material was high compared to other materials. By considering results of the static and modal analysis, it was concluded that the carbon epoxy material was best material compare to other materials. Further, shock analysis was done on the bike chassis frame for carbon epoxy material. The stresses for all load steps were less than the stresses of the material. By considering all results, finally, it was concluded that the bike chassis frame was safe for static and shock loads.

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