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DESIGN & ANALYSIS OF CHASSIS OF TWO-WHEELER EV

[1]Aditya A. Deshmukh, [2]Akshay A. Bhokare, [3]Sanket V. Gawas, [4]Omkar A. Gawali, [5]Nishant R. Sukalkar

[1]B.E. Student, [2]B.E. Student, [3]B.E. Student, [4]B.E. Student, [5]Assistant Professor
Department of Mechanical Engineering,
I.S.B.& M. College of Engineering, Pune, India

Abstract: This study is aimed to developing frame of a two-wheeler, two-seater motorcycle, whereas considering strength, safety and optimum performance of the vehicle. The said study has been carried out with a two-step approach. The first step includes modelling considering aesthetic point of view as well as determination of loads acting on the frame. The second step is about stress analysis using finite element analysis software and design modifications for weight reduction without affecting structural strength. We are also going to do a comparative study of three different materials using the ANSYS software to select the best suited material for the purpose by considering vehicle strength and cost. The proposed design of the chassis will be designed to be used as a standard chassis for commutator EV so the considerations will be according to the mostly used battery capacity and common weight consideration.

Key points: - Chassis, FEA, Electric Vehicle, ANSYS.

I. INTRODUCTION

The electrification is most believable way to achieve clean and efficiently transportation that crucial to sustainable development of whole world. The automotive industry today facing with some of the most significant technical challenge in history. Most of the countries in the world there are rules and regulations are changed because if emissions of vehicles. These challenge along with quickly changes customers preference and increasing market demand for better vehicle performance and market demand increasing for vehicle reliability so automobile companies thinking about requirements and find better ways to design better vehicle at minimum cost with shorter period.

The prime concern where more efforts need to be put in is the weight and size of the systems and components, with a view of increasing range, speed, payload and grade ability of the vehicle. A motorcycle frame is a motorcycle's core structure. The frame supports the major components and systems of the vehicle (motor, transmission system, etc., provides the hinge points for both front, and rear suspension and supports the rider and any pillion or luggage. The frame acts as a skeleton for the vehicle on which different components' area unit mounted mistreatment fast applications providing them with strength and rigidity in order that they will perform their desired operation in the vehicle. A frame design is dependent on the suspension, steering and transmission subassembly design of the vehicle and hence gives flexibility to optimize it in terms of weight and durability. Among the vehicle structural components, the frame is the most important part in the vehicle. The frame is required to support the various loads of the components and systems of the vehicle as well that of the rider, pillion and payload and sustain numerous forces and torques induced by bumping, braking and acceleration. Under normal operating conditions, it is subjected to dynamic forces transmitted from the front and rear suspension systems. The frame is subjected to time varying loads during its service life which may lead to fatigue failure.

Thus, in the design and optimization of a motorcycle frame, the weight must be minimized, centralized and lowered, while factors such as strength, stiffness and durability should meet the design targets. An effective design is one which performs the required task efficiently and is safe under extreme operating conditions, while being economical in the material used as well as the manufacturing process needed yet having an aesthetic appeal. Analysis aids in understanding the behaviors of a component under a particular loading cycle for both failures and redundancies. Therefore, analysis gives us a mathematical model which indicates scope for optimization and weight reduction for an overdesigned component. The automotive chassis is one of the most important structure of any propelled vehicle because of its multifaceted role on vehicle dynamic behavior. Our aim is to presents the design and the development of a chassis, for the one-seated prototype electric vehicle. The main target is to evaluate chassis deformation, based on static analysis and modal analysis, in order to reduce weight and at the same time achieve proper vehicle operation in a demanding low energy consumption race.

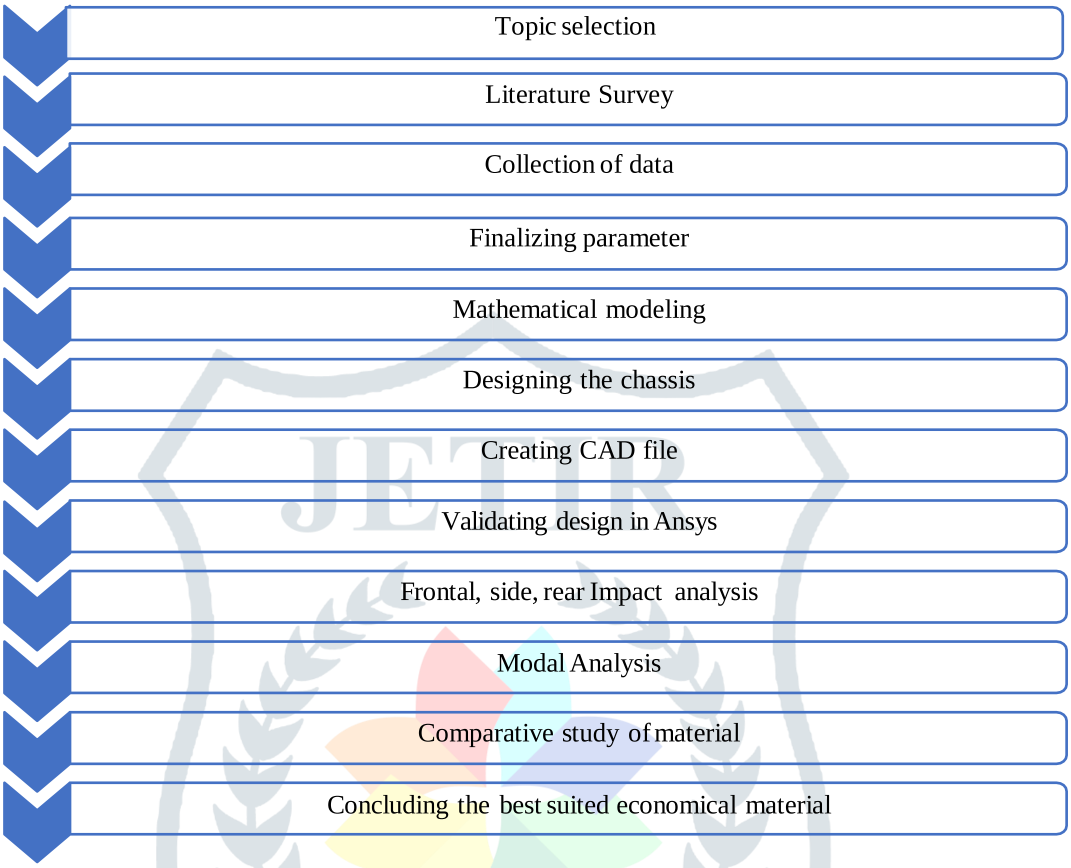
II. SCOPE

The use of electric vehicles will result in less consumption of fossil fuels with less charging cycles of batteries. The durability and convenience to consumer can be improved by using this type of vehicle. Batteries can be charged during idling or by solar charging system. Battery Structure can be improved so that charging cycle & charging time will be Minimum. With optimizing the material cost of the chassis will help in reducing the overall cost of the bike resulting a more economical option to conventional IC engine two-wheeler.

METHODOLOGY

For this research, we had undergone through the following steps described in the following methodology flowchart.

Table 1: Methodology flowchart



ASSUMPTIONS AND CONSIDERATIONS IN EARLY STAGE OF DESIGNING

TRAIL-

It's the distance on the ground between a straight vertical line drawn through the Centre of the front wheel spindle and an axis line drawn through the Centre of the headstock axis. When the trail is larger than the straight line of vehicle stability is larger. It makes turning harder. Trail is measured in distance. Too much trail makes motorcycle difficult to turn and too little makes it unstable. Comparing the rake and trail numbers for different motorcycles, it may give you some idea of how much easier it would be to handle and how much the related between them is deep. To maintain good stability and proper handling with the fork angle being in the normal range, a certain amount of trail is designed in. Generally, there are exceptions such as the more trail a motorcycle has, the more stable it can be. However, increase the trail by too much and it gets back to chopper-like handling. So too little trail and the motorcycle's stability begins to be dramatically affected.

Figure 1: Trail

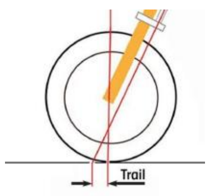
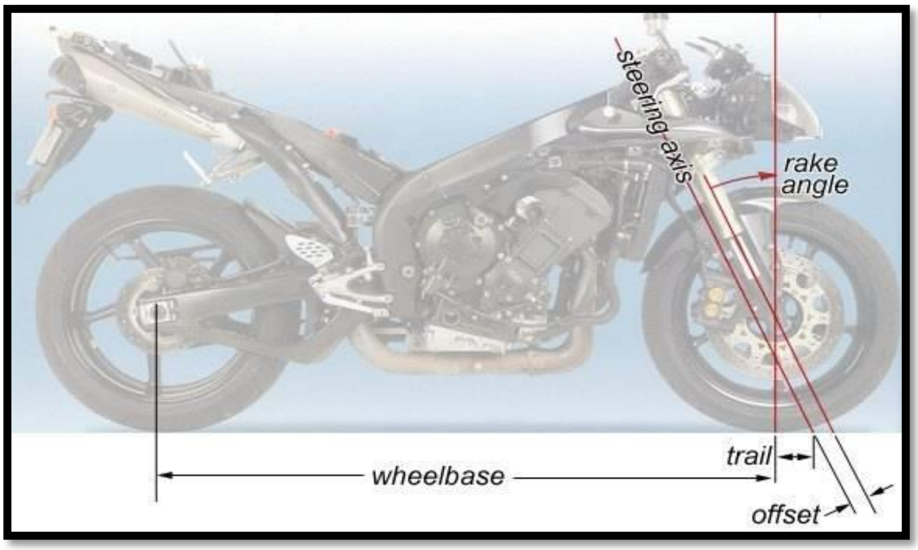


Figure 2: Standard geometry of a 110cc IC Engine bike



- Front Wheel Diameter: 610mm
- Rear Wheel Diameter: 457.2mm
- Rake Angle: 16-25 degrees
- Wheelbase: 1300 mm
- Trail: 127.39 mm

Load considerations-

- Rider and pillion weight- 100 kg
- Battery weight- 4×10 kg = 40 kg
- Another electrical components = 10 kg

III. MATHEMATICAL MODELLING RESULTS

Table 2: Results

Sr. No	Paramet ers	Valu e
1	Rolling Resistance	19.62 N
2	Grade resistance	0 N
3	Acceleration force	24 N
4	Total Tractive effort	43.62 N
5	Torque Required on the Drive Wheel	13.74 N-m
6	Load Torque	15.915 N-m
7	Charging Time	2 hr. 50 min
8	Range (at 50 kmph)	60 km (Appx)

Motor Specification	48-volt 30Ah (600 RPM)
Battery specification	4 batteries of 12-volt 30ah (in series)

As the above calculations suggest the torque required to move the vehicle is less than the torque developed by the hub motor. The motor will give a top speed of nearly 50kmph.The battery will take 2 hrs. 50 min to get full charged with a 500 -watt input. The battery will give a minimum range of approx. 60 km at top speed in a single charge.

So as per the above calculation the selection of a 48 -volt 30 Ah hub motor is suitable for the purpose and the four 12-volt batteries connected in series will provide enough range for the purpose to be served.

IV. CAD MODEL

Computer-aided design (**CAD**) is the use of computers to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. Designs made through CAD software are helpful in protecting products and inventions when used in patent applications.

CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. While designing of the CAD model of our chassis we have used CATIA V5 software as it was familiar to us and we have learnt it during the course of our syllabus. It is a multi- platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), PLM and 3D, developed by the French company Dassault Systems.

Figure 3: Electric Bike Layout

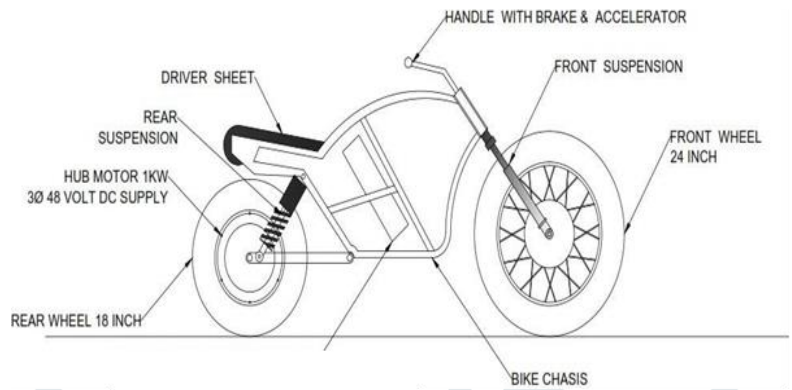
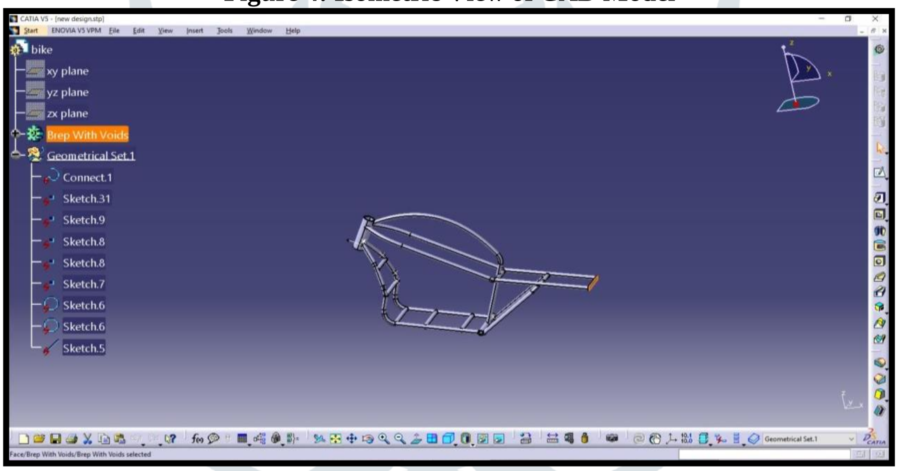


Figure 4: Isometric View of CAD Model



V. MATERIAL SELECTION

A motorcycle frame is the part that combines the seat, suspension, battery and Motor. The frame should be ideal, weigh a touch and will have perfect geometry. But more than these, the material utilized in the motorcycle frame should be better, large and will give fine handling. Therefore, the automobile engineer should focus more about the choice of material. The selection process should consider things like light weight, safety, economically effective and excellent comfort. Among these factors the engineers are using many materials through the years to produce the effective frame. The frame quality and character will vary with reference to the material utilized in the frame. The most frequent used materials are described. The material should have good rigidity and simple to work like welding. The material should have fine quality like light weight, strong, cheap in cost so that it fits the motorcycle perfectly.

- STEEL

Steel is a cheap material which can be used easily. It is popularly used as the frame in 70s and 80s. It is fine and heavy material to work. Even though they are cheap, the material gets eroded easily. The steel is stronger but harder to form. In light weight motorcycles the steel cannot be used as frame. It can get oxidized easily and cannot be used for a long time. It has good impact during crush situation, but the increased weight reduces the fuel economy of motorcycle. Many improvements have been done in steel to make it light weight and not affected by corrosion as it lasts longer. Meanwhile it is used in cheap motorcycles and not mostly in sports motorcycles

- CARBON FIBER

Comparing to steel and aluminum, the carbon fiber gives good rigidity and more light weight, but the standard of the motorcycles is reduced. Like titanium, the carbon fiber is also too costly. The motorcycle frames produced by carbon fiber are light in weight and has good mechanical properties. So only few bike frames are produced with carbon fiber. The carbon is combined with epoxy to get good results, but it has never been used in motorcycle frames.

- ALUMINIUM

Aluminum is used is modernized bikes as its most common character of light weight. It is also strong enough and light weight which made it to use these in most of the sports bikes. The material can be made more stiffness than steel which makes it better than other materials. The aluminum has good resistance against corrosion and in heat transmission. In recent times the using of aluminum material for frame is increased to large scale in both cars and motorcycle manufacturing. Many standard racing motorcycles are fitted with aluminum materials.

Mild Steel E250

Table 3: Mild Steel Properties

PROPERTIES	VALUE
Density	7850 kg/m3
Young's Modulus	210 GPa
Poisson's Ratio	0.3
Yield Strength	250 MPa
Ultimate Strength	410 MPa

Aluminum Alloy (AA6063)

Table 4: Aluminum Alloy Properties

PROPERTIES	VALUES
Density	2690 kg/m3
Young's Modulus	68.3 GPa
Poisson's Ratio	0.3
Yield Strength	160 MPa
Ultimate Strength	190 MPa

Carbon Fiber 230 GPa

Table 5: Carbon Fiber Properties

PROPERTIES	VALUES
Density	1800 kg/m3
Young's Modulus	230 GPa
Poisson's Ratio	0.1
Yield Strength	3.2 GPa
Ultimate Strength	3.5 GPa

VI. ANALYSIS

Finite Element Analysis Method

Finite Element Analysis consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. There are generally two types of analysis that are used: 2 -D modelling, and 3-D modelling. While 2-D modelling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modelling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress.

Points of interest may consist of fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

Steps involved in FEM

In general, there are three phases in any computer-aided engineering task:

- **Pre-processing** – defining the finite element model and environmental factors to be applied to it
- **Analysis solver** – solution of finite element model
- **Post-processing** of results using visualization tools

Pre-processing

The first step in using FEA, pre-processing, is constructing a finite element model of the structure to be analyzed. The input of a topological description of the structure's geometric features is required in most FEA packages. This can be in either 1D, 2D, or 3D form, modelled by line, shape, or surface representation, respectively, although nowadays 3D models are predominantly used. Once the finite element geometric model has been created, a meshing procedure is used to define and break up the model into small elements. In general, a finite element model is defined by a mesh network, which is made up of the geometric arrangement of elements and nodes. Nodes represent points at which features such as displacements are calculated. FEA packages use node numbers to serve as an identification tool in viewing solutions in structures such as deflections.

Analysis (Computation of solution)

The next stage of the FEA process is analysis. The FEM conducts a series of computational procedures involving applied forces, and the properties of the elements which produce a model solution. Such as structural analysis allows the determination of effects such as deformations, strains, and stresses which are caused by applied structural loads such as force, pressure and gravity.

Post-processing (Visualization)

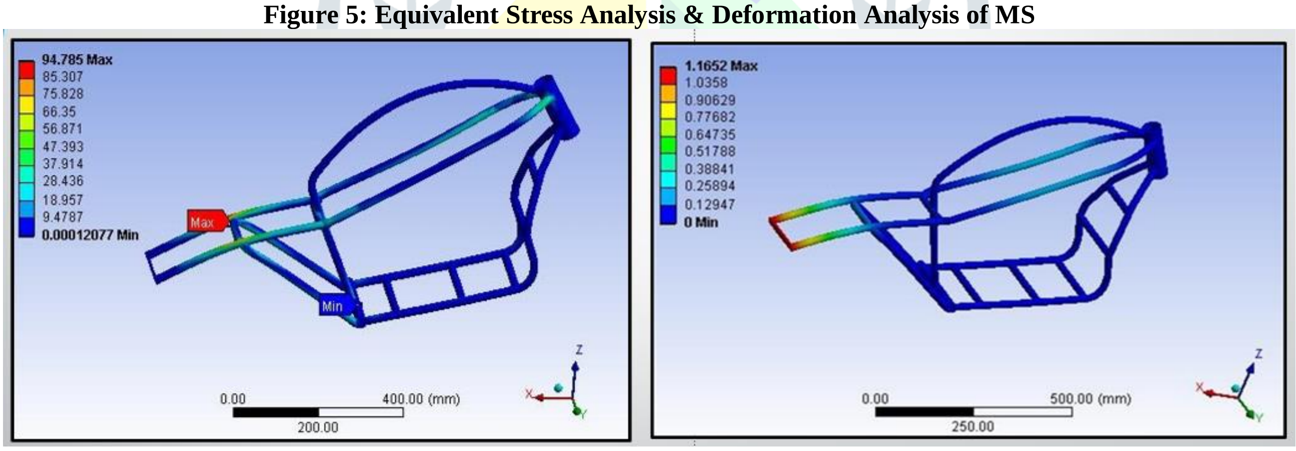
These results can then be studied using visualization tools within the FEA environment to view and to fully identify implications of the analysis. Numerical and graphical tools allow the precise location of data such as stresses and deflections to be identified.

FEA Solution Results (for MS E250):

No of Nodes: - 109537

No of Elements: - 56642.

Figure 5: Equivalent Stress Analysis & Deformation Analysis of MS

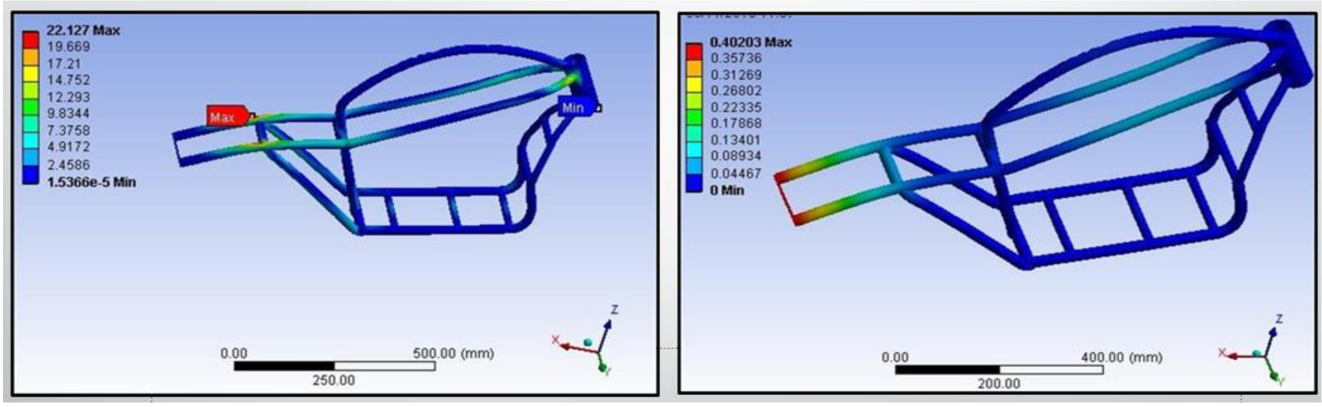


FEA Solution Results (for CF 230 GPa):

No of Nodes: - 51502.

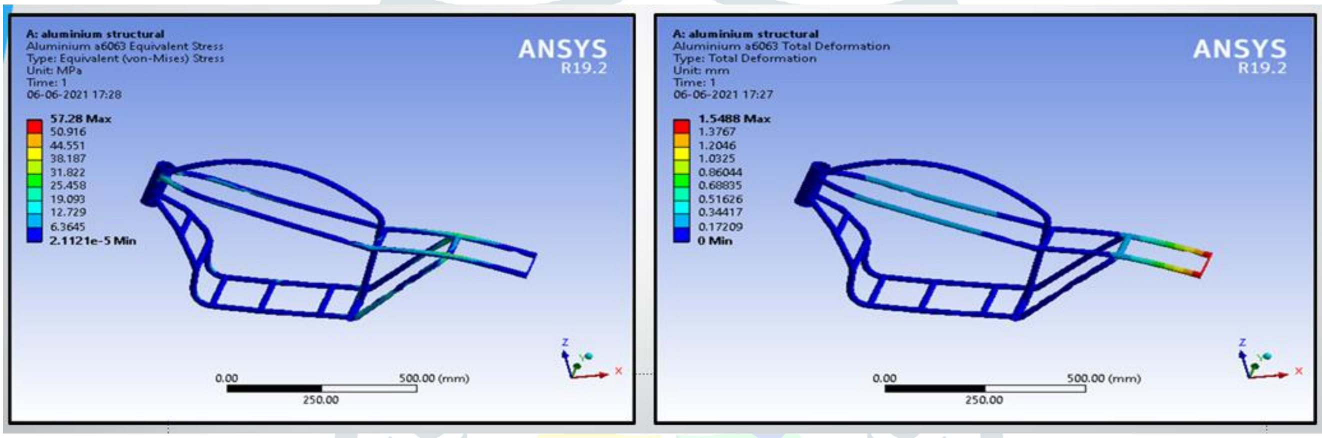
No of Elements: - 27325

Figure 6: Equivalent Stress Analysis & Deformation Analysis of Carbon Fiber



FEA Solution Results (for Aluminum Alloy AA6063):
No of Nodes: - 65925
No of Elements: -33469

Figure 7: Equivalent Stress Analysis & Deformation Analysis of Aluminum Alloy



VII. FEAM RESULT & DISCUSSION:

Table 6: FEAM Result

	Mild Steel (E250)		Carbon Fiber 230 GPa		Aluminum Alloy (AA6063)	
Stress	Yield Strength	Maximum Calculated stress	Yield Strength	Maximum Calculated stress	Yield Strength	Maximum Calculated stress
	250 MPa	94.785 MPa	3.2 GPa	22.127 MPa	160 MPa	57.28 MPa
Mass	9.535 kg		2.5048 kg		3.521 Kg	

As we can see in the above results all the three materials selected are safe for our design as the stresses induced in them are well within limits. If we talk about the mass of chassis using these different materials the Carbon fiber 230 GPa gives the lightest chassis which is 2.5 kg after that aluminum alloy forms a chassis of 3.5 kg and then the mild steel E250 with 9.5kg chassis, but after considering cost of material and cost of manufacturing of these chassis E250 turns out to be the most economical material which encourage us to select the same for our chassis.
shares on the factor scores.

Impact Analysis
In automobile design, crash and structural analysis are the two most important engineering processes in developing a high-quality vehicle. Computer simulation technologies have greatly enhanced the safety, reliability, and comfort, environmental and manufacturing efficiency of today's automobiles. This significant achievement was realized with the advanced software and

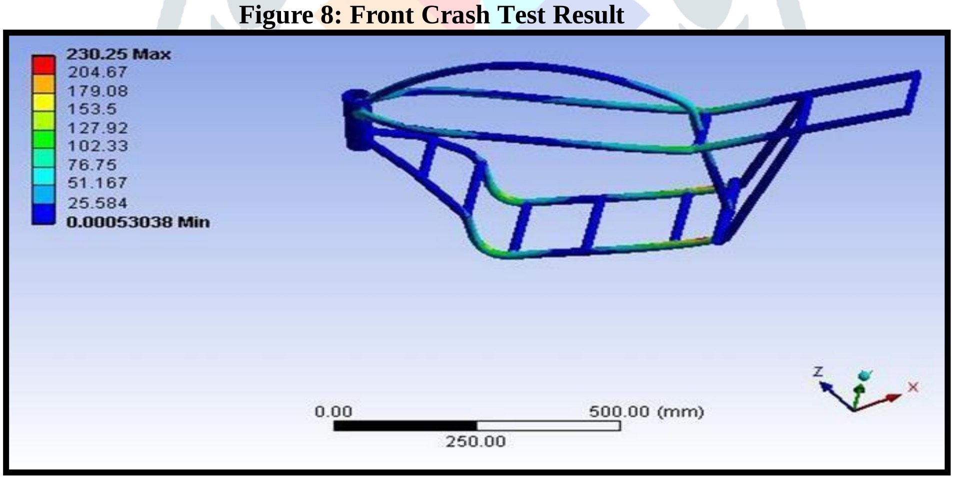
powerful computers that have been available in the last twenty years. The primary concern for drivers and passengers is safety. Governments have responded to this key concern and expectation with an increasing number of regulations. Although the details may vary slightly from country to country, the fundamental requirements are almost similar. A vehicle is expected to provide adequate protection to drivers and passengers in a not so serious accident. To protect the occupants of a car, there are many new tangible safety features such as airbags; ABS control brakes, traction A less tangible feature that cannot easily be seen by drivers and passengers is the crash response behavior. In a well-designed automobile, the car body and various components are the protective layer for the occupants of the vehicle. They serve as the crumpling zone to absorb the energy of impact. The traditional approach involves multiple iterations of design, prototype and crash tests. The process is time consuming and expensive. The availability of high- performance computers and crash simulation software has revolutionized the process. Instead of relying on experimental validations, the safety design process is supplemented with computer simulation to evaluate the design. Since the inception of crash simulation, the product cycle of a new automobile has been reduced by half and the resultant vehicle is safer, better and more comfortable.
Most auto bodies today use stamped sheet as structural members that are spot welded together to form a unitized body. This unitized structure is called the body -in white (BIW). BIW structural members support most of the loads designed for strength, fatigue resistance, stiffness, as well crush loads for crashworthiness.

Crashworthiness tests criteria and model requirements
In the automotive industry, crashworthiness connotes a measure of the vehicle's structural ability to plastically deform and yet maintain a sufficient survival space for its occupants in crashes involving reasonable deceleration loads. Restraint systems and occupant packaging can provide additional protection to reduce severe injuries and fatalities. Crashworthiness evaluation is ascertained by a combination of tests and analytical methods. Currently vehicle crashworthiness is evaluated in three distinct modes.

- Frontal.
- Side.
- Rear.

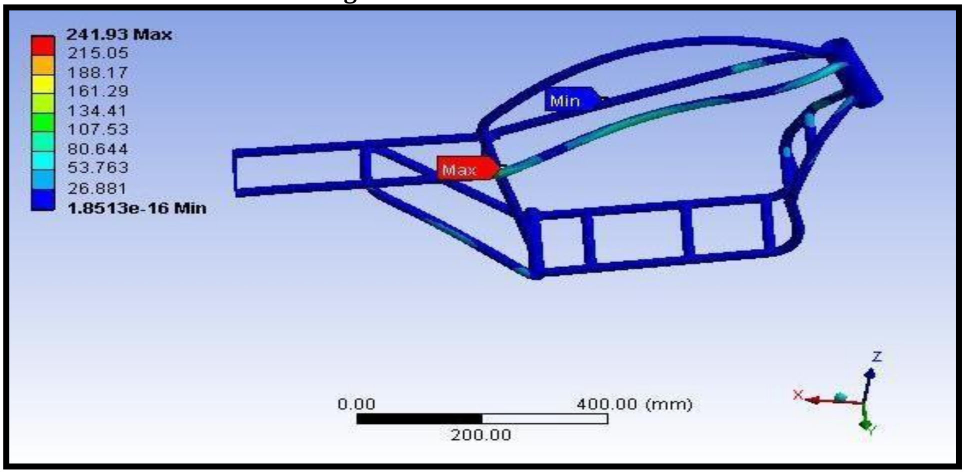
Frontal impact requirements:
- 60 kmph onto a fixed wall.
- Purpose of this test is to examine the Deformation & stresses developed in the chassis members.
- Evaluates the structural performance of the vehicle.

Figure 8: Front Crash Test Result



Side impact requirements:
- Impact Mass: 3700 N. (377.2949 Kg)
- Purpose of this test is to represent crash type that poses greatest risk to the riders (Striking Vehicle)
- Purpose of this test is to examine the Deformation & stresses developed in the chassis members.

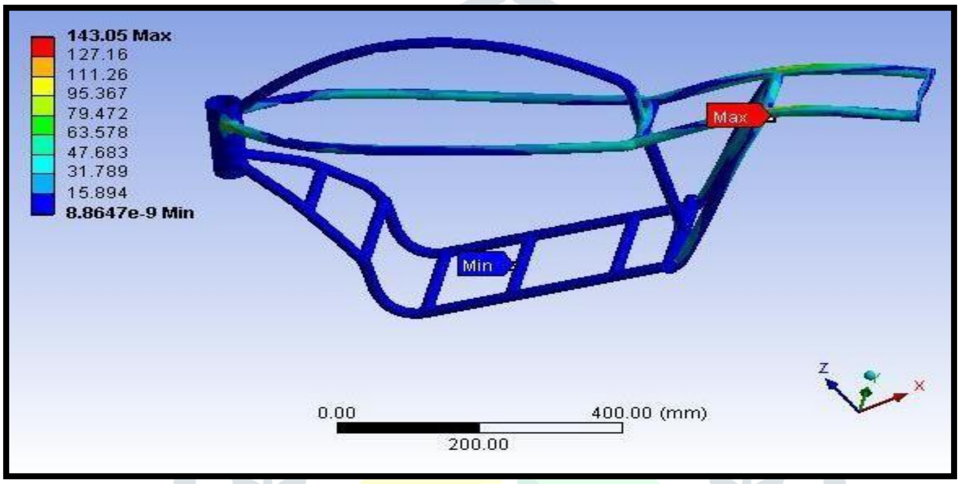
Figure 9: Side Crash Test Result



Rear impact requirements:

- Impact Mass: 3700 N. (377.2949 Kg)

Figure 10: Rear Crash Test Results

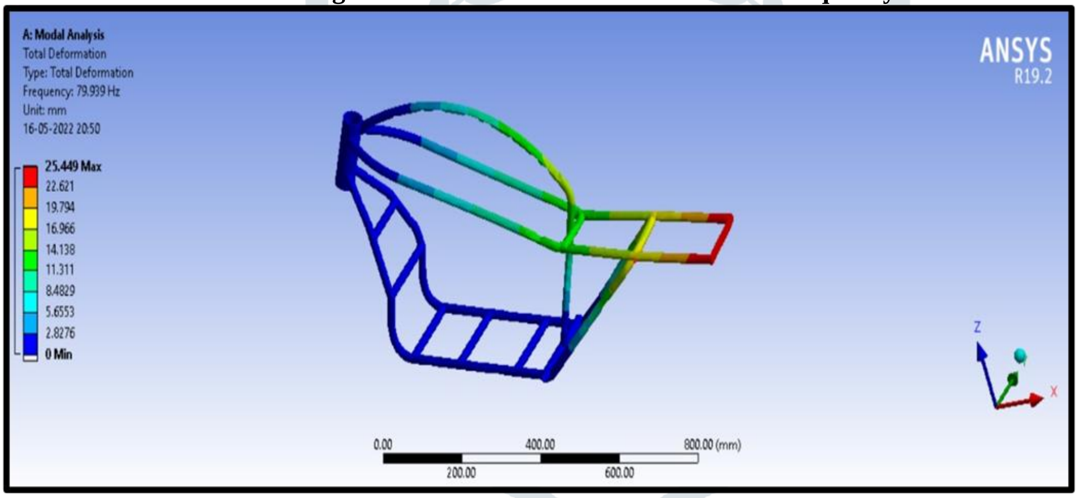


Modal Analysis

The frame is a skeleton upon which parts like Battery, controller and motor are mounted. So, it is very important that the frame should not buckle on uneven road surface. Also, it should not be transmitted distortion to the body. Two-wheeler frames can be made of steel, aluminum or an alloy. Mostly the frame is consisting of hollow tube. If the natural frequency of two-wheeler frame is coinciding with excitation frequency, then the resonance will occur. Due to resonance the frame will undergo dangerously large oscillation, which may lead excessive deflection and failure. To solve these problems, experimental modal analysis is very essential. Natural frequency, damping and mode shapes are the inherent structural properties and can be found out by experimental modal analysis. Experimental Modal analysis (EMA) is the process of determining the modal parameters of a structure for all modes in the frequency range of interest.

Modal analysis is an efficient tool for describing, understanding, and modelling structural dynamics. The dynamic behavior of a structure in a given frequency range can be modelled as a set of individual modes of vibration. The modal parameters that describe each mode are: natural frequency or resonance frequency, (modal) damping, and mode shape. The modal parameters of all the modes, within the frequency range of interest, represent a complete dynamic description of the structure. By using the modal parameters for the component, the model can subsequently be used to come up with possible solutions to individual Problems. Modal frequency response analysis is an alternative approach to determining the frequency response of a structure. Modal frequency response analysis uses the mode shapes of the structure to reduce the size, uncouple the equation of motion (when modal or no damping is used), and make the numerical solution more efficient. Due to the mode shapes are typically computed as part of characterization of the structure, modal frequency response Analysis is a natural extension of a normal mode analysis.

Figure 11: Mode Distribution & Natural Frequency



VIII. FUTURE DEVELOPMENTS

The most important possibilities for increasing energy efficiency of electric vehicles would be considered, regarding energy savings accumulated in the vehicle itself and increasing the range of performances of the cars with given initial resources. Some of the possibilities that should provide such a progress nowadays are

- Using energy under braking.
- Using waste heat energy generated in Brake drums.
- Additional supply by solar cells.
- Improved mechanical energy transmission system.
- Improved bike shell design.
- Increasing of efficiency of power convertors.
- Special design of electric engines.
- Using supercapacitors, fuel cells and new generation batteries.
- Route selection on the criterion of minimum consumption in real time.
- Parameter monitoring inside and outside of the vehicle and computerized system control with optimization of energy consumption.

Today, the problem of energy becomes so important that an entire industry is turning towards clean, renewable energy (solar energy, wind energy, etc.). Prototypes of hybrid vehicles with the announcement of mass production scheduled for the near future have become everyday occurrence. In addition, many cars are designed to use only electricity as motive power, which reduces emissions to zero. Photocells in a glass roof generate electricity, even at lower intensity of solar radiation; this current operates using a fan in a vehicle. In this way the vehicle interior has a constant supply of fresh air and pleasant temperatures (up to 50%

lower), although the motor vehicle is turned off so that fuel economy is evident. The solar roof is only the beginning, while the development of city cars is going toward solar vehicles prototype. A solar vehicle is an electric vehicle powered completely or significantly by direct solar energy. Usually, photovoltaic (PV) cells contained in solar panels convert the sun's energy directly into electric energy. The term "solar vehicle" usually implies that solar energy is used to power all or part of a vehicle's propulsion. Solar power may be also used to provide power for communications or controls or other auxiliary functions. Major efforts are invested in the development of high energy density batteries with minimum ESR. Also, current research show that fuel cells have reached needed performances for commercial use in electric vehicles. Supercapacitors that provide high power density increase the acceleration of vehicle as well as collecting all the energy from instant braking, therefore improvements of the characteristics of power supply are made.

IX. CONCLUSION

- The Concept Developed by us is a prototype of an electric bike propelled by the hub motor which can be used as a personal mobility vehicle preferable for a ride within 60- 70 Kms like for visiting University Campus, Grocery Shops & nearby Places.
- The design is finalized by keeping in mind that a vehicle should be pollution free, should provide better efficiency & comparatively reasonable cost. The prototype vehicle also plays a vital role in saving the fossil fuels as well as the air pollution.
- We have carried out mathematical modeling to support our selection of motor and battery with suggest that the motor is capable to drive the bike and the battery is sufficient to provide a range of about 60-70 km in a single charge.
- The CAD drawing gives an insight to the actual design of the chassis which we have validated in Ansys using different loading and materials.
- In that we found out the chassis designed is safe for all the static loading conditions for all three material which we have considered i.e., E250, AA6063, Carbon fiber 230 GPa.
- But in view of cost of manufacturing of chassis and cost of material. Chassis of AA6063 and Carbon fiber are highly Costly to manufacture and the cost of the material itself is also very high.
- Whereas the mild steel E250 is comparatively economical, and the manufacturing process required to make a chassis of E250 is also easily available at low cost.
- If we put aside the cost criteria Carbon fiber and AA6063 are highly preferable as they provide better strength to weight ratio which help to increase range of the vehicle and to reduce the overall weight of bike.
- Similarly, by keeping safety measures in mind we have performed various tests like Front Impact Crash Test, Side Impact Crash Test, Rear Impact crash Test, Modal Analysis, Natural Frequency Analysis of the vehicle chassis On Ansys Workbench and found that vehicle chassis is within permissible limits. We have aimed to develop to develop a standard chassis on which every electric vehicle kit will get installed or the existing kit can be replaced with new advanced one.

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