International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 8 Issue 01 Ver. I || Jan 2019 || PP 08-16

Design and Analysis of Frame of an Electric Bike

Vignesh.M*[1], Dr. Arumugam K[1], Vinoth.S[1], Hariharan.S[1]
[1]*(Department of Mechanical Engineering, Vel tech High tech Dr.Rangarajan Dr. Sakunthala Engineering College, India)*
Corresponding Author: Vignesh.M

Abstract: *E-bikes are electric bikes which are driven by the use of electricity as the source of fuel. E-bikes are opted for its eco-friendliness and cost-effectiveness for transportation. In the present study, optimum design for an electric bike was modeled and analyzed for stress and failure rate for commercial purpose. Frame is backbone of the bike; it supports and holds the whole load. The main objective of the paper was to design and fabricate a light weight still strong, safe, and economical than the conventional ones. The material used is of AISI standard. The analysis comprised of static simulations and torsional analysis for sudden impacts of all the components in the frame. It could be concluded that the design of the e-bikes was so fabricated that it could withstand impacts.*

Keywords *-Design, Frame, Electric bike, swing arm, Torsion Analysis.*

Date of Submission: 21-12-2018 Date of acceptance: 05-01-2019

I. Introduction

The rise of demand and constantly increasing cost of petrol and diesel has been ruling India for ages; society needed a non-negotiable solution especially in India. Transportation is very important and in order to augment it, people started seeking transportation by different means of energy. Electric vehicles gave a breakthrough solution to satisfy the needs required thereby it started to flourish, by overcoming the hindrance [1]. Electric Bikes are two wheeler vehicles which uses electricity as the source of fuel. Electric motorcycles are noiseless, pollution free, zero-emission, and electrically driven. The operation and speed are controlled by the battery. To extend the variety of e-bikes and improve the production, fuel cells and petrol-electric hybrids could be introduced which are also in the verge of development and thus improving the efficiency of the electric drive system. The usage of electric bikes has turned out to be a solution for reducing pollution to a larger extent. To burgeon the sale of e-bikes it needs to be enhanced in quality, hence in the present study the e-bikes are designed with frame which is light in weight when compared to conventional bikes for the purpose of efficacy.

II. Scope of the research

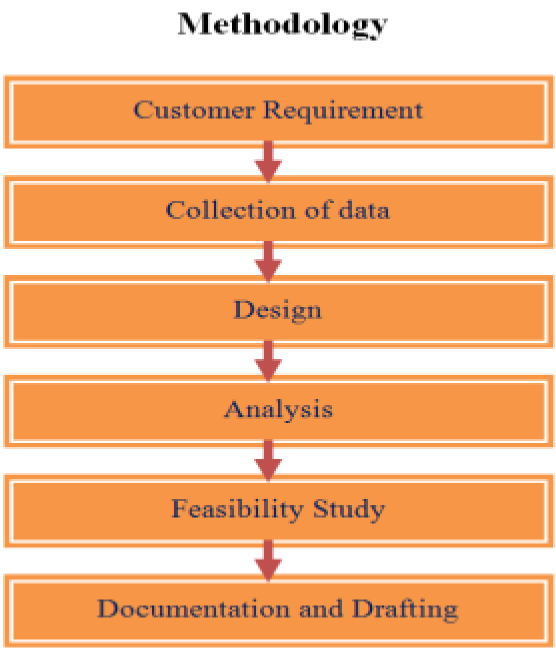
Manufacturers try to merge in the development of technology with their products with an illusion of solving the current populations demand thereby only increasing their profit, failing to consider the facts/conditions such as terrain, climatic changes, increased consumption rate etc.

This study concentrates on design of an e-bike, which would be effective, light weight as well as sturdy frame. In the present study, the electric bikes are designed and analyzed using design software namely Creo 2.0 and analysis software namely Ansys 15 and 16.

III. Methodology

The methodology section depicts a flowchart based on how the design and analysis of the frame was done, based on the requirement of the customer. The collection of data consists of several factors such as availability, machinablity, cost, reliability, feasibility and ergonomics. The total length, height and weight were also taken into considerations.

Figure I - Methodology



IV. Material Selection

The selection of the material in design depends on various factors such as load, function, climatic condition, lifetime, and overall expenditure. Taking the above factors into consideration, material selection was done in order to design an efficient and economical type of frame. Steel Alloys, Aluminium and its alloys, Titanium, Carbon Fiber were preferred type of materials during selection. Comparatively, AISI 4130 Alloy Steel [2] was used in the present study as it is easily available, cost effective, and has improved mechanical properties.

Table I - Material Composition

Element	Content (%)
Iron (Fe)	97.03 – 98.22
Chromium (Cr)	0.80 – 1.10
Manganese (Mn)	0.40 – 0.60
Carbon (C)	0.280 – 0.330
Silicon (Si)	0.15 – 0.30
Molybdenum (Mo)	0.15 – 0.25
Sulfur (S)	0.040
Phosphorous (P)	0.035

Table II - Mechanical Properties

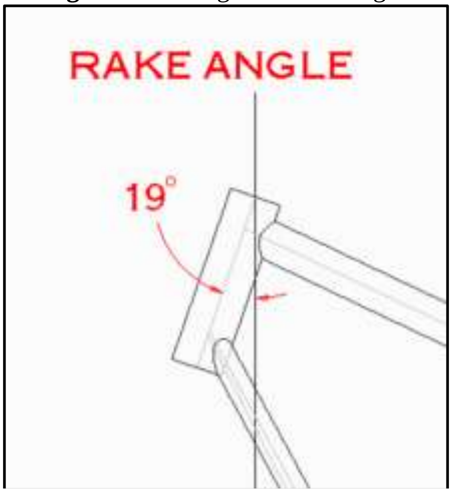
Properties	Metric
Ultimate Tensile strength	560 MPa
Yield Tensile strength	460 MPa
Modulus of elasticity	190-210 GPa
Bulk modulus	140 GPa
Shear modulus	80 GPa
Poisson's ratio	0.27-0.30
Density	7.85 g/cm³
Melting point	1432°C

V. Design

5.1 Selection of rake angle

The selection of rake angle is the crucial part in designing of bike frame. Rake Angle also called as steering head angle, which is the angle between the neck and the vertical axis of the wheel axle. It determines the type of vehicle whether it is a cruise or sport type vehicle. It plays a major role in inducing stability of the vehicle. The angle for the front neck with respect to the vertical axis is 19°which might optimize the length of bike [3].The figure II displays the design of rake angle.

Figure II - Design of Rake Angle



5.2 Setting of wheel base geometry

After the completion of neck angle, considering the wheel base of 1530mm, a base line is drawn to initiate the design of the frame for the mountings such as motor, battery, controllers and other accessories as per customer's requirements. It also includes the construction of the frame's main link seat tube; which acts as the base for placement of rider's seat as well as suspension. Additional significance is considered for the selection of the bend angle and diameter of the tubes. Finally the top tube, down tube and supporting structures were also considered and developed towards completion.

The design which was completed is being illustrated below [4].

Figure III - Design of Frame of Electric Bike

Figure III A- Front View

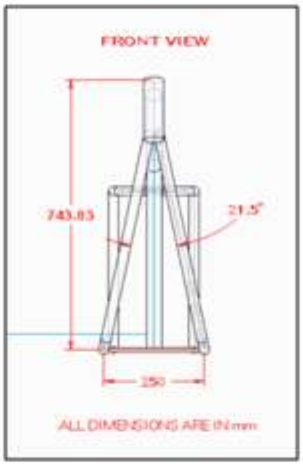


Figure III B- Top View

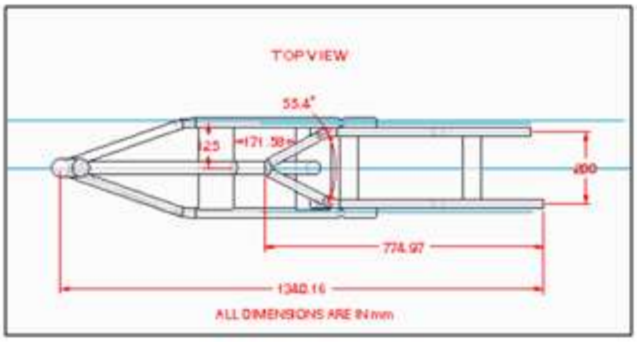
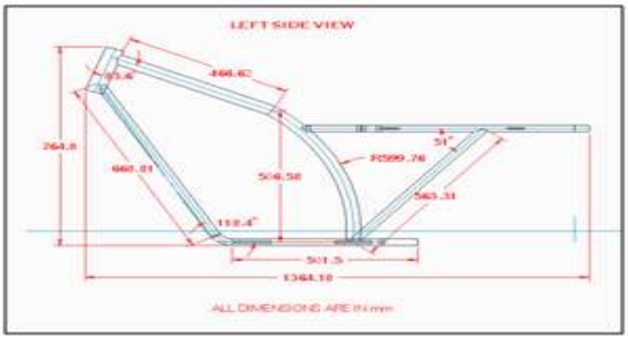


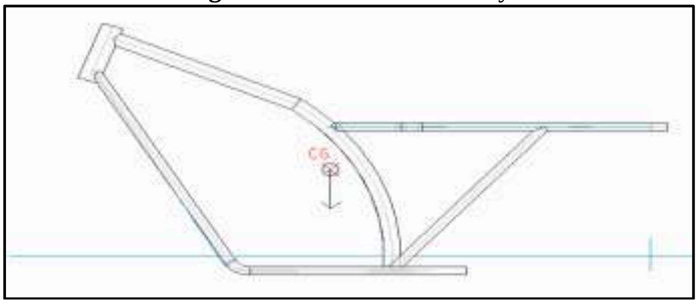
Figure III C – Left Side View



5.3 Centre of Gravity:

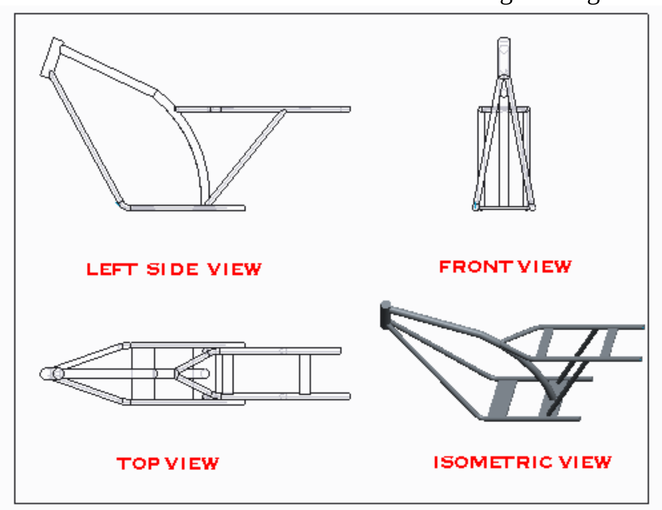
The center of gravity is the point where gravitational forces act in the body. In a uniform gravitational field, the center of mass serves as the center of gravity. A force applied to the center of gravity causes pure translation. The centre of the gravity is determined and denoted in this frame and displayed below [5, 6].

Figure IV – Centre of Gravity



The below figure illustrates the different directional views of our designed chassis.

Figure V- Different directional views drafted in engineering drawings

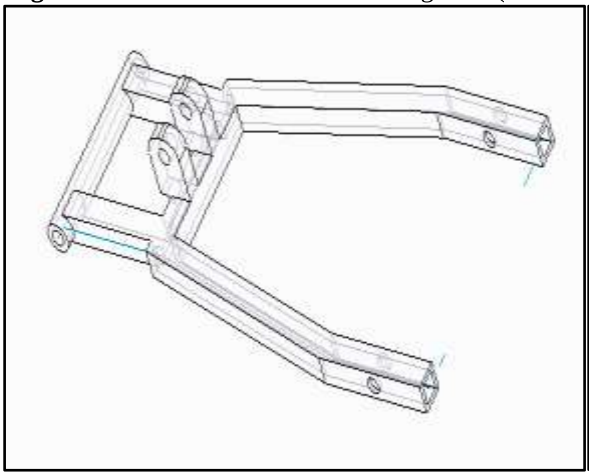


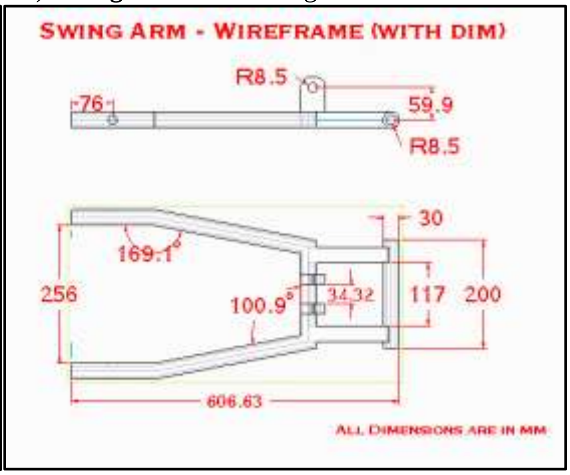
5.4 Swing Arm:

Swing arm is an ideal mechanical link which connects the suspension with transmission system. It was connected to chassis with the help of connecting pin. The suspension provides the action, in order to maintain the consistent contact between wheels and roads. For such sufficient action, the swing arm acts as the major platform for it [7].

The below figure displays isometric view of swing arm.

Figure VI A – Isometric view of Swing Arm (Wireframe) **Figure VI B** – Swing Arm with Dimensions

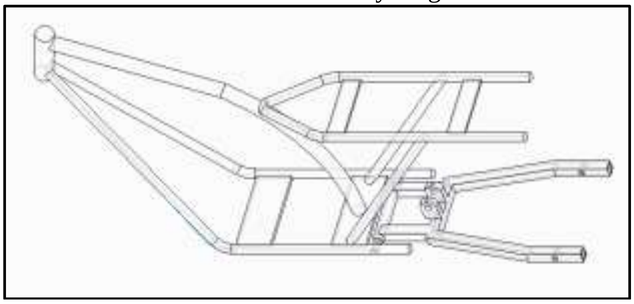




After design completion of frame and swing arm separately, assembly was performed by combining both the frame and the swing arm. Thus an assembled design was produced as a result.

An isometric view of Total frame after assembly is shown below.

Figure VII – Isometric View of assembly diagram of the whole frame



5.5 Design calculations

The following calculations are made considering that 2g force acts,

Approximated weight = 220 kg (the weight of the bike + driver)

Impact load = 2*9.81*220

= 4316.4 N

Also, Impact time = (Mass * Velocity)/Impact load

Assuming the maximum speed = 58 km/h,

i.e. velocity = 16.11 m/s

Impact time = (220*16.11)/4316.4

= 0.82 s

yield stress = 460 MPA

Table III - Factory of Safety

Front impact	Side impact
The total working stress for Front impact = 220.37 MPa FOS = 460/220.37 = 2.09	The total working stress for Side impact = 262.62 MPa FOS = 460/262.62 = 1.75
Rear impact	Torsion test
The total working stress for Rear impact = 244.71 MPa FOS = 460/244.71 = 1.88	The total working stress for Torsion impact = 180.92 MPa FOS = 460/180.92 = 2.54

VI. Analysis

6.1 Impact Test

The impact test is a method to resolve the toughness of the frame of the material under varying loading circumstances. The main concept is to test the robustness of the materials of the frame. During to impact loads, the material absorbs a certain amount of energy. If the absorbed energy exceeds the nominal limit of the material then breakage takes place. Thus the amount of energy that material could absorb can be determined. Material toughness basically determines the amount of the energy that could be absorbed, if this exceeds then fracture occurs [8].

With the aid of Computer Aided Engineering (CAE), the results of stresses been found out using Ansys software has been displayed below.

Table IV – Results of Ansys for Front Impact Test

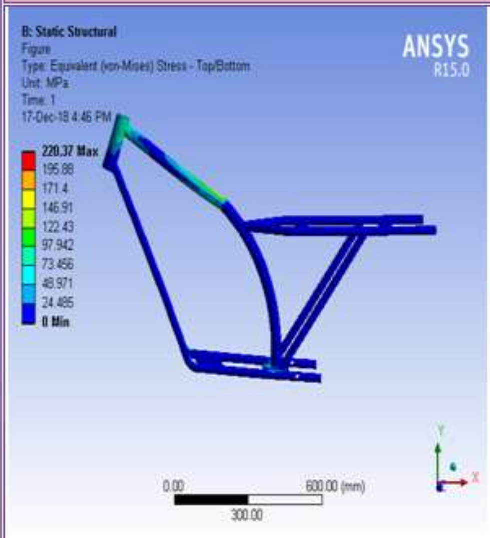
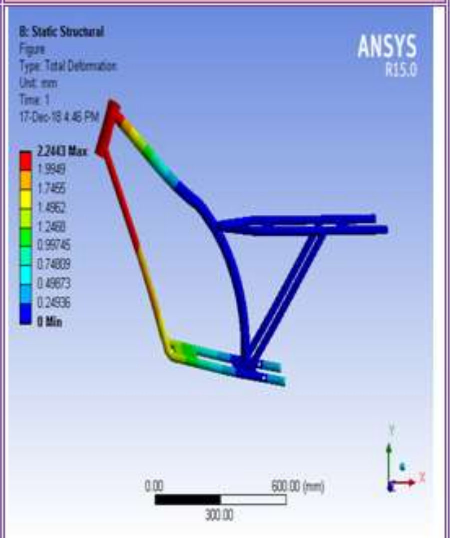
Front Stress	Front Deformation
	

Table V – Results of Ansys for Side Impact Test

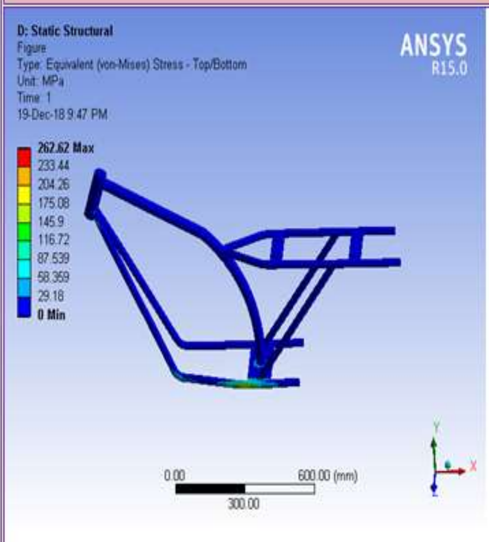
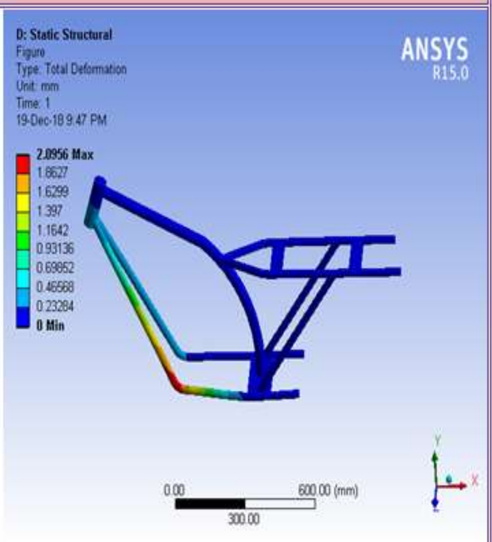
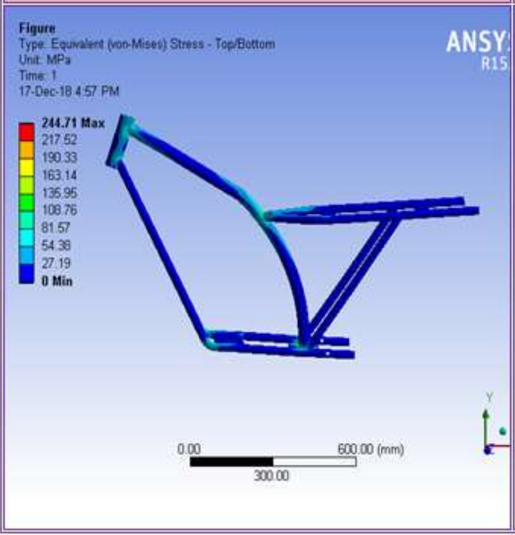
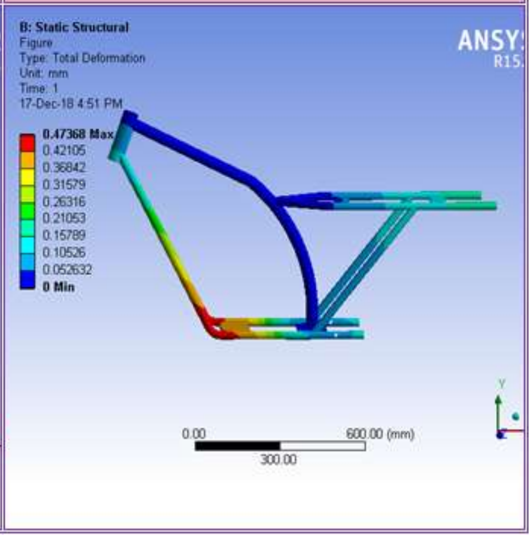
Side Stress	Side Deformation
	

Table VI – Results of Ansys for Rear Impact Test

Rear Stress	Rear Deformation
	

6.2 Torsional Test

The torsional test is done in order to prevent Torsional fatigue failure. Torsional Test is conducted in analyses in order to find out the performance of the structure when a twist or torsional force is acted upon if a load is transferred from suspension to the frame. Determination of the strength and rigidity of the material to withstand the loads is mandatory. Torsion test is used to measure the torsional strength, stiffness and stress-strain properties of the frame and to determine if there are any deformations in the frame. A vehicle traveling in an uneven ground environment, it causes frame deflections which are induced due to the load transfer from the suspension of the vehicles. Torsional stiffness plays an important role in these torsion tests.

With the aid of Computer Aided Engineering (CAE), the results of stresses been found out using Ansys software has been displayed below.

Table VII – Results of Ansys for Torsional Test

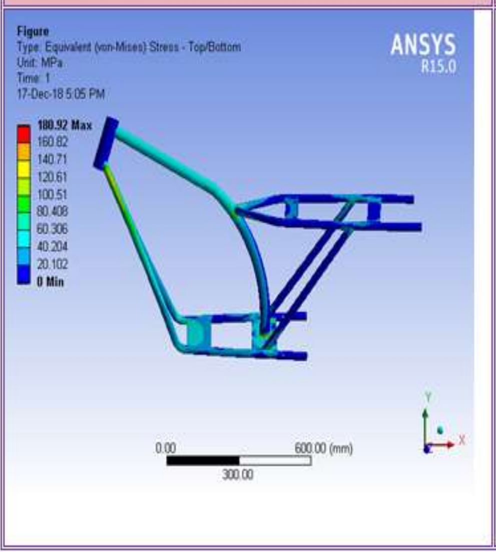
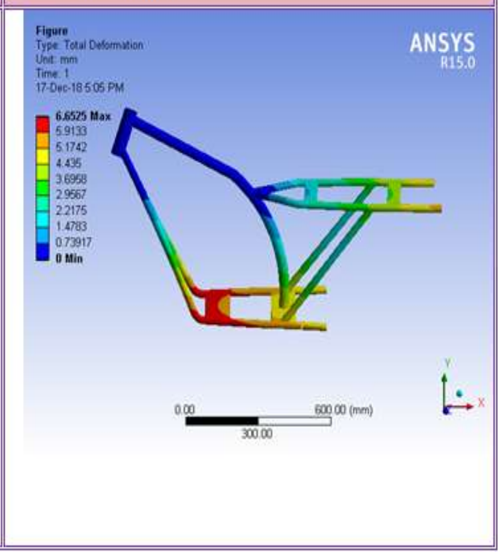
Torsional Stress	Torsional Defomation
	

Table VIII –Values taken from results of Analysis Test

Analysis	Load	Stress (MPa)	Deformation (mm)	FOS
Front Impact	2G	220.37	2.443	2.09
Side Impact		262.62	2.09	1.75
Rear Impact		244.71	1.821	1.88
Torsional		180.92	6.652	2.54

6.3 Harmonic Analyses

Harmonic response analysis is defined as the ability to predict the continuous dynamic behavior of the structures, through which we can verify whether the design is safe or not from resonance, fatigue etc.

Harmonic response analysis is a method used to find out the steady-state response of a linear structure of loads that fluctuate harmonically with time. Through this methodology, we receive a graphical output, of displacement versus frequency at several loads. Using this graph the peak responses are determined and stresses are distinguished at that point. It is of three different methods that can be calculated namely Full, Half, and Mode Super positioning. We have undergone the Mode super positioning method. Using the super Positioning mode, we have implemented the analyses and the results have been displayed below.

In this is process, the overall load of 220 kg has been divided and distributed at various required positions such as battery in the front, and weight of driver in the riders seat and the rest of the load at the bottom of the frame. The mode of deformation studied in this analysis is 8. The combined results of static analysis and modal analysis are then subjected to harmonic analysis, where the frequency of 255 Hz is then divided into 10 divisions to determine the cyclic loads. The variant loads applied on the chassis at different time intervals have been plotted between amplitude and frequencies.

Figure VIII –Graphical output of Freq VS Amp

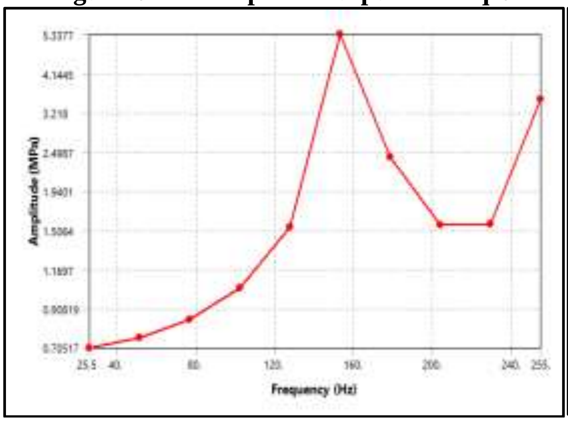


Figure IX – Result of Harmonic Response

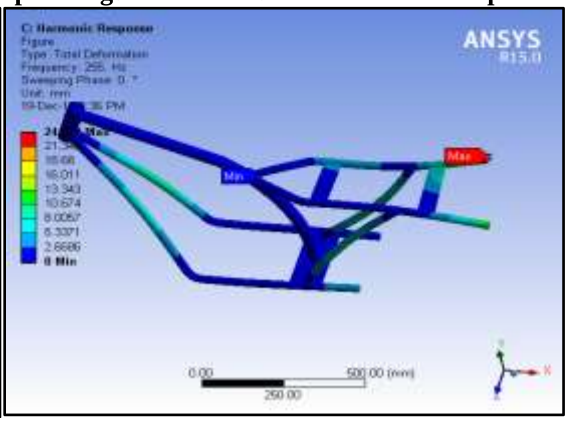


Table IX – Values taken from results of Harmonic Analysis

Mode	1	2	3	4	5	6	7	8
Min Displacement (mm)	0							
Max Displacement(mm)	26	25.51	26.33	30.87	39.326	30.482	28.307	47.001
Frequency(hz)	65.50	134.31	138.5	154.21	167.83	213.38	251.3	254.71

VII. Proposed Future Work

The entire design of the paper is based on backbone type frame, so if monocoque or other types of frame can be used, the end result must be verified whether it can be much more effective and reliable for the requirements. The design of the frame that this paper deals with can still be improved in many other ways to obtain superior and effective vehicle structure depending upon the various requirements. Different material can be substituted and analyzed for better efficiency, but still the material availability, machinablity and cost plays a major role in selection of different material. Swing Arm is yet to be in analyses progress.

VIII. Conclusion

- Using the results which are illustrated in the paper, the overall design is safe, effective, lightweight and reliable for the needs.
- Analysis results also prove to be much safer, still various analyses such as fatigue test and buckling can be done for finding our unsafe or non-reliable result.
- Instead of the material AISI 4130 various materials can be used such as carbon fiber and titanium.
- The carbon fiber and titanium alloy restricts the design as it costly but it is compared to be much stronger than the material we have used. So depending upon the requirement the efficient one can be chosen.
- Due to the choosing of AISI 4130, the loading conditions have been restricted, so if any other stronger material has been chosen the loading conditions can be expanded.

Reference

[1]. Abagnalea C, Cardoneb M, Iodicea P, Marialtoc R, Stranoa S, Terzoa M, Vorraroabc G., Design and Development of an Innovative E-Bike. Energy Procedia, 101, 2016, 774-781.
[2]. Ifeanyichukwu U. Onyenanu, Swift ONK, Atanmo PN, Design and Analysis of a Tubular Space Frame Chassis for FSAE Application, Journal of Emerging Technologies and Innovative Research, 2 (10), 2015, 497 -201.
[3]. Sagar Pardeshi 1 , Pankaj Desle 2, Design and Development of Effective Low Weight Racing Bicycle Frame, International Journal of Innovative Research in Science, Engineering and Technology, 3(12), 2014, 18215 - 18221
[4]. Ujjal Kalita, Yenduru Surya Teja, Darisi Sri Veera Venkata Manikanta., Design and Analysis of Go-Kart Chassis, International Journal of Engineering Development and Research, 6(2), 2018, 290-295.
[5]. Dr. Kirpal Singh, Automobile engineering Vol. 1 by 13th edition 2012, Standard publication, Delhi 13th edition 2013.
[6]. Dr. Kirpal Singh, Automobile engineering Vol. 2 by Standard publication, Delhi 13th edition 2014.
[7]. Ashish Powar, Hrishikesh Joshi, Sanket Khuley and Yesane DP. Analysis and Topological Optimization of Motorcycle Swing-Arm. International Journal of Current Engineering and Technology, Special Issue-6, 2016, 270-274.
[8]. Rishabh. S. Khobragade[1], Sanket Moriya[2], Design and Fabrication of SUPRA [F1] Vehicle, International Research Journal of Engineering and Technology, 5(9), 2018, 798- 808.

Vignesh.M" Design and Analysis of Frame of an Electric Bike" International Journal of Engineering Science Invention (IJESI), vol. 08, no. 01, 2019, pp 08-16