Design and Analysis of Hybrid E-bike chassis

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Abstract – *Chassis is an important and a crucial part of any vehicle system. It is a framework that provides a firm support to the vehicle. Chassis supports various component systems like drive train, engine, transmission system and suspension system. There are different types of chassis frames depending on the type of vehicle and its application. The project includes designing and analysis of a double-cradle frame chassis. This type of chassis is most commonly used in commuter bikes and café racers. A double-cradle frame consists of two adjacent tubes or pipes running under the engine. The major advantage of this type of chassis is that is cost-effective, highly stable and provides more strength and rigidity than downtube chassis. The design and modeling of chassis was done in Solidworks 2019, which is most widely used CAD package in industries. The testing and analysis of the chassis was performed with the help of ANSYS WORKBENCH 2020 R1. The analysis consists of the several impacts and scenarios where the chassis should withstand the loads and impacts. This development of chassis is based upon the ergonomic and structural studies to withstand the cyclic loading during the drive.*

Key Words: **Design, Chassis, Frame, Bicycle Frame, Bike, CAD, Solidworks, CAE, ANSYS, Structural analysis, FEA.**

1.INTRODUCTION

The bicycle is a known format of transportation and is being used over a century. Many iterations along with research and developments were made to make the chassis and a bike more user-friendly, more aesthetic, safe and more efficient for the rider. The main reason for research is to improve comfort, minimizing the mass of the frame, maximizing lateral stiffness in the load transfer from the hands, and feet to the drive, maximizing the strength capabilities of the frame to allow for a higher load capacity or a better load distribution, and adjusting the vertical compliance of the frame to tune the softness of the ride [10]. As a world is leading towards the use, and implementation of green energy or eco-friendly products, the bicycle is most opted a solution. There are numerous types of a chassis used in mobility solutions, but the most common and reliable chassis type used for a commute in a daily life is a double cradle chassis. The safety of the chassis or a frame is a major concern in the designing, and should be considered through all stages. The automotive chassis is tasked with holding all the components together while driving. This chassis design is a combination of an electric bike and a bicycle frame which meets the demands, and requirements of modern-day maneuvering, such as good-looking aesthetics, a posture of riding, a feel of riding the traditional bicycle, etc. The combination of these both concepts will be more appealing to an Indian society.

1.1 Problem Statement

To design and analyse chassis for hybrid electric bike that can sustain loads and impacts.

1.2 Objective

- To study the working of automobile chassis.
- To study the design procedure of chassis.
- To investigate the forces and loads acting on chassis.
- To prepare 3D CAD model of chassis according to ergonomic and force considerations.
- To perform finite element analysis on chassis to validate the chassis.
- To suggest solutions for new materials, changes in standard design and geometry.

1.3 Literature review

The need of electric bike i.e., green mobility solution which will be sustainable in future generations need the deep research and development [11]. The chassis used for the electric bike need to be light weight, firm, strong and rigid to hold all the components and withstand the forces [10]. The designing of the chassis considering human ergonomics and force considerations. Various analysis considerations and loads acts on frame while riding into various different cases which are enlisted by Bharati A. Tayadea, T.R. Deshmukhb in their research article [9]. The materials which can be preferred for manufacturing the most suitable and feasible chassis is also listed in article published by Mr. Rajeev Gupta, Mr. G.V.R. Seshagiri Rao [8].

2. Methodology

The methodology used in this paper consists of modeling the bike frame in Solidworks software and then analyze the chassis using Finite Element Analysis (FEA) software ANSYS Workbench. In this research paper, the designing of frame is done considering kinematics and strength of materials which will enhance the performance.

2.1 Material

There are wide range of materials used in bike frames, in earlier decades the bike frames were originally manufactured with wood, iron, etc. which made them heavy, fragile and unstable. On the contrary, in recent times fames are made primarily from aluminum, steel, titanium and carbon fiber.[8]

Table -2.1.1: Material Properties

Properties	Aluminium 6061T	Mild Steel 1018
Density (g/cm^3)	2.7	7.87
Modulus of Elasticity	68.9	205
Poisson's Ratio	0.33	0.290
Ultimate Tensile Strength (MPa)	310	440
Tensile Yield Strength (MPa)	276	370
Shear Modulus (GPa)	26	80
Weldability	Excellent (TIG welding)	Excellent and cheap (Arc welding)
Cost per Kg	Rs 177/Kg	Rs 43-54/Kg

2.2 CAD Modeling

The bike frame 3D modeling was done in Solidworks 2019 software. The main dimensions of the bike frame are shown below. Fig no. 2.2.1. The bike frame consists of many tubes, sheet metal, fixtures and mountings.

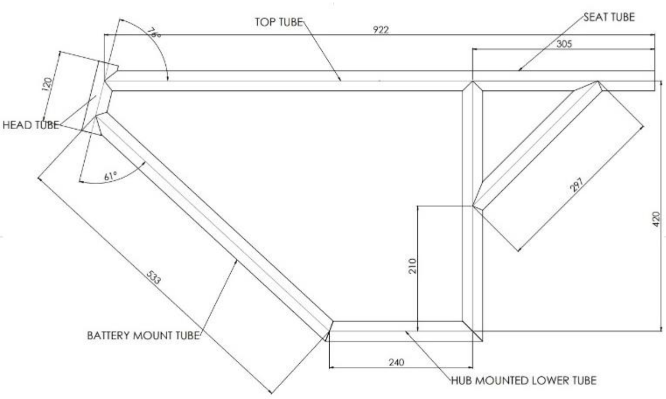

Fig. no. 2.2.1 Dimensional Sketch

The tubular chassis provides more strength and also reduces weight. The sheet metal is used for manufacturing of seat, battery and controller mounts. Specialized mountings are designed for specific parts such as swing arm, shock absorber, pedal hub, etc.

Solidworks provides variety of functions like planar sketch, 3D sketch, 3D modeling and extrusion, sheet metal, structural members, weldments, etc. The chassis was initially drawn in 3D sketch workspace according to the true scale dimensions of the bike. This was followed by adding structural members and weldments, so as to add tubes in the chassis. Once the tubular chassis is completed, the sheet metal command was used for making mounts for seat, fuel tank and battery mount. Dimensional draft was made with the Solidworks drafts.

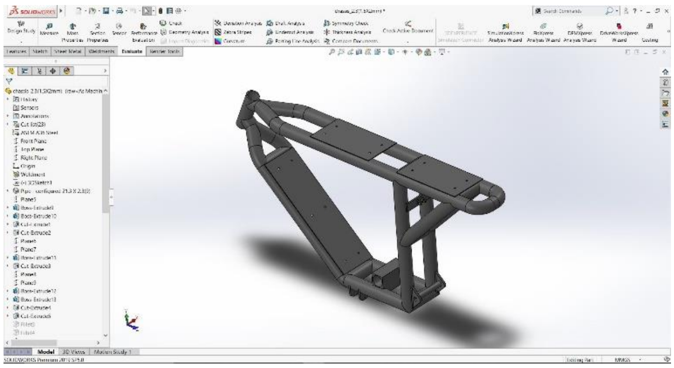

Fig -2.2.2: Chassis CAD model

Once the CAD model is created, the model is then rendered for capturing the different views. Rendering is a technique used to create realistic visuals of the CAD model. The tool used for rendering is Photoview 360 in Solidworks.

Fig -2.2.3: Chassis isometric view rendering

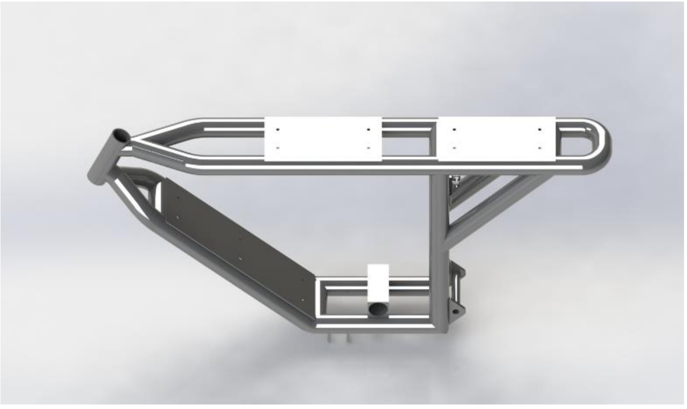

Fig -2.2.4: Chassis side-top view

2.3 Finite Element Analysis on chassis

The analysis is one of the important parts in automobile designing as it will test the designed model for various cases and determine the performance characteristics. The design created in Solidworks, is then imported to ANSYS Workbench project schematic. The model is imported as .igs format. the CAE analysis is categorized into three different parts pre-processing, solver and post processing.

2.3.1 Pre-processing

Pre-processing is the initial step of analysis, feeding the material properties i.e., engineering data in ANSYS Workbench library. There are two different kinds of materials are feed into ANSYS library. Then the further step will include the meshing. Meshing is discretization of components into small parts. Meshing is an integral part of the engineering simulation process where complex geometries are divided into simple elements that can be used as discrete local approximations of the larger domain. The mesh influences the accuracy, convergence and speed of the simulation.

Tetra mesh is been used for chassis with the following mesh parameters

Table no. 2.3.1.1 Mesh details

Sr. no	Parameter	Value
1	Element size	7 mm
2	Defeature size	0.035 mm
3	Capture curvature	0.0709 mm
4	Capture proximity	0.0709 mm

Statistics	
Nodes	104753
Elements	93124

Fig. no. 2.3.1.1 Nodes and elements created

Table no. 2.3.1.2 Mesh quality details

Sr. no.	Parameter	value
1	Element quality	0.7
2	Aspect ratio	2
3	Jacobian	1.1

2.3.2 Solver

ANSYS mechanical solver is taken into consideration the project schematic set as per scenarios chassis need to be tested. The conditions will be [9]

- **A. Static starts up-** this condition implies the initial starting or pedaling of bike.
- **B. Steady state pedal-** steadily peddling bike over normal road.
- **C. Front impact-** in the accidental situation, bike getting hit from front most side.
- **D. Rear impact-** in the accidental situation, bike getting hit from rear most side.
- **E. Rear wheel braking impact-** when rider applies brakes, due to swing arm it experiences rear impact at swing arm mount.

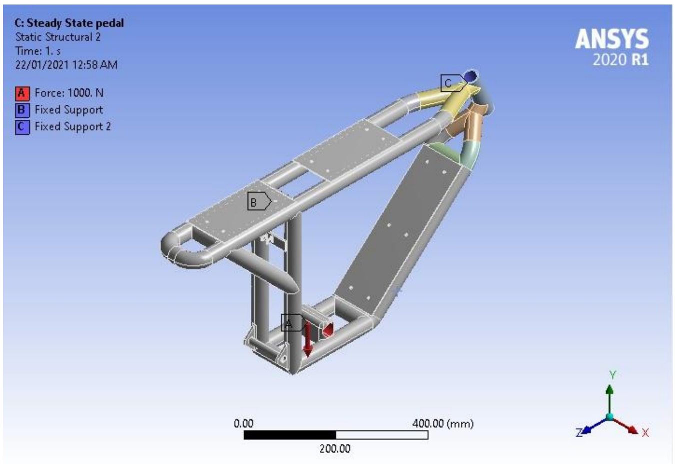

Fig no. 2.3.2.1 steady state pedal

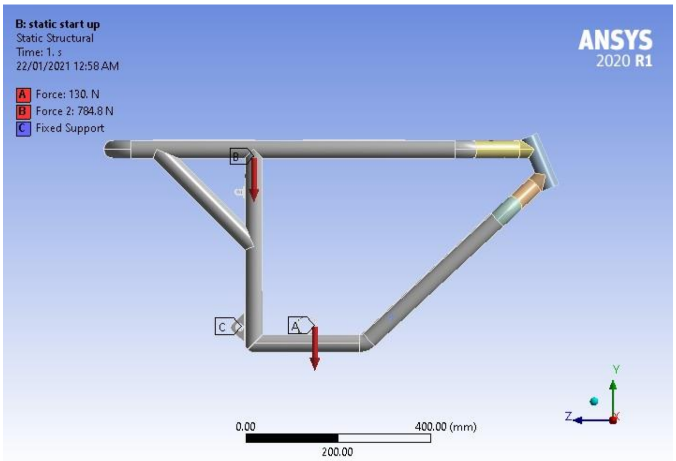

Fig. no. 2.3.2.2 Static start up

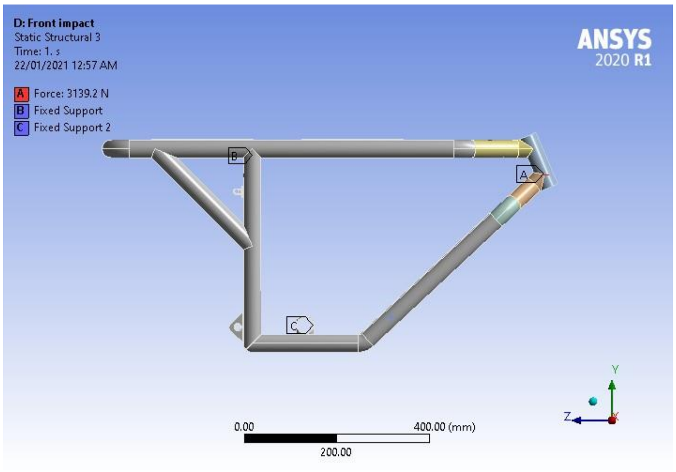

Fig. no.2.3.2.3 Front impact

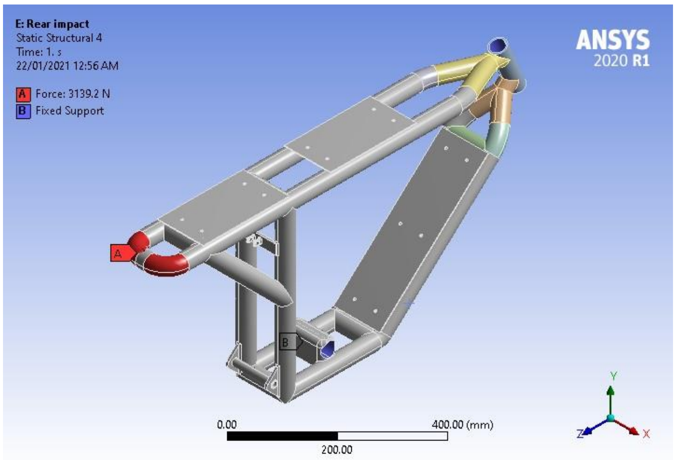

Fig. no.2.3.2.4 Rear impact

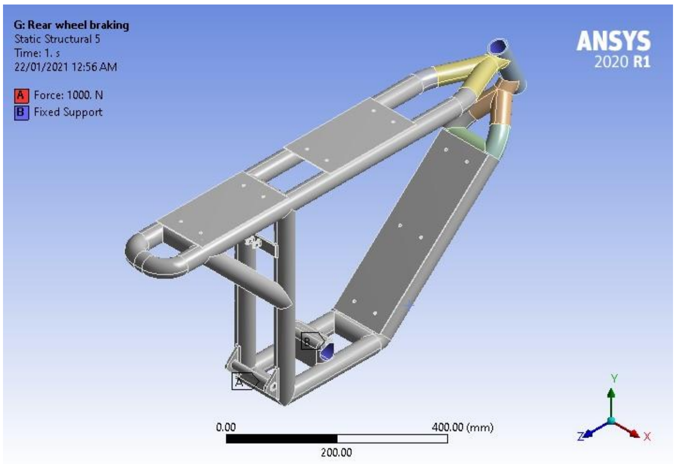

Fig. no. 2.3.2.5 Rear wheel braking

2.3.3 Post processing

Post processing is the ANSYS's inbuilt software which shows the results. After performing finite element analysis that is generating mesh, feeding the engineering data (material properties) and applying boundary conditions, the model is been solved. Investigation and reading the outputs post processor comes into picture.

Deformation, stresses and factor safety is calculated by the solver and ANSYS shows it in pictorial format.

i. **Results for MS 1018**

- **Deformation-**

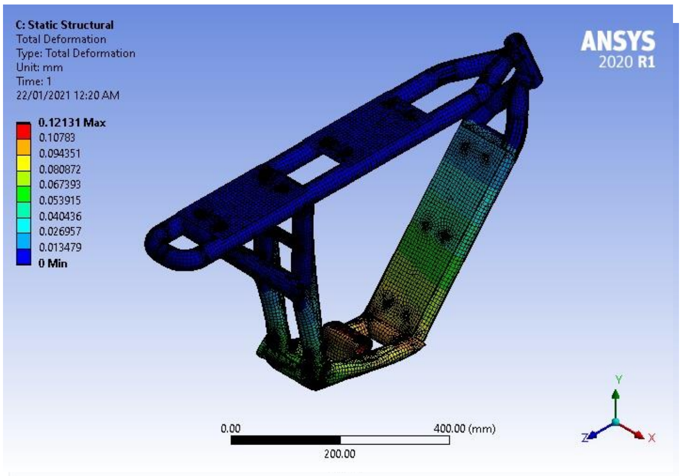

Fig. no. 2.3.3.1 Deformation static start up

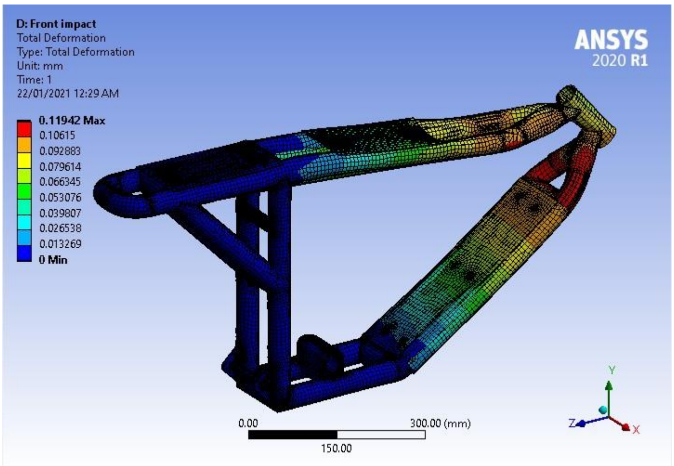

Fig. no. 2.3.3.2 Deformation steady state pedal
Fig. no. 2.3.3.3 Deformation front impact

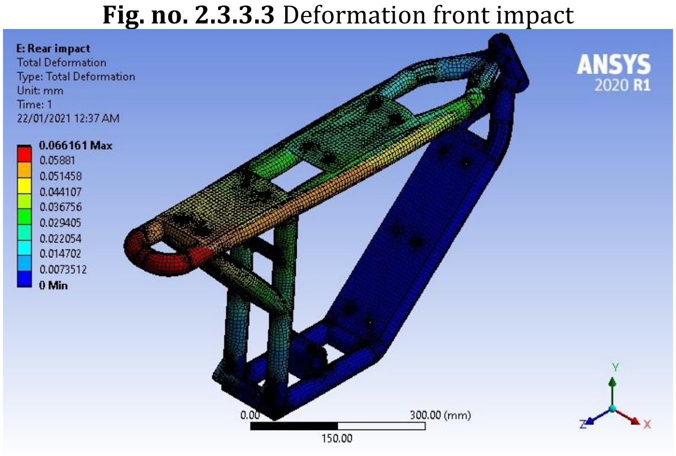

Fig. no. 2.3.3.4 Deformation rear impact

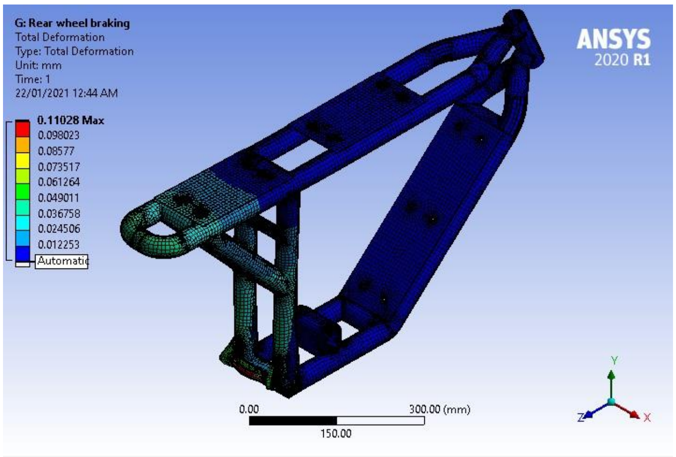

Fig. no. 2.3.3.5 Deformation rear wheel braking

- **Stress formation-**

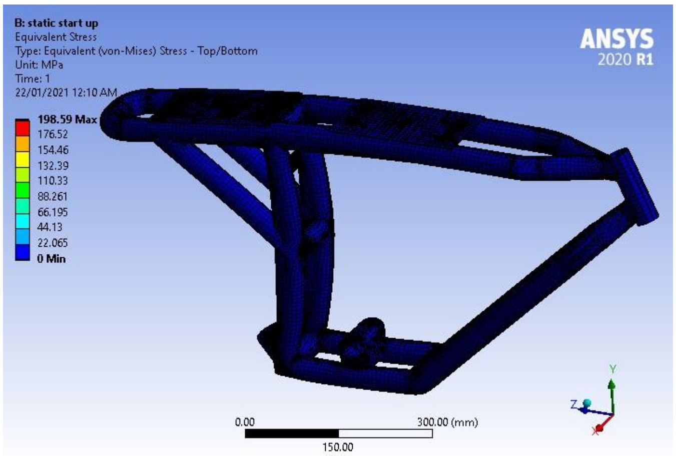

Fig. no. 2.3.3.6 Stress static start up

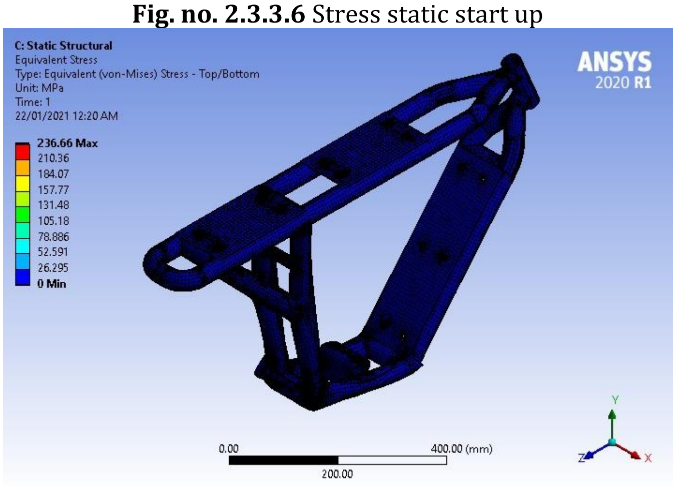

Fig. no. 2.3.3.7 Stress Steady state pedal

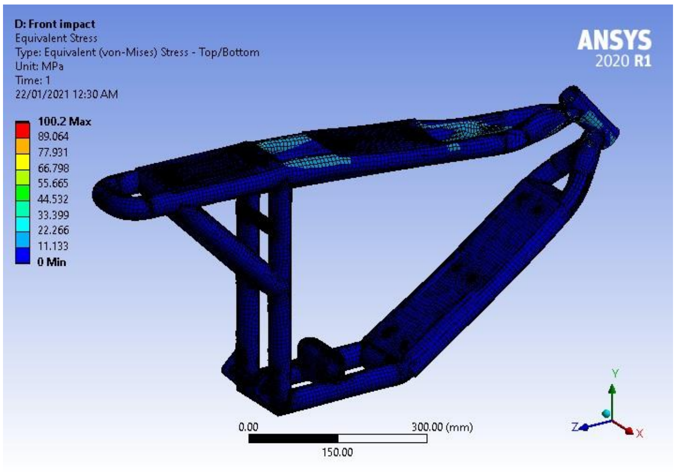

Fig. no. 2.3.3.8 Stress front impact

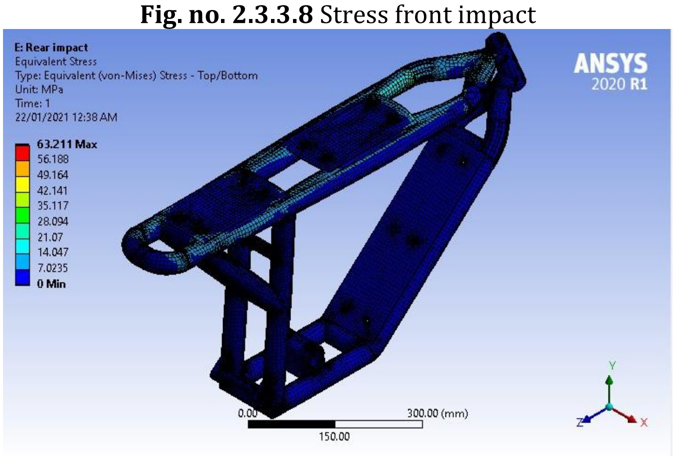

Fig. no. 2.3.3.9 Stress rear impact

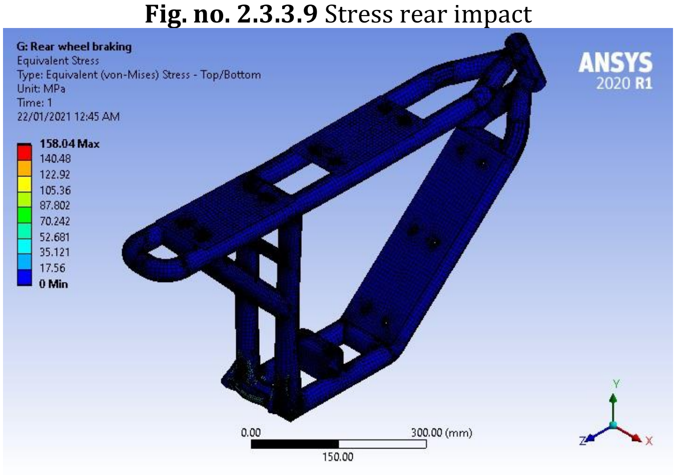

Fig. no. 2.3.3.10 Stress rear braking

ii. Results for Aluminium 6061 T

- **Deformation-**

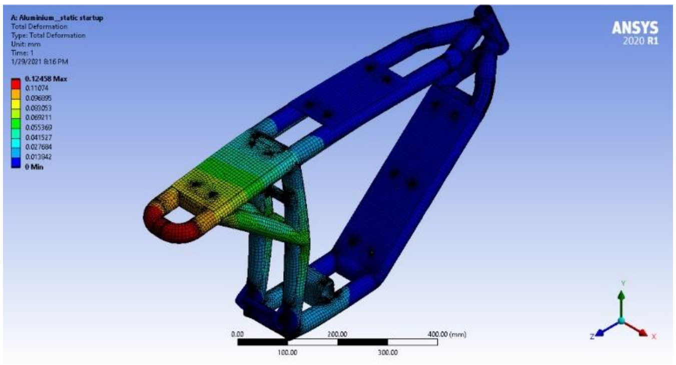

Fig. no. 2.3.3.11 Deformation static start up

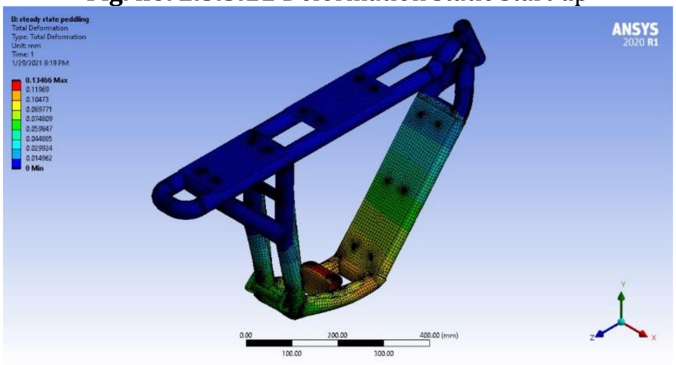

Fig. no. 2.3.3.12 Deformation steady state pedal

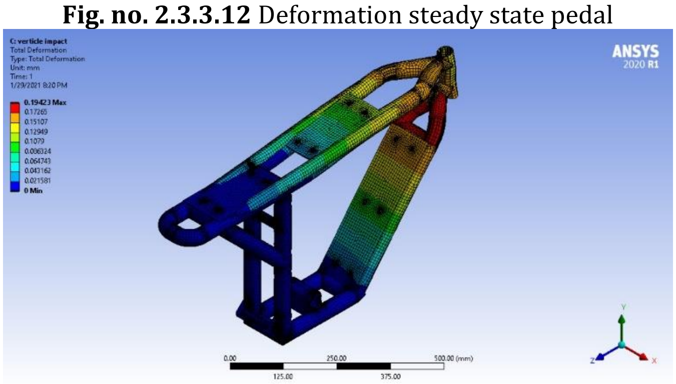

Fig. no. 2.3.3.13 Deformation front impact

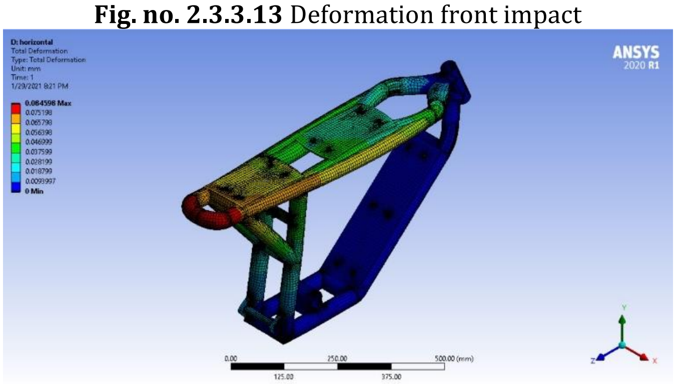

Fig. no. 2.3.3.14 Deformation rear impact

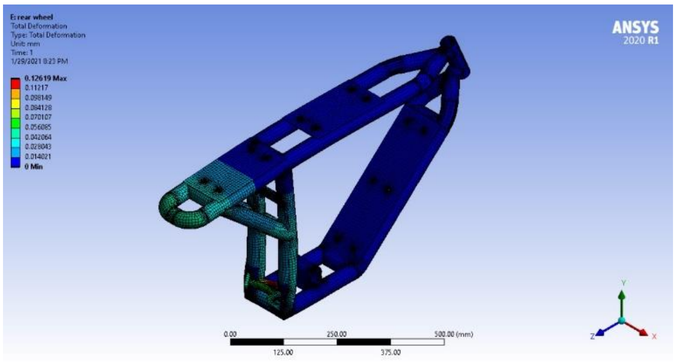

Fig.no. 2.3.3.15 Deformation rear wheel braking

- **Stress formation-**

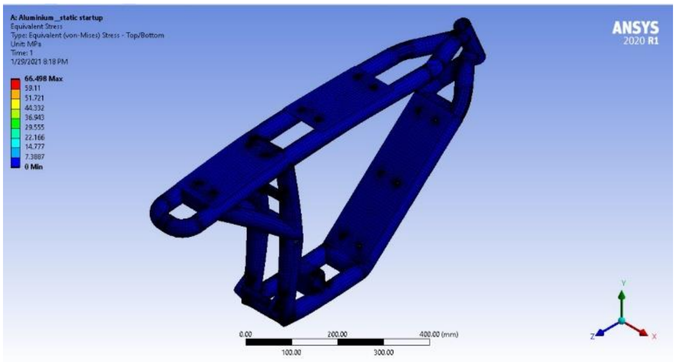

Fig no. 2.3.3.16 stress static start up

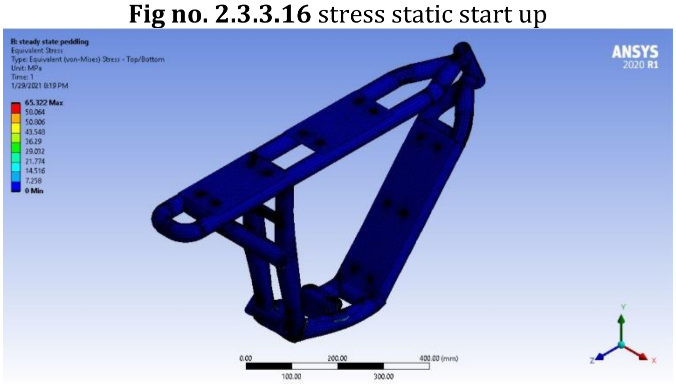

Fig. no. 2.3.3.17 stress steady state pedal

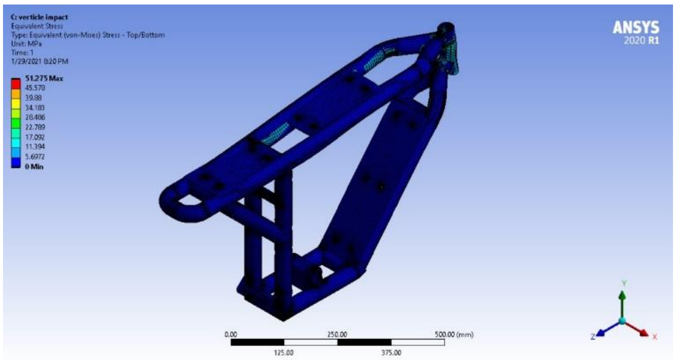

Fig. no. 2.3.3.18 stress front impact

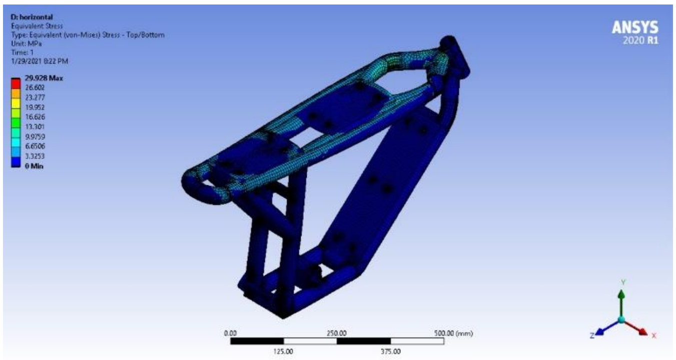

Fig. no. 2.3.3.19 stress rear impact

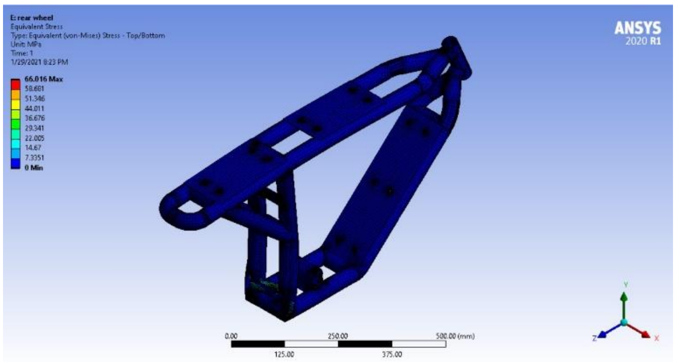

Fig. no. 2.3.3.20 stress rear wheel braking

Table no. 2.3.3.1 Result table

Sr. no.	Conditions	Deformation (mm)		Equivalent Von Misses Stress (MPa)		FOS	
		MS 1018	Al 6061 T	MS 1018	Al 6061 T	MS 1018	Al 6061 T
1	Static start up	0.1	0.12	198.5	66.49	1.86	4.15
2	Steady state pedal	0.12	0.13	236.6	65.32	1.56	4.2
3	Front impact	0.11	0.19	100.2	51.27	2.49	5
4	Rear impact	0.06	0.08	63.21	29.92	3.95	9.2
5	Rear wheel braking impact	0.11	0.12	158.4	63.16	2.34	4.18

Chart no. 2.3.3.1 Deformation comparison

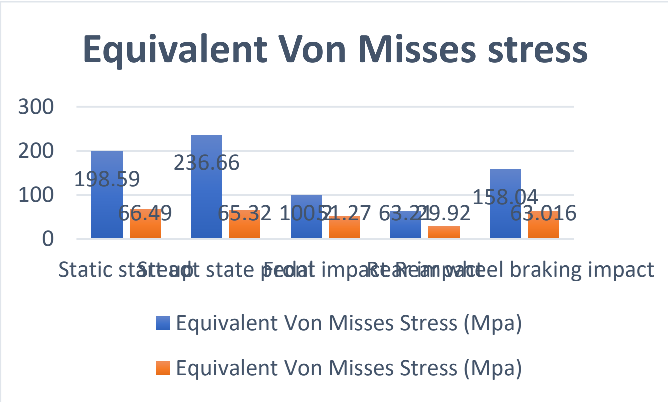

Chart no. 2.3.3.2 Equivalent von misses stress comparison

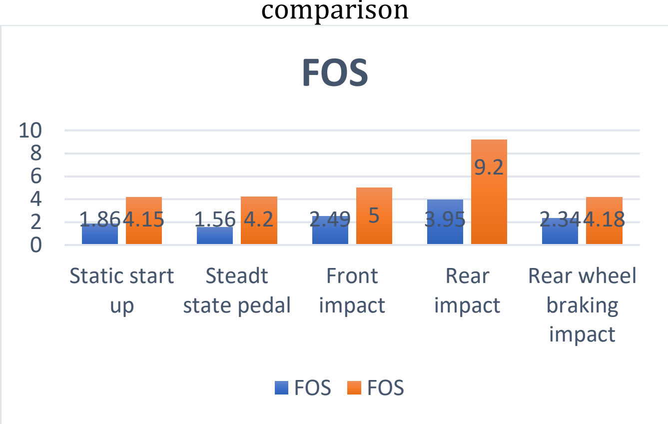

Chart no. 2.3.3.3 FOS comparison

3. CONCLUSIONS

[1] From the results derived by FEA analysis, the chassis design is safe in all applied conditions and shows negligible deformation under the loads applied. The FOS calculated is well within the safe limits while stress concentration is also under safe zone.
[2] By comparing the FEA results of two materials used for manufacturing of bike frame as analyzed. And according to the results, aluminium shows the better FOS results and less stress concentration. While MS 1018 shows the significant FOS and stress values which are also fail safe. Deformation of both the materials is almost similar. MS 1018 will be preferred over AL 6061 T because it shows similar deformation, it is cost effective and possesses higher weld efficiency.
[3] From this it is concluded that using MS for chassis will increase the weight because of higher density but at the same time it gives more strength, rigidity, weldability and reduces cost.

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