iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** VI **Month of publication:** June 2019

DOI: http://doi.org/10.22214/ijraset.2019.6202

Analysis of Mountain Bike Frames by ANSYS

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Abstract: The main aim of this paper is to outlines the use of a finite element model to study the behaviour for a standard bicycle frames under a range of measured cases. Here some load cases are considered. The load cases are mainly given at key areas as the hub, the bottom, handlebars, seat post and saddle. The occurrence of load situation which occur at the time of riding and climbing. The stress acting within the bicycle are analyzed with respect of frame performance relating to static strength related to load applied. Most modern bicycle have diamond shaped frame. The solution to the existing problem is to provide the most reliable and a proven tool of structural engineering: Finite Element Analysis (FEA) and ANSYS. The modelling of the frame is done on SOLIDWORKS with development of several concepts for the performance of the frame. In this project the bicycle frame is replaced with Magnesium alloy (AZ91D) to perform analysis by ANSYS, ie for static analysis under different load conditions. The alloy taken for analysis is compared with Aluminium 6061-T6. For that a particular weight of the person was considered ranging from 80-100 kg.
Keywords: Bicycle frames, finite element analysis (FEA), ANSYS, Mg AZ910, Al 6061-T6

I. INTRODUCTION

The mountain bike or mountain bicycle is mainly designed for off-roading. Mountain bikes have many similarities with other bikes, but have many features designed to enhance durability and performance in any terrain. This mainly consist of a front or full suspension, large knobby tires , more durable wheels , more powerful brakes, and lower gear ratios for climbing steep grades. Mountain bikes are typically ridden on mountain trails, single track, and other unpaved surfaces. These are built to handle these types of terrain and features. This type style for bicycle is made with heavy- weight construction mixed with stronger rims and wider tires. The frame is designed to support the external loads acting on the bicycle. The traditional materials used in mountain bicycle frame were steel or aluminium alloy. The structural analysis of the frame is a very important stage in the design process of the bicycle. The finite element method was used to analysis the structural behaviours of mountain bicycle frame. Mountain bicycle frame modelling was done in SOLIDWORKS software. The analysis of the frame was done using ANSYS 16 software.

The development of new material is based on the need for low weight coupled with high strength and stiffness acting on bicycles. The solution for the existing problem is to provide the most reliable and a proven tool of structural engineering; the Finite Element Analysis Method (FEA) and ANSYS. This paper focuses on comparing the selected material for bicycle frame on the basis of less cost and deformation occurring with high strength and performance. This can be done by using structural material like FEA analysis.

II. METHODOLOGY

A. Project Description

The mountain bike traditional material is replaced with the advanced composite materials to increase the strength and reduce the cost. The replacement of the material used for manufacturing bicycle frames with magnesium alloy and perform the strength, FEM ,structural analysis, analysis, static analysis, dynamic analysis and report the variations under different loading conditions.

B. Material Selection

Material having high tensile and compressive strength, having high corrosive resistance, low cost are the material properties to be required for this frame. Magnesium alloy, Aluminium alloy(low cost) materials are selected for this process.

TABLE 1
MECHANICAL PROPERTIES OF THE MATERIAL SELECTED

Alloy	Density (g/cc)	Modulus of Elasticity (GPa)	Poisson's Ratio	Ultimate Tensile Strength (MPa)	Tensile Yield Strength (MPa)	Shear Modulus (GPa)
Aluminium 6061-T6	2.7	68.9	0.33	310	276	26
Magnesium AZ91D	1.89	55	0.29	160	240	17

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue VI, June 2019- Available at www.ijraset.com

C. Design

The mountain bike frame modelling was done in SOLIDWORKS software. The main dimension of the mountain bike consists of many tubes made of AZ91D and Al 6061- T6. The frame is the main component of a bicycle, in which that the wheels and other components are connected. The main parts of the mountain bike frame can be divided into top tube, seat tube, front tube, rear tube, suspension.

TABLE II
Design Parameters Of Bike Frame

PARAMETER	VALUE
Head tube angle	73.50
Seat tube angle	73.50
Seat tube length	580 mm
Top tube length	570 mm
Chain stay length	360 mm
Head tube length	120 mm

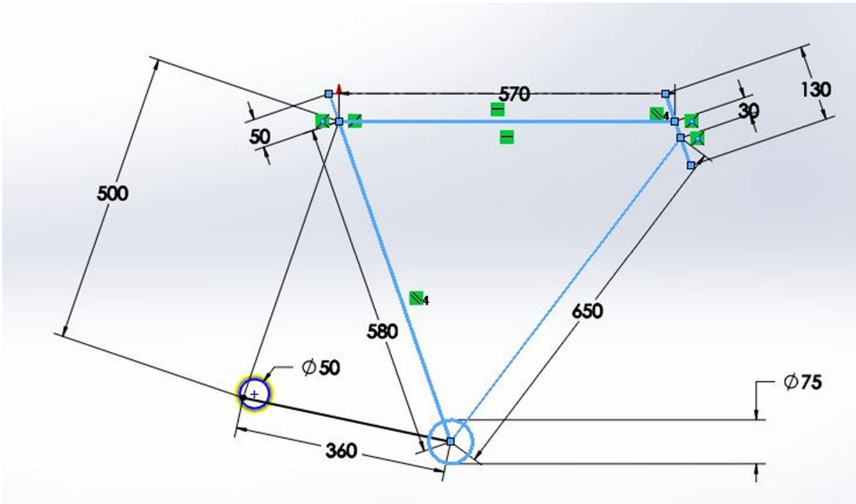

Fig. 1 Sketched model

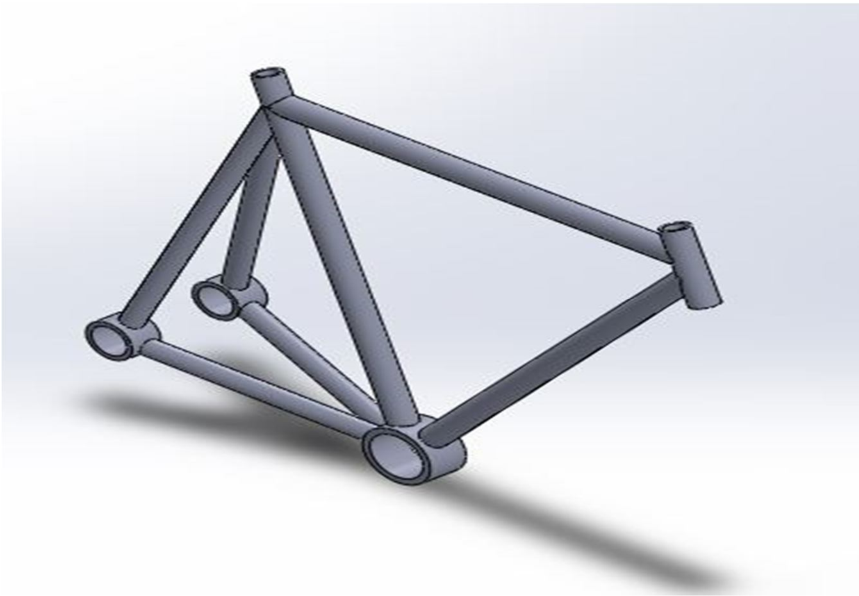

Fig. 2 3 D Model

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
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D. Analysis

To verify the stresses for bicycle frame it is compared with FEA analysis. The problem to be modelled is a simple bicycle frame shown in the following figure. The frame is to be built of 2 different alloys

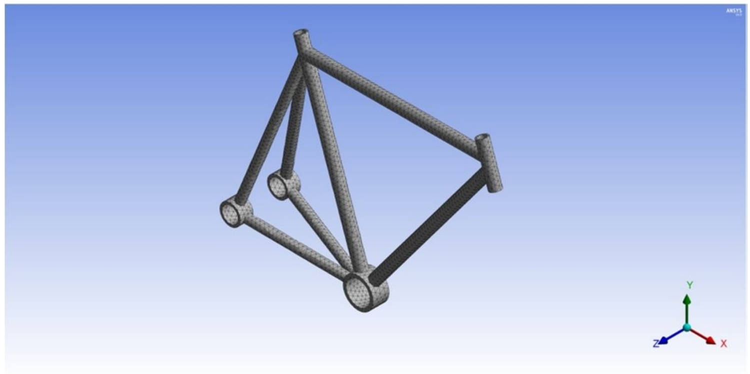

Fig. 3 Bike frame with meshing of 5mm

1) *Loads and Boundary Conditions*: The modelled bicycle frame is made to apply with following load cases as a part of the investigation of the frame. The load cases are applied on all the 5 frames individually. The load cases are namely:

a) Static start up.
b) Steady state pedalling.
c) Vertical impact.
d) Horizontal impact.
e) Rear wheel braking.

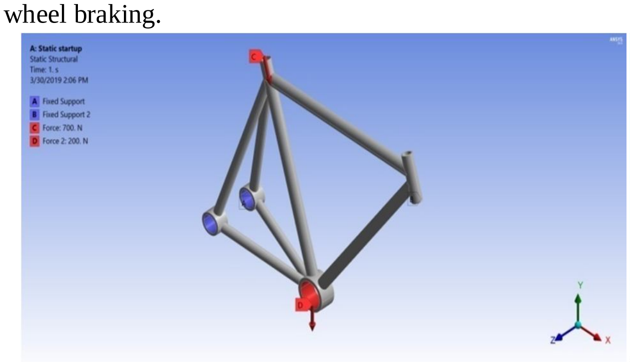

Fig. 4 static start-up

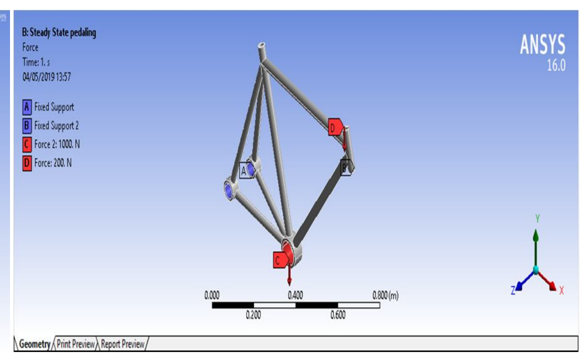

Fig. 5 steady state pedalling

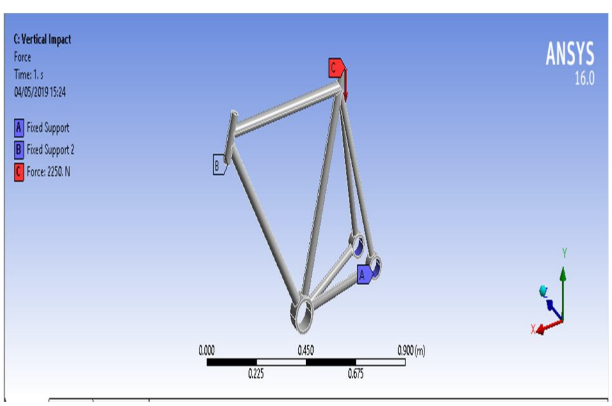

Fig. 6 vertical impact

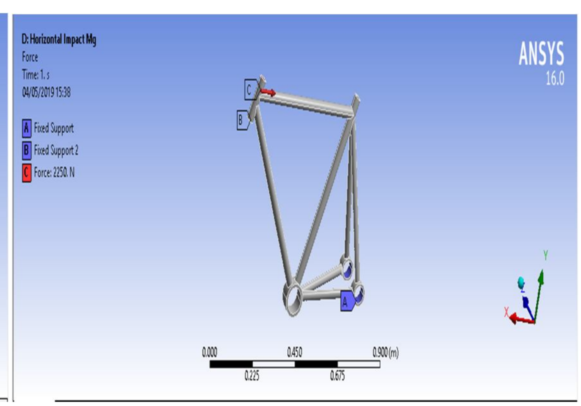

Fig.7 horizontal impact

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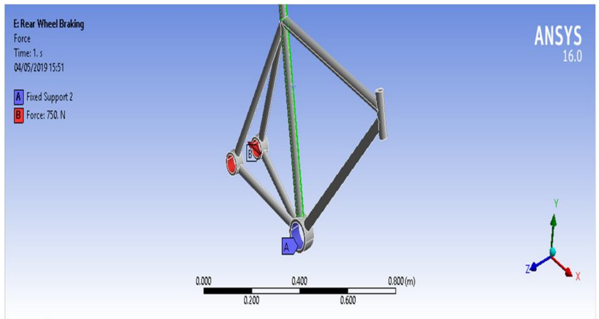

Fig 8 rear wheel breaking

III.RESULT AND DISCUSSION

As there are 2 different alloys, so we have to make 2 different tables in order to present the resultant stress in different loading cases for all alloys.

A. Aluminium (Al6061-T6)

TABLE III

Normal Stresses IN (X- AXIS) Members (MPa) IN Al 6061-T6

Load Cases	Normal stresses (x- axis) in members (MPa)				
	Top tube	Down tube	Seat tube	Seat stay	Chain stay
Static startup	1.89	0.002	2.46	2.16	0
Steady state pedalling	.562	2.53	2.24	2.81	0
Vertical impact	3.31	4.13	7.44	-.579	0
Horizontal impact	9.21	6.14	4.09	1.02	0
Rear wheel breaking	0	0	1.2	4.8	5.4

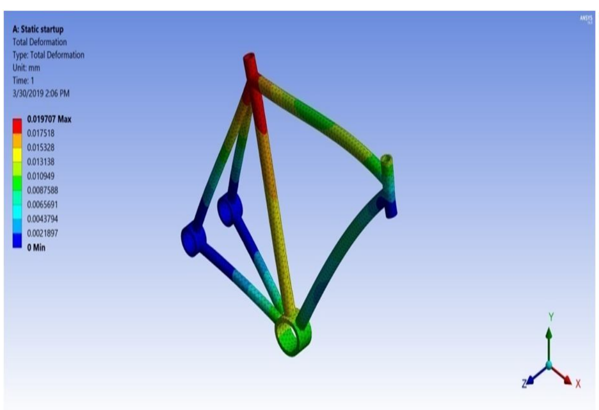

Fig. 9 Static start up

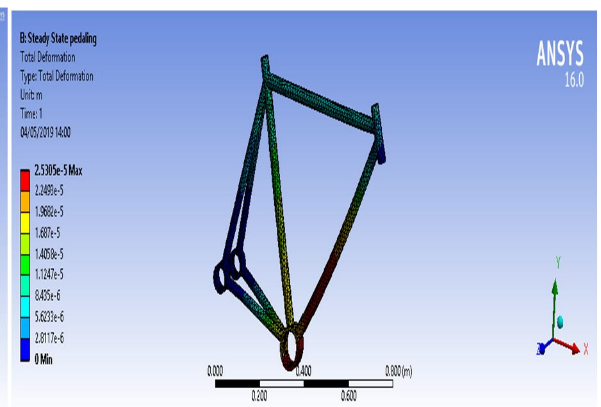

Fig.10 Steady state pedalling

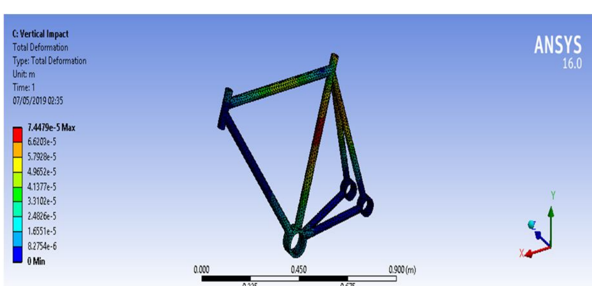

Fig. 11 Vertical Impact

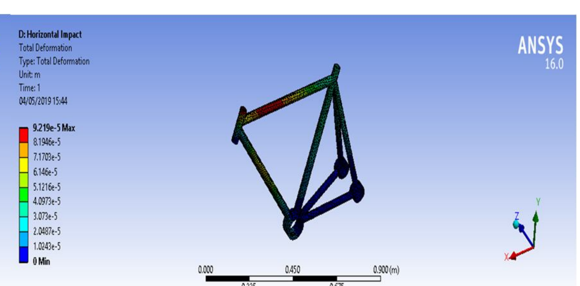

Fig.12 Horizontal Impact

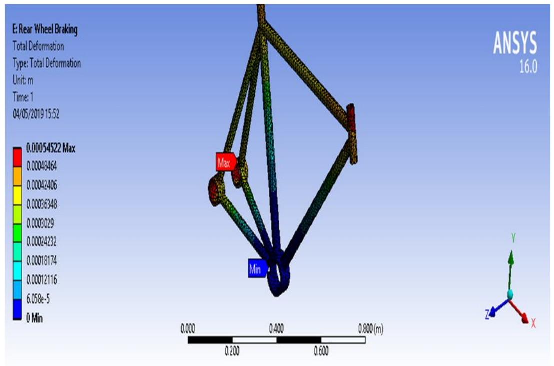

Fig.13 Rear Wheel Braking

B. *Magnesium alloy*

TABLE IV

Normal Stresses (X-AXIS) IN Members (MPa) IN Magnesium Alloy

Load Cases	Normal stresses (x- axis) in members (MPa)				
	Top tube	Down tube	Seat tube	Seat stay	Chain stay
Static startup	1.69	0	3.05	2.33	0
Steady state pedalling	1.05	3.17	2.47	.705	0
Vertical impact	4.15	4.18	9.34	6.22	0
Horizontal impact	11.6	7.7	5.15	1.28	0
Rear wheel breaking	0	0	3.7	5.03	6.8

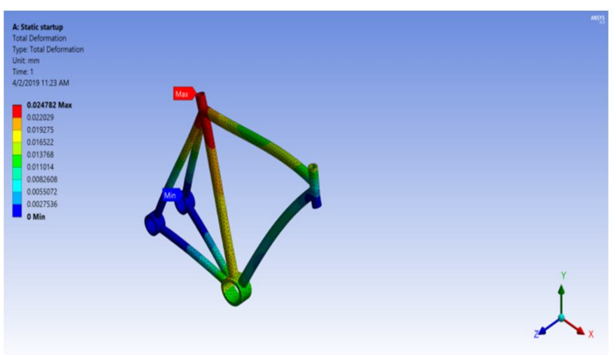

Fig. 14 Static startup

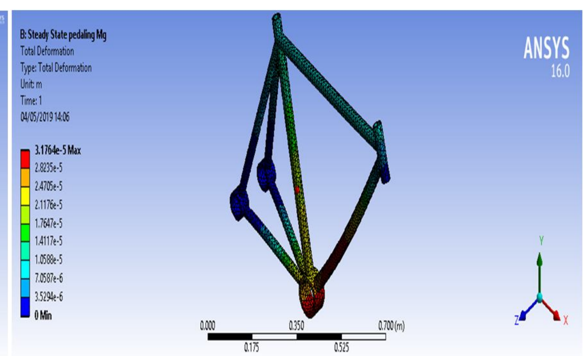

Fig. 15 Steady pedalling

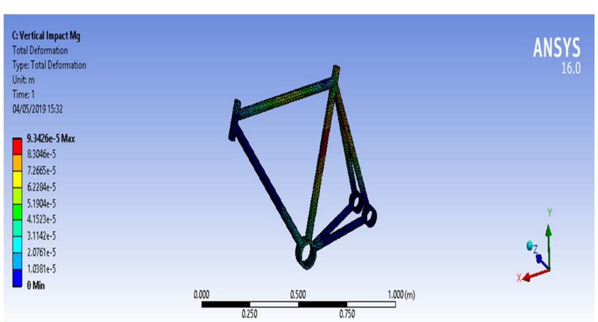

Fig. 16 Vertical Impact

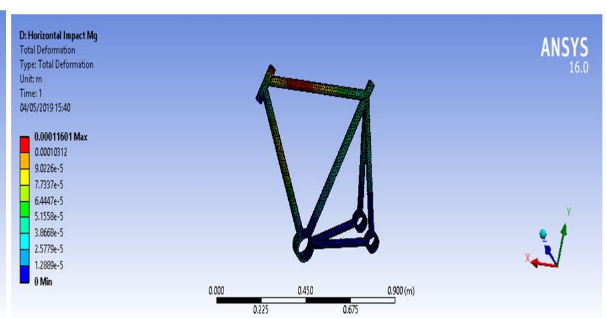

Fig. 17 Horizontal Impact

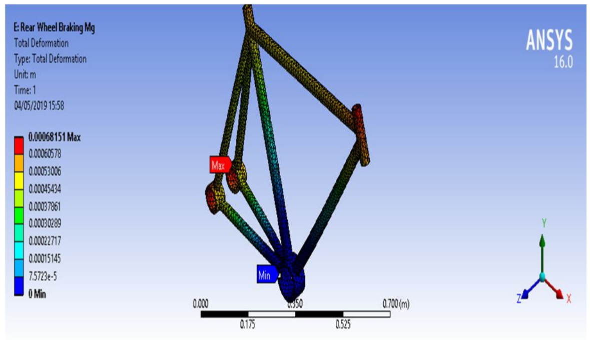

Fig 18. Rear Wheel Breaking

C. Equivalent (Von–Mises) Stress Analysis for Bike Frames

1) Aluminium 6061-T6:

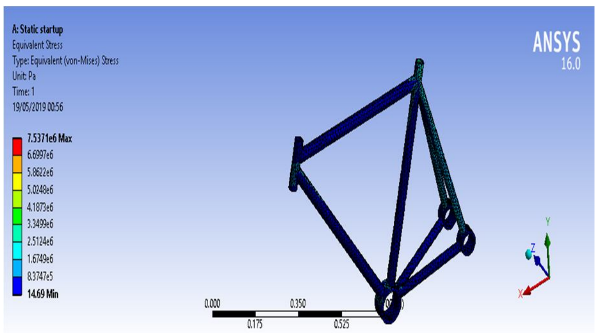

Fig 19. Aluminum static startup

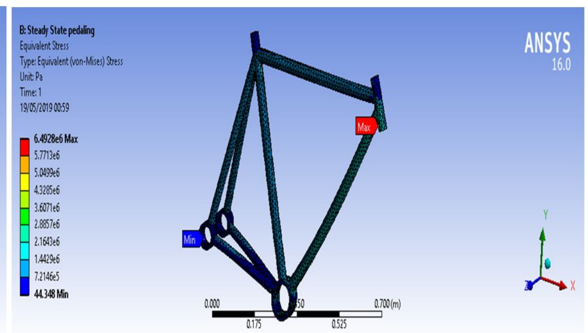

Fig 20. Steady state pedalling

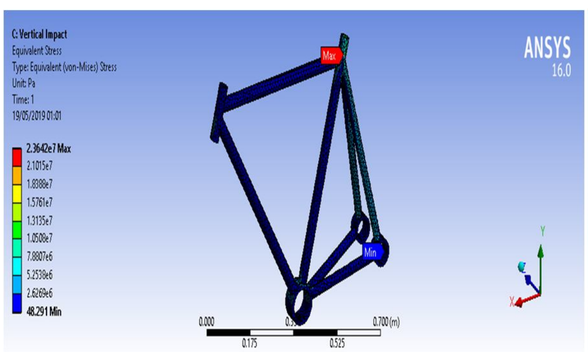

Fig 21. Vertical impact

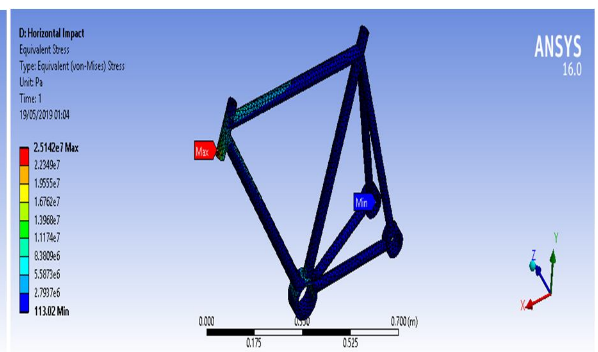

Fig 22. Horizontal impact

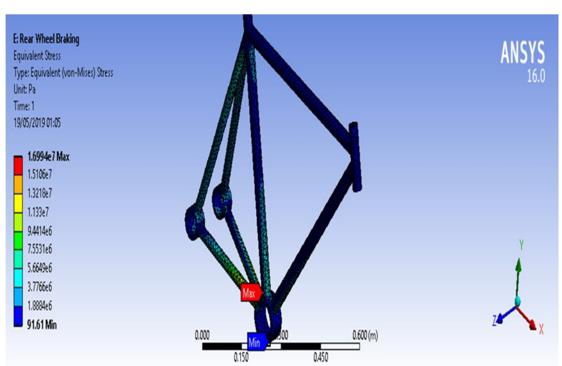

Fig 23. Rear wheel breaking

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
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TABLE V

Equivalent (Von- Mises) Stress in Member (Mpa) in Al 6061 t6

Load Cases	Equivalent (von-Mises) Stress in members (MPa)				
	Top tube	Down tube	Seat tube	Seat stay	Chain stay
Static startup	4.55	0	7.53	4.18	0
Steady state pedalling	7.21	6.49	5.77	5.04	0
Vertical impact	2.62	0	23.6	21.0	0
Horizontal impact	25.1	22.3	0	0	0
Rear wheel breaking	0	0	0	15.7	16.99

2) Magnesium Alloy

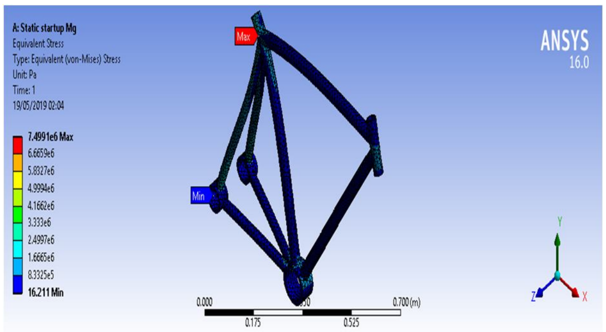

Fig 24. Magnesium static startup

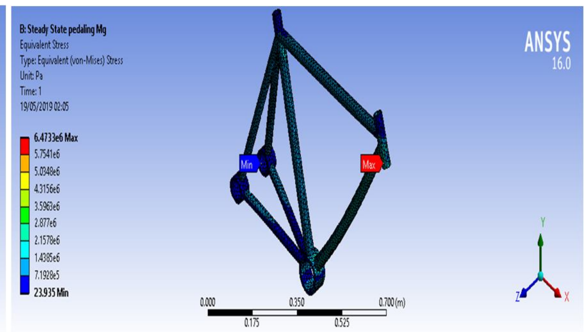

Fig 25.Steady state pedalling

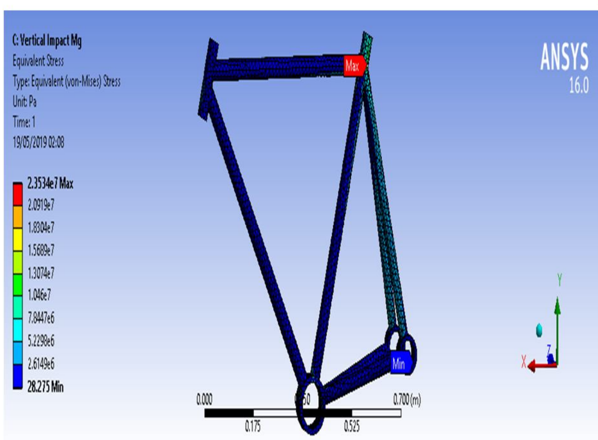

Fig 26. Vertical impact

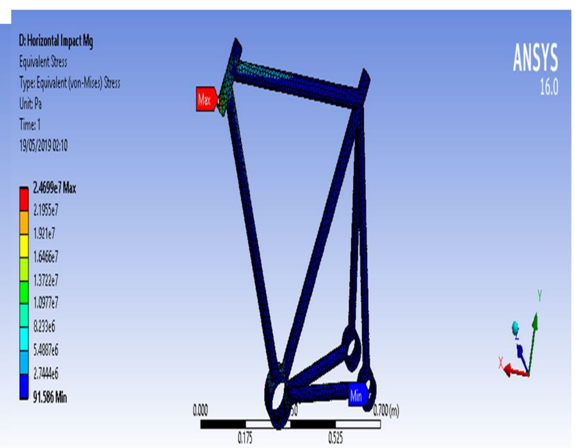

Fig 27. Horizontal impact

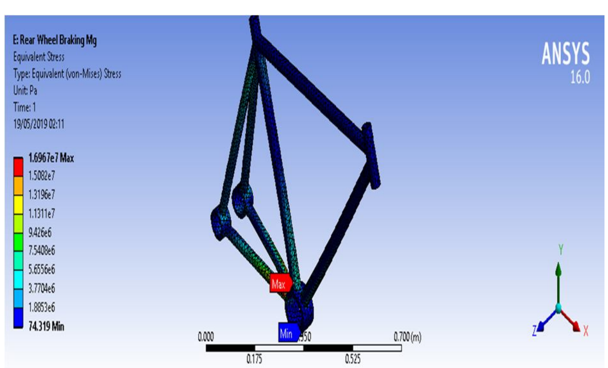

Fig 28. Rear wheel breaking

TABLE VI
Equivalent (VON- Mises) Stress IN Member (MPa) IN Magnesium Alloy

Load Cases	Equivalent (von-Mises) Stress in members (MPa)				
	Top tube	Down tube	Seat tube	Seat stay	Chain stay
Static startup	5.83	0	7.49	5.83	0
Steady state pedalling	4.31	6.47	5.75	5.03	0
Vertical impact	20.9	0	23.5	7.84	0
Horizontal impact	21.9	24.6	0	0	0
Rear wheel breaking	0	0	0	15	17

D. Comparison Of Maximum Stress Obtained For Different Cases

The maximum values of stresses obtained for the different loading cases for different alloys are compared in order to ascertain the properties of material alloy to take the impact of the loading.

TABLE VII
Comparison OF Maximum Stresses IN Al 6061- T6 AND Mg Alloy

ALLOYS	Maximum stress obtained for different cases (Mpa)				
	Static start up	Steady state pedalling	Vertical impact	Horizontal impact	Rear wheel braking
Aluminium 6061-T 6	7.53	5.77	26.2	22.3	16.9
Magnesium Alloy	7.49	6.47	23.5	24.6	17

E. Comparison Of Maximum Deformation Obtained For Different Cases

The maximum values of deformation obtained for the different loading cases for different alloys are compared in order to ascertain the properties of material alloy to take the impact of the loading.

TABLE VIII
Comparison Of Maximum Deformation In Al 6061 T6 And Mg Alloy

ALLOYS	Maximum deformation obtained for different cases (mm)				
	Static start up	Steady state pedalling	Vertical impact	Horizontal impact	Rear wheel braking
Aluminium 6061-T 6	0.024	0.025	0.074	0.092	0.054
Magnesium Alloy	0.030	0.031	0.093	0.11	0.068

- Magnesium Alloy happens to be the most deformed alloy with a deformation of 0.030, 0.031, 0.093, 0.11, 0.068 mm for static start up, steady state pedalling, vertical impact and horizontal impact loading cases respectively.
- Aluminium 6061-T is the most deformed alloy for rear wheel braking loading case with a deformation of 0.56 mm.

The increasing order of deformation can be made out from the figure which is as follows:
Magnesium alloy < Aluminium 6061-T6.

F .Cost of Material

TABLE IX
Comparison OF Cost OF Materials IN Al 6061 T6 and Mg Alloy

ALLOYS (plates)	COST OF MATERIAL (Rs/plate)
ALUMINUM 6061-T 6	280
MAGNESIUM ALLOY	500

IV. CONCLUSION

A mountain bike frame is designed with standard dimensions for a person with a weight of 85 to 100 kg. It has been designed for off road cycling. The lengths of the tubes are taken in accordance to the rider's height. Modelling of the designed bike frame is done in SOLIDWORKS software. In this paper the bike frame is designed in 2 different material alloys i.e, Al alloy and Mg alloy so as to analyze and compare the frame material according to one's need. For these 2 frames, 5 different load cases are defined in order to make out the stress and deformation in each frame. Equivalent (von-Mises) stress analysis for all material alloys for all load cases is performed in ANSYS to make a comparative study. A comparative study is also made for the total deformation in the members of alloys for all load cases. After the analysis on both materials Al alloy has a less chance of deformation than Mg alloy and is also found economical. Magnesium Alloy happens to be the most deformed alloy with a deformation of 0.030, 0.031, 0.093, 0.11, 0.068 mm for static start up, steady state pedalling, vertical impact and horizontal impact loading cases respectively. Aluminium 6061-T6 is the most deformed alloy for rear wheel braking loading case with a deformation of 0.56 mm.

The increasing order of deformation can be made out from the figure which is as follows: Magnesium alloy < Aluminium 6061-T6.
The increasing order of stress acting can be made out from the figure which is as follows: Magnesium alloy < Aluminium 6061-T6.

V. ACKNOWLEDGMENT

Presentation inspiration and motivation have always played a key role in the success of any venture. First of all we would like to thank GOD, the Almighty for his kind blessings upon us for the completion of this seminar. We express our sincere thanks the Principal, St. Thomas College of Engineering and Technology, Chengannur.

We acknowledge our indebtedness and deep sense of gratitude to our Project guide Mr. Sajimsha B (Asst. Professor, Department of Mechanical Engineering), for his valuable guidance and kind supervision. We surrender our esteemed and sincere thanks to all the faculty members of Mechanical Engineering Department for their help and timely suggestion. We are also thankful to our parents and friends for their motivation and support.

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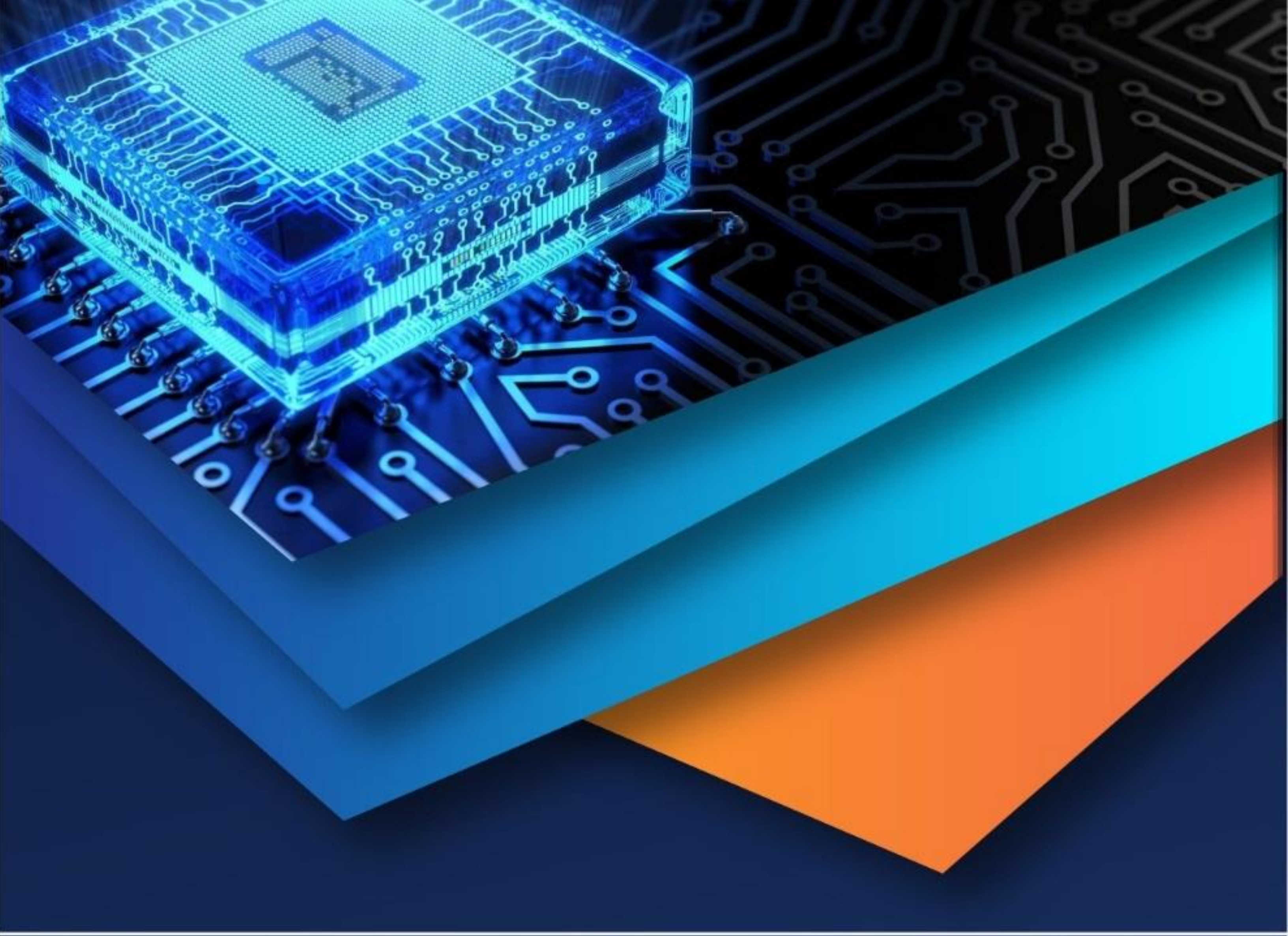

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