DESIGN AND ANALYSIS OF LIGHTWEIGHT ELECTRIC SCOOTER

Aathira Kamath U[1], Arjun Saxena K S[2]

[1,2]Under Graduate Student, Dept. of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India

---

Abstract - *The number of petrol and diesel vehicles on roads increase day-by-day. It causes a lot of environmental problems. So, there has been focus on green energy vehicles, especially electric vehicles, over the last few decades. In this paper, a two-wheeler electric vehicle is designed and also focus is given to make it lightweight, so as to reduce its cost. Also, various components used in the scooter are studied like BLDC motor, Lithium-ion battery etc. The modelling and analysis of the two-wheeler electric vehicle were done using Solidworks software. The results indicated that the Von-mises stress and total deformation were less and the fatigue life was more for the designed vehicle. So, it was concluded that, the proposed design of the lightweight two-wheeler electric vehicle offers sufficient strength and is safe for use.*

Key Words: **Electric Scooter, Lightweight, Aluminium alloy 6063, Li-ion battery, BLDC motor, Solidworks, Finite Element Analysis.**

1. INTRODUCTION

Over the last few decades, there has been an increased focus on green energy and reduction of impact of transportation on climate change. The environmental problems caused by petrol and diesel vehicles has been huge. This led to the evolution of electric vehicles. The evolution of electric vehicles is an important step for economic and social development of many countries, including India. Electric vehicles have zero pollution, zero emissions and are noiseless. They have less maintenance due to very few moving parts.

The electric system of the vehicle plays a major role in its design. The electric system consists of battery, motor, potentiometer and other electronic equipment. The most important thing is that the electric system gives power to the motor which helps in the running the vehicle. The electrical energy which is stored in the battery is used by the motor, which converts electrical energy to mechanical energy. A proper electric system is important to ensure driver and vehicle safety in case of collision [1].

A major disadvantage of these electric vehicles is that it is costly compared to conventional petrol or diesel vehicles. In order to reduce costs, electric vehicles can be made of lightweight materials. Lighter vehicle needs smaller batteries and are more efficient. Materials like Aluminium alloy helps in reducing the weight of the vehicle. So, the main objective of this paper is to design and analyze a lightweight mobility two-wheeler electric vehicle.

2. DESIGNING

The dimensions of the vehicle are based on the average size of a person. The height of the steering column, placement of footrest and seat to handle bar distance etc. is decided such that it is comfortable for the customers.

Fig -1: 3D model of Scooter

All the design parameters and their dimensions are shown in **Table 1**

Table -1: Design specifications

Parameters	Dimensions
Length of the scooter	1200 mm
Width of the scooter	240 mm
Handle height	980 mm
Seat height	520 mm
Wheel diameter	300 mm
Head tube angle	25°

2.1 CALCULATION OF WHEEL DIAMETER

Distance travelled by vehicle per minute = 2πrN
where r is radius of the wheel and N is the rpm
Let maximum velocity of the vehicle be 20 km/hr
20 km/hr = 0.333 km/min
Now 2πrN = 0.333
N = 350 rpm (rpm of motor)
Therefore r = 151.57 mm
So, diameter of the wheel is approximately taken as 300mm

3. MAJOR COMPONENTS

3.1 BRUSHLESS DC MOTOR

Currently, there are various technologies available for electric motors. However, most suitable for electric scooters is the brushless DC motor with permanent magnets.

A brushless DC motor has a rotor with permanent magnets and a stator with windings. The control electronics replace the commutator and brushes and energize the stator sequentially. Here the conductor is fixed and the magnet moves. The current supplied to the stator is based on the position of rotor. It is switched in sequence using transistors. The position of the rotor is sensed by Hall effect sensors. Thus, a continuous rotation is obtained.

Advantages of brushless DC motors includes, more precise due to computer control, more efficient, no sparking due to absence of brushes, no brushes to wear out, electromagnets are situated on the stator hence easy to cool, motor can operate at speeds above 10,000 rpm under loaded and unloaded conditions, responsiveness and quick acceleration due to low rotor inertia [2].

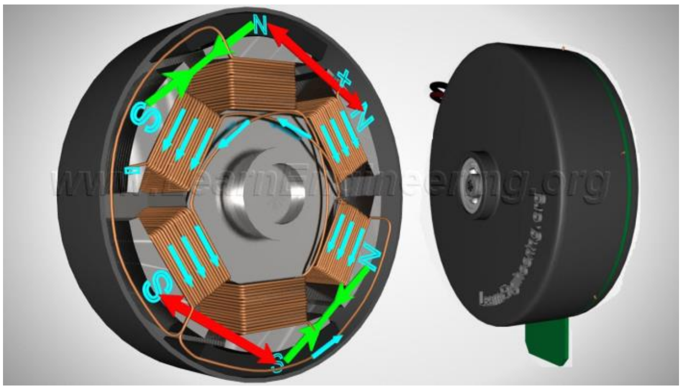

Fig -2: Brushless DC motor

3.2 LITHIUM-ION BATTERY

Lithium is a very light metal extracted and refined from the soil in certain parts of the world. There is quite a lot of it around, but its use in batteries dates only from 1980, so it's a relative newcomer to the battery world. It is one of the lightest chemical elements and also has one of the largest electrochemical potentials (i.e., is capable of holding more electric charge) and all this is packed in compact and light batteries.

Weight, or rather its lightweight, is the most obvious advantage of lithium over a lead-acid battery and is self-evident the moment you pick one up. If lead is one of the heaviest metals around then lithium is one of the lightest. This means you can easily carry your lithium-ion battery out of the scooter and recharge it with ease.

But weight isn't the only advantage. Not only are lithium-ion batteries lighter they are also longer lasting and they charge faster. Manufacturers say that lithium-ion batteries are also the perfect green alternative to lead-acid batteries and this is true insofar as their longer life span means they generate less waste to be recycled than lead-acid batteries.

The energy density of lithium-ion is typically ten times that of the standard lead acid battery. This means there is higher energy density potential. Essentially, it equates to a longer life span and a lighter weight (approx. one third the weight of a lead acid battery) for the same output of power. Like lead acid and gel mobility batteries, Lithium-ion batteries are also maintenance-free and rechargeable [3].

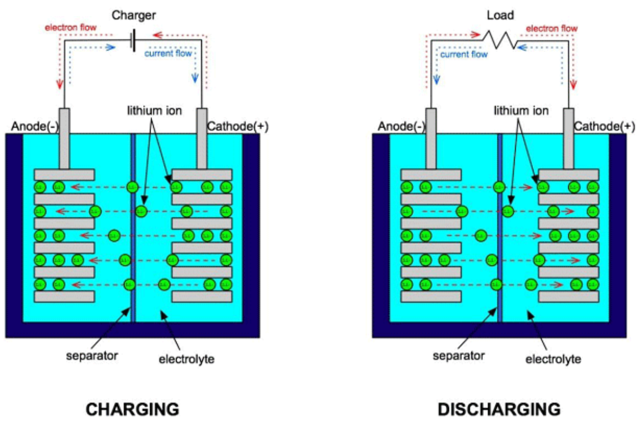

Fig -3: Lithium-ion battery

3.3 DISC BRAKE

Disc brakes are more powerful and require less hand strength to operate. They are not a rim-brake as they do not clamp the rim but rather to a hub-fixed rotor. Disc brakes require a compatible hub, wheel rim, and frame or fork. Here Mechanical cable disc brake is used. They can handle high heat without damaging the tire. Disc brakes are completely immune to trail debris, water, and mud. If a rider runs through a creek deep enough to get the rotor wet or muddy the hard pads will remove the water and mud off the rotor immediately with their phenomenal strength and pressure. Disc brakes are stronger, more dependable in dirty environments, and are immune to heat [4].

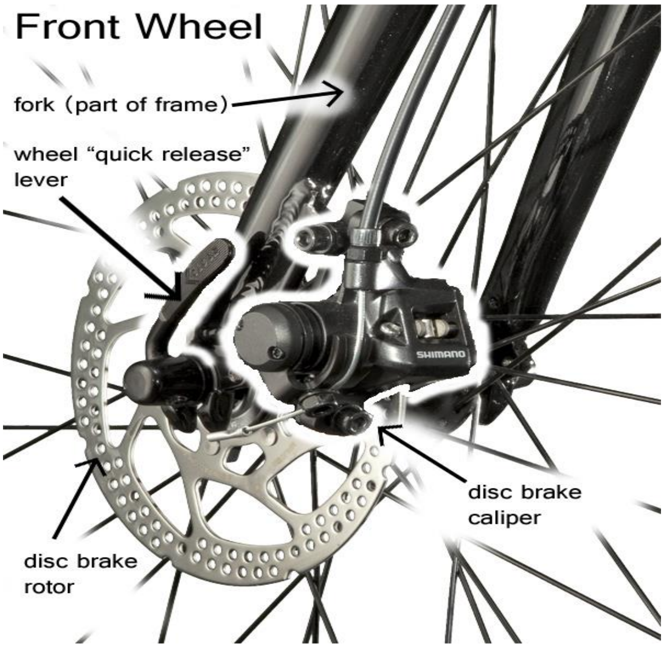

Fig -4: Brake components

3.4 SPEED CONTROLLER

In electric scooters, carbon or plastic membrane contact potentiometers are used as speed regulation elements. Its advantages are its simplicity and it often does not require signal conditioning [5].

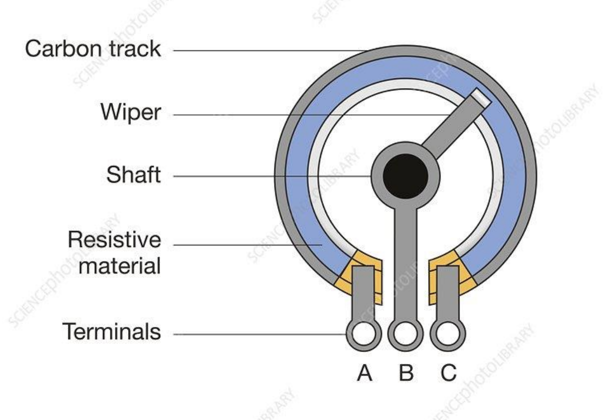

Fig -5: Rotary potentiometer

4. MATERIAL SELECTION

Aluminium alloy 6063 can be as strong as steel, but at a third of the weight. It is much lighter, durable, weather proof and is not affected by UV rays. So, it has a long lifespan, good surface finish, high corrosion resistance and is readily suited for welding and can be easily anodized [6].

Table -4: Composition of Al6063

Material	Percentage composition (%)
Magnesium	45
Iron	35
Copper	10
Silicon	6
Other	4

Table -5: Properties of Al6063

Properties	Magnitude
Density	2.68 g/cm^3
Poisson's ratio	0.33
Youngs modulus	75 GPa
Elongation	16%
Yield strength	75 Mpa
Hardness	25 BHN
Tensile strength	126 MPa

5. RESULTS AND DISCUSSIONS

5.1 STATIC ANALYSIS

Static analysis is an important procedure for designing a structure. Using static analysis, the response of the structure to the applied external forces is being obtained. Here, static analysis of the scooter is conducted by fixing the front and rear hub and applying a UDL of 1500 N. The results are obtained and the total deformation and von-mises stress are shown below [7].

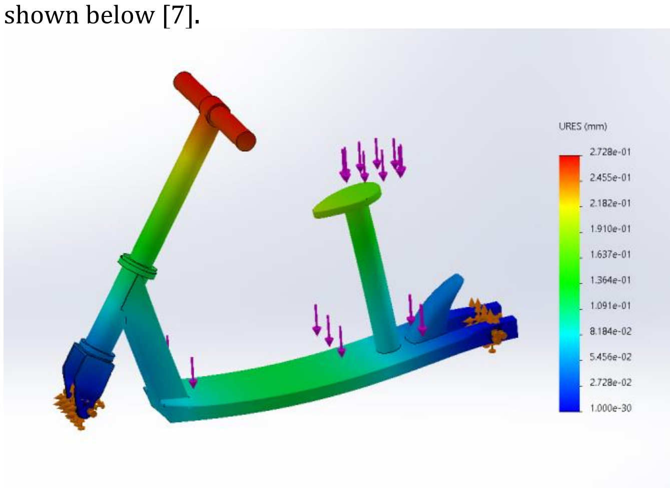

Fig -6: Total deformation

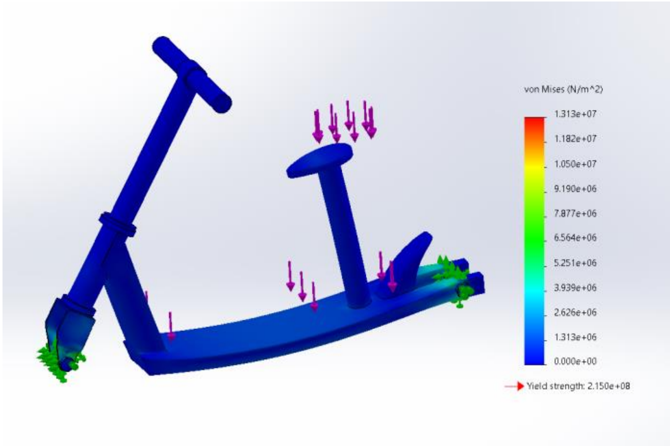

Fig -7: Von-mises stress

Table -4: Deformation and Stress

Value	Deformation (mm)	Von-mises stress (MPa)
Minimum	0.001	0
Maximum	0.2728	13.13

5.2 MODAL ANALYSIS

Modal analysis is used for finding the natural frequencies of a structure at various modes. Thus, different mode shapes with different natural frequencies are obtained from this analysis. Here, modal analysis of the scooter is conducted by fixing the front and rear hub. The results are obtained for the first five modes and the corresponding natural frequencies and displacements are shown below [7].

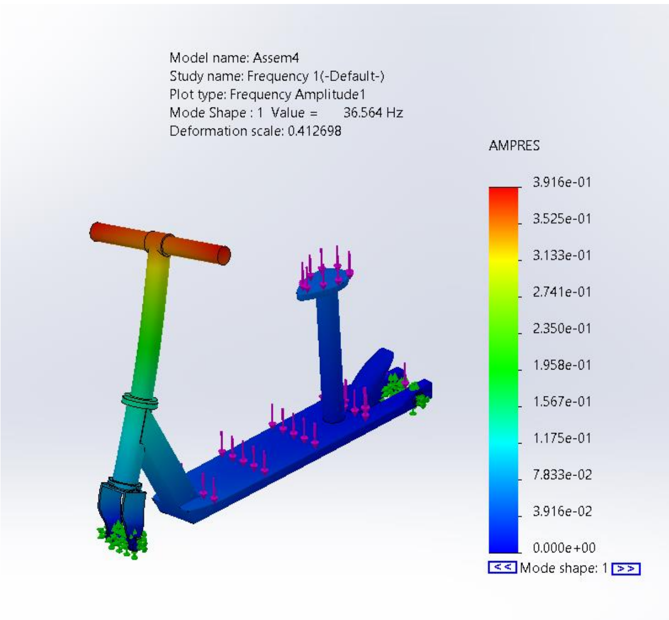

Fig -8(a): Mode 1

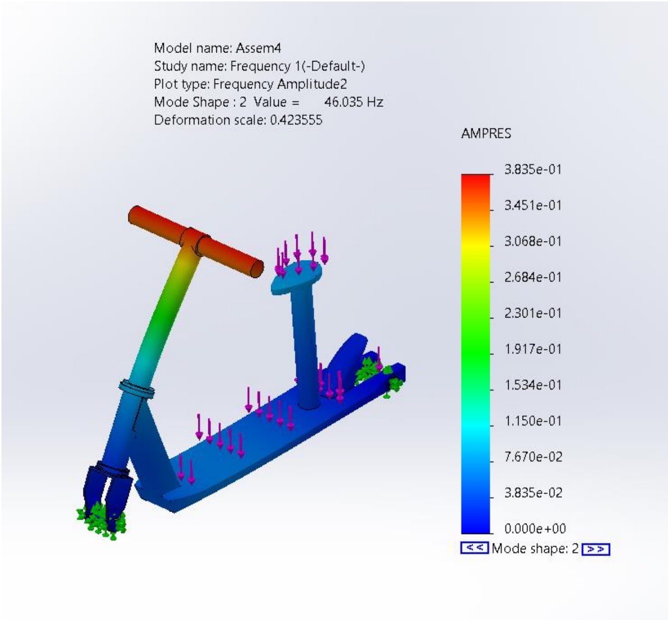

Fig -8(b): Mode 2

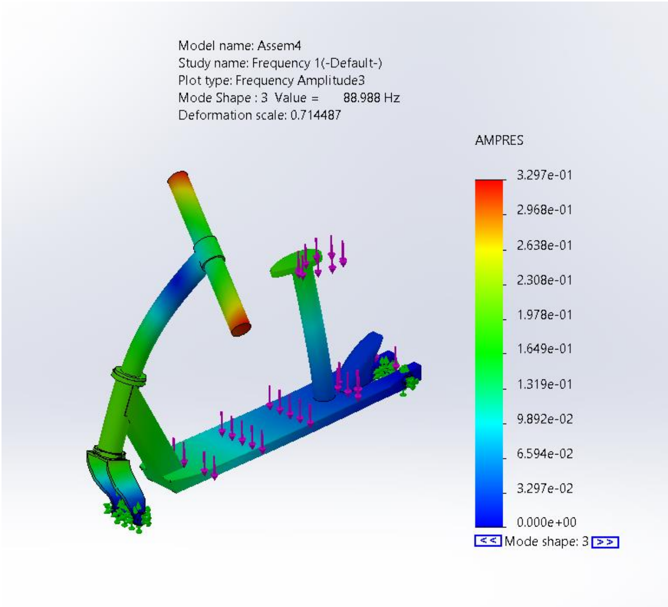

Fig -8(c): Mode 3

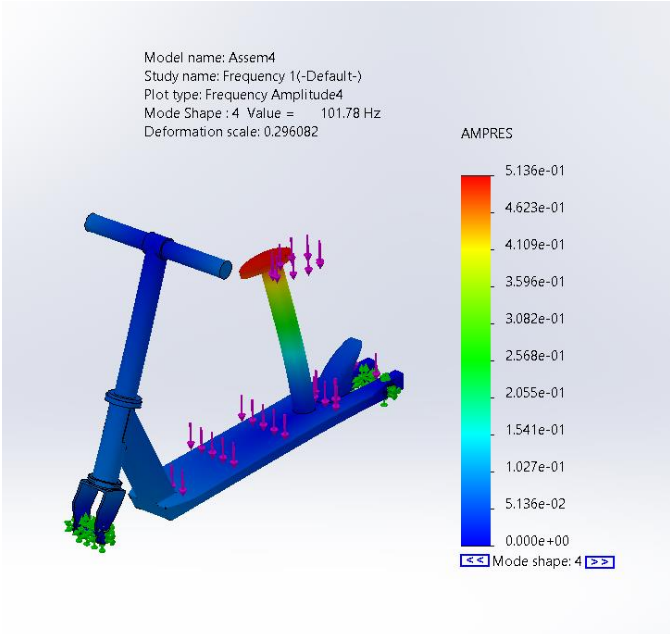

Fig -8(d): Mode 4

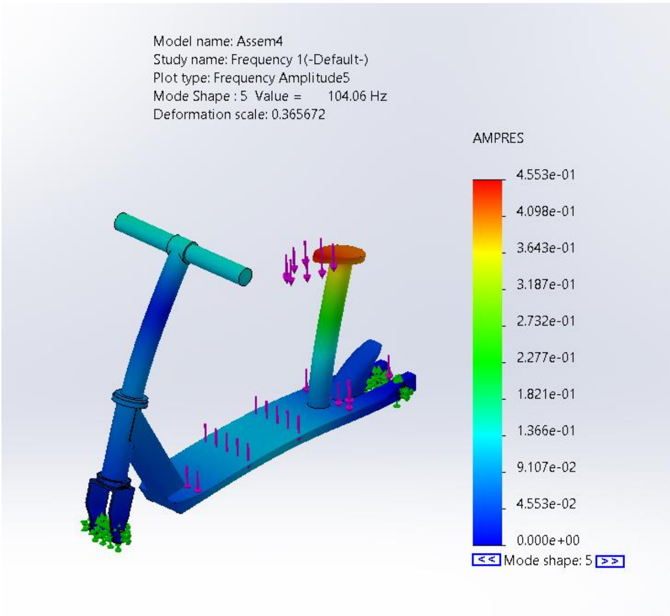

Fig -8(e): Mode 5

Table -5: Frequency and displacement for first five modes

Different modes	Frequency (Hz)	Displacement (mm)
Mode 1	36.564	0.413
Mode 2	46.035	0.424
Mode 3	88.988	0.715
Mode 4	101.78	0.296
Mode 5	104.06	0.366

5.3 FATIGUE ANALYSIS

Fatigue is a phenomenon that is observed when repeated loading and unloading weakens an object over time, even when the induced stresses are considerably less than the allowable stress limits. Setting up a fatigue analysis in Solidworks Simulation will allow us to determine whether a product will be able to withstand usage requirements over a period of time and not just if the product will hold up a single specified load environment. Thus, the loads acting was identified and fatigue analysis was conducted. The results are obtained and the damage percentage and fatigue life of the scooter are shown below [8].

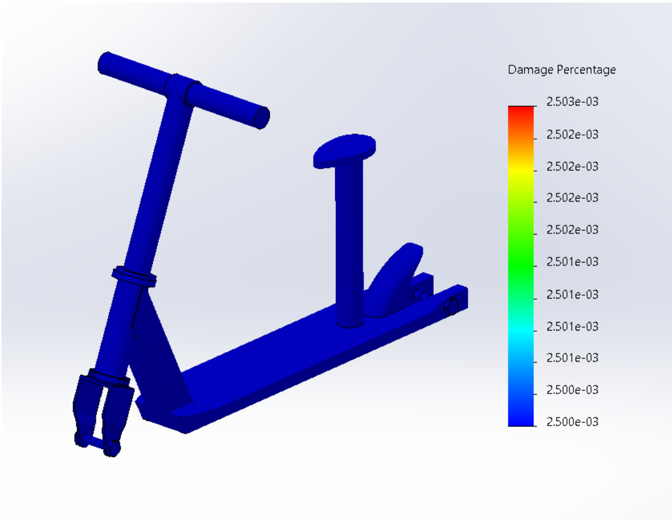

Fig -9(a): Damage percentage

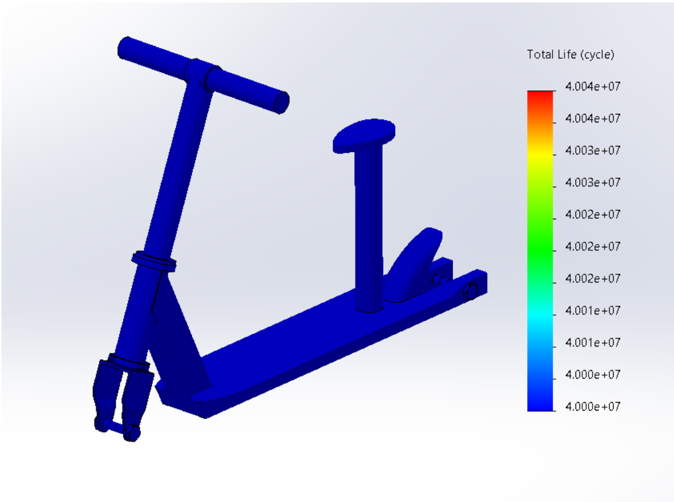

Fig -9(b): Fatigue life

6. CONCLUSION

A lightweight electric Scooter was designed and analyzed using Solidworks software. For ensuring lightweight Aluminium alloy 6063 was used as the material for the scooter due to its excellent strength to weight ratio. From

Solidworks software the weight of the designed model was approximately around 18kg. After considering all other components, the overall weight of the scooter was around 23kg. Then analysis was conducted. Firstly, from static analysis it was observed that the magnitude of total deformation and von-mises stress were low. From the modal analysis different natural frequencies at various modes were obtained. It was observed that at higher modes the natural frequency will be also higher. And finally, from the fatigue analysis damage percentage (0.0025) and fatigue life ($4x10^7$) of the designed scooter was found out. From that it was clear that the damage percentage is very low and the fatigue life is very high. So, it was concluded that, the proposed design of the lightweight two-wheeler electric vehicle offers sufficient strength and is safe for use.

REFERENCES

[1] Mahesh S. Khande, Mr. Akshay S. Patil, Mr. Gaurav C. Andhale, Mr. Rohan S. Shirsat, Design and Development of Electric scooter, May 2020.

[2] Ionuț Daniel Smarandescu, Petre-Marian Nicolae, About Electric Scooter Mobility. Aspects Regarding the Designing of a Brushless DC Motor for an Electric Scooter, April 2016.

[3] Sunwoo Yuk, Kiwon Choi, Sang-Geon Park 2 and Sukmin Lee, A Study on the Reliability Test of a Lithium Battery in Medical Electric Wheelchairs for Vulnerable Drivers, June 2019.

[4] Pritam Pain, Abhishek Chakraborty, Deep Dewan, Development of Braking System in Automobiles, March 2020.

[5] Chi-Sheng Tsai, Ching-Hua Ting, A low-cost Non-contact Potentiometer with Fault Isolation for Electric Scooter Speed Regulation, May 2012.

[6] S. Chandrasekhar, M.L.S. Deva Kumar, Preparation & Mechanical Characterization of Aluminium 6063 Metal Matrix Composite Reinforced with Graphite & Silicon Carbide, August 2019.

[7] Kaveri.S Kadam, Nikhil.S. Sambhar, Ms. Namrata.M. Bora, Shubham. R. Bhakare, Swapnali.W. Gaikwad, Design and Analysis of E-Scooter Chassis Frame, June 2020.

[8] Mahesh Gowda Patil, B Ravindra, H S Manjunath, Stress and Fatigue analysis of Weldment of Rectangular Column Structure, September 2018.