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Electric Skateboard Incorporating Foot Operated Ackerman Steering System

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Abstract:- With the increasing awareness about resource depletion and ever-increasing fuel prices, people are finding new, innovative, cheap, effortless and quick means of transportation for commuting short distances. Of all the available options, e-skateboard is the cheapest but generally very unstable and accident-prone because the rider has to tilt his body to change the direction of motion making the commute dangerous and suited to only experienced riders. This project helps in overcoming this issue while not disturbing the advantages, such as cheapness and portability. The foot operated steering system helps in changing the direction of motion by light push on the steering lever with the rider's leg while the rider stands still on the stable skateboard chassis. The mechanical components are thoroughly analyzed for developed stresses, deformation and safety. The parts and subsystems are designed using SolidWorks, Autodesk Inventor and Pro-E and analyzed using Ansys 15. The electronic components like motors, batteries and speed controllers are selected after vigorous study, market research and cost analysis. Ackermsan type steering geometry is used in steering system of the e-board. The basic aim of this project is fabricating an electronic skateboard, powered by a powerful brushless DC motor and incorporating in it an efficient and safe steering system.

Keywords:- *Skateboard; BLDC Motor; Ackerman Steering; Solidworks 15; Pro-E Wildfire 5.0; Ansys 15*

I. INTRODUCTION

Although electrical skateboards are not very common in India, they are growing rapidly in Europe and America. With the social media effect and word to mouth advertising, Indians are getting to know about the advantages of e-skateboards and it is not long before they start gaining ground in India. There are already many e-skateboard manufacturers looking here as a huge potential market. However, e-skateboards come with their own set of disadvantages. Skateboards (normal and electric) available today use their trunks as the means of changing the direction. The trunk is the part of the skateboard attached below the deck (board) and containing the wheels. The rider has to lean in the direction he wants to go. His body should also lean with the turn. Therefore, lot of practice is required to become skilled at riding a skateboard and thus it is not advisable for a layman to ride it on the road or for commuting short distances. Not to mention the poor road conditions and lack of control on speeds.

This project involves fabricating an electric skateboard, equipped with an electric motor and remote is available in the hands of the rider. As a result controlling speed is very easy and effective. To change the direction, a foot-operated lever is provided. The rider just has to push the lever with his legs in the direction he wants to go. While doing so, only the lever will move and not the entire body (chassis) of the skateboard, thus the rider will stand still during the turning, making it very easy and stable. The rider will thus be in complete control of the vehicle. Due to the easiness and comfort in riding, any person can use the skateboard.

The skateboard will use a Brushless DC motor as its power source, which will be connected to an electronic speed controller (ESC), which will be connected to the lithium-polymer batteries. A servo tester will be connected to the ESC and will be used as the remote to control the speed. The frame is designed after analysing the expected stress, deformation and factor of safety due to loading after analysis on Ansys15. The chassis carries a rotating member, which is rotated with the lever welded to it. The rotation thus obtained is in horizontal direction. To transmit the rotation perpendicularly, bevel gears are used.

II. ELECTRONICS

A. Motor

Direct Current (DC) motor is generally used in electric skateboards due to its constant torque characteristics and ability to control speed. This project utilizes a Brushless DC (BLDC) motor due to increased advantages such as higher efficiency, less noise, high torque to weight ratio and increased life.

Fig 1:- Motor

The motor selected here is a 6374 BLDC motor having power 2.8 kW and kV rating 170. 6374 signifies that the diameter of the motor is 63 mm and the length is 74 mm. The shaft diameter is 10 mm.

B. Electronic Speed Controller (ESC)

An electronic speed control or ESC is an electronic circuit that controls and regulates the speed of an electric motor. It is effectively the brain of the skateboard and is connected to the batteries, motor and remote.

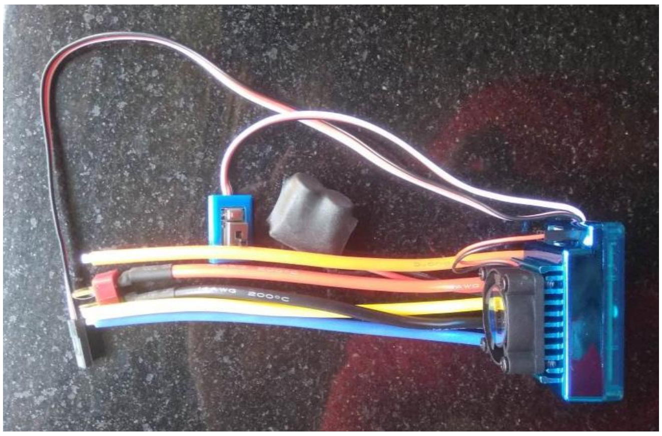

Fig 2:- Electronic Speed Controller

C. Battery

Generally, lithium-ion and lithium-polymer (Li-Po) rechargeable batteries are used in electric vehicles. Considering the cost, availability and ease of use, this model is equipped with two 3s Li-Po batteries connected in series. 3s indicates there are 3 cells of 3.7 V each connected in series. Therefore, the total voltage of battery is 11.1 V hence, two such batteries connected in series will give 22.2 V. The battery used here has a capacity of 2200 mAH.

Fig 3:- Battery

D. Remote

A servo tester, connected to the ESC is used as the remote to control speed. The rider just has to rotate the knob on the servo tester to increase and reduce the speed of the motor.

Fig 4:- Servo Tester

E. Circuit Diagram

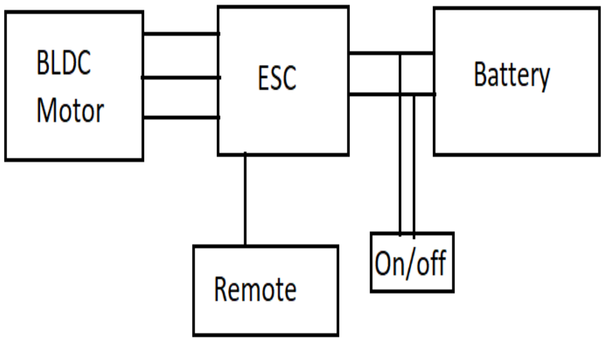

Fig. 5:- Electronic Circuit Diagram

III. CHASSIS

The chassis is 2-D and has three bearing mounts welded to the main frame at its centre. A pipe passes through these bearings. This pipe is the rotating member, which is rotated with the help of a lever welded to it.

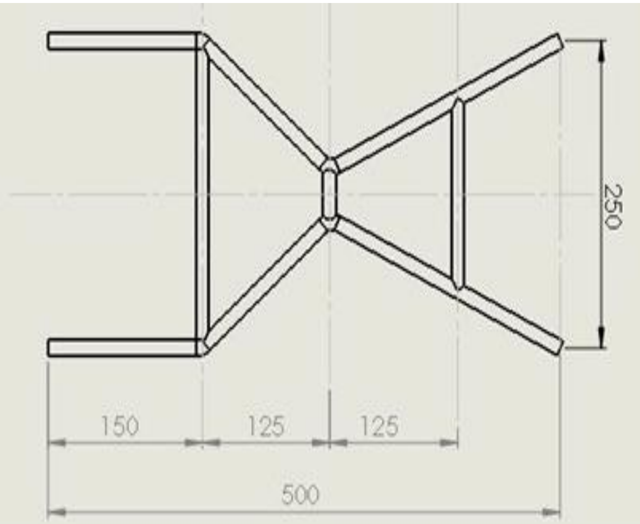

Fig. 6:- Chassis Dimensions

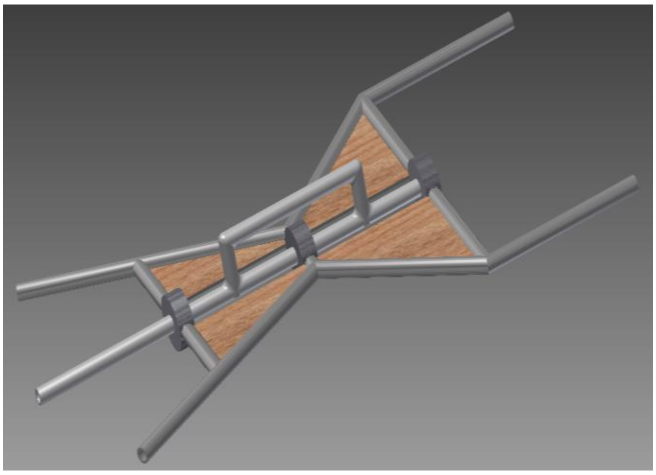
Fig 7:- Model of Chassis on Autodesk Inventor

A. Prototype

After a series of analysis of the different proposed chassis, the following design was selected considering the optimum factor of safety, low deformation on impact and convenience in manufacturing. A prototype of the actual chassis was made using PVC pipes to study the ergonomics of the rider and placement of the components.


Fig 8:- PVC Prototype of Chassis

B. Material and Procedure of Manufacturing

The material used for chassis is C-45 with yield strength 250 N/mm2. This material is selected based on its physical properties, market availability and low cost. The side members of the chassis are manufactured using bending while the mounts are created on a lathe machine. Tungsten Inert Gas (TIG) welding is used to weld the pipes and mounts.

C. Static Structural Analysis

For the ease of analysis, the bearings and mounts are considered as members of the chassis with same dimensions. Ansys Workbench 15 is used for analysis. The mesh size selected is 3mm and shape is tetrahedrons.

- Fixed constraints: Front Knuckle Joints and Rear Bearing Joints
- Load: 70 kg (weight of the rider) on the shown members

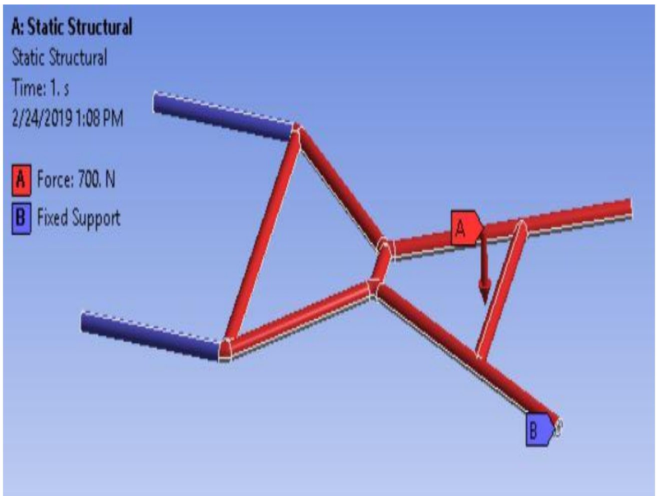

Fig 9:- Chassis Constraints and Forces

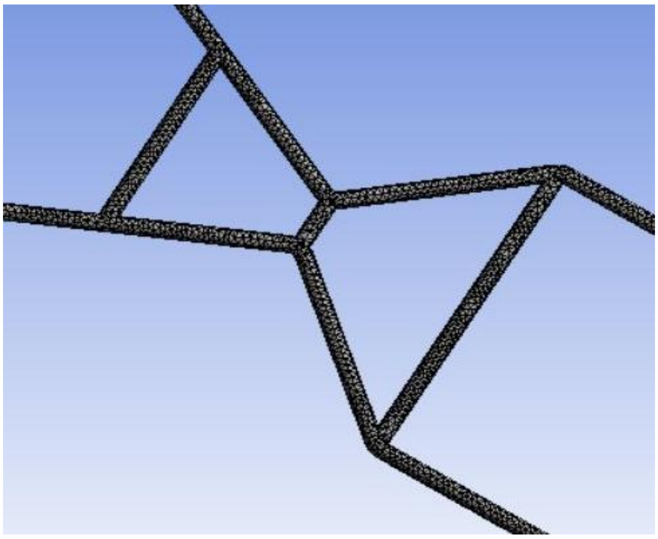
Fig 10:- Chassis Mesh

D. Results Of Analysis

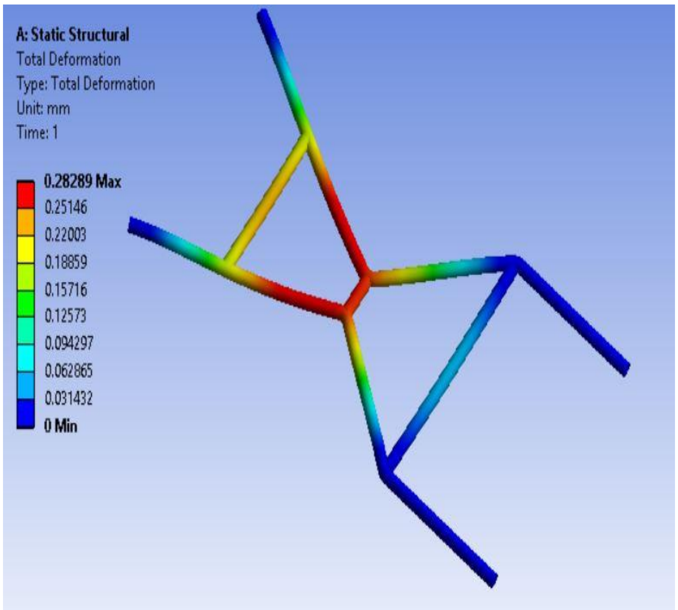

Fig 11:- Deformation

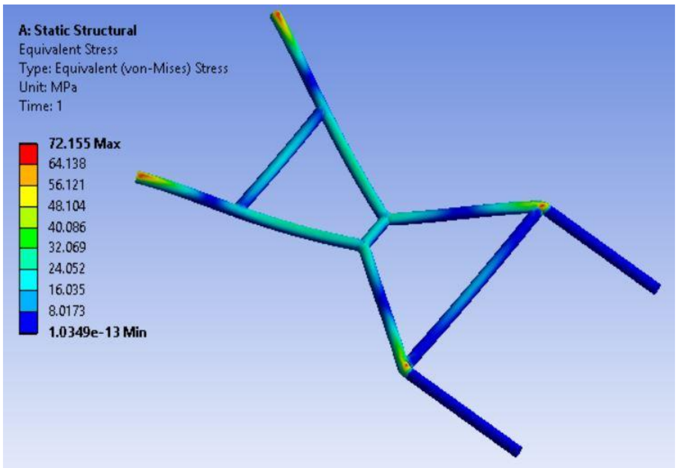

Fig 12:- Von-Mises Stress

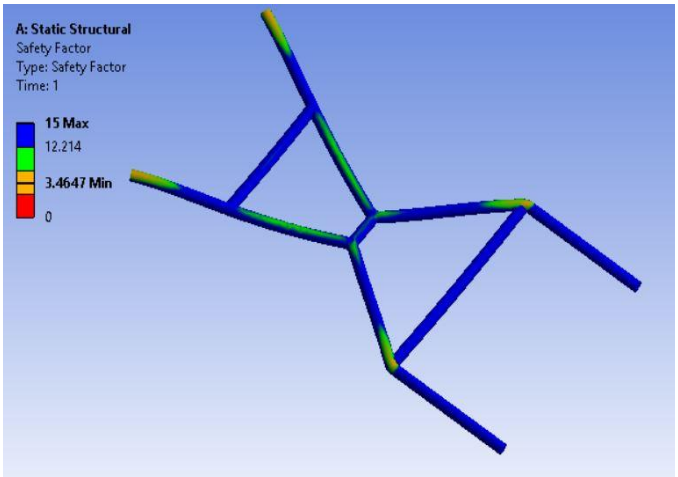

Fig 13:- Factor of Safety

As the safety factor obtained is 3.47, the chassis can be considered safe.

Deformation (mm)	Von-Mises Stress (MPa)	Factor of safety
0.283	72.155	3.465

Table 1:- Results of Analysis of Chassis

IV. STEERING SYSTEM

This model utilizes Ackerman type steering system. The steering is system is designed to operate with the help of a foot-controlled lever. The motion is then transmitted to the steering column with the help of bevel gears. The bevel gear rotates the steering column. A triangular plate welded to the column rotates with it, which in turn rotates the tie rods and the entire stub axle assembly. The tie rods are connected to steering plate and steering arm via rod-ends. The kingpin is free to rotate about the knuckle bolt, which passes through the knuckle welded to the chassis.

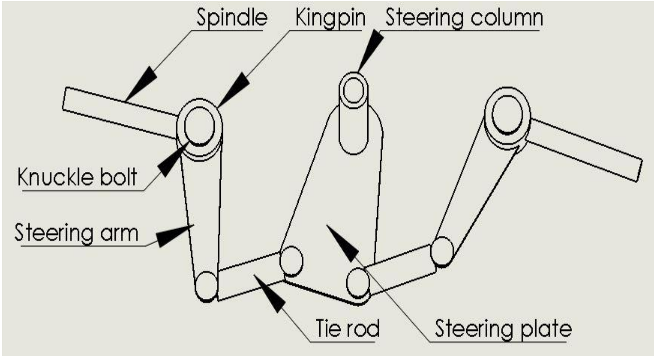

Fig 14:- Steering System Nomenclature

A. Steering Geometry

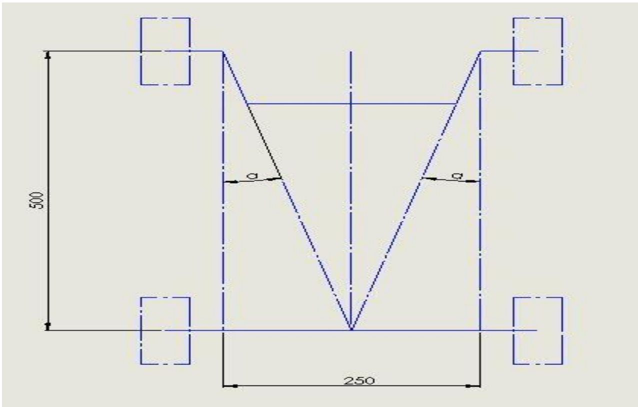

Fig 15:- Steering Geometry – I

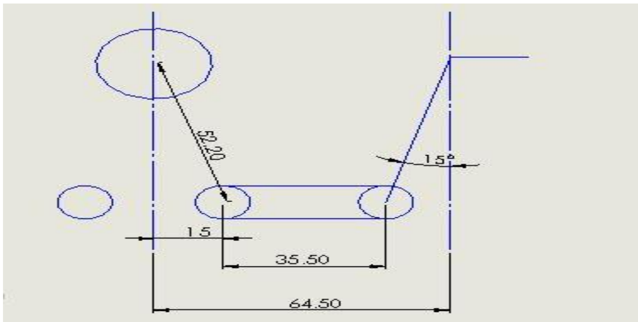

Fig 16:- Steering Geometry – II

For 100% Ackerman, the interpolation line of the steering arm should meet at the rear axle.

Tan a = 125/500
a = 14.03°
Since it is difficult to manufacture the stubaxle with such precision, we take a = 15°
Tan 15 = 120/l
l = 466.5 mm
New %Ackerman = 93.3%
By geometry, length of tie-rods = 35.5 mm

B. Material and Procedure of Manufacturing

All the components are manufactured using MS C-45 due to easy availability and low cost.

Component	Quantity	Method of Manufacturing
Triangular plate	1	Laser cutting
Tie rods	2	Internal threading (tapping)
Stubaxle	2	Turning and boring (Lathe) – Kingpin
		Turning (Lathe) – Spindle
		Laser Cutting – Steering arm
Rod-ends	4	OEM

Table 2:- Steering System Manufacturing Methods

C. Static Structural Analysis of Stub-Axle

The analysis is done on Ansys Workbench 15 after modelling on Pro-E Wildfire. Tetrahedron mesh is used with mesh size 2 mm.

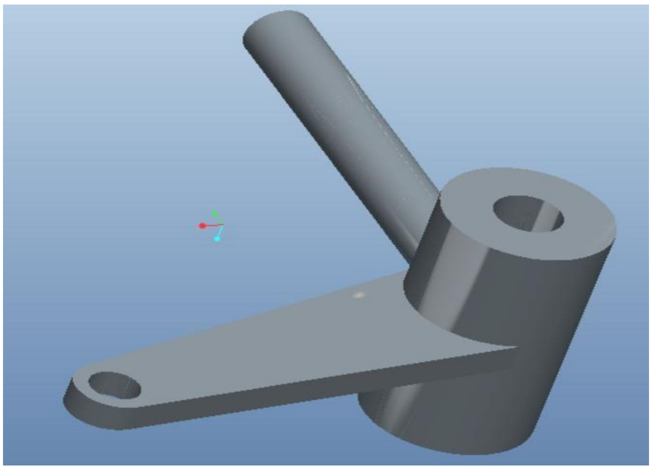

Fig 17:- Pro-E Model of Stub-Axle

- Fixed constraints: Part of kingpin bolted to knuckle
- Load: Considering the entire weight of the vehicle (including the rider) 80 kg on a single front wheel in extreme conditions, the ground will impart the same normal force in the upward direction on the tires and this force will act on the end of spindle as shown

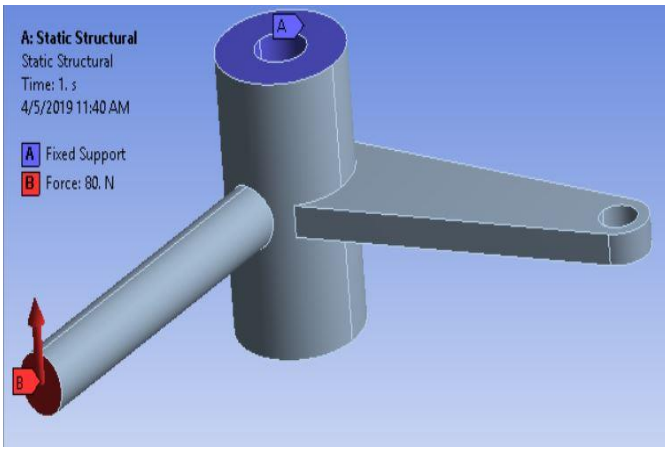

Fig 18:- Stub-Axle Constraints

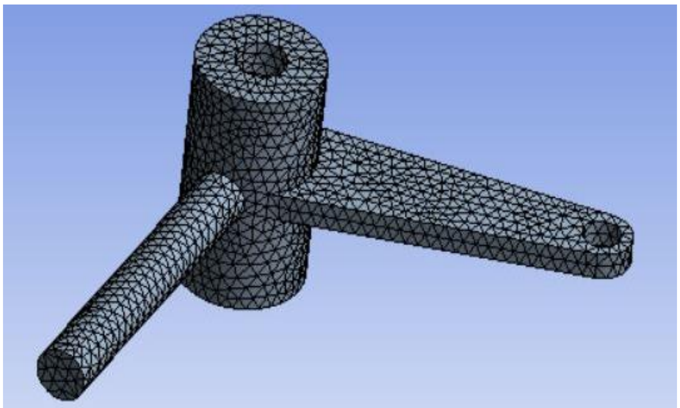

Fig 19:- Stub-Axle Mesh

D. Results of Analysis

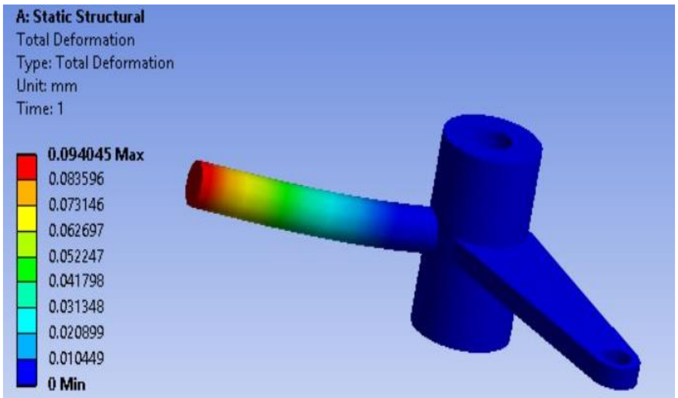

Fig 20:- Stub-Axle Deformation

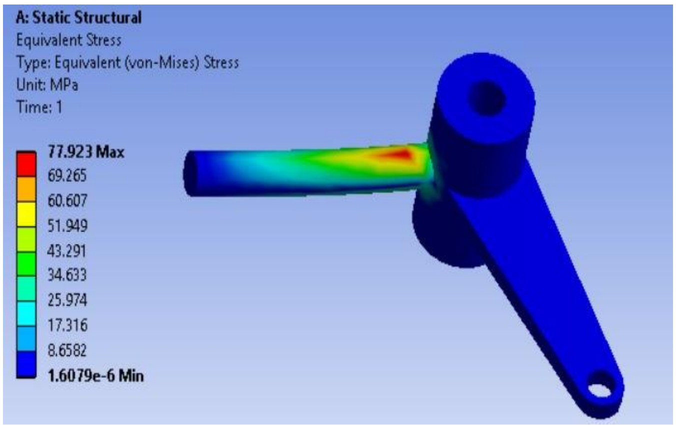

Fig 21:- Stub-Axle Stress

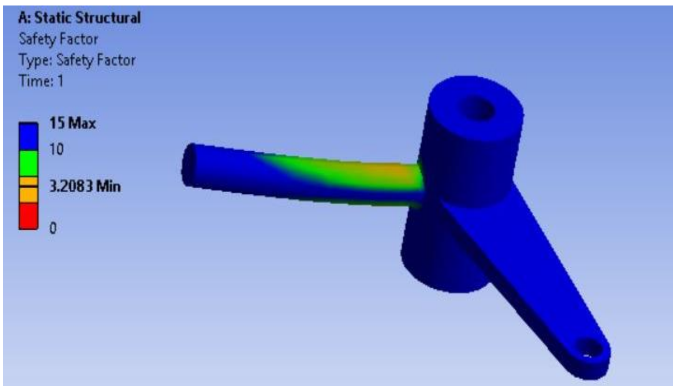

Fig 22:- Stub-Axle FOS

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As the factor of safety obtained is 3.2, the stubaxle can be considered safe.

Deformation (mm)	Von-Mises Stress (MPa)	Factor of safety
0.094	77.923	3.208

Table 3:- Results of Analysis of Stub-Axle

V. TRANSMISSION

Chain and sprocket mechanism is used to transmit the power from the motor to the wheels. A hollow axle connects the rear wheels and is mounted to the chassis. The material of axle is C-45 with outer diameter 20 mm and thickness 2 mm. This size is standard size available in market. The teeth on driving and driven sprockets are 10 and 35 respectively. The required top speed is 20 kmph.

A. Calculatuions

Motor rpm = Motor kv * Battery Voltage
= 170 * 22.2 = 3774 rpm
Assuming efficiency as 75%,
Actual rpm = N1 ≈ 2800 rpm
Power delivered by motor,
P = 2.8 kW
P = 2*3.14*N1*T1/60
T1 = 9.55 Nm
Torque provided by motor = 9.55 Nm

No. of teeth on driver sprocket = Z1 = 10
No. of teeth on driven sprocket = Z2 = 35
N1/N2 = Z1/Z2; N2 = 800 rpm
Torque on rear wheels = T2 = 60*P/(2*3.13*N2)
= 23.88 Nm

Velocity = v = 3.14*D*N2/60
Keeping top speed as 20 kmph i.e. 5.56 m/s
D = Diameter of wheel = 125 mm

To start from rest, the motor needs to overcome the Frictional Force, F1
F1 = µ * mg
Assuming coeff. of static friction = 0.42 and mass = 80 kg,
F1 = 329.61 N
Torque required to start the skateboard from rest,
T = F1 * R = 329.61 * 0.0625 = 20.6 Nm < T2
Hence, the motor will work fine.

Tip diameters of motor sprocket (Da1) and wheel sprocket (Da2)
Da = p/tan (180/Z) + 0.6p
Therefore, we get
Da1 = 23.35 mm, Da2 = 84.5 mm

Sprocket will be mounted on the center of the rear shaft

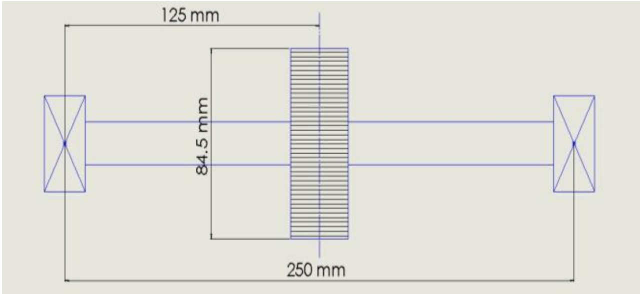

Fig 23:- Rear Axle

Torque on the shaft T = 23.88 Nm
Tangential Force on sprocket,
F = 2T/D = 2*23.88/0.0845 = 454.86 N
Considering pressure angle = α = 20°
Normal load acting on tooth of sprocket,
W = F/ cos α = 454.86/cos (20) = 484 N
Maximum bending moment is at the center, as sprocket is mounted on the center
M = WL/4 = 484 * 0.25 / 4 = 30.25 Nm

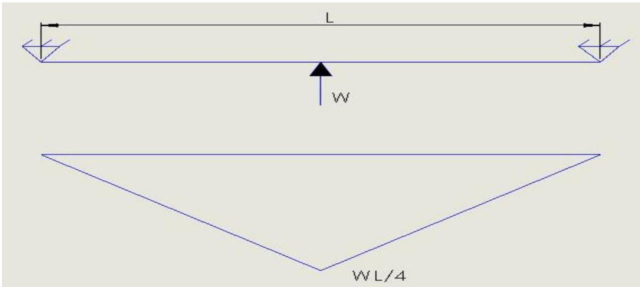

Fig 24:- Bending Moment Diagram

Now, the equivalent moment Te is given as

$$Te = \sqrt{M^2 + T^2} = \sqrt{23.88^2 + 30.25^2}$$
$$= 38.54 \text{ Nm} = 30.4 * 10^{\wedge}3 \text{ Nmm}$$

T = 23.88 Nm
M = 30.25 Nm
Te = 38.54 Nm

D = 20 mm ; d = 12 mm

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\frac{M}{\pi\,(D^4 - d^4)/64} = \frac{\sigma}{D/2}$$

σ = 41.104 N/mm2

$$\frac{\pi D^3 \left(1 - \left(\frac{d}{D}\right)^4\right)}{16} \times \tau = Te$$

τ = 26.18 N/mm2

Using C-45, τ = 90 N/mm2
FOS = 3.44

Hence, the axle is safe

B. Static Structural Analysis

The analysis is done on Ansys Workbench 15. The mesh shape is tetrahedron with size 2 mm.

- Fixed constraints: Bearing points
- Moment: Equivalent torque of 38.54 Nm is applied on the axle

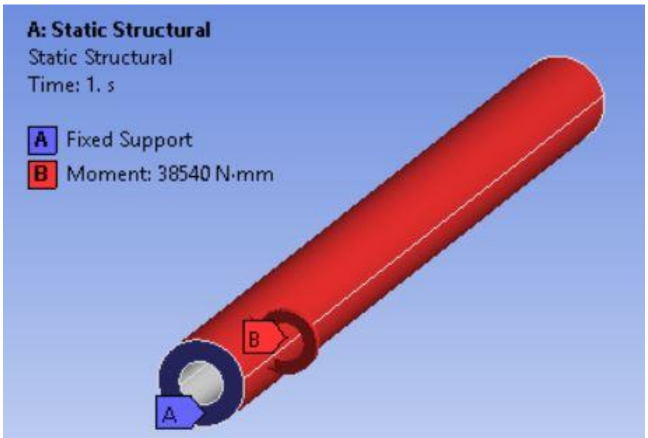

Fig 25:- Axle Constraints

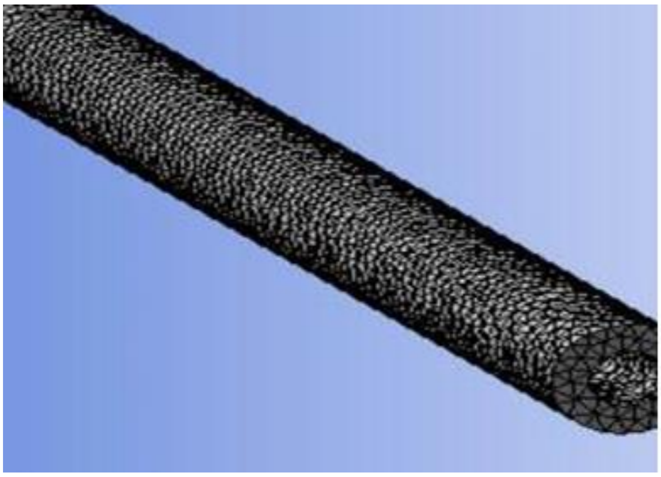

Fig 26:- Axle Mesh

C. Results of Analysis

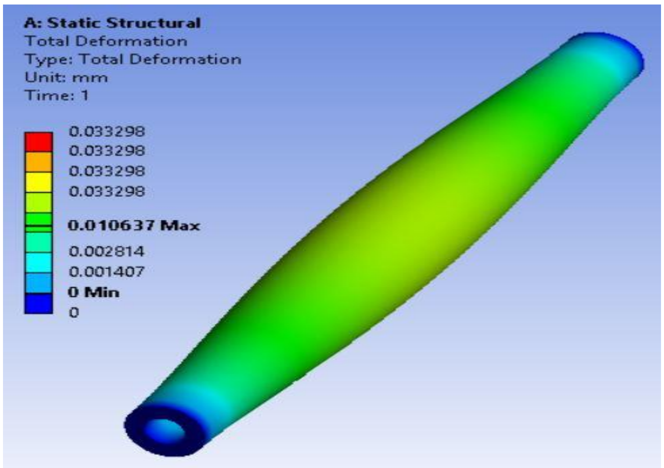

Fig 27:- Axle Deformation

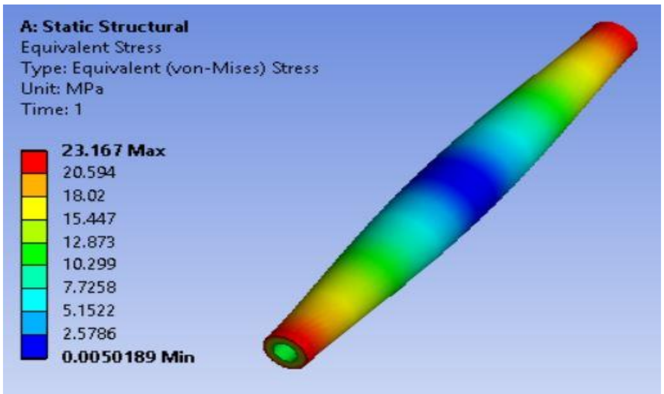

Fig 28:- Axle Stress

Hence, the value of stress obtained by analysis (23.167 MPa) is very close to the calculated value (26.18 MPa). Therefore the design of axle is safe.

Deformation (mm)	**Von-Mises Stress (MPa)**	**Factor of safety**
0.0106	23.167	3.44

Table 4:- Results of Analysis of Axle

VI. CONCLUSION

The fabricated skateboard can thus achieve the top speed of 20 kmph. According to the information and experience provided by electric skateboard users all over the world, maximum range of 8 kms can be achieved on full charge. This design can overcome the shortcomings of traditional skateboards considerably. This is also safer and easier for the rider. The powerful motor, combined with the innovative steering system is what makes this project unique. This paper has reviewed techniques used to fabricate the e-skateboard and the electronics involved as well. The development of this model is a step forward to achieving the goal of electrification of the automobile industry.

REFERENCES

[1]. P. Viswabharathy, P. Boobalan, M. Arun Wingston, “Design and Fabrication of Electric Skateboard for Off Road Application,” IIJETER; Vol. 5, Issue 3, March (2017)

[2]. Jeevanantham, Sivakumar, Pavithran, Pradheep, Rajakrishnan, Rajaprasath. “Design and Fabrication of Solar Longboard,” IJARIIE; Vol. 3, Issue 4, 2017

[3]. Zhidong Zhang, “Design of Controller in Electric Bicycle,” Modern Applied Science, Vol. 5, No. 5, October 2011

[4]. “Electric vehicles,” IEEE Spectrum, pp. 18–101, November 1992

[5]. M. Terashima, T. Ashikaga, T. Mizuno, and K. Natori, “Novel Motors and Controllers for high-performance electric vehicle with four in-wheel motors,” IEEE Trans. Ind. Electron., vol. 44, pp. 28–38, Feb. 1997

[6]. https://www.electric-skateboard.builders