# STEEL WORK DESIGN AND ANALYSIS OF A 2-WHEELED SCOOTER

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**Abstract -** This motorized Two-wheel scooter is specifically designed for low speed, and hence is more suitable for short distance commute. It incorporates a mild steel frame which houses the transmission mechanism. This transmission system in its self is a motor- chain-sprocket assembly: a 350w DC motor powered by a 24v, 18A battery generates sufficient torque which is transmitted by a 16 toothed sprocket through a chain comprising of 64 links to a rear sprocket (22 teeth) attached to the rear wheel. On either side of the handle bar is the brake lever (left) and speed controller (right) for ease of navigation. The stress analysis reviled that the maximum stress induced on the frame due to design load is 49.156N/$m^2$. The maximum design load of this scooter is 686.7N, and from the graph analysis the scooter travels at a maximum velocity of 0.51m/s. The graph also reviled that the velocity of the scooter is inversely proportional to the load. Similarly, the discharge rate of the battery increases as the load is increased. Also, the scooter velocity is directly proportional to the rate of battery discharge. The continuous working time of the battery is 40min at rated load and normal working condition.

**Keyword**; Scooter, electric vehicle, design, velocity, motorize, wheel.

## I. INTRODUCTION

The effect of the emissions from fossil fuel operated engines has increased the interest of private and public sectors in the use of cleaner energy sources especially for the purpose of transportation. These effects extends from human health to vegetation, buildings and structures (Ojoloet al, 2017). To address this menace, a lot of electro-mobile devices as well as solar powered automobiles have evolved. In the year 2015, the global threshold of electric cars on the road rose from 1 million to 1.26 million (Pierpaolo, 2017) this shows the joint commitment of the government and industries towards securing affordable and clean energy for the human society.
The research of (Adelekan 2016) shows that the demand for transport services in Nigeria exceeds the supply.
It is unfortunate that even short distance transport systems in Nigeria still use fossil fuel as their source of power which in its little way contributes to the degradation of the environment as well as the health of humans in the surrounding. The high risk of accidents in congested areas as well as high traffic noise warrant us to begin to consider a simpler, more economical and environment friendly means of transportation which can be adopted for use within short distances.

With urban populations on the rise, it's time to put our minds to the proactive grindstone. Because too many cars already on every freeway and trains and buses struggling to keep up with each cities multiplying population, the time is rapidly approaching for commuters to take their transportation into their own hands. Thus this has led to design and construction of an environmental friendly low cost motorized scooter.

## II. DESIGN PHILOSOPHY

The design of the motorized scooter will be governed by the following:

- The machine should be considerably cheap and affordable.
- It should be simple and easy to operate
- It should be easy to maintain
- It should be user friendly
- It should be environment friendly

### 2.1 Components of the Machine

The scooter has the following basic components
- Brushed dc motor
- ½" Sprockets
- ½" chain
- 24volt battery
- 10mm ball and roller bearings
- Frame ( handle bar, floorboard and front wheel fork )
- Tire hubs
- Tire shafts
- Braking device
- Speed controller
- Tires

## III. DESIGN FOR VARIOUS PARTS

The various parts of the machine were properly designed for, within appropriate design considerations.

### 3.1DC Motor

The choice of the dc motor was guided by the following design consideration:

**3.1.1Design load**

this refers to the maximum load the scooter can support/carry so as to run at a specified speed range without failing. It comprises of both the weight of the rider and the weight of the scooter itself. Mathematically,

Design Load = weight of scooter + weight of rider (Newton) (1)

**3.1.2Weight of scooter:**

this is the summation of the weight of all the components that makes up the scooter. The weight analysis of the scooter is given below

- Battery – 10kg
- DC Motor – 5kg
- Frame/handle bar – 4kg
- Other accessories – 1kg

Total mass of scooter = 10kg+5kg+4kg+1kg = 20kg

**3.1.3Mass of rider:**

This was estimated to be 50kg. This figure was estimated based on assumption that the average weight of a Nigerian teenager will be around 50Kg. Hence, from eqn.1 the total design load is given below;

$\text{Design Load} = 20\text{kg} + 50\text{kg} = 70\text{kg}$

But $F = W = mg$ (Kurmi and Gupta, 2005)

(2)

$F = 70 \times 9.81 = 686.7\text{N}$

**3.1.4Power required to drive the design load**

Power (P) = Torque ($\tau$) x angular velocity (W)(Kurmi and Gupta, 2005)

ie. $P = \tau \times W$ (3)

But, $\tau = F \times r$ (4)

Where r = radius of the sprocket through which the force is applied

**3.1.5Sprocket pitch diameter (D)**

It is given by the product of the Sprocket pitch diameter constant, K (for the corresponding No. of teeth) and the chain pitch, p (in inches).

Ie. $D = K \times p$ (Richard and Keith, 2011) (5)

For a 22-teeth sprocket, $K = 7.0266$

Therefore, from eqn. (5), $D = 7.0266 \times 0.5\,(\text{in}) = 3.5133"$

$D = 89.237\text{mm} = 0.089237\text{m}$

$\text{Sprocket radius, } r = D/2 = 0.04461\text{m}$

From eqn.4: $\tau = 686.7\text{N} \times 0.04461\text{m}$

$\tau = 30.63\text{Nm}$

Angular velocity $\omega = \frac{2\pi N}{60}$ (6)

Where: N = speed of driven shaft (rear wheel shaft) in rpm

$\text{Taking } N = 120 \text{ rpm}$

From eqn.3,

$P = \tau \times \omega = \frac{2\tau\pi N}{60}$ (Kurmi and Gupta, 2005)

$P = \frac{2 \times 30.63 \times \pi \times 120}{60} = 384.91\text{Watt}$

Therefore power required to drive the designed load is 384.91Watts

**3.2 Sprocket Selection**

The choice of sprocket was dependent on the desired speed and torque. Being that the scooter is designed for low speed, and requires greater torque to overcome the applied load, the driving sprocket smaller than the driven sprocket.Thus the sprocket selection follows the following:

**3.2.1Driving Sprocket: No. of teeth 16**

Type: #40

Pitch: ½"

**3.2.2Driven Sprocket: No. of teeth 22**

Type: #40

Pitch: ½"

$\text{Speed Ratio} = \frac{\text{No.of teeth on large sprocket}}{\text{No.of teeth on smaller sprocket}} = \frac{T_2}{T_1}$ (7)

$\text{Speed Ratio} = \frac{22}{16} = 1.375$

**3.3Chain Dimensions**

The equations for calculating the chain length, L and center distance between the two sprockets, C are shown in equation 8 and 9 respectively

**3.3.1Chain pitch = ½" No. 40**

**3.3.2Chain length, L (in pitches) is given by:**

$L = \frac{2C}{p} + \frac{N+n}{2} + \frac{p\left(\frac{N-n}{2\pi}\right)^2}{C}$ (8)

$C = \frac{P}{8}\left[2L - (N-n) + \sqrt{(2L-(N+n))^2 - \frac{8}{\pi^2}.(N-n)^2}\right]$ (9)

Where: C = center to center distance between the two sprockets (in inches)

L = chain length (pitches)

N = number of teeth on larger sprocket

N = number of teeth on smaller sprocket

P = chain pitch

Given the following values:N = 22, n = 16, p = 0.5. Assuming a center distance, C of 28cm (11.024in);

$L = \frac{2*11.024}{0.5} + \frac{22+16}{2} + \frac{0.5\left(\frac{22-16}{2\pi}\right)^2}{11.024}$

$L = 44.096 + 19 + 0.0414$

$L = 63.1374 = 64 \text{ pitches}$

Similarly, using eqn. (8)

$c = \frac{0.5}{8}\left[90 + \sqrt{90^2 - 29.1805}\right]$

$c = 11.240\text{inches} = 28.549\text{cm}$

### 3.4Battery

The battery of choice for this particular scooter is the Sealed Lead Acid Battery (SLA), due to their ability to generate high current. The size of the battery used is based on the power rating and current required to drive the DC motor.

Recall that power, P = IV (9)

Where I = current (18amp) and V = voltage (24v)

Therefore, $P = 18 \times 24 = 432\text{watt}$

This value of 432watt is higher than the input power of 350watt required by the DC motor. Hence, the battery used has the following rating: 24v, 18AmpH

### 3.5Frame Design

With the frame being a structure, the stability, strength and rigidity of members must be ensured. The basic objective in frame design is to produce a structure capable of resisting all applied loads without failure during its intended life. The materials used for this purpose aremild steel pipe, angle iron (mild steel) and cylindrical hollow pipe (mild steel), because of their good mechanical properties.

The frame dimensions are given as:

Height = 20cm

Length = 55cm

Width = 24cm

Handle bar extension (adjustable): 100cm (from top of the frame, i.e. surface)

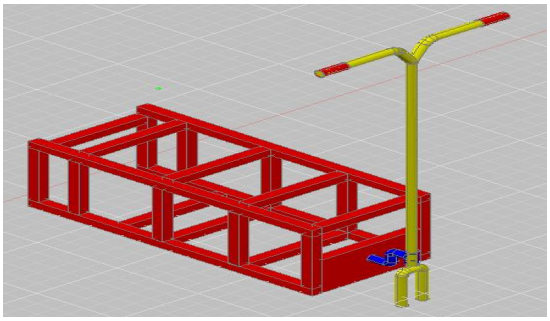


**Fig. 1: Scooter Frame**

## IV. STRESS ANALYSIS ON FRAME

The stress on a member is given by the equation (Kurmi and Gupta, 2005):

$$\sigma = \frac{P}{A}\ (N/m^2) \qquad (10)$$

where: P = load on the member (N)

A = cross sectional area of the member on which the load acts ($m^2$)

P = design load of rider = 686.7N

A = (25.4*550) $mm^2$ =13970 $mm^2$

Therefore principal normal stress on each beam of the frame:

$$\sigma = \frac{686.7}{13.970}\ (N/m^2) = 49.156 N/m^2$$

The maximum stress on the frame beam is given by (Kurmi and Gupta, 2005) as;

$$\sigma_{max} = \frac{\sigma_x + \sigma_y}{2} + \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2} \qquad (11)$$

where: $\sigma_x$ = normal stress on the x axis

$\sigma_y$ = normal stress on the y

$\tau$ = shear stress on the xy plane

But $\sigma_x = 0$

$\sigma_y = \sigma = 49.156\ N/m^2$

$\tau_{xy} = 0$

Therefore:

$$\sigma_{max} = \frac{0 + 49.156}{2} + \frac{1}{2}\sqrt{(0 - 49.156)^2 + 0}$$

$$\sigma_{max} = 49.156 N/m^2$$

Material Yield strength, $\sigma_y = \sigma \times N$ (Where N= Factor of safety)

For mild steel material under live load, N is given by (Kurmi and Gupta, 2005) as 8

Therefore: $\sigma_y = 49.156 \times 8$

$$\sigma_y = 393.248\ N/m^2$$

## V. SPEED CONTROL MECHANISM

The regulation of the speed of the scooter is achieved through a control throttle. This device incorporates the use of variable resistors arranged such that they alter the amount of current that passes from the power source (battery) to the motor.

Using Ohms equation relating current, velocity and resistance, the variable resistors were able to be determined (Rajput, 2004) as:

$$R = \frac{V}{I}\ (\Omega) \qquad (12)$$

Where V= Voltage (Volts) and I= Current (Amp).

The allowable current rangeis 10.42A to 14.58A

**Table1: battery current and corresponding resistance required**

| S/N | Current (Ampere) | Resistor (Ohms, Ω) |
|---|---|---|
| 1 | 10.42 | 2.30 |
| 2 | 11.46 | 2.09 |
| 3 | 12.50 | 1.92 |
| 4 | 13.54 | 1.77 |
| 5 | 14.58 | 1.65 |

## VI. MACHINE CONSTRUCTION

The machine was constructed using essentially the welding machine, drilling machine, grinding machine, sheering machine and shaping machine. For the frame, a1" × 1"square pipe was marked and cut using meter rule, scriber and hack saw respectively, before using try square and welding machine to set and join them appropriately. The angle bar was also marked and cut to size. The bearing housing was fabricated using mild steel cylindrical pipe cut to specified dimension. A flat plate of 1mm thickness was marked, cut and shaped round to cover one end of the pipe. The circular openings (for the shaft) on the bearing housing were achieved by the use of the vertical drilling machine, making use of appropriate drill bits for the holes. The battery casing was constructed using a 1mm mild steel sheet which was marked, cut and shaped using the scriber,

shearing and shaping machines respectively. The various joints on the frame were achieved using the shielded metal arc welding process (SMAW), and the electrode used is that of gauge 12. The transmission layout consists of the dc motor and the rear wheel. The motor was mounted firmly to the base frame using M13 bolts and nuts. The rear wheel on the other hand was mounted by fitting the hub (which carries the driven sprocket) to the tyre and then passing the shaft through the whole assembly to the two bearings on either sides of the frame at the rear end. The alignment was assured by the use of a spirit level (plumb). By proper calculation for chain as specified above, the chain was cut to the required length using a chain breaker and was joined back using a master-link. The chain was then fitted unto the two sprockets for power transmission. The brake was fitted to the rear wheel and the control lever mounted on the handle bar was connected to the brake using suitable cables.

## VII. RESULTS

Test was performed on the machine with varying parameters as shown in tables 2 and 3:

**Table 2: Test results for various variables**

| S/N | Load, P (N) | Torque, τ (Nm) | velocity, v (m/s) | Speed, N (RPM) | Discharge Time ,t (min) | Distance covered, S(m) |
|---|---|---|---|---|---|---|
| 1 | 392.40 | 26.26 | 0.59 | 127.29 | 46.27 | 1637.60 |
| 2 | 441.45 | 28.45 | 0.55 | 117.46 | 43.14 | 1423.62 |
| 3 | 490.50 | 30.68 | 0.51 | 109.10 | 40.00 | 1224.00 |
| 4 | 539.55 | 32.82 | 0.48 | 101.82 | 37.65 | 1084.32 |
| 5 | 588.60 | 35.01 | 0.45 | 95.47 | 35.30 | 953.10 |
| 6 | 637.65 | 37.20 | 0.42 | 89.83 | 32.94 | 830.10 |
| 7 | 686.70 | 39.39 | 0.40 | 84.86 | 31.74 | 761.76 |

**Table 3: Discharge rate for designed load (686.7N) at various speeds**

| S/N | Velocity, (m/s) | Discharge Time ,t (min) |
|---|---|---|
| 1 | 0.36 | 28.24 |
| 2 | 0.40 | 31.37 |
| 3 | 0.44 | 34.51 |
| 4 | 0.47 | 36.86 |
| 5 | 0.51 | 40.00 |

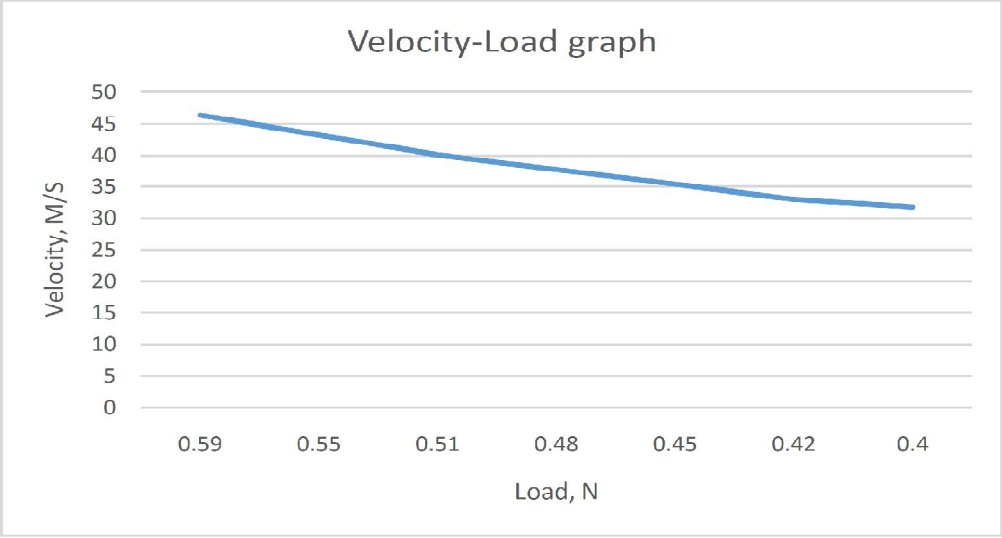



**Fig. 2: Graph of load against velocity**

From the graph shown in fig.2, the velocity of the scooter is inversely proportional to the load it carries. That is, the higher the load on the scooter, the slower the velocity. The maximum velocity of the scooter at design load (686.7N) is 0.51m/s

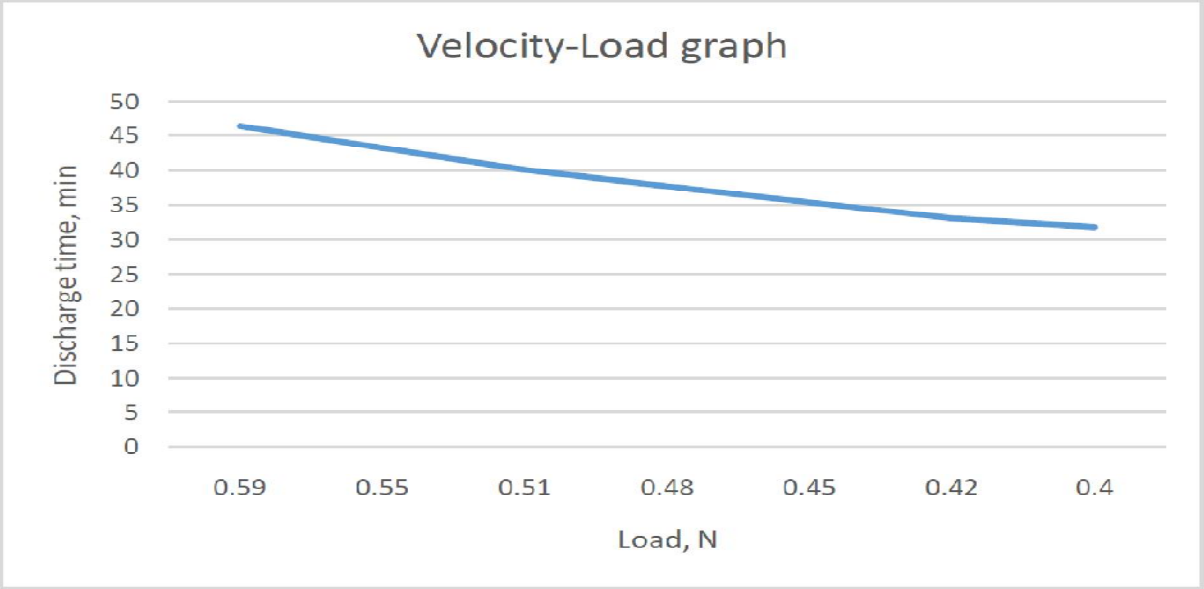



**Fig. 3: Graph of load against battery discharge time**

From fig. 3 it is seen that the higher the load, the faster the rate of battery discharge and vice versa.

## VIII. MACHINE EFFICIENCY

The scooter efficiency was evaluated in the following ways:

- **Motor efficiency:**
  this the ratio of the power delivered by the battery into the motor (power input) to the power delivered by the motor (power output).

Therefore, motor efficiency, $\eta_m = \frac{P_{out}}{P_{in}}$

$\eta_m = \frac{350}{432} * 100 = 81\%$

## CONCLUSION

The design and construction of the scooter was done in accordance to accepted design considerations. The result of the conducted test show that the velocity of the scooter is dependent on the load it is carrying. The higher the applied load, the slower the speed and vice versa. This is so because higher load require more power to overcome the inertia due to the load and also requires higher motor torque to keep the scooter in motion.

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