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Research Article

# Multipurpose Single Electric Powered Wheel

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**Abstract:** Nowadays, Electric powered vehicles are the most efficient mode of transport. Electric motors are rotating the shaft of any vehicle or in the case of the hub motor the wheel itself. In this project, we are working on a single electric-powered wheel that will be used at multiple places with some easy adjustments in clamping. Our electrically powered wheel can improve the mobility of people with disabilities, as an electric scooter and for various other purposes. An electric hub motor is used in a wheel with which the battery and all the electric circuits are placed around the handlebar for easy accessibility. This will reduce man efforts, to make all these operations work through one mechanism. When this wheel is clamped to its other attachments, a new functional use of this electric powered wheel can be put to use.

**KEYWORDS:** Multipurpose, Electric powered wheel, Hub motor, Lithium-ion Battery, ECU, Clamps, Speedometer, controller.

## I. INTRODUCTION

Electric-powered vehicles are the future as our natural resources are on the verge of extinction. The transport industry is the major industry which is using electricity as a fuel for the movement of its vehicles. To add to this industry, we have made a battery-powered wheel that can be used to power automotive that require human force for its movement. Using electricity as a fuel makes it more eco-friendly only in case if its electricity is produced through renewable sources of energy. The wheel serves various other purposes such as for making ease of movement for people having disabilities [11][14] which will make them independent, they can now easily control their wheelchair movements [13] as per their wish, further making a little changing in clamping we can also use this single powered wheel as an electric scooter which will help to commute and transport goods in local. Operating of this single electric wheel will be so smooth, all controls are available on handlebars with ease of access [12]. Clamping different attachments are user-friendly and can be easily done in a couple of minutes with minimum changes in the fixture.

To make the wheel motorized, we have added electric motors and battery making it much eco-friendly and pollution-free. We have used a lithium polymer battery which will also reduce the weight of this mechanism and increase the life of the battery and helps in fast charging too. All connections are done to the ECU better known as a controller [12]. The ECU is the main unit that sends electric current to the motor according to the response of the throttle. Forward and reverse both way drive is available in this vehicle. Battery, motor, speedometer, throttle system, horn all of these are connected to ECU. This mechanism is easy to use and cost-effective and can be used at multiple places. It has a compact and sturdy design which makes it mobile. Using this solves a lot of problems and also provides fun to the driver. Especially people who are disabled can now match their lifestyle with others. It precedes our expectations and performs pretty well; further, improvement can be done.

## II. LITTERATURE REVIEW

[1].Sankardoss, V. &Purushothaman, Geethanjali. (2019). Design and Low-Cost Implementation of an Electric Wheelchair Control. IETE Journal of Research. 1-10. 10.1080/03772063.2019.1565951: - This paper discusses the design and low-cost implementation of direction and speed controller for an electric wheelchair [1] actuated using a permanent magnet direct current (PMDC) motor.

[2].Nazir, Samir & Wong, Y.S. (2012). Energy and Pollutant Damage Costs of Operating Electric, Hybrid, and Conventional Vehicles in Singapore. Energy Procedia.: -This is part of broader work to compare the costs and benefits of EVs with hybrid and ICE vehicles in Singapore. (C) 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the organizing committee of 2nd International Conference on Advances in Energy Engineering [2] (ICAEE).

[3].Cheng, K.W.E. (2009). Recent development on electric vehicles. 2009 3rd International Conference on Power Electronics Systems and Applications, PESA 2009. 1 - 5.: -This paper provides an overview of the recent work of electric vehicle in the region [3]. The paper describes the development and the comparison of different part of components.

[4]. Nowell, G. &Gillie, Mary. (2013). The Future for EVs: reducing network costs and disruption. 10.2-10.2. 10.1049/cp.2013.1915.: - This paper provides an overview of the futuristic predictions and methods to control the system of charging EVs directlyusinga device called Esprit [4].

[5].Tsukamoto, Tomohiro & Shibata, Kazumi & Tominaga, Takashi &Akutsu, Susumu. (2013). Battery for electric vehicle.: -this paper discusses about a battery configured as a plurality of battery cells for an electric vehicle with one board for supplying electric power to an electric motor [5]. Each battery cell is provided with positive and negative electrodes on the side of the board.

[6].Himarosa, Rela&Sunardi,. (2020). Design, Frame Analysis and Manufacture of Handcycle Prototype. Journal of Physics: Conference Series. 1471. 012058. 10.1088/1742-6596/1471/1/012058.: - This study designed a handcycle as a mode of transportation to facilitate the accessibility of persons with disabilities [6]. The design of the handcycle was designed on a prototype scale.

[7].Duvigneau, Fabian &Perekopskiy, Sergey & Kasper, Roland & Gabbert, Ulrich. (2017). Acoustic optimization of an electric wheel hub motor.: - In this paper an innovative concept for designing the electrical drive of automobiles is presented which allows optimizing the acoustic behavior on a virtual basis[7]. In special, the acoustics of an electric wheel hub motor is studied in detail.

[8].Heo, Yoon & Hong, Eung-Pyo& Mun, Mu-Seong. (2013). Development of power add on drive wheelchair and its evaluation. 2013 9th Asian Control Conference, ASCC 2013. 1-6. 10.1109/ASCC.2013.6606244.: - In this study, the design specification of a driving motor for a PADW is determined via modeling[8], and a light-weight wheelchair is developed by adopting an in-wheel motor that is detachable from the wheelchair and allows conversion between the manual and the powered modes freely.

[9].Hong, Eung-Pyo& Kim, Yong-Cheol & Kim, Gyoo-Suk & Ryu, Jae-Cheong & Mun, Mu-Seong. (2011). Development of Driving System for Power Add-on Drive Wheelchair. Journal of the Korean Society for Precision Engineering. 28.: - This paper provides an overview of the design exECUtion and development of power add-on driven wheelchairs[9].

[10].Dietrich, Christian & Bayer, Jens &Behm, Rolf &Bansmann, Joachim &Diamant, Thomas. (2016). The durability of stainless-steelbonding. ADHESION ADHESIVES&SEALANTS. 13. 26-31.

10.1007/s35784-016-0036-z.: - In this paper, an in-depth study has been carried out into the influence of laser treatment[10] on the durability of stainless-steel bonding.

## III. COMPONENTS

### A. Hub Motor

Torque in a motor is produced using electric current through tightly coiled wire placed between the poles of a magnet and the coil that around them,producing E.M.F that rotates the wheel in desired direction. The hub motor [7]is used in our project which are incorporated into the hub of a wheel and drives it directly.

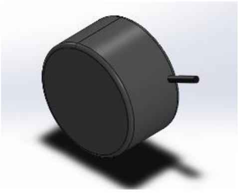


**Figure: Hub Motor**

### B. DC Battery

The battery used is to supply the power to various electrical components like speedometer, throttle system, hub motor, horn, lights, etc. We have used a lithium-ion battery pack [5] with 48to 60V capacity with aluminum casing as it allows us to use multiple batteries combined with reliable operations when compared to other forms of cell and battery technology including Nickel Cadmium and Nickel Metal Hydride, NiMH [3]. A lithium-ion battery is light in weight as compared to a Lead-acid battery and easily available in the market.

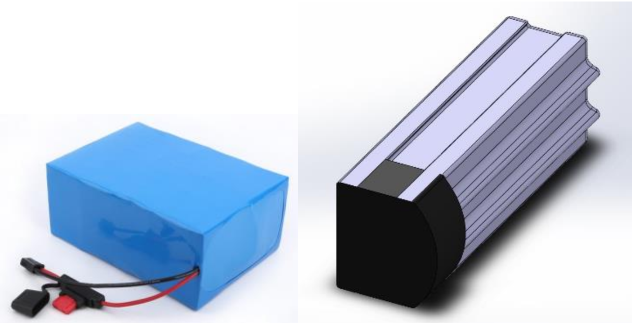


**Figure: Li-ion Batterywith Aluminum Casing**

### C. Motor Controller

A motor controller is a device or group of devices that can coordinate in a predetermined manner according to the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor[12], selecting forward or reverse rotation, regulating the speed, regulating or limiting the torque, and protecting against overloads and electrical faults. Most of the motor controllers in the market are using an H-bridge circuit where we can control a large motor using a small signal. All electrical components wiring isconnected to the controller. In our project, the motor controller is integrated within the odometer.

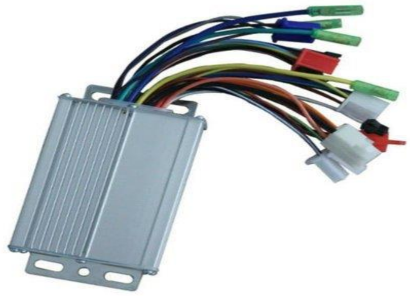


**Figure: Motor Controller**

## D. Throttle system

A throttle is used to control the speed and other facilities of a vehicle.We've used a grip operated throttle which is mounted on the right side of the handle bar [12].

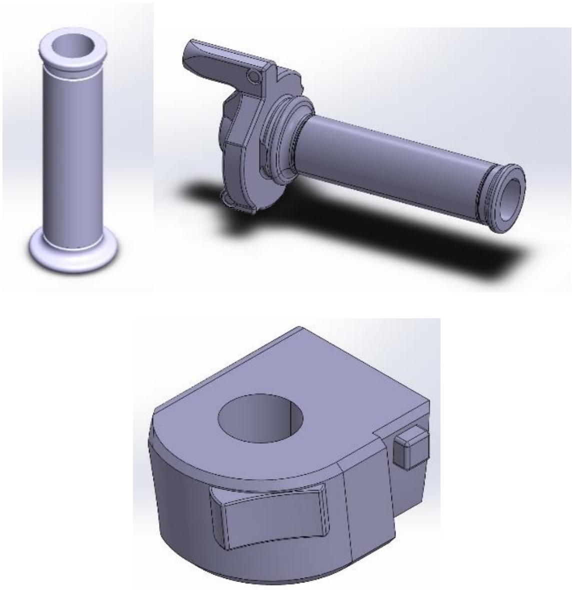


**Figure: Throttle System**

## E. Speedometer

Speedometer is a device which measures and display the instantaneous speed[17]. It also shows the total distance vehicle has covered, how much charge is left in battery, how far it can go with particular mode.

**Figure: Speedometer**

### F. Wheel

The wheel consists of a hub motor.A high grip wheel[9] is used in our vehicle. The wheel rim is connected to the hub motor with the help of spokes. We've used a tubeless tire with 210mmradius and the rim is made up of alloy steel. The weight of the tire is 1.5 kg along with the rim.

**Figure: Wheel**

### G. Brake

Brake is used to stop the movement of wheel. Here we have used disc brakes[16] or power brakes for ease. Along with that, we've used a break leaver to actuate the braking process with ease.

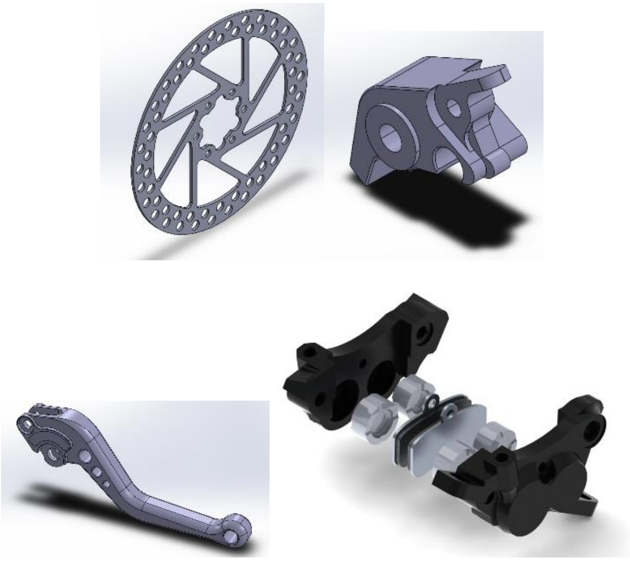


**Figure: Disc Brake and it's components**

### H. Light and Horn

The driver uses the horn to warn others of the vehicle's approach or the presence or to call attention to some hazard. Every vehicle is required to have horns according to law. We have used a modern horn with an attached wired button for easy adjustments. High-intensity LED headlights and taillights [18] are used in our vehicle for proper illumination of the road ahead of the driver. These are an important component of a vehicle as they make drivers aware of oncoming hazards.

**Figure: Horn and light parts**

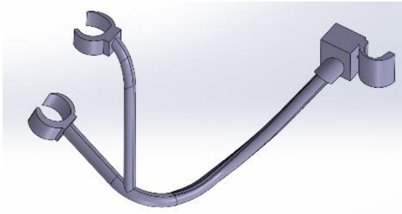
### I. Frame Material

For frame material, we have used mild steel.MildSteel[6] is significantly stronger and more durable [10] than its aluminum counterpart, making it an excellent choice for E-bikes. MildSteel-framed bikes can absorb more blows with suffering damage[15]. Mild steel is also less expensive than carbon fiber and it is also denser, i.e., we can use thinner walled tubes.

**Figure: Mild Steel tube**

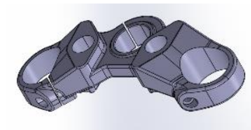
### J. Clamp

The device uses a pair of standard bicycle clamps situated at the end of two extended symmetries with detachable parts, which make it easy to plug and use. Designed to fit most folding/ rigid, adult and pediatric chairs and carts. A quick-release valve [20] is used to easily engage or disengage the machine to any cart or wheelchair.

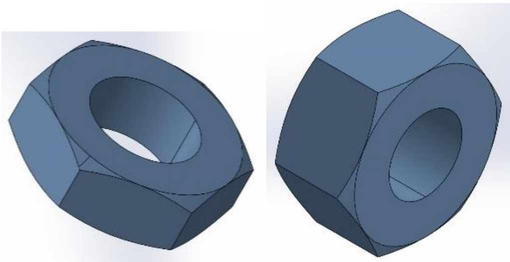


**K. Joints and misclenous parts**

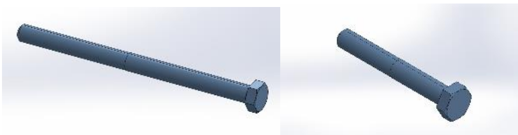
Top Yoke:-



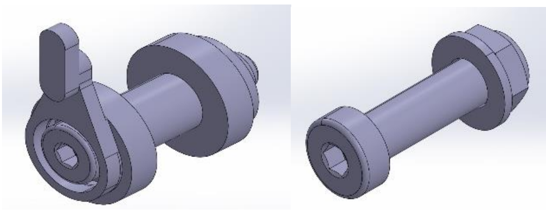
Nuts:-



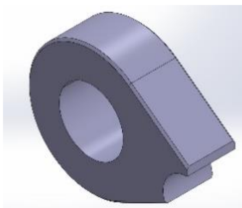
Bolts:-



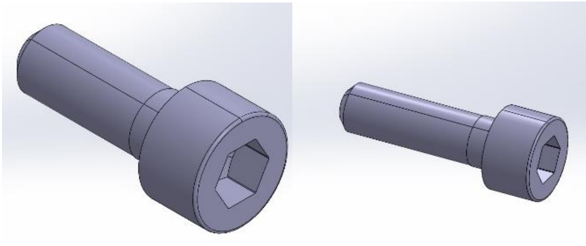
Handle arm and arm screw :-



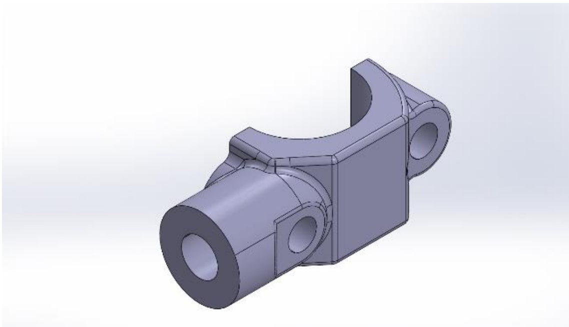
Handle adjuster: -



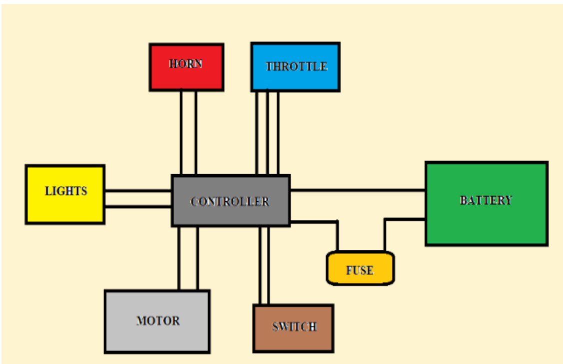
Screws: -



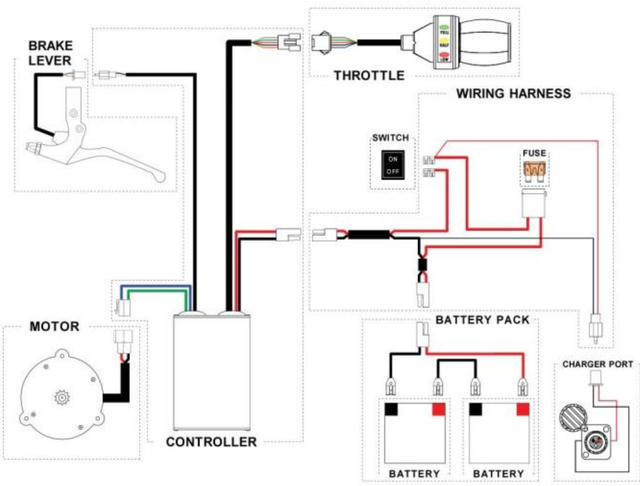
Clamp: -



## IV. BLOCK DIAGRAM

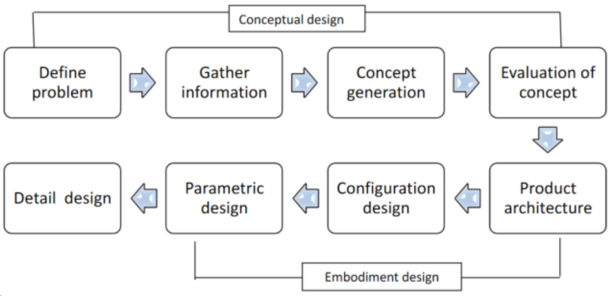



## V. CIRCUIT DIAGRAM



## VI. DESIGN

We've used solid works to design all the components of our vehicle. To start with, we made parts of all the components using multiple commands like extrude, cut, mirror, draft, etc. for its




design.

The design of its frame is inspired by an electric scooter. The figure below shows the main design of the monowheel attachment with clamps and other parts. The yoke of the handle is attached using clamps and rods for easy adjustment according to the rider or cart.

**Figure. Actual design without wheelchair**

Different section view of the attachment shows isometric and other views of the mono wheel in different angles. The four clamps at the end of stem are used for strong grip of the wheel.

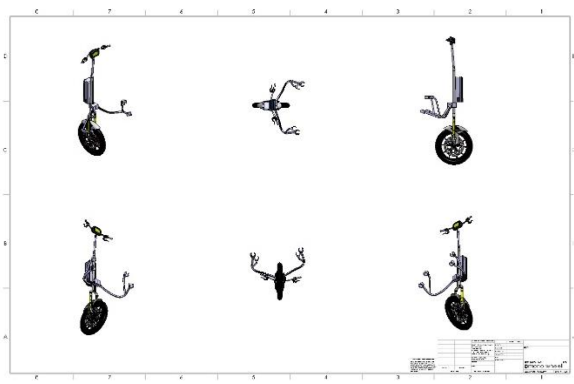


**Figure. Different views of the attachment**

The design of the wheelchair is assembled using the assembly section in solid works. We've taken the dimensions of a standard wheelchair for explanation of the it's working.

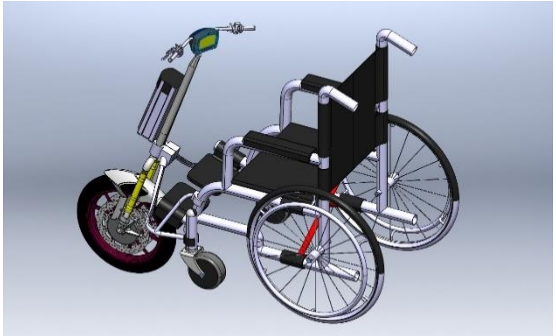


**Figure. Actual design with wheelchair**

The below sheet gives us a brief idea of the different views of the complete assembly after attaching it to the wheelchair.

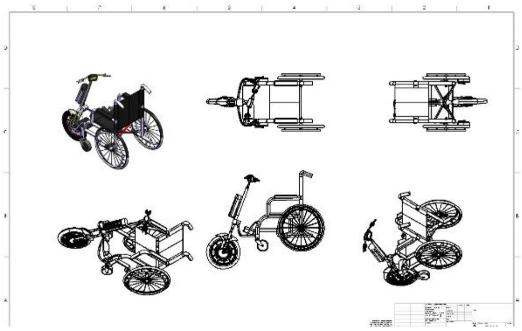
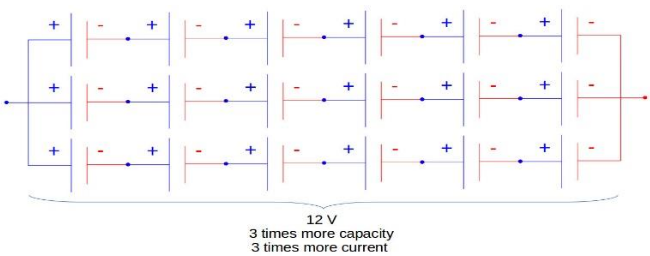


**Figure. Different views of attachment with wheelchair.**

## VII. CALCULATIONS

### A. BATTERY

Individual battery cells are grouped together into a single mechanical and electrical unit called a **battery module**. The modules are electrically connected to form a **battery pack**[21].In order to increase the current capability and the battery capacity, more strings have to be connected in **parallel**. For example, 3 strings connected in parallel will triple the capacity and current capability of the battery pack.




The voltage level of the battery determines the maximum electrical power which can be delivered continuously. Power *P [W]* is the product between voltage *U [V]* and current *I [A]*:

$$P=U\cdot I$$

we have calculated the average energy consumption for propulsion $E_p$. On top of the energy needed for propulsion, the high voltage battery must supply the energy for the vehicle's auxiliary devices $E_{aux}$ *[Wh/km]*, like a 12 V electrical system, lights, horn, etc. Also, we have to consider the efficiency of the powertrain $\eta_p$ *[-]* during the conversion from electrical energy to mechanical energy.$\boldsymbol{Eavg=(Ep+Eaux)\cdot(2-\eta p)}$

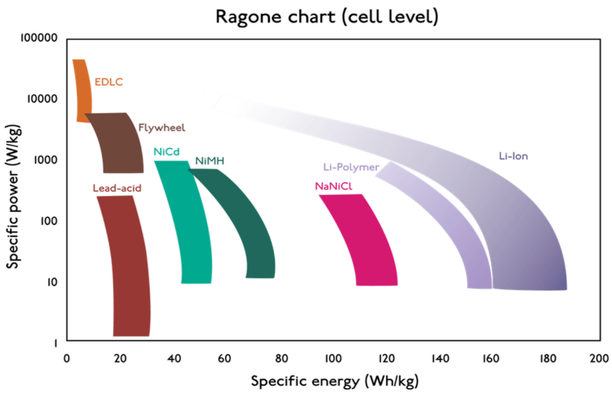



**Figure. Ragone diagram cell level adapted from Van Den Bossche 2009[21]**

## B. TIRE

For the power source of the electric motor, a certain country used different power, because it depends on the Law of the country. Rechargeable batteries used for the e-scooter are 40 to 65km/h. To calculate the force distribution on the tire, a maximum load of 200kg is applied to the chair. The location of the centre of gravity is assumed to be at the seat centre. W = mg = 200kg * 9.81m/s

For static case analysis, the summation of moments at all points and forces in all directions equals zero. To calculate the force exerted on the front tire, $N_F$; $\sum M_R=0$

$N_F*(P+Q) - W*(P) = 0$

$N_F = W*P/ (P+Q)$
$= 1962*360/ (360+1100.6)$
$= 483.58N$

## C. Steering Fork Forces

Fork offset, Of= 50mm

Steering throat length, Sth= 275mm

Length of fork, Lf= 345mm

Rake angle, θR= 25°

$\sum Mb=0$

Fa(Sth) –NFsin(θR)(Lf) = 0

Fa= NFsin(θR)(Lf)/Sth

= 483.58 sin(25º)(345)/275

= 210.56N

$\sum FRN$=0

Fa –Fb+ NFcos(θR) = 0

Fb= Fa + NFsin(θR)

= 210.56 + 483.58 sin(25º)

= 395.62N

$\sum FR$θ=0

Fc –NFsin(θR) = 0

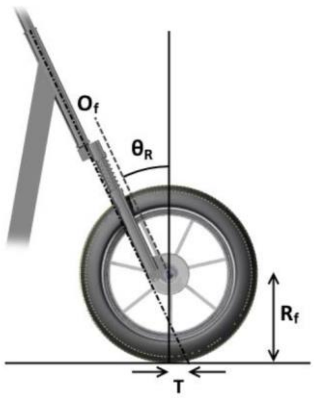
Fc= NFcos(θR)

= 483.58 cos(25º)

= 446.77

## D. TRAILCALCULATION

Trail[22] is defined as the distance between the contact points of the front tire with the imaginary line extended from the steering axis.




$$Trail, T = Rf \sin\theta R - Of \cos\theta R$$

Where;

Radius of tyre, Rf= 210mm

Rake angle, θR= 25º

Fork offset, Of= 50mm

The trail is calculated to be 42.8mm

## E. SELECTION OF HUB MOTOR

**PM SCALING LAWS:**

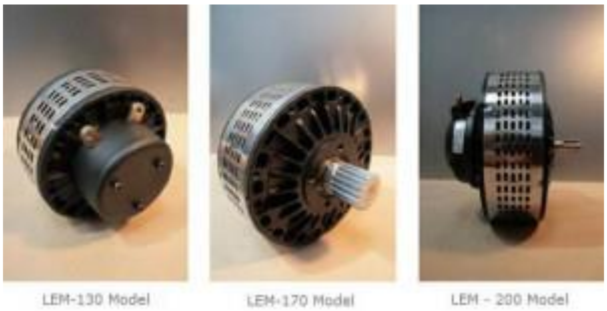
Hub motors, such as those used for bicycles, belong to the category of small PM motors (permanent magnetic). These motors by nature have a lower efficiency than large ones. These are the relationships with the motor diameter d.

- Maximum power $P_{max} \sim d^4$
- Efficiency $\eta \sim d^2$

So, the efficiency of an electromotor is proportional to the square of the diameter. If we use the motor only at a certain speed and torque, the efficiency can be optimized.

**HUB MOTOR WEIGHT:**

Hub motors are too heavy and too large for the little power they deliver. The cause is that the manufacturer takes no unnecessary risks to avoid repairs during the guarantee period. Some 250W hub motors weigh more than 3kg. To illustrate, here is an example of a high-efficiency axial gap dc motor [23] from Lynch Motor Company. The LEM 130 95s model has a weight of 3kg and an output of 3kW. The peak efficiency is 87%

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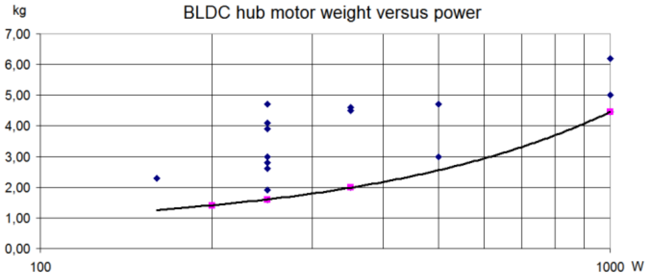
*Lynch axial gap motors*

Here is another example, the "LRP 50920 Vector 8 Brushless Modified" RC car motor: **1.360W, 275g, efficiency 91%**.

*LRP 50920 Vector 8 Brushless 1.360W 275g Efficiency 91%*

It should be noted that all these motors are high speed. After considering these motors, I wonder whether it is possible to build e-bike hub motors with higher efficiency and with a lower weight. But often there is no effort to save weight. This is an e-bike hub motor with a weight of 3.9kg and power of just 250-500W.

We made a list of PM motors [23] with their weight. There is a line that indicates the lightweight motors. Motors above the line are unnecessary too heavy.




| Manufacturer | Type | Power [W] | Weight [kg] |
|---|---|---|---|
| Tongxin-Cute | Q75 | 200 | 1.20 |
| Tongxin-Keyde | 98SWXR36 | 180 | 1.40 |
| Tongxin-Cute | Cute-85 | 250 | 1.76* |
| Tongxin-Cute | Cute-100 | 350 | 2.09* |
| Tongxin-Cute | Cute-128 | 500 | 3.00 |
| Tongxin-Cute | Cute-12 | 1000 | 4.45 |
| Bafang | SWXK | 250 | 2.80 |
| Bafang | 350W | 350 | 4.60 |
| Crystalyte | 209 | 250 | 3.90 |
| Crystalyte | 404 | 1120 | 5.50 |
| Goldenmotor | MBG36F | 250 | 2.60 |
| Goldenmotor | MBG36R | 250 | 3.00 |
| Goldenmotor | HBS36R | 1000 | 5.00 |
| Bionx | PL-250 Light | 250 | 4.10 |
| Bionx | PL-500 HS | 500 | 4.70 |
| Conhismotor | 48V 1000W | 1000 | 6.20 |
| Conhismotor | 48V 350W | 350 | 4.50 |
| Conhismotor | 24V 250W | 250 | 4.70 |
| Tongxin | 36V moto | 160 | 2.30 |
| Bafang | SWXU | 250 | 1.90 |
| | | | |
| Lynch Motor Company | 95S | 4000 | 3.00 |
| Lynch Motor Company | D127 | 21000 | 8.50 |
| Lynch Motor Company | D135 | 29000 | 11.00 |
| Perm motor | PGM 132 | 7200 | 11.00 |
| Mars motors | ET-M | 12500 | 10.90 |

* the motor weight (without cables) is measured by myself.

It is noticeable that for many hub motors, the supplier has no data or graphs. They are suspected in advance:

- There are charts, but because of insufficient motor performance, these are not published.
- The engine has more power than allowed by law to obtain more power during acceleration and therefore obtain a higher ranking in consumer tests.

The motor data that always must be known is **k, Ri,** and **Tf**. It is possible to extract the data from the motor chart.

## VIII. METHODOLOGY

The multipurpose single-powered electric wheel is a battery-powered single wheel to convert simple vehicles into automated ones [4]. This wheel uses a simple clamping mechanism that can be attached to various non-powered vehicles. The wheel is powered by a pack of rechargeable Lithium-ion batteries and thus has no environmental hazards [2]. The wheel can turn any normal wheelchair into an automatic wheelchair reducing man’s efforts of pushing and making them feel more independent. With some simple attachments, it can be used as a scooter to commute to nearby places without facing traffic jams and for other purposes as well. This multipurpose single electric-powered wheel is a unique concept no one has ever tried to make, a mechanism that can be used by various people and have various applications using simple clamping.

## IX. FUTURE SCOPE

- The complete automation can be achieved.
- Adaptable clamps with every surface clamping can be made.
- It will be more flexible and easier to use.
- The vehicle can also be linked to smartphones, so that one can access all features like GPS, battery levels, etc. from their cell phones[19].
- The extent of usability of this vehicle can be increased.
- Fast charging and good range per charge can be achieved by having advancements in the battery.
- Can be used to transport medium weight goods within a factory or to its surrounding markets.

## X. ADVANTAGES

- The setup of the vehicle is Simple and compact.
- Vehicle is easy to handle and ecofriendly.
- It can move in both forward and reverse motion.
- With an adjustable yoke, anyone with any height can adjust the steering according to their comfort.
- Lower maintenance cost.
- Saves natural resources.
- Storage space allows you to carry your bags, backpacks and packages with comfort.
- Most suitable for disabled people with spine injuries or any other problem.
- A good option for sports.
- Can be attached to shopping carts also.

## XI. LIMITATIONS

- Made for small trips and short ranges.
- Inefficient for heavy loads.
- Cannot clamp with flat surfaces.

## XII. CONCLUSION

Efficient operation and low cost can be assured in this project. In various ways, you can use this and multipurpose applications. It is efficient and economical as compared to other available resources. While taking consideration of its uses and price of the model. This vehicle becomes relatively affordable when compared to other vehicles. This gives the facility to work as an electric wheelchair, electric scooter, and automatic movement of the pram with an e-scooter. Making it electric helps to control pollution [2], being ecofriendly and concentrated towards future source [4] of energy. The size of the vehicle is smaller and lighter as compared to other automatic vehicles available in the market. In this project, we will capable of helping disabled people [14] who can't afford to buy expensive automatic wheelchairs, and also, we can use this vehicle to commute in the locality as an e-scooter. Hence it reduces the no. of vehicles required to perform the different tasks and saves human efforts.

## XIII. REFERENCE

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