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Design and Development of a Short Range Electric Mobility Device

Ishan Hiremath and Avanti Nalawade

Department of Automobile Engineering, Rajarambapu Institute of Technology, Sangli, India.

ABSTRACT

The aim of this project is to design and develop an electrically operated automatic mobility device for personal transportation in short range mobility. According to design and functional requirements, different mechanical and electrical components have been selected for the implementation. In today's world this personal mobility product allow us to travel convenient, quick, safe and without any harm to environment. This report includes design, analysis and manufacturing strategy for the electric mobility device. This device is specially designed for short range transportation. It is cost effective, efficient and environment friendly device.

KEYWORDS: Short Range Electric Mobility Device, Segway, Brushless Direct Current (BLDC), Handlebar, Static analysis, Handle wobble.

Introduction and Relevance

Introduction

Electric personal mobility device is need of today's world. In today's world where we are in search of new options for conventions transportions this personal mobility devices are becoming popular and environment friendly. Such devices include electric scooters (e-scooters), Segway's, hoverboards, u-wheels, powered mini scooters (go-peds), and powered unicycles. However, personal vehicles are an integral part of modern city life, providing several benefits to individuals. In the future, there will be an overall increase number of users of electric mobility throughout the world. As the populations is increasing it will lead to increase in pollution due to vehicles, traffic problems, noise pollutions and many more. It is need of today's world to shift to electric mobility and personal transporation devices to travel nearer distance.

The above trends have resulted in a wide discussion about sustainable transportation in metropolitan areas. In broad terms, the movement to sustainable urban transportation involves accessibility and the generation of wealth by cost-effective and equitable means, while safeguarding the health and minimizing the consumption of natural resources and the emission of pollutants. As global warming and climate change are the major issues in world, pollution is major cause for this. With increasing population, there is rapid increase in personal vehicles. Carbon monoxide, nitrogen oxide, and other toxic gases are released from convention vehicles. An emission from a typical passenger car is 4.6 metric tons of carbon dioxide per year. Shifting to electric transporation will help to reduce pollution and its adverse effect.

The concept of the project is to develop an electrically operated automatic mobility device for personal transportation in short-range mobility. It is a device which is proposed to be an affordable three-wheeled and electrically operated and to be used for on-campus transportation. This personal mobility device is environment friendly, safer and convenient option.

The Segway is the a self-balancing personal transportation machine designed for a single person to go anywhere. With its fully electric drivetrain, the Segway carries a person with advantage of noiseless, smooth and efficient without producing adverse environmental emissions. It's easy and driver friendly to operate. Its two-wheels part will contribute to provide better balancing. Motor and battery placed in the base of the device to keep the Segway upright and to maintain centre of gravity of device. This Segway comes with throttle and brakes for speed variation and braking application. More imporatantly it is cost effective, environment friendly and safer option for personal transporation.

Motivation

With ever-increasing fuel costs and laziness, there is an emerging market for personal human transporters. Such devices can potentially save fuel by greatly reducing the mass of the transportation machine. Nowadays there are more petrol and diesel vehicles on the road which cause an increase in air pollution which can damage our health and lifestyle. The world is moving towards electric vehicles and in such aspects, a vehicle which produces zero-emission in the environment and works on electrical energy is one of the best options for individual transportation purpose.

As we can see from the 20th century, the population is continuously increasing day by day. So the transportation demand of all the people in urban and ruler areas is also increasing. Due to an increase in the population, new technologies are coming into the market. So by observing and considering the technologies and the demands of the people for personal transportation we come to this topic.

Aim and Objective

- The project aims at the design and development of a mobility device for short-range personal transportation, having entirely electrical propulsion.
- Being electrically driven, it is an environmentally friendly product.
- The safety of the rider is of paramount concern while developing the product, hence incorporating features like the dead.
- The predominant aspiration is to develop the product at an affordable price making it feasible for the consumer to purchase.

Literature Review

Introduction

The purpose of this literature review is to study the working characteristics and design concepts of the Segway and other three-wheeled electric vehicles present in the market. This study will help us to gain an understanding of the existing research relevant to a short-range mobility device and to present that knowledge in the form of a written report.

Literature review

1. **Designing a short-range wheeled mobility device for women in India.** Faculty of Industrial Design, National Institute of Design, Ahmedabad, India IEEE Transactions on Education, 52(1), pp.157-168: The design of appropriate rehabilitation technology requires the careful consideration of numerous interdependent design parameters. To make the design successful, the technical, functional, economic, and cultural environments in which the technology will be used should be well understood. This paper presents a case study of design and fabrication of novel low-height mobility devices for disables women within the context of rural and low-income India. Detailed design analysis from different perspectives was performed with consideration of user feedback throughout the design process.
2. **Sivapragash, C., Kamalamoorthy, N., Arthi, B., Saranya, B., Sharmila, B. and Shivaranjani, S., "Personal aided auto equilibrium transporter" Int. J. Engg. Res. & Sci. & Tech, 2015, 240.: Segway is a personal transporter.** The present model of Segway costs high and hence not used by many people. The reason for the high cost is the use of a hub motor and lithium-ion battery. This paper based on an idea to overcome the above difficulties by making a cost-effective and modified Segway. In this modified design, brushed DC motor and lead-acid battery are used and electric braking is provided. This PAAET is design for usage of transportation inside an office, an industry or in any tourist place. The battery charging provided in two modes, first is by fixing a solar panel to the vehicle and second is mechanically by rotation of the motor. The PAAET design can be a better option of transportation within a short-range.
3. **Nguyen, H.G., Morrell, J., Mullens, K.D., Burmeister, A.B., Miles, S., Farrington, N., Thomas, K.M. and Gage, D.W., 2004, December. Segway robotic mobility platform.** International Society for Optics and Photonics in Mobile Robots XVII (Vol. 5609, pp. 207-220).: This paper presents Segway RMP development project is to quickly create a minimally modified machine. This paper based on mobile robotic platform. As compared to existing platforms, this Segway RMP is faster, cheaper, and more agile. It has small footprint and a zero turning radius, and yet can carry a greater payload. This paper is about the history and development of the platform, its characteristics.
4. **Anita soni., Krishnan Kumar. "Application of BLDC motor in E-bike."** International journal of engineering sciences and research technology, ISSN:2277-9655.
   The report is a project related to E-bike which runs with the help of electricity or a 48V DC supply. This E-bike is capable to run 45-50km on complete charging which takes 3-4hrs. This report includes information related to e-bike components and their installation in the model. According to the author, they used a permanent magnet DC type motor with a nominal power of 350W. The report mentions the detailed procedure for the installation of the hub motor and controller unit. It also includes the connections for the battery and accelerator. They used a KELEN charger for an e-bike. According to the report performance of this e-bike is better as compared to other bikes.
5. **Omkar Kachare., "Gyroboard single wheel motorized skateboard", International journal of electrical and electronics engineering., ISSN(P): 2278-9952., Vol.7, issue 5, Aug-sept 2018.**
   Gyro board is a single-wheeled self-balancing skateboard. This report describes the self-balancing technique using the gyroscope. The system uses an MPU6050 device which is used to track motion. This report includes information about developing a control system to control the motions like roll, pitch, and yaw. This project is about development of a Gyro board in which an on-board sensor reads that the foot is settled on the platform, which allows the brushless motor inside

the wheel to know it's good to go. Lean forward and the board's gyroscope balances and accelerates, sending you up to 5km/hr.

6. **A. tashakori, M. ektesabi, and N. Hossein-Zadeh. "Characteristics of the suitable drive train for electrical vehicle", Proceeding of 2011 International Conference on Instrumentation, Measurement, Circuits and Systems (ICIMCS 2011), VOL 2, Pages: 51-57, DEC 12-13, 2011, Hong Kong, China.**

   The motor is a very basic and essential component in the electric vehicle therefore it is very important to select wisely. The motor is one of those components which contributes to the overall performance of the vehicle and this report helps to select the motor. This report includes a comparison of different motors that can be used in an electric vehicle. This comparison is done based on speed, torque, and power characteristics. They compare BLDC motor, brushed DC motor, and induction motor. This report also compares motors based on performance, efficiency, and reliability.

Design and Analysis

Design Calculation

In the design of the electric mobility device selection of the correct motor which fulfills the requirements is very essential. The requirement is power delivered by device is varies from zero to peak power of motor and motor speed for respective power of device speeds from zero to 15 km per hour.

The power required by the motor to propel the device and rider depends upon the total weight of the device with rider and gradient of the slope, from the above data we get the force components acting on the device through which we can specify the power required for the motor.

Total mass of structure = 20 kg

Weight of rider = 80 kg

Battery mass = 15 kg

Therefore, total mass = 20 kg + 80 kg + 15 = 115 kg Approx. = 120 kg

As a design criterion, it could be defined that Segway should be able to move

1. In a 10% slope at a speed of 10 km/hr.
2. Reach a maximum speed of 15 km/hr. on plain ground.

For case I:

The power needed to move a Segway at 5km/hr. in a slope of 10° can be calculated by,

$$P = F \times V = mg\sin\theta \times V \qquad \text{.....(1)}$$

$$= (120 \times 9.81 \times \sin 10 \times 5 \times 5) \div 18 = 312.3 \text{ W}$$

For the sager side consider 600 Watt.

For case II:

To reach a speed of 15 km/hr, it is necessary to determine rolling resistance

$$\text{Rolling resistance} = Cr \times mg \qquad \text{.....(2)}$$

$$= 0.018 \times 110 \times 9.81 = 19.42 \text{ N}$$

To produce 20 N at 15 km/hr

$$P = (20 \times 15 \times 5) \div 18 \qquad \text{.....(3)}$$

$$P = 84 \text{ W}$$

RPM of motor:

Velocity = radius × average vel × 0.10472

Radius= 8inch = 0.2032m

$20 \times (5\backslash 18) = 0.203 \times 0.10472 \times \text{rpm}$

Average velocity = 261.3875 rpm

Conclusion

The nominal output power of motor 350 Watt will satisfy both the case.

250 to 300 rpm motor is required.

Motor Selection

In the motor selection, we have two choices with us that AC motor and DC motor. There are two constraints due to which we prefer DC motor to AC motor. A major disadvantage of the AC motor is the operating current, which we cannot store and an investor is required, which again increases the cost. And another disadvantage is size, the AC motor is big in comparison with the DC motor. And that's why we preferred DC motor to AC motor.

Now there are again types of DC motor like stepper DC, Brushless DC, Brushed DC electric motor. The below table gives detailed information about DC motor, through which we can easily find the best one for our application.

TABLE 1

Available DC motor

Type	Advantages	Disadvantages	Application	Typical drive
Stepper DC	Precision positioning Stepper DC High holding torque	Slow speed Requires a controller	Positioning in printers and floppy drives	Multiphase DC
Brushless DC electric motor	Long lifespan Low maintenance High efficiency	High initial cost Requires a controller	Hard drives CD/DVD players Electric vehicles	Multiphase DC
Brushed DC electric motor	Low initial cost Simple speed control	High maintenance (brushes) Limited lifespan	Treadmill exercisers Automotive starters Toys	Direct (PWM)

Based on the comparison table, the BLDC motor can be selected for its advantages.

Brushless Direct Current (BLDC) motor is a type of synchronous motor, where magnetic fields generated by both stator and rotor have the same frequency. The BLDC motor can be divided in 1-phase, 2-phase, and 3-phase. Three-phase motors are widely used in E-bikes.

The 350-W rear hub motor is selected with the following performance details:

- Hub Motor Voltage: 48V (brushless)
- Power Rate: 350 W
- Weight: 5 Kgs

Fig. 1. Rotor and stator BLDC wheel hub motor

Battery selection

See the below equations to calculate the range from amperage and voltage:

Ah (Amp hours) × V (volts) = Wh (Watt hours) .....(1)

Select a 48-V, 10-AH battery with 480 Wh.

P (power) = Work / t (time) .....(2)

P × t = Work = Force × distance .....(3)

Force = mass × acceleration .....(4)

Distance = Wh / Force .....(5)

Distance= Wh / Force .....(6)

Electric bicycles are often restricted to a speed of 25 km/h across level ground. From the above equations, a 480-Wh battery can roughly provide a range of a total of 55 km.

Motor ampere rating:

Power = voltage × ampere

Ampere rating = 350 W / 48 V

= 7.29 ampere

Battery rating - Ah

Suppose, we want 5 hours run time on a single charge

Therefore,

The Ampere hour rating required for the battery is

= 7.3 A × 5hr

= 36.5 Ah

-Wh

48V × 36.5 Ah = 1752 Wh

= 1.752 kWh

= 1.8 kWh

The battery selected is 4 units of 12 volts SLA battery.

The rating of each battery is as follows

-12V

-12Ah

-144Wh

Controller Selection

The motor controller uses an 8-bit microcontroller (CY8C24533) which has a maximum clock frequency of 24MHz for computing. The motor controller works on a feedback loop receiving the position of the rotor from the hall sensor output and sequentially energizing the next pole in order. The switching mechanism of energizing the poles is controlled by a set of nine transistors (T430), three for each pole.

Block diagram for control of the selected motor.

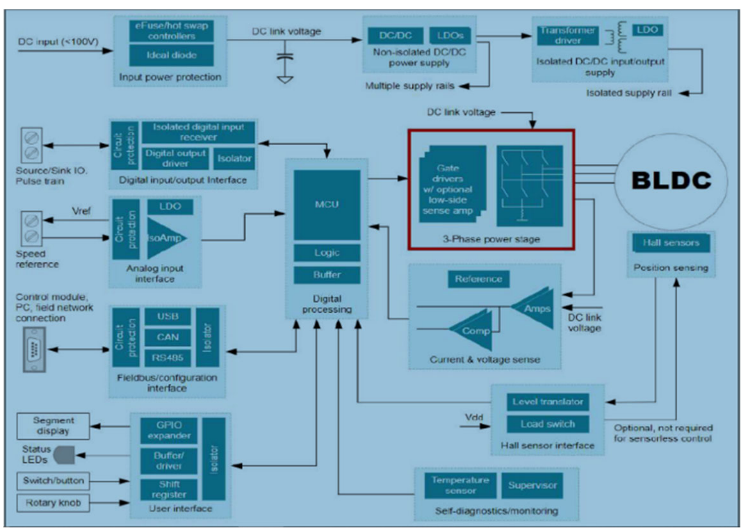


Fig. 2. Block diagram of BLDC motor control (Texas instrument broucher)

Key Electrical Characteristics of wheel hub Controller

- Rated voltage: 48 VDC
- Rated power: 500 W
- Motor speed: approx. 0-30 km/h variable-speed by handlebar
- Speed restriction: Maximum 20 km/h (by Jumper)
- Battery under-voltage protection: 41.5 ± 0.5 V

Fig. 3. CY8C24533 PSOC Programmable chip

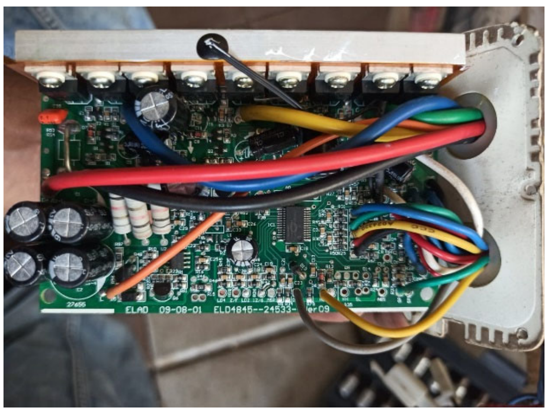


Fig. 4. Wheel hub 48 V/500W BLDC controller

The chosen motor has Hall Effect sensors built-in:

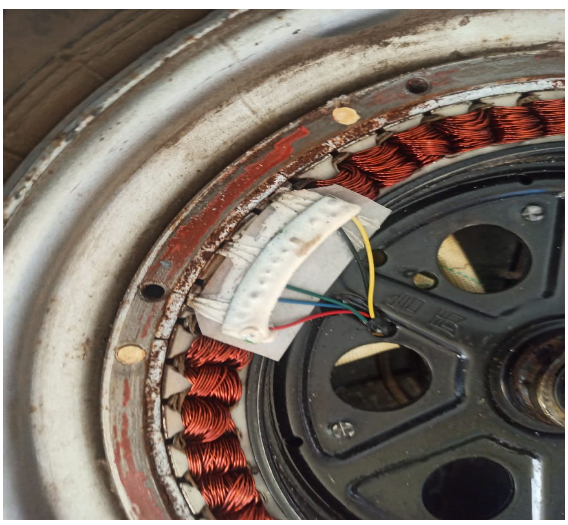


Fig. 5. Built-in Hall Effect sensor

Design for manufacturing of a product

Modeling is a very important aspect of design manufacturing and assembly. One can get an overall idea of the dimensions and aesthetics of any product. Overall modeling and assembly of electric mobility devices are done in CATIA-v5. All design is as per the dimensions fixed during theoretical design calculation. For software analysis of the CATIA model of the electric mobility device, Ansys software is used. Software analysis is very helpful to analyze the safety of the vehicle and also the optimization of a design.

While designing any type of mobility device the most important Part is collecting anthropometric data. It plays an important role in vehicle ergonomics. There are many important design-related points and considerations which need to be addressed to achieve the major objectives of collecting anthropometric measurements.

We want to design a product that is possible to operate by a user of any height. So while collecting anthropometric data and working on ergonomics we kept our strategy i.e., "Design for all". Ease of Manufacturing and possibilities are needed to be taken into consideration while designing.

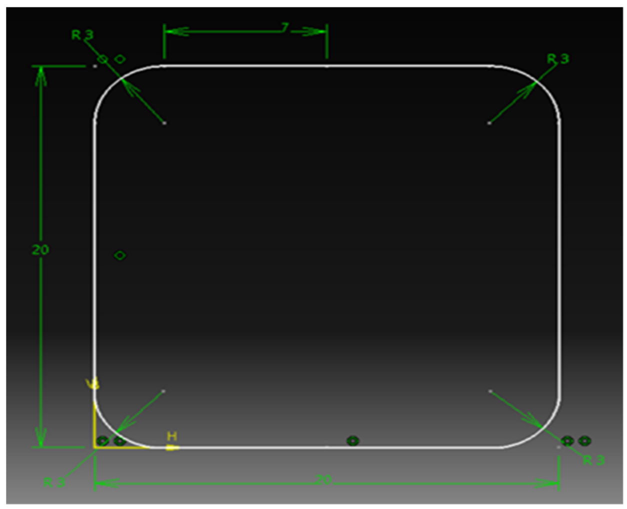


Fig. 6. Platform dimensions

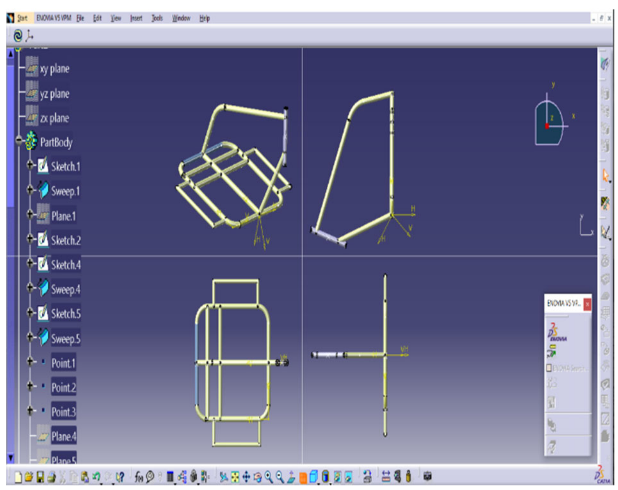


Fig. 7. Rollcage in catia

TABLE 2

Anthropometric data for handlebar

No	Parameters	Values (in mm)
1	Height of elbow from ground	1000-1100
2	Distance between shoulders	450-550
2	Length of forearm	350
3	The average length of the palm of a hand	160-180
4	The average width of the palm of a hand	150-170
5	Average handle diameter	25-30
6	Average handle diameter with grip allowance	30-40

- **Handlebar:** From the above data final dimensions for the handlebar are:
  Total handlebar height: 1050mm
  The total length of the handlebar: 1140mm
  Handle diameter: 25mm
  Handle material: AISI 4130 (mild steel carbon)
  Thickness: 1.16mm

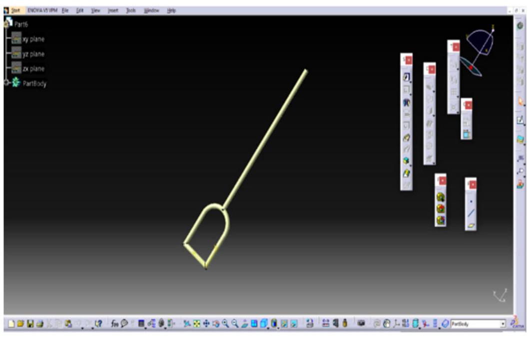


Fig. 8. CAD Model of handlebar

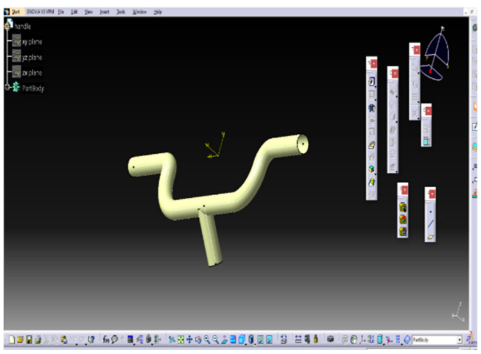


Fig. 9. CAD Model of handle

Static analysis

Static analysis of product is imporatant for efficiency and precision for final product. For static analysis of product we use finite element analysis method. Static analysis is done to estimate behaviour of product and its parts under certain conditions.

Structural analysis imporatant to analyse the performance of a product under different loads and forces and possibility of failure. Using fatigue analysis factor of safety and future possibilities of any cracks in structure can be determined.

The dimensions for material are determined by the maximum bending stress generated in the structure. The maximum bending moment is determined by shear force and bending moment diagram.

$$\sigma_b = M_b * y/I \qquad .....(1)$$

Where,

σ_b - bending stress
M_b - Max bending moment
Y - Distance from centre to outer fibre
I = Moment of Inertia of hollow pipe

The material selected for the structure is SS316.

The forces acting on the structure are the loading force which is 2 times the static force and axial force. The results are given in the below table.

TABLE 3

Structural analysis data for structure

Component	Structure
Number of nodes	234971
Element size(mm)	1 mm
Maximum equivalent stress(MPa)	39.455 mpa
Maximum deformation(mm)	0.13625
Factor of safety	2.2107

TABLE 4

Structural analysis data for handlebar

Component	Handle
Number of nodes	93775
Element size (mm)	47025
Maximum equivalent stress (MPa)	43.053 mpa
Maximum deformation(mm)	0.99182
Factor of safety	1.388

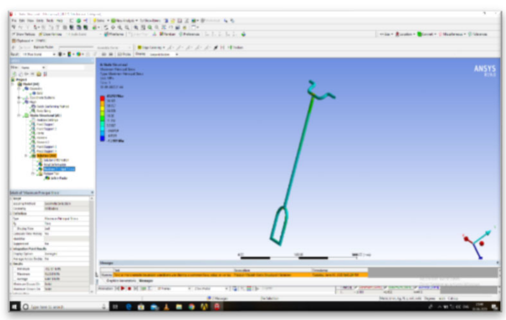


Fig. 10. Maximum principle stress handlebar

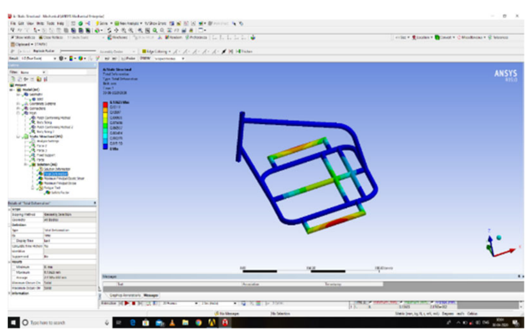


Fig. 11. Total deformation rollcage

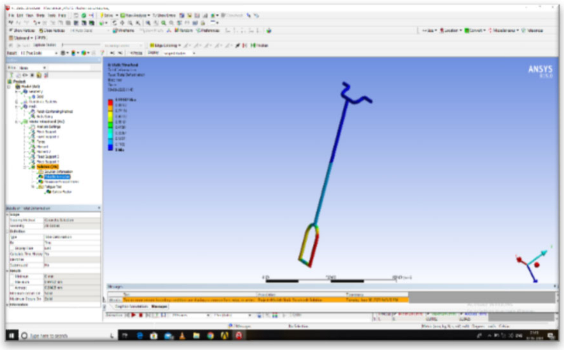


Fig. 12. Total deformation handle bar

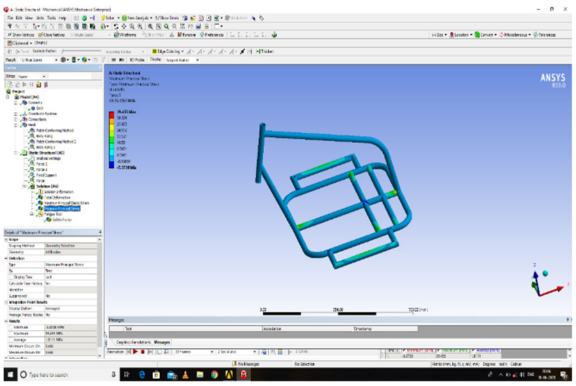


Fig. 13. Maximum principle stress rollcage

Prototype Development

Introduction

After completing the design and software analysis of the mobility device next and very important step is to take down the design into a real prototype. The development process is started with a proper project plan so different manufacturing activities can be done simultaneously it helps to save time and energy.

The fabrication process comes up with different activities like cutting, grinding, welding, etc. while doing fabrication work the necessary safety should be carried out and safety equipment are need to be used.

One more technical precaution taken into consideration is the measurement equipment is properly calibrated and with accurate readings. And also use that equipment with the proper method so work can be done precisely.

The development workflow is done as shown in subchapters:

Material and part procurement

After the R&D stage in the software development lifecycle, we have a clear vision of product structure, the problem it solves, who the target user is, and other products in market for similar application.

The material for chassis is steel and it should be corrosion resistant for a desired application or environment along with it is imporatant to consider its Strength and fabrication characteristics. In marked there are more than 60 grades available of stainless steel. To select appropriate grade it imporatant to consider all the physical properties of material which are required for application.

Selected of material

Material- SS316

Properties-

1. SS316 contains additional molybdenum that gives it improved corrosion resistance.
2. The austenitic structure gives excellent toughness.
3. Fusion welding performance is excellent both with and without fillers.

Fabrication of device:

After the material procurement, the actual fabrication of the device gets started. During the fabrication of the device, it is very important to handle instruments properly and use safety equipment's also like gloves, welding goggles, boiler suits, shoes, etc.

The development of the device started with the fabrication of the base structure. The round pipe material is preferred for the fabrication because of the following reasons:

- It gives the more welding area in comparison with L-shape or square, also by profiling operation pipe material fits at an exact position at any angle and any direction and gives good weldability.
- Bending operation is much better on the pipe section because it bens properly in 3D bends also there is less deformation and shrinking of material takes place in comparison with L-shape and square section.
- Also, the pipe section is less in weight and gives the same strength due to shape and volume.

Table 5

SS316 properties

Property	Value
Density	8.00 g/cm^3
Melting Point	1400°C
Modulus of Elasticity	193 GPa
Electrical Resistivity	0.74 x 10-6 Ω.m
Thermal Conductivity	16.3 W/m.K
Thermal Expansion	15.9 x 10-6/K

Development of the handlebar

After the development of the base of the device, the next important step in the development of the handlebar. The objective of the handlebar is to give directional stability and rigid strength. Assembly of the handlebar is as following:

- The handlebar is assembled to the base via a bearing, a bearing is placed in between the York of the handle and the cup of the handle.

- York again contains two mounting to hold the wheel shaft and positive locking is been provided through nut locking.
- Extended height is provided as per requirement by welding the handle column to the York.

Wheel assembly: The maximum load coming on the base is then transferred to the wheels, and also wheels are the rotating component of the device. Wheel dimensions are defined by power and torque calculation as seen earlier chapter.

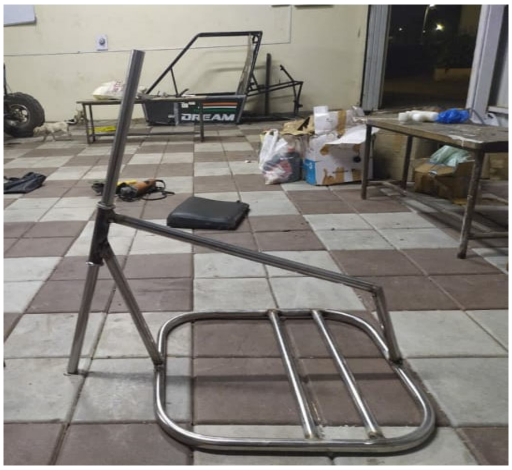


Fig. 14. Developement of structure

Fig. 15. Developed prototype with assembled wheels

Platform: After the assembly of wheels, it's time to assemble batteries and electronics and which is mounted on the platform. As the battery and controller are going to be mounted on the platform it should be rigid, anti-corrosive, and aesthetically well. By considering all points into consideration we come up with the ss316 material.

TABLE 6

Material properties comparison chart

Properties	SS310	SS 316	SS 440
Density	7.89g/cc	7.89g/cc	7.7g/cc
Modulus of elasticity	196GPa	193GPa	200GPa
Tensile strength	245MPa	290MPa	1230MPa
Ultimate tensile strength	550MPa	580MPa	1750MPa

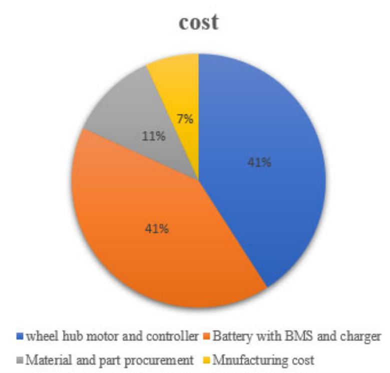
Though SS440 has good mechanical properties its manufacturing properties are not as good enough as SS316. For the ease of manufacturing, we choose SS316.

Prototype expenditure: Here we developed the prototype of a concept product, so for the working prototype development we used scrap material mostly and reduced the cost, but the cost of an actual product is going to be expensive because of the use of standard components and manufacturing process.

TABLE 7

Cost projection for the development of a prototype

Components	Cost (Rs)
A wheel hub motor and controller	18000
Battery with BMS and charger	**18000**
Material and part procurement	5000
Manufacturing cost	**3000**
Total	44000



Testing and Validation

Introduction

Testing and result of an actual working prototype are very necessary to check the working capabilities and sustainability of a product. In the case of an electric vehicle along with a sustainability check, performance testing is also one of the important parts. In this chapter, we discussed the various tests performed to check compatibility, sustainability, and performance of vehicles. Also, results obtained from various tests are discussed in detail.

Tests performed:

1. Driving on cement road(at top speed)
2. Driving off-road (reliability check)
3. Driving with heavy load (reliability check)
4. Braking test
5. Range test
6. Gradability test

Above all tests are conducted on city roads and in college campuses. Above all tests are designed in such a manner that it will check all performance parameters of the vehicle. Results obtained from the above test were compared and analyzed with target values.

TABLE 7

Test plan

Sr. No.	Test name	Parameters to be tested	Target values	Measurement equipment
1.	Driving on a cement road	Top speed	15km/hr.	speedometer
2.	Driving off-road	reliability	-	-
3.	Driving with a heavy load	reliability	-	-
4.	Braking test	Brakes are working	Brakes are working in dynamic conditions and structure is also stabled.	observation
6.	Range test	range	16km	GPS
7.	Gradability test	Max. grade	10 degree	Grade measuring app

TABLE 8

Result summary

Sr. No.	Test	Target value	Achieved value	Remark
1.	Speed test	15km/hr	20km/hr	A good above target value
2.	Brake test	Four-wheel lock	Four-wheel lock	Target achieved
3.	Range test	16km	16km	Target achieved
4.	Gradability test	10 degree	10 degree	Target achieved

Validation

After testing the prototype on various road surfaces, we discovered the following shortcoming of the prototype.

Iteration 1- weight distribution

In the first iteration, when the rider stood up on the platform, a significant amount of weight distribution was exclusively distributed at the rear. As a result of this, the front tyre would often lose traction.

Following changes are made to distribute the load more towards the front:

I. Figure 'A' shows the adjustment made in the lateral members of the platform.

II. Wheelbase was increased by the shifting rear axle further in the rear.

Fig. 16. Design of structure before iteration

Fig. 17. Design of structure after iteration

The second iteration after above the mentioned rectifies displayed significant improvement in the front wheel traction. And that can be further improved in product development by doing proper weight distribution and Cg calculations, and we get a better wheelbase to track ratio, which helps in good traction and proper stability of the structure.

Iteration 2- Handle wobble

During testing, it is noticed that any unevenness on the road surface would manifest into undesirable handle wobble. It was primarily due to a long handle arm member as cantilever lacking in rigidity. It was rectified to some extent by giving the extra support to the extended handle member and using a U-shaped horizontal member this issue can be completely eliminated by using fork suspension (tripod), furthermore, handlebar height adjustment can be integrated.

Fig. 18. Handle wobble

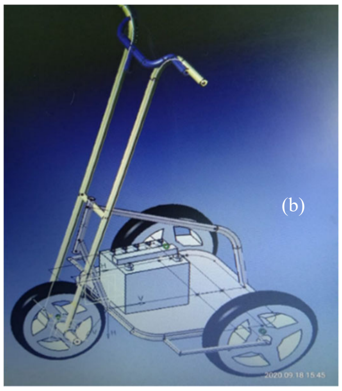


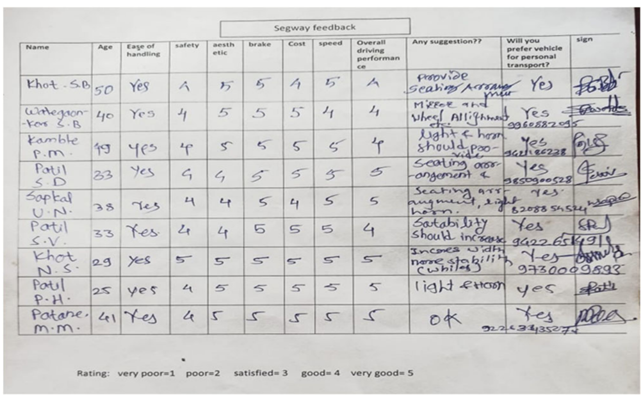
Fig. 19(a)&(b) New handle design to overcome problem

Iteration 3- Electronic braking (regenerative braking)

The prototype completely relies on mechanical braking as the motor controller used does not have an option for electric braking but the controller now available in the market has electric regenerative braking. This would improve handling characteristics significantly.

Testing feedback

Testing feedback is taken from the random user, we provide the ride and take their feedback for the better development of a product.



Segway feedback

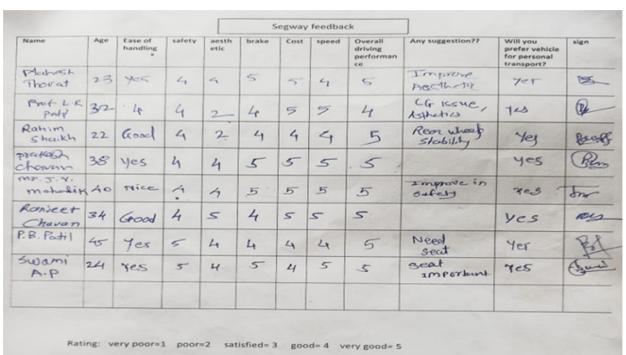
Name	Age	Ease of handling	safety	aesthetic	brake	Cost	speed	Overall driving performance	Any suggestion??	Will you prefer vehicle for personal transport?	sign
Khot. S.B	50	Yes	4	5	5	4	5	4	Provide seating Arrangement	Yes	[illegible]
Wategaon-kar S.B	40	Yes	4	5	5	5	4	4	Mirror and wheel Allignment etc.	Yes 9960882095	[illegible]
Kamble P.M.	49	Yes	4	5	5	5	5	4	light & horn should provide	Yes 9421186228	[illegible]
Patil S.D	33	Yes	4	4	5	5	5	5	Seating arrangement &	Yes 9850900528	[illegible]
Sapkal U.N.	38	Yes	4	4	5	4	5	5	Seating arrangement, light horn.	Yes 8208854524	[illegible]
Patil S.V.	33	Yes	4	4	5	5	5	4	Satability should increase	Yes 9422654919	[illegible]
Khot N.S.	29	Yes	5	5	5	5	5	5	Increase width more stability (wheels)	Yes 9730009893	[illegible]
Patil P.H.	25	yes	4	5	5	5	5	5	light & Hoorn	yes	[illegible]
Patane. M.M.	41	Yes	4	5	5	5	5	5	ok	Yes 9226334352??	[illegible]

Rating: very poor=1 poor=2 satisfied= 3 good= 4 very good= 5

Fig. 20. Feedback

Average feedback

Average feedback is calculated from the above all user's feedback and form that we get numbers for overall performance 4.70 out of 5.



Segway feedback

Name	Age	Ease of handling	safety	aesthetic	brake	Cost	speed	Overall driving performance	Any suggestion??	Will you prefer vehicle for personal transport?	sign
Mahesh Thorat	23	yes	4	4	5	5	4	5	Improve Aesthetic	yes	[illegible]
Prof L.R. Patil	32	4	4	2	4	5	5	4	CG issue, Asthetics	Yes	[illegible]
Rahim Shaikh	22	Good	4	2	4	4	4	5	Rear wheel stability	Yes	[illegible]
prakash chavan	38	yes	4	4	5	5	5	5		yes	[illegible]
Mr. J.Y. mahadik	40	Nice	4	4	5	5	5	5	Improve in safety	Yes	[illegible]
Ranjeet Chavan	34	Good	4	5	4	5	5	5		yes	[illegible]
P.B. Patil	45	Yes	5	4	4	4	4	5	Need seat	Yes	[illegible]
Swami A.P	24	Yes	5	4	5	4	5	5	seat important.	Yes	[illegible]

Rating: very poor=1 poor=2 satisfied= 3 good= 4 very good= 5

Fig. 21. Feedback

TABLE 9

Average performance

Safety	Aesthetic	Brake	Speed	Cost
4.17	4.17	4.76	4.76	4.70

Conclusion

In this report, a personal transportation prototype is proposed as an ideal solution for short-range mobility. The biggest advantage of such a product is that it is eco-friendly and user-friendly. The objective is to prototype a low-cost product model for limited mobility. The prototype is designed for specific requirements. Technical choices were made about the electric motor, battery, configuration, and ergonomics involved. The sizes of mechanical elements were finalized. The base of the prototype was designed for 120 kg. After the design, the development of the prototype was carried out. To assess the performance of the prototype, several tests were carried out as well as a survey based on a rating was done to record the user experience.

During the testing phase, various tests like a range test, brake test, gradient test, and reliability test were conducted on the prototype. It was found that the prototype achieved a maximum range of 15km as compared to the target value of 10km during one cycle of charging and discharging. The brake test was also completed by the prototype, it was found that the prototype stopped easily without losing any balance. The top speed achieved by the prototype was found to be 20 kmph, against the targeted speed of 15 kmph. It was found that the Segway could move on a grade of 10º with a speed of 5 kmph with a weight of 70 kg. The prototype would be a perfect solution for short-range mobility for an area like a college campus, industry ground, malls, hospital.

Feedback from 20 people of different categories and ages of the society was taken through a questionnaire in which, it was found that the Segway prototype got an average rating of 4.7 out of 5. From them, several suggestions were received which shall help to improve the next product. This prototype has some positive as well as some negative aspects. Segway prototype provides good space for standing to the rider, so that rider can easily drive a Segway prototype, the aesthetic look of the prototype is also good as concluded from the survey. But the main drawbacks are weight transfer and handle wobble at top speed which can again solve in a product.

After extensively testing of prototype and eliminating a few problems with a lot of iteration work and documenting the people review feedback, it is evident that the prototype could be developed into an affordable product.

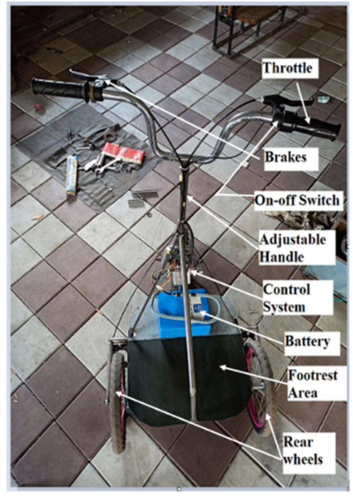
Appendix - A

(a) Isometric veiw

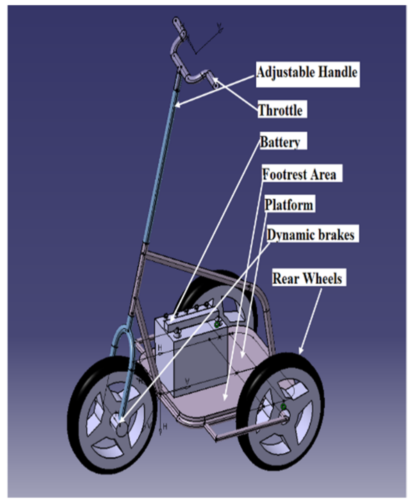
(b) Top view

(c) Control System Assembly

Catia Assembly



(d)



(e)

(f) Catia assembly

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Address correspondence to: *Mr. Ishan Hiremath, Department of Automobile Engineering, Rajarambapu Institute of Technology, Sangli, India.*
Email: hiremathishan@gmail.com