

Design and Fabrication of Foldable Electric Motor Powered Three Wheel Vehicle

Jayesh S. Renge¹, Ronak P. Rathore², Shubham V. Bakade³, Suprit P. Bardekar⁴.

¹ Department of Automobile Engineering, DPCOE, Maharashtra, India.

² Department of Automobile Engineering, DPCOE, Maharashtra, India.

³ Department of Automobile Engineering, DPCOE, Maharashtra, India.

⁴ Department of Automobile Engineering, DPCOE, Maharashtra, India.

ABSTRACT

The population of world is increasing and the area is decreasing. We are in the stage of compact world, where all things are going to compact, the time is to think about the vehicle which can be folded easily and can be taken everywhere. The basic aim behind our project is to make a portable vehicle which would be easy to handle by both genders and it should emit 0% emission, also keeping in mind the parking problems, we have decided to make a portable suitcase vehicle which can be folded easily. So after the use, one can fold a suitcase and can carry it along with him or her as a luggage and keep it in home or wherever there is place for the size of suitcase. For power supply we have introduced DC brush motor, which will not consume fuel for running thus preventing emissions problems. The DC motor will work on batteries which can be charged at home. Since batteries can be charged, the project is more economical to middle class peoples. We have applied our engineering knowledge as well as some references from Mazda's Suitcase car for the development of this product. It is an environment friendly, small & cheap project which can be held by any household member and used within certain limits on public roads. While designing, we have concentrated on power, economy, ease and comfort of riding and low maintenance cost. Also we have concentrated on ergonomics factor to give the user a comfortable ride.

Keywords: -compact, portable, suitcase, economical, environment friendly and no emission.

1. INTRODUCTION

As the population is increasing there is an increase in demand of automobiles. Due to an increase in automobiles, people will require space for driving and also for parking. As we know there is limited space available and due to an increase in the number of cars on roads they are causing traffic congestion and with that they require a place for parking. In addition to these pollution is also a priority nowadays. The pollution is reaching new limits day by day. So the idea of a foldable and portable vehicle comes into concept.

The Suitcase Car is a car which can be folded in a suitcase; hence it does not require the parking place. The size of the suitcase car is 46"x 22", so it is five times smaller than normal car. Due to its compactness it can be used in various shopping malls, industries, college campuses etc. Portable car can be used to cover short distance at many instances. It can be used for travelling purpose on the roads.

It was originally designed & built in 1991 as part of a design contest held at Mazda's Engineering department which was created with a simple idea to have a 3-wheeled car inside a suitcase. Instead of waiting in line for a taxi or shuttle, just open your suitcase & drive off. It was powered by a 42 cc, 2 stroke engine, as suitcase car is running on the two stroke engine with the speed of 27 mph it can run for 2 hours with the fully filled fuel tank. It can be

assembled in about 5 to 10 minutes & comes with functional brake lights & turn signals. Vehicle was rebuilt in 1994. Because of two stroke engine vehicle, it causes pollution as well as noise.

In order to overcome above mentioned disadvantages in the present invention, we can replace engine with motor and battery. But it will add more weight to vehicle. Portable vehicle can be assembled and disassembled whenever required as well as we can carry it within the suitcase anywhere. If required we can assemble it in just less than ten minutes and drive it. In this portable vehicle we used three wheels, out of that the power is given to rear wheels via shaft and steering of the vehicle is done by front wheel. Power is produced in vehicle using a DC brush electric motor.

If there is no use of vehicle then we can just simply disassemble the vehicle parts & can keep it in the suitcase. This portable vehicle can carry weight up to 90kg and it has Maximum speed of 20 km/hr.

1.1 Objective

- To build a suitcase vehicle to overcome problems arising due to shortage in space.
- Time required for assembly and disassembly should be as less as possible.
- The maintenance of suitcase vehicle should be low.
- The vehicle should be light weight so it can be lifted.
- Driver comfort is also important factor, so it must not be compromised.

1.2 Scope

- Designing and fabrication of foldable vehicle: The designing of the vehicle had been done and fabrication of vehicle will be achieved with respect to designing procedure.
- Selection of propulsion mechanism: As introduced before we can either use gasoline engine or a motor with battery arrangement. We had decided to go with electric motor for propulsion mechanism for the vehicle.
- Testing of vehicle: Virtually, analysis on chassis was done to ensure driver safety. After fabrication test were performed on vehicle to check its stability, velocity and acceleration and deceleration capabilities.

1.3 Methodology

The work had been done and was consisting of following phases:

- Design and Analysis
- Manufacturing
- Test

Design & Analysis phase:

In design phase, we had designed the structure of the vehicle on CAD software on the basis of design calculations for each part of vehicle. After the design phase, we analyzed the structure on ANSYS 15.0. Necessary changes were made.

Manufacturing Phase:

We have completed our manufacturing phase, in which we manufactured our project or vehicle within time limit. We had tried our best to stick with the calculated design data and giving our project precision and accuracy.

Test phase:

In test phase, we tested our project at different parameters such as vehicle's speed, acceleration, braking etc. We also compared it with go-kart competition as our project is kind of a go kart. Changes were done on the project with respect to calculated test data.

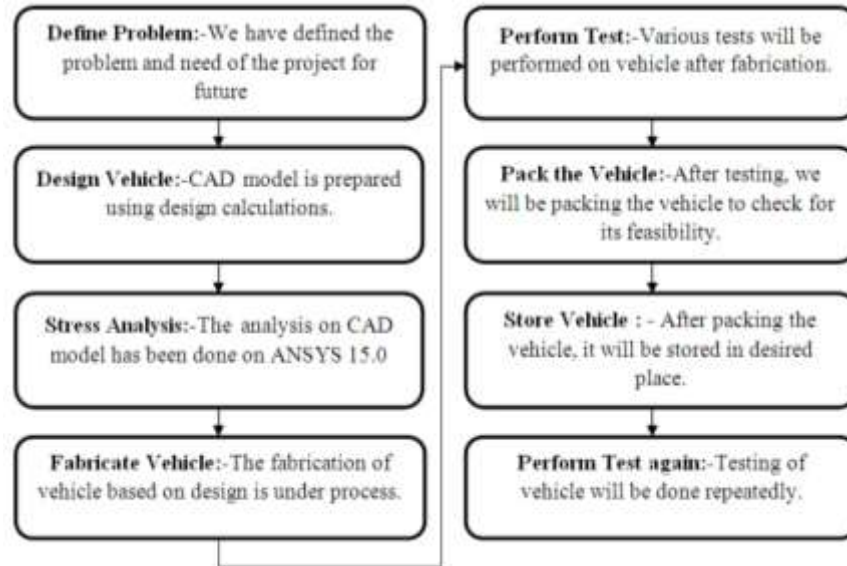


Chart -1: Flowchart of Methodology

2. LITERATURE REVIEW

2.1 History of Foldable Vehicle

The seeds of Mazda's 'suitcase car' – a functioning car built into a piece of luggage – had been sown in the run-up to the company's 1991 'Fantasyard' event, an inter-departmental contest to see which group of employees could come up with the most innovative and creative solution to produce a 'moving machine'.

The early 1990s were a golden era for Mazda. Mazda had already successfully reimagined the roadster with the MX-5 and won Le Mans with the rotary-powered 787B racer. It was the perfect time for Mazda to develop a suitcase car. Unfortunately, they did not mass produce the vehicle.

The selected group of seven engineers from the Manual Transmission Testing and Research Group convened and set to work on their creation. They purchased the largest Samsonite suitcase they could find and a Pocket Bike motorbike. The 33.6cc, 1.7 hp, two-stroke engine, handlebars and 4-6 inch-diameter tires from the Pocket Bike were then fitted into the suitcase. The rear wheels could be slotted onto the outside of the case while the front wheel would pop through a removable hatch in the front. The suitcase car took just a minute to assemble and had a top speed of 30km/h. While the original prototype was accidentally destroyed just a few months after the Fantasyard event, one suitcase car still remains in existence and it gives same performance till today, without any change from last 24 years.



Fig-1: Mazda Suitcase Car

If you're concerned about safety, the suitcase car has turn signals and brake lights. If you need additional safety features, maybe it's best that you stick to cars that can't be folded up and carried.

The "Suitcase Car," as it's referred to, was created as part of a design contest held by the automaker's engineering department at that time. The three-wheeled vehicle would be rather handy if one didn't feel like waiting in line for a taxi or shuttle; he/she could just open his/her suitcase and drive off.

The Suitcase car is now maintained by Road/Race Engineering in Huntington Beach, California.

2.2 Literature survey

Bjarni Freyr Gudmundson and Mr. Esben Larsen in their research paper have discussed about various techniques in which the foldable electric motorbike can be developed. They made a conceptual design and did detailed analysis on specification, material selection, design and structural analysis, component selection, test drive. Their basic idea behind manufacturing this type of design was to give the comfort and compact ability to the driver, so that driver can feel safe and comfortable to enjoy the every ride of kart. For making a vehicle the following subsystems such as chassis subsystem handling subsystem, wheel and tire subsystem, brake subsystem and power train subsystem should be designed and fabricated. They worked on the power train for the vehicle and also initiated work on developing powerful, light weight motorbike. They thought about the cost and efficiency of vehicle. To minimize the cost of the vehicle, they used electric arc welding as it is cheap and reliable option available. They also made a foldable electric bike, providing with their all details and procedure. They also discussed about various future works that can be done on their project. [1]

Mr. Sachin Achari with his team has discussed the feasibility, use and design procedure of the foldable tri scooter. They made effort in the experimental analysis as well as in design part of the project. Their main aim was to design a portable automobile which should be very easy to carry as well as easy to handle by both the sexes with equal ease. The aim was also that it should be environmental friendly and should be non-polluting. They used D.C motor as their main power source due to which there is no emission at all and also the problem of fuel consumption can be solved. Also keeping in mind the parking problems, they made a triscooter which can be folded easily, so after the use one can fold the triscooter and can carry it along with him/her. Their design allows users to easily transport the triscooter using less space when it is "folded" into a compact size. They were the first to offer foldable triscooter in the market. While designing they concentrated on power, economy, ease and comfort of riding and low maintenance cost. Also they concentrated on ergonomics factor to give the user a comfortable ride. Their objectives included folding ease, Portability, Reliability and retailer network. They used mild steel as the frame material welded in suitcase shape which serves as the base to hold all the accessories such as motor, weight of the load to be conveyed and the weight of the person driving the unit. They also discussed about advantages of the foldable triscooter. [2]

Mr. Akash Chaudhary Raghuvanshi with his team had made effort in developing foldable kart chassis. They understood the thing that the world is going towards the compactness, where the all things are going to compact and its time is to think about vehicle which can be folded easily and can be taken everywhere as a luggage. By this innovative idea, he conducted the structural analysis on the frame of their kart vehicle and developed a GO KART named as "ASHVA" which can be folded by its mid with the help of a joint that connected between its two chassis front chassis-rear chassis. They knew that Karts are used to just take the experience of racing cars. Mostly they are very entertaining vehicles in the markets. Taking this into consideration they manufactured an automobile that would be something really out of the box. As the speed of kart varies on the power of engine and how much fuel it takes. The chassis of kart was made up from the mild steel and the joint of kart had been made up of mild steel. This joint gave more power and stability to their vehicle. They used mechanical chain to transmit the power from the engine to the axle of kart. For a better karting experience, rack and pinion system was used by them. A fish body is a perfect aerodynamic natural structure, one can get inspired with hence the chassis of the kart was developed with an igniting idea of a fish body. Selection of material plays an important role on strength and safety of the product that was the reason they chose AS-202 stainless steel round tubes as a chassis material. Also they chose the material for shaft so that it can bear all the stresses. They discussed about the material selection procedure. They made an effort in describing the joints that can be used in foldable vehicle chassis. [3]

Researchers at MIT with backing from General Motors Corp. are building a prototype of a lightweight electric vehicle that can be cheaply mass-produced, rented by commuters under a shared-use business model, & folded &

arranged like grocery carts at subway stations or other central sites. It's called the City Car, and the key to the concept lies in the design of its wheels. [4]

2.3 Other Researches

Karts are used just to take the experience of racing cars. Mostly they are very entertaining vehicles in the markets. Karts are likely the basic concepts of car nothing else. As the speed of kart just varies on the power of engine and how much fuel it takes, the chassis of kart is made up from the mild steel and the joint of kart had been made up of mild steel. This joint gives more power and stability to the vehicle. Student competition based on the product they designed and fabricated is a good activity carried out by university students. Here mechanical chain is used to transmit the power from the engine to the axel of kart.

Generally karts speed varies from 45 Km/Hr. – 65 Km/Hr. and this kart also had a speed of 52 Km/Hr. As joint gives the support to the both chassis front as well as it also helps to bears maximum force on it so that chassis have good strength and can bear maximum weight in comparing of other karts. For less turning radius we used simple rack and pinion. National Go-Kart championship is a platform where nation comes together with bringing new ideas of their minds in automobile field. This completion gives the basic knowledge of car and increases manufacturing skills of students. There is not much research about go-kart design. Most of the research is about the safety and injury. Risk compensation theories hypothesize that if individuals use safety belts, they will drive in a more risky manner than if they do not use safety belts due to an increased perception of safety.

Following objectives were taken into consideration-

- **Folding ease:** Folding should be easy, stress-free, and take no more than 10 minutes after user becomes familiar with the tri-scooter.
- **Portability:** It should be easily transportable for both women and men. It should be easy to handle and should be portable.
- **Reliability:** It should have a stable ride, confident feel, and similar performance to a conventional bike. Fit various sized people, should be easy to maintain and reliable.
- **Retailer Network:** Program should offer two to three price points such as a good, better and best" philosophy. Sales and service should be very convenient and available to users via local retailer networks.

"**FOLDABLE TRISCOOTER AND BIKE**" is the electrically operated consisting of the following different sub-components:- D.C. Motor, Frame, Charger, Battery, Wheels, Drive, Tricycle. There are also foldable electric bike available in market within the range of \$400.



Fig-2: Suitcase Bike

D.C. Motor: The motor is having 250 watt capacity with maximum 800 rpm with torque capacity of 50 Nm. Its specifications are as per the following:-

- Current rating - 14 Ampere

- Voltage rating - 24 volts D.C.
- Cooling - air cooled
- Bearing - single row ball

Frame: It is made from the mild steel body along with some of the light weight components, welded in suitcase shape which serves as the base to hold all the accessories such as motor, weight of the load to be conveyed and the weight of the person driving the unit. Also it should be able to overcome the stresses, which are coming due to different driving and braking torques and impact loading across the obstacles in the traveling ways. It is with the linkage and wheels to propel it and the platform plates. It is drilled and tapped enough to hold the support plates.

Platform: It is the robust base for holding the uniformly or concentrated load along with the weight of the driving person. It is manufactured from the mild steel square pipe welded in suitcase shape with top sheet of 3 mm thickness. Platform is directly bolted and welded to the framed platform; the alignment of the platform is always kept perfectly horizontal while it is loaded or un-loaded.

Battery: It is the accumulator of electric charge. It must store the electrical energy produced by the generator by the electrochemical transformation and give it back again on demand. E.g. while starting.

Construction: The basic element of battery is the cell. It contains the plate block which consists of a set of positive plates and a set of negative plates. The individual plates are separated from one another by separators placed in between. The cell is filled with the mild sulphuric acid. The block cases e.g. of a 12V battery, is divided in to six cells that are mutually sealed and are tightly closed at the top by the block case cover. The individual cells are connected in series by the cell connector. At the first and the last set of plates, the end poles are welded. Following are the different components of battery:-

- Block case, block cover: It is manufactured from acid resistant insulation material, partly from the hard rubber, mostly from plastic e.g. polypropylene.
- Plates: These are manufactured from lead grid with embedded highly porous effective mass from very small lead particles (positive plates). The effective mass is chemically transformed while charging and discharging.
- Separators: Micro porous insulation plates from acid-resistant plastic. They prevent contact between positive and negative plates, but must allow the electrolyte to pass through.
- Electrolyte: It is the Mixture from chemically pure sulphuric acid (H_2SO_4) and desalinated or distilled water.

The electrolyte should not be made impure by the mineral salts of water. The sulphuric acid is separated into columns of positive H ions and negative SO_4 ions by mixing with water. If the poles of the cell are connected by a load (incandescent lamp), electrons flow from the negative pole to the positive pole. Due to the scarcity of electrons at the negative pole, bivalent positive lead is produced from the neutral lead which combines with the bivalent negative SO_4 group to form lead sulphate $PbSO_4$. At the positive pole, bivalent positive lead is produced from the quadrivalent positive lead of the oxide through the electron supply. The combination with O_2 is therefore ruled out and a combination with SO_4 is introduced, leads sulphate $PbSO_4$, and is likewise produced. The oxygen atoms released combine with the hydrogen atoms of the electrolyte to form water. The density of the battery decreases.

Discharged condition: Positive plates, effective mass lead sulphate $PbSO_4$ negative plates, effective mass lead sulphate $PbSO_4$, Acid density 1.12 kg/cm^3 , Acid density in degree 160, Cell voltage, unloaded 1.75 V. High current discharge while discharging with high currents, e.g. while starting, it is to be noted that the water formed in the inside of the plates must mix with the remaining acid. The battery therefore needs relaxation pauses during high current discharges.

Deep discharge: Complete discharge of a battery must be avoided since the resulting lead sulphate has a larger volume and therefore there is the danger of breakage of the effective mass from the plate grid. Deep discharged batteries should be immediately recharged.

FOLDABLE MOTORBIKE: These aren't a new invention, according to Di Blasi, the American company making these bikes; the model has been around for quite many years now. It weighs in at less than 30 kg (64 lbs.) & can be folded to fit in a bag measuring 73 cm (L) by 53 cm (H) by 30 cm (W), i.e., less than 5 cubic feet, or into the trunk of any standard car. Using its 1.3 - 3800 rpm engine, it can reach speeds of 50 kmph (about 30 mph) & according to Di Blasi, gets up to 130 miles per gallon (though its fuel tank holds only 3/4 of a gallon), and comes with a price tag of \$2000.

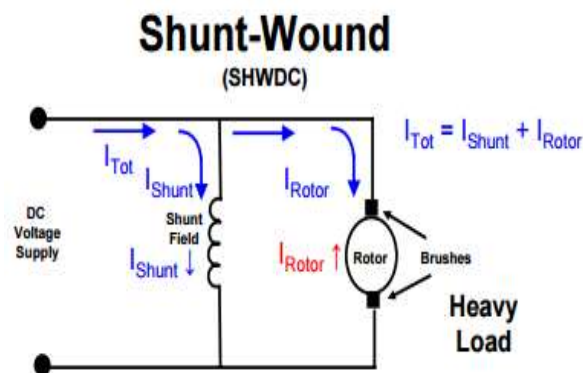


Fig-3: Folding Motorbike

An electric motor is an instrument which converts electrical energy into mechanical energy. In normal motoring mode, most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force within the motor. In certain applications, such as in the transportation industry with traction motors, electric motors can operate in both motoring and generating or braking modes to also produce electrical energy from mechanical energy. General-purpose motors with highly standardized dimensions and characteristics provide convenient mechanical power for industrial use.

Motor consists of Rotor, Stator, Windings, Air Gap, and Commutator which works together to convert electrical energy into mechanical energy which may be linear or rotary depending upon motor. There are four types of brushed DC motors. The first type is the Permanent Magnet Brush DC Motor. Second, the shunt-wound brushed DC motor. Third is the series-wound DC motor and fourth is the compound-wound brushed DC motor which is a combination of both the shunt and series wound brushed DC motors.

Shunt-wound brushed DC motors have the field coil in parallel (shunt) with the rotor. The current in the field coil and in the rotor are independent of one another, thus, the total current of the motor is equal to the sum of the shunt current (or stator current) and the rotor current. So, during normal operation, as the supplied voltage is increased the total current of the motor will increase causing the stator and rotor fields to increase. As total current increases motor speed will increase, thus motor torque will decrease. However, once you put a load on the motor the rotor current will increase causing the rotor field to increase. If the rotor current increases then the shunt current will decrease causing the stator field to decrease. This will cause the motor speed to decrease, thus the motor torque will increase.



Shunt-wound brushed DC motors have the performance characteristics of decreasing torque at high speeds and a high but more consistent torque at low speeds. The current in the field coil and in the rotor are independent of one another, thus, the total current of the motor is equal to the sum of the shunt current (or stator current) and the rotor current. As a result, these motors have excellent speed control characteristics. Shunt-wound brushed DC motors are typically used in applications that require 5 or more HP such as industrial and automotive applications. As compared to permanent magnet brushed DC motors, shunt wound brushed DC motors have no loss of magnetism and are more robust. Some drawbacks are that shunt wound brushed DC motors are more expensive than permanent magnet brushed DC motors and have the potential of motor runaway if the shunt current decreases to zero. This is a very dangerous condition that can lead the motor to literally break apart.

Principal of operation of DC Motor:

- When a current carrying conductor is placed in a magnetic field. It experiences a force.
- In case of DC motor, the magnetic field is developed by the field current i.e. the current flowing in field winding.
- The armature winding is connected to an external dc source; hence it plays the role of the current carrying conductor placed in the magnetic field.
- Due to force exerted on it when placed in the magnetic field, it starts rotating and the armature starts rotating.
- The direction of rotation depends on the direction of the magnetic field produced by the field winding as well as the direction of magnetic field produced by the armature.

Effect of increase in load:

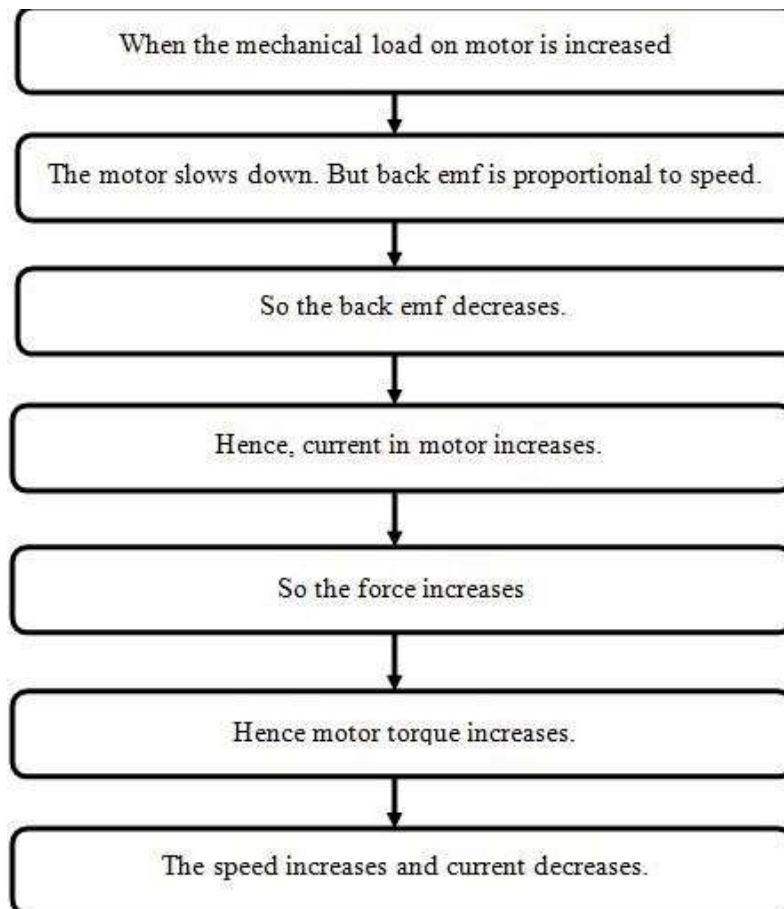


Fig-5: Effects of load on motor.

Characteristics of DC Motor:

Torque Armature Current characteristics:

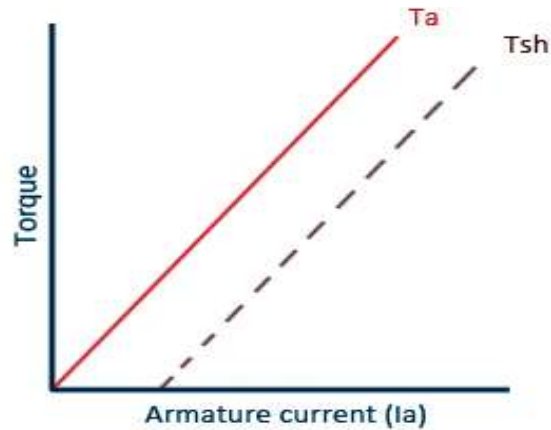


Fig-6: Torque Armature Current characteristics

- The torque armature current characteristics of DC shunt motor shows that the starting torque (at the time of starting the motor) is not very high.
- To generate higher starting, we have to increase armature current, to a very large value because torque is directly proportional to armature current. This may damage the motor.
- So shunt motors should be used in those applications which demand a moderate starting torque.

Speed Armature current characteristics:

- As the load on the motor is increased, the torque demands increases. To generate higher torque the motor draws more armature current.
- As armature current increases, voltage also increases.
- As the value of resistance is small, the drop in voltage is small. Hence the reduction in speed is not significantly large.
- So the characteristic is slightly dropping as shown in figure, as we increase the load from no load to full load.
- However the reduction in speed is so negligible, that the DC shunt motors are considered as constant speed motors.

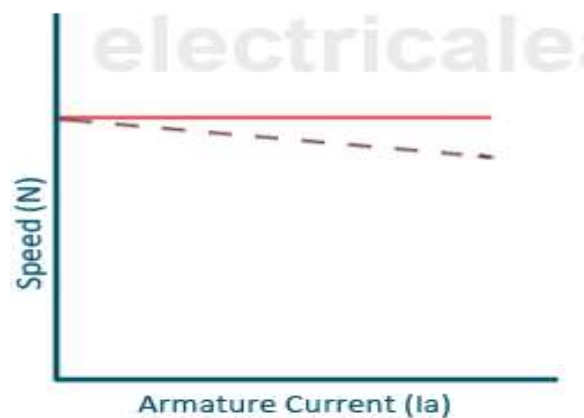


Fig-7: Speed Armature current characteristics

Speed Torque characteristics:



Fig-8: Speed Torque characteristics

- At no load, torque produced by motor is less and rotates at constant speed.
- As the load is increased, the torque requirement also increases. To generate the required amount of torque, the motor has to draw more armature current and more armature current can be drawn if a speed decrease is more.
- Therefore, as load increases, torque will also increase and the speed decreases.

3. COMPONENTS

Listings of main components are done as follows:

- Suitcase
- Electric motor
- Drive
- Wheel
- Chassis
- Steering
- Shaft
- Brakes
- Reverse Switch
- Battery

3.1 Suitcase

Suitcases are used to store belongings while travelling as well as at homes. So we are building a vehicle in suitcase of proper dimension. Proper dimensions will allow the user to handle as well as to store the vehicle in any corner space available to him/her at home.

Table-1: Suitcase specifications

Parameter	Specification
Length	29"
Breadth	22"
Thickness	11"
Capacity	110kgs



Fig-9: Suitcase

3.2 Electric Motor, Controller & Throttle

Electric Motor:

We have chosen electric motor instead of IC engine in our project. But due to space constraints, we opted for electric motor. Motor which we used is reduction electric DC motor which provides required torque. Also reason behind choosing this motor is we did not want emission issues with our vehicle. Only disadvantage with this motor is increase in size of battery and decrement in RPM. Also this reduction motor comes with controller and throttle control for handle. Specification for the electric motor is provided below:

Table-2: Motor Specifications

Parameters	Specifications
Type	DC Motor
Voltage	24
RPM	4000
Rated Wattage	250w
Rated Current	14.7A
Torque	22 Nm
Reduction Ratio	5.78:1



Fig-10: Electric Motor

Controller:

Controller is a device that serves to govern the performance of an electric motor. This may have automatic or manual means of starting and stopping the motor, selecting forward and reverse rotation, selecting and regulating or limiting the torque and protecting against overloads and faults. The given controller is of manual starting or stopping Direct on Line (DOL) type which is controlled by using throttle. This is pre-loaded with software to work for the given electric motor. This works for all functions given above.



Fig-11: Controller for 250W Electric Motor

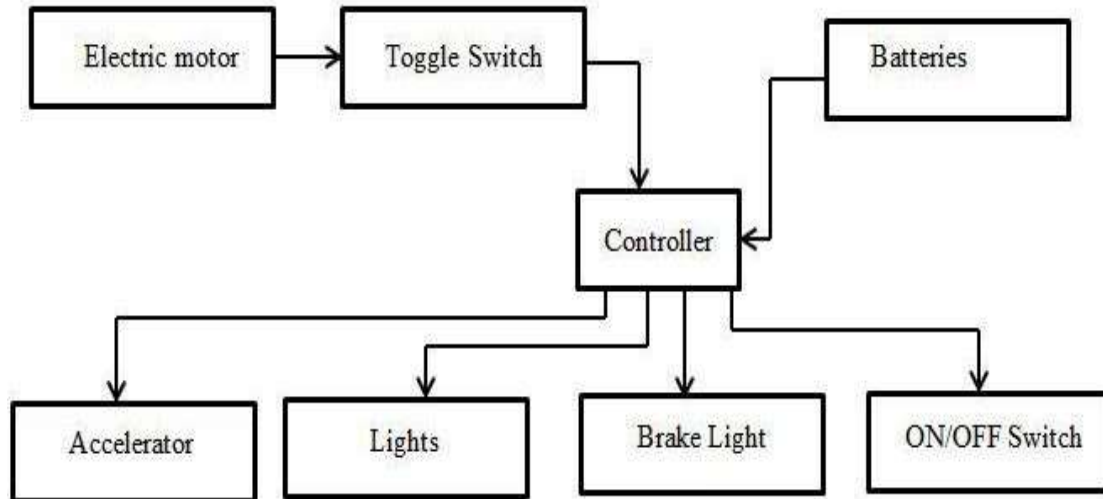


Fig-12: Block Diagram of controller connections

Throttle:

Electronic Throttle control (ETC) is an automobile technology which electronically connects the accelerator pedal to the throttle, replacing mechanical linkages. ETC consists of accelerator pedal module, ETB and ECM. There are throttle positions sensor embedded in ETB which helps in determining the required throttle. The given ETB works on potentiometer.



Fig-13: Electronic Throttle Body

3.3 Drive

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle using a chain. Since there is a reduction gear mounted in electric motor, that's why we do not need different gear ratios and because of this we are using direct chain drive. Moreover gearbox in vehicle will increase in weight; we are rejecting the use of gearbox. Motor sprocket has attached to motor and with its specification we have designed our shaft ratio. Since there was already reduction setup in motor we were trying to achieve 1:1 ratio from motor output to shaft. Pinion details are as follows.

Table-3: Chain Drive Specifications

Parameters	Specifications
Type	Direct chain drive using clutch
Pinion	9 Teeth's
Module	2.75 mm
Pitch	9.2364
Gear Ratio	1.4
Center distance	200mm

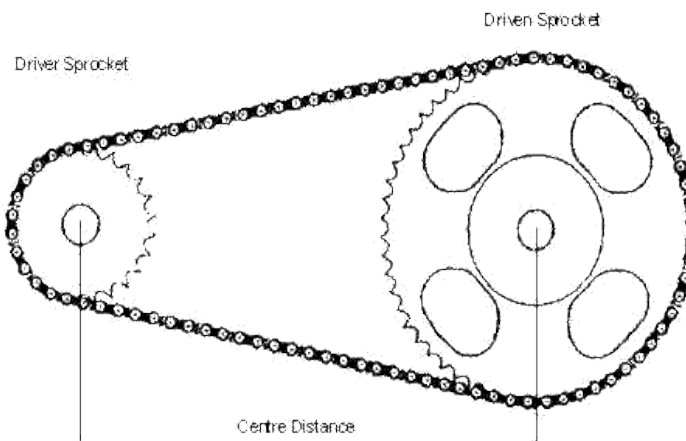


Fig-14: Chain Drive

3.4 Wheel

We have used three wheels for the vehicle. Out of these three wheels, one wheel at front steering handle and other two wheels used with shafts at rear of the vehicle for propulsion purpose. These wheels are made up of hard rubber which will help in transferring weight to the roads. Due to their smaller size and high weight handling capacity they are best for use. Specifications for the used wheel are as follows:

Table-4: Wheel Specifications

Component	Parameters	Specifications
Front wheels		
	Quantity	1
	Size	8"
Rear Wheels		
	Quantity	2
	Size	8"



Fig-15: Wheel

3.5 Chassis

We have used perimeter type chassis frame which provides more space and area for mountings. It is also the internal part of vehicle. It also helps in distributing space equally over the vehicle. We have manufactured the chassis in two different parts which can be assembled by an intermediate member. We have compared many different materials such as AISI 4130, AISI 1020, AISI 1006 and ASTM A500 GRB. Comparisons of these materials are provided below.

Table-5: Material Comparisons

Parameter	AISI 4130	AISI 1020	AISI 1006	ASTM A500
UTS (MPa)	1075	380	295	300
YTS (MPa)	986	205	165	210
Density (g/cc)	7.85	7.87	7.87	7.85
Poisson's ratio	0.29	0.29	0.29	0.26
Elasticity Modulus (GPa)	205	200	205	205
Cost	₹ 550/ mtr	₹ 400/ mtr	₹ 250/mtr	₹ 350/ mtr

Out of these materials ASTM A500 Gr B has used. The reason behind using this grade above all others was that it provides much strength and cost efficiency. The AISI 4130 is much good in strength but is costly and moreover we do not require this much strength for vehicle. Frame has made up of square pipe with following dimensions:

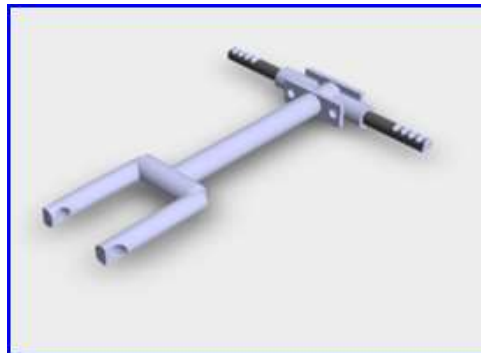
Table-6: Chassis Material Specifications

Parameter	Specifications
Dimension	1" & 3/4 th " Pipe with 1.6 mm thickness
Material	ASTM A500 Gr B
Yield tensile strength	210 MPa
Ultimate tensile strength	300 MPa
Bulk Modulus	140 GPa
Shear modulus	80 GPa
Poisson's Ratio	0.26
Density	7.85 g/cc

3.6 Steering

The primary purpose of the steering system is to allow the driver to guide the vehicle. As the vehicle is not too heavy so we used a simple steering mechanism. Following things were mounted on steering handle.

- Handle Driven Single Wheels
- Brakes on handle
- Throttle on handle

**Fig-16:** Steering handle

3.7 Shaft

A solid shaft of circular cross section has used. As maximum bending force and torque was coming on shaft so the solid shaft has opted. Brakes and rear sprocket has mounted on the shaft.

Table-7: Shaft Material Specification

Parameter	Specification
Material	Stainless steel 302 (annealed)
SUT	620 MPa
Elastic modulus	193 GPa
Poisson Ratio	0.25

3.8 Brakes

Brakes have used to stop the vehicle. As the vehicle has speed limitation of 35 Km/h, we have used mechanical brakes. The system includes disc and caliper which actuates by using linkages from brake handle at steering.

Table-8: Brakes Specifications

Components	Parameter	Specifications
Caliper		
	Piston Diameter	15 mm
	No. of pistons	2
	Area of piston	176.6 mm ²
Disc		
	Outer diameter	160 mm
	Inner diameter	134 mm
	Mean effective radius of rotor	73.7 mm
	Thickness	2.5 mm



Fig-17: Mechanical Brakes

3.9 Reverse Switch

Reverse switch or toggle switch has been used in the vehicle to move it into reverse direction. This has been achieved using 3 Way- 6 point toggle switch. This switch reverses the current phase coming to it and provides the output to reverse the direction of motor. It has been provided in vehicle so that the driver will not need to get out of the car to move it into reverse direction.

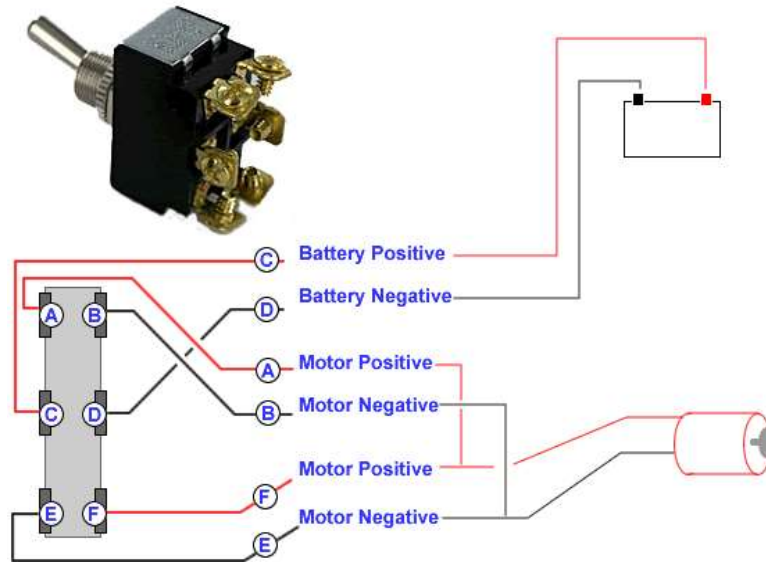


Fig-18: Toggle Switch 3 Way

3.10 Battery

We have used alkaline batteries for our vehicle’s electric motor. They have high capacity than their respective counterparts as well as small in size. Since motor was of 24 V and 14.7 A, two batteries of 12 V were sufficient to use.



Fig-19: Alkaline Battery

4. DESIGN & PERFORMANCE

4.1 CAD Model

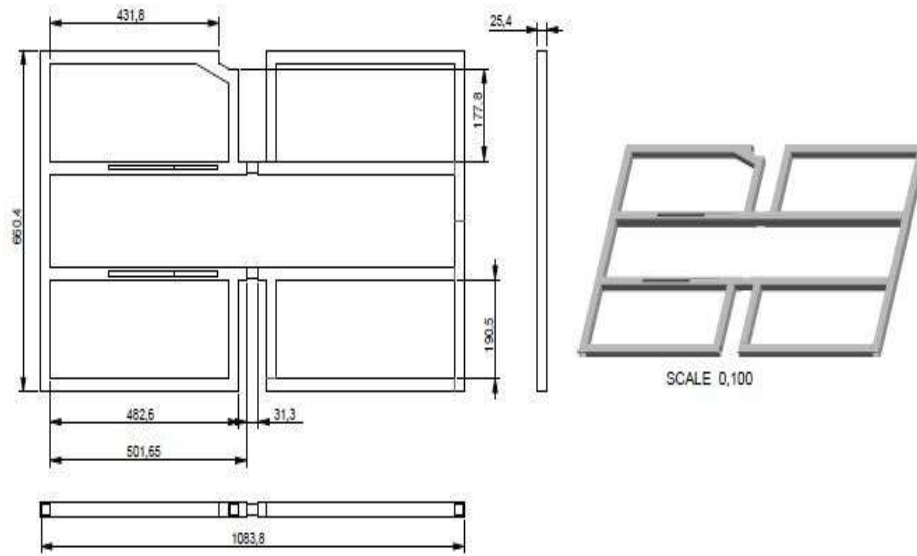


Fig-20: CAD model

4.2 Sprocket & Chain

No. of teeth on sprocket $T_2 = T_1 \times 1.4 = 9 \times 1.4 = 13$

Diameter $D_2 = T_2 \times \text{module} = 13 \times 2.75 = 35.75\text{mm}$

Chain Length:

$$l = \frac{T_1 + T_2}{2} + \frac{2C}{P} + \frac{(T_2 - T_1)^2 P}{4\pi^2 C} = \frac{13 + 9}{2} + \frac{2 \times 200}{9.2364} + \frac{(13 - 9)^2 \times 9.2364}{4\pi^2 \times 200} = 54.49\text{link} = 55\text{link}$$

$$= 55 \times 9.2364 = 508\text{mm}$$

4.3 Shaft

Maximum torque $T = 28.11\text{Nm} = 28110\text{Nmm}$

Maximum bending moment $M = 35 \times 9.81 \times 6.5 \times 2.54 = 56687.085\text{ Nmm}$

Considering FOS= 4

Acc. Max. Shear stress theory:

$$\tau_{max} = \frac{1}{2} \times \sqrt{\sigma_b^2 + 4\tau^2} = \frac{1}{2} \times \sqrt{620^2 + 4 \times (0.5 \times 620)^2} = 438.406\text{ MPa}$$

$$TE = \sqrt{M^2 + T^2} = \sqrt{56687.085^2 + 28110^2} = 63273.989\text{ Nmm}$$

$$D = \sqrt[3]{\frac{16TE \times FOS}{\pi \times \tau_{max}}} = \sqrt[3]{\frac{16 \times 63273.989 \times 4}{\pi \times 438.406}} = 14.233mm$$

Acc. Normal stress theory:

$$Me = \frac{1}{2} \times (M + \sqrt{M^2 + T^2}) = \frac{1}{2} \times (56687.085 + \sqrt{56687.085^2 + 28110^2}) = 59980.54 Nmm$$

$$D = \sqrt[3]{\frac{32 Me \times FOS}{\pi \times \sigma_b}} = \sqrt[3]{\frac{32 \times 59980.54 \times 4}{\pi \times 620}} = 15.79mm = 16mm$$

Therefore, considered shaft of 16mm or greater than it for design.

4.4 Bearing

Bearing load: 60 kg.....assumed

Load factor for chain drive: - 1.5

Bearing load (total) = 60×1.5 = 90 kg = 882.9 N

For the machines working 8 hr/day

$L_{10h} = (12000 - 20000)$ hrs.

$L_{10} = 60 \times L_{10h} \times 40h/106$

$L_{10} = 60 \times 3567.690 \times 20000/106$

$L_{10} = 4281.228$

$C_1 = P (L_{10})^{1/3} = 882.9 \times (4281.228)^{1/3} = 14336.199$

But standard Value for $C_1 = 15900$ for bearing 6007

So selecting bearing = 6007

$D_2 = 47mm, B_2 = 20mm$

4.5 Transmission

Velocity:

$$v = \frac{2\pi Nr}{G} \times \frac{60}{1000} = \frac{2\pi \times 4000 \times 0.0762}{1.4 \times 5.78} \times \frac{60}{1000} = 14.2 Kmph$$

Tractive resistance = AR+GR+RR ... (I)

AR= Aerodynamic resistance

$$AR = \frac{1 \times Cd \times \rho \times A \times v^2}{2} = \frac{1 \times 1.15 \times 0.4558 \times 1.225 \times 3.88^2}{2} = 4.83 \text{ N}$$

GR= Grade Resistance

$$\text{Which is given as, } GR = W \times \sin\theta = 90 \times 9.81 \times \sin(5) = 76.94 \text{ N} \dots (2)$$

RR= Rolling resistance

$$\text{Which is given by, } RR = fr \times W = 0.01 \times 9.81 \times 90 = 8.83 \text{ N} \dots (3)$$

Putting Values from eqⁿ 1, 2, 3 in eqⁿI, we get,

$$TR = 4.83 + 76.94 + 8.83 = 90.6 \text{ N}$$

Traction:

$$TF = \frac{Te \times G \times \eta_t}{r} = \frac{0.8 \times 5.78 \times 1.4 \times 0.9}{0.0762} = 129.37 \text{ N}$$

Torque:

$$Td = Te \times G = 0.8 \times 5.78 \times 1.4 = 6.4736 \text{ Nm}$$

Acceleration:

$$a = \text{tractive effort} / \text{mass} = 129.37/70 = 1.85 \text{ m/s}^2$$

4.6 Brakes

For effective braking of vehicle the braking torque of wheels should be greater than Engine Torque at wheels. The designing of brake system is based on this factor.

Generally lever ratio lies between 4 to 6. We assumed it as 4.

The force applied on the piston= 90 N

Net force on lever end

= lever ratio × force on the Pedal

$$= 4 \times 90 = 360 \text{ N}$$

Force produced by caliper piston = Force produced at lever end = 360 N

Force on rotor = Force produced by caliper piston = 360 N

Total frictional force

= Forced on rotor × coefficient of friction between pads & disc × No. of caliper

$$F = 360 \times 0.4 \times 1 = 144 \text{ N}$$

$$\text{Deceleration} = \text{Force/mass} = 144/90 = 1.6 \text{ m/s}^2$$

Stopping Distance

$$= (\text{velocity}^2) / (2 \times \text{deceleration}) = (3.88)^2 / (2 \times 1.6) = 4.726 \text{ m}$$

Stopping time

$$= \text{Velocity} / \text{deceleration} = 4.726 / 1.6 = 2.95 \text{ s}$$

Total stopping time

$$= \text{Stopping time} + \text{Driver Reaction}$$

$$= 2.95 + 1.5 = 4.45 \text{ s}$$

Effective Radius of rotor

$$= 2(R^3 - r^3) / (3(R^2 - r^2))$$

$$= 2(80^3 - 67^3) / (3(80^2 - 67^2)) = 73.3 \text{ mm}$$

Braking Torque

$$= \text{Braking force} \times \text{Effective Radius}$$

$$= 144 \times 0.0733 = 10.55 \text{ Nm}$$

$$\text{Torque at wheel} = 9.58 \text{ Nm}$$

Torque at Wheel < Braking Torque

Therefore, Design is Safe.

5. ANALYSIS

$$\text{Impact force} = \frac{1.2 \times M \times v}{T} = \frac{1.2 \times 100 \times 9.72}{1} = 1166.4 \text{ Kg.m/sec}^2 = 1166.4 \text{ N} \sim 1200 \text{ N}$$

5.1. Front Impact

It has been done using software on front part of vehicle. Vehicle's weight and forward velocity has used to calculate force arising due to impact. Front bar of chassis has used to absorb impact force and rear bar has been used as a fixed support.

Total Deformation has checked for changes arising due to impact force. The total deformation has been equal to 0.0011552 m

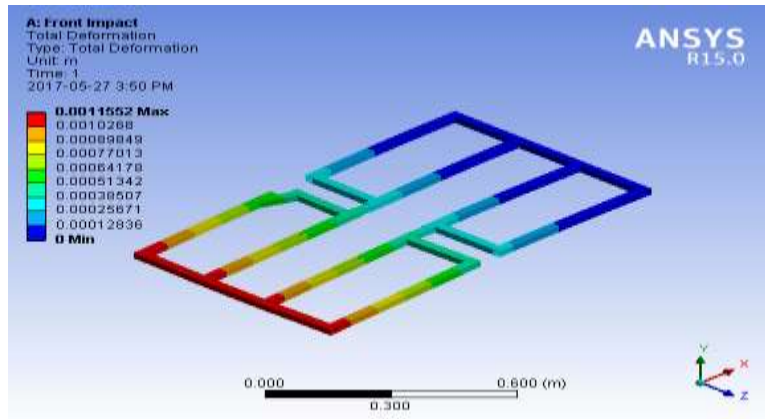


Fig-21: Total Deformation-Front Impact

Maximum Principal Stress has performed to check stresses arising during collision occurred on front end of chassis. Maximum principal stress value has been equaled to $2.25e^7$ Pa

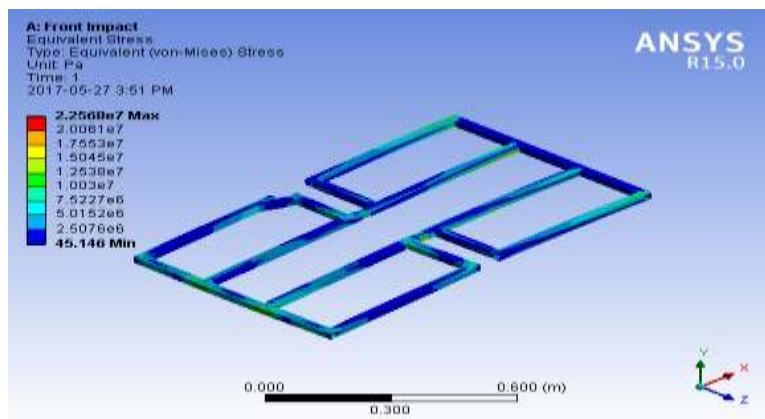


Fig-22: Equivalent Stress- Front Impact

Safety Factor has checked to identify ratio of working stress to design strength. It has equal to 3.81 which signifies much better result.

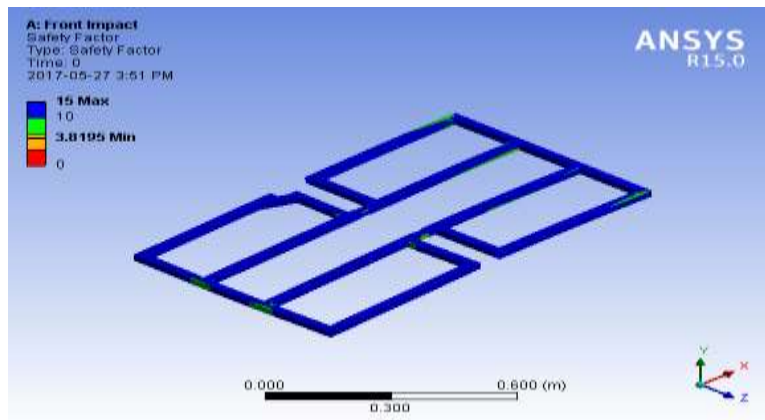


Fig-23: Safety Factor-Front Impact

2. Rear Impact:-

Analysis for rear impact has been performed on vehicle. For this mass and velocity of an incoming vehicle is taken into consideration. Rear end bar has force acting over it and front end bar acts as a fixed support.

Total Deformation due to collision has calculated as 0.00118 m.

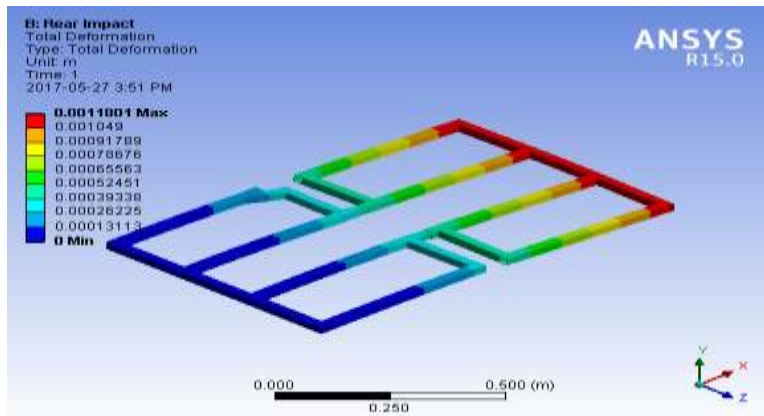


Fig-24: Total Deformation-Rear Impact

Equivalent stress of the value 2.06×10^7 Pa has been observed during rear end collision. This value is largely affected by velocity of an incoming vehicle.

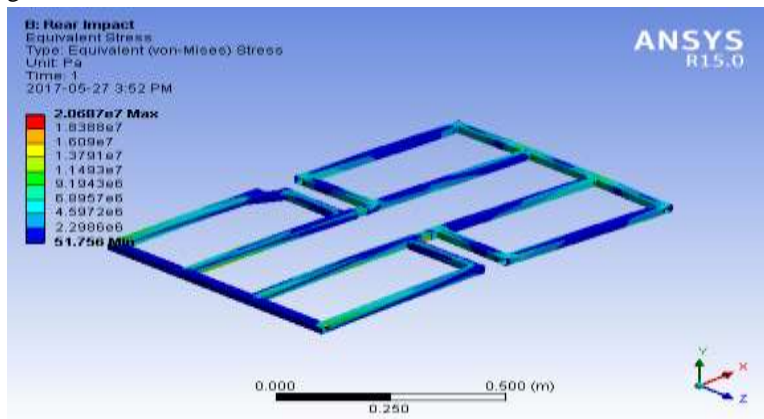


Fig-25: Equivalent stress-Rear Impact

Safety Factor of 4.16 has observed which also signifies about the strength and load bearing capacity of chassis.

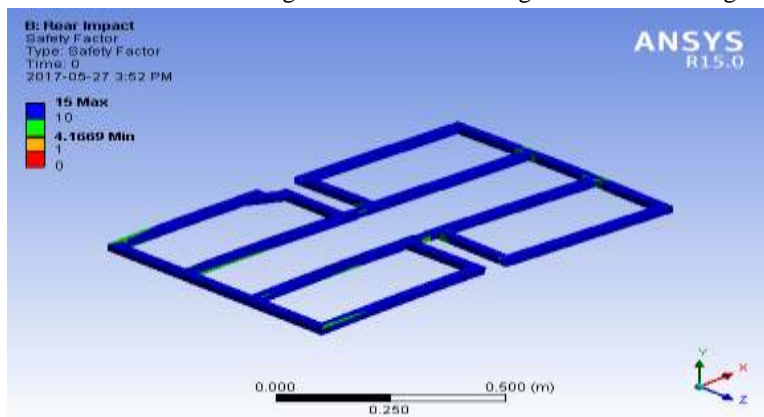


Fig-26: Safety Factor-Rear Impact

3. Left Impact

Left impact analysis has performed to check side performance of chassis during collision.

Total Deformation of 0.00147 m has been observed.

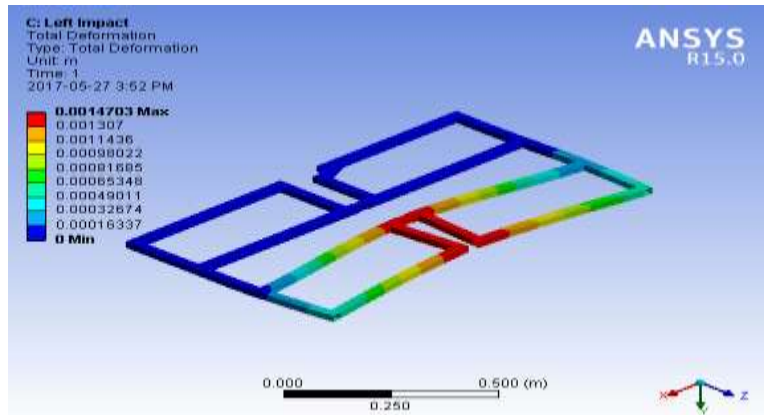


Fig-27: Total Deformation-Left Impact

Equivalent stress of $1.103e^8$ Pa has been observed after left impact analysis was performed. This signifies low stress generation during any impact.

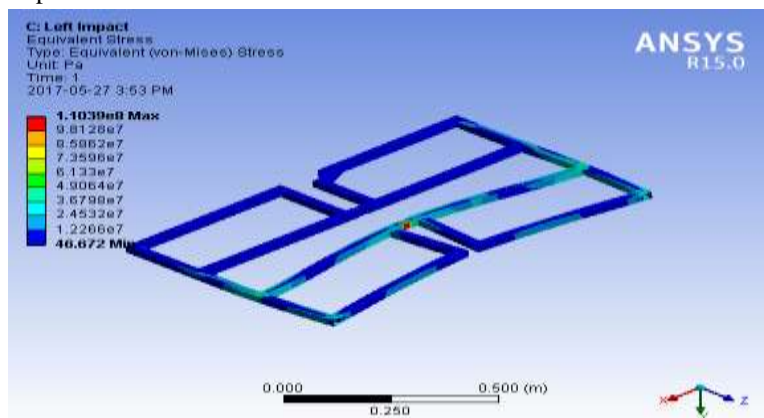


Fig-28: Equivalent Stress-Left Impact

Safety factor of 0.78 has observed after analysis test. The value of 0.78 signifies low strength ratio but it has been affected by incoming vehicle.

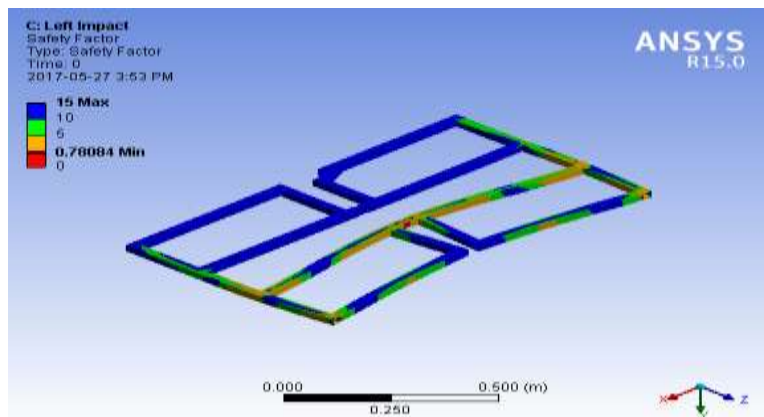


Fig-29: Safety Factor-Left Impact

4. Right Impact

Right Impact is also a side impact test which is carried out on other side of vehicle. It also signifies side performance of chassis during impact.

Total Deformation during right side impact has value of 0.0012 m. The result is significantly less and will not cause major defect on chassis.

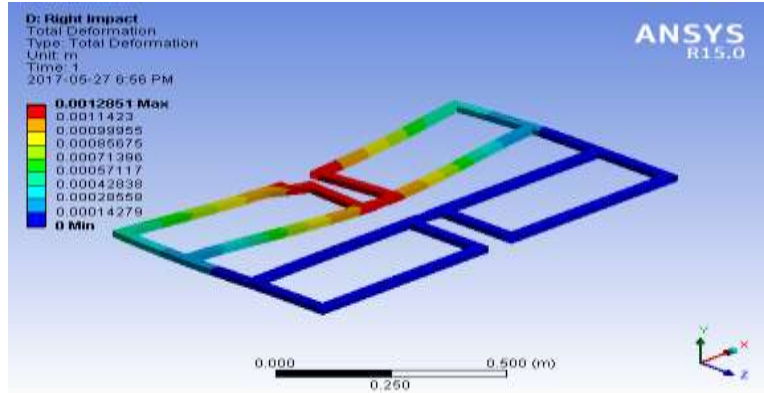


Fig-30: Total Deformation-Right Impact

Equivalent stress of $9.77e7$ Pa has observed which determines the range of stress generating in chassis during any impact.

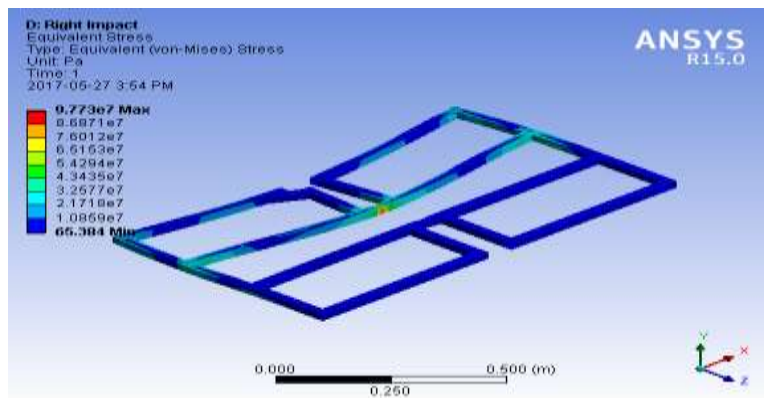


Fig-31: Equivalent Stress-Right Impact

Safety factor of 0.88 has observed which signifies that there is less difference between design and working stress in chassis. Since it is in permissible limit we can continue with this safety factor.

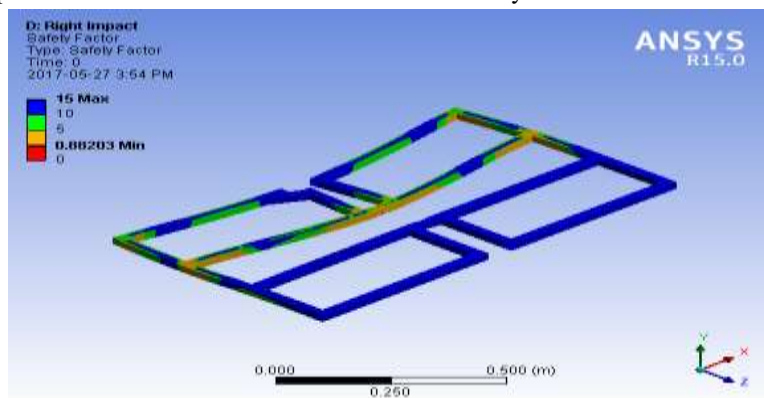


Fig-32: Safety factor-Right Impact

6 ASSEMBLY

All the parts of the suitcase car have mounted inside a suitcase. The car consists of the two halves these are joined by the nut and bolt to make a rigid structure. The rear half contain the engine which is connected to the rear axle by a chain drive. The rear axle is fixed on chassis. Main shaft contains transmission sprockets and brake disc attached to suitable side. Wheels are 8" in size and made up of rubber. Roller bearings have used to transmit the load coming on the chassis of the car. Seat has mounted on rear chassis part. Seat of car made up of fiber and which is light in weight.

The front half of the chassis contains the handle which is used to give direction to the vehicle. The front wheel is 6" in size and contains a center bearing. The handle is linked to the member of the chassis such that it can trace a rotating motion. The handle contains an excluded part which supports the foot load of the rider. The whole suitcase is divided into three compartments so that in one compartment contains the detachable tires, the second one contains the handle and seat and the third one contains the transmission system and engine. The suitcase car is designed and built for use on a paved closed circuit track. The track should be clean and without obstacles of any kind. It takes hardly 3-4 minutes to install. An adult or younger person can drive it. It is suitable for campus purpose.

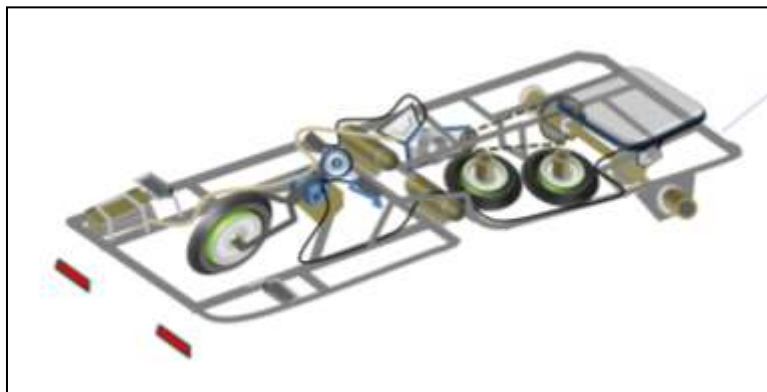


Fig-33: Layout of chassis with parts

7. FABRICATION

7.1 Suitcase Work

First of all we have prepared suitcase for car by cutting and drilling it as per the mounting requirements. Some parts of suitcase have cut using portable cutter machine to make the space for wheels which helps the vehicle to move from one place to another. Some holes made into suitcase to help it in accommodating chassis using nut & bolts. This has achieved using portable drilling machine.



Fig-34: Suitcase Work

7.2 Chassis Fabrication

Chassis was fabricated into two separate parts i.e. front and rear part which can accommodate different parts of vehicle. For this material ASTM A500 square pipe was cut into proper dimensions which has described in design phase in CAD model. These cut pipes have welded together using spot welding process. When the chassis part was ready grooves for sliding part of chassis were made to join two different parts of chassis. After all these we have fixed chassis into suitcase using nut & bolts.



Fig-35: Front Chassis Part



Fig-36: Rear Chassis Part

7.3 Shaft & Rear Wheels Mountings

Shaft has manufactured from outside of prescribed dimension. Rear wheels have mounted on shaft. Shaft has attached to chassis frame using hubs which are used for holding shaft through bearings. These bearings were press fitted on hubs to stop its linear movement and helps in rotating shaft on its support. Wheels and bearing were purchased from outside.



Fig-37: Rear Axle mountings

7.4 Steering & Front Wheels Mountings

Steering handle has manufactured after cutting pipes of required length. Arrangements have made to accommodate throttle body, brake lever, and front wheels. Steering column fitted in bearing to help in rotating movement of column which is used for giving direction to moving vehicle. We used Spot welding in this process.



Fig-38: Steering Handle construction

7.5 Motor Mountings

Angle rods have used to mount electric motor within chassis and suitcase to reduce its movement while working.



Fig-39: Electric Motor Mountings

7.6 Chain Drive Mountings

The transmission of our vehicle has obtained by chain mechanism. We used two sprockets for transmission of torque from motor to drive shaft. One sprocket has mounted on motor which has 9 teeth's and another at drive shaft of vehicle which has 13 teeth's. The shaft's sprocket integrated with its hub so that the hub is directly bolted to shaft.



Fig-40: Chain Drive Mountings

7.7 Brake & Brake Light Mountings

Brake lever has mounted on steering handle which helps in actuating the brake caliper situated on rotor in rear of vehicle. The caliper-rotor arrangement mounted on shaft and is rigidly fixed to vehicle's chassis. The brake used is a mechanically operated disk brake which has wire arrangement attached to both lever and caliper which helps in braking.



Fig-41: Brakes Mountings

Brake light consists of 12V light emitting diode strips. They have been connected to controller. The brake lever is also connected to the controller. When the brake lever is pressed, brake switch is pressed and signal is produced and transferred to controller to glow light.



Fig-42: Brake Light

8. TESTING

The vehicle has been tested for velocity using different loads on a constant distance between two points. This test has been conducted to determine the effects of various loads on the vehicle. According to velocity results, other performance parameters can be determined. Velocity and brake test setup is shown below:



Fig-43: Velocity Test Setup

Distance had been marked on track. Length of 1200 meters is provided to run the vehicle and 5 meters to stop the vehicle. This distance will be divided by time required by vehicle to complete the track. Stopping distance will be measured from braking zone line. To calculate effects of various loads on vehicle's speed, we have tested the vehicle on different loads. Results are as shown below:

Table-9: Velocity Test Result

Sr. No.	Loads (Kgs)	Distance (Meters)	Time (s)	Velocity (Meter/second)
1.	50	12	6.18	1.94
2.	65	12	6.31	1.9
3.	80	12	8.57	1.4
4.	95	12	8.88	1.35

It is clearly shown that vehicle speed decreases as load on vehicle increases.



Fig-44: Complete Open Vehicle



Fig-45: Packed vehicle

The process of packing the vehicle into suitcase from open one took five minutes. It took 10 minutes to open the packed vehicle to make it ready for drive. It was within the prescribed time limit.

9. COST EXPENDITURE

Table-10: Cost Expenditure

Sr. No.	Material/Part	Specification	Quantity	Cost	
				Estimated(₹)	Actual(₹)
1	Foldable briefcase	29"x22"x11"	1	1500	1000
2	ASTM Pipe	1"x1"x0.078"	10 meters	3000	2800
3	Electric Motor, Controller, Throttle	24 V, 15 A	1	8000	6000
4	Wheels	8" & 6"	3	1300	950
5	Sprocket	13 teeth	1	200	150
7	Chain	1 meter	1	300	250
8	Brake levers		2	50	50
10	Friction pads		2	100	120
11	Disc	0.16 meters	1	100	110
12	Shaft	D=19mm, L=0.8 meters	1	1000	800
13	Headlight		1	200	180
14	Indicators		2	100	60
15	Brake light		1	100	80
16	Switches		3	200	100
17	Battery	12 V	2	3500	3400
18	Miscellaneous	Nuts, Bolts, Etc		600	500
		Total		20250/-	16550/-

10. ADVANTAGES

- This vehicle has an advantage due to its folding characteristics.
- This type of vehicle fits in a category of Portable vehicle which means handling of vehicle from one place to another is easier without any hesitation.
- This vehicle is compact in size so it can be used where other vehicles have restriction due to their huge sizes i.e. in big shopping mall and industries.
- This vehicle can be assembled in 5 to 10 minutes and similarly disassembles in the same time.
- The vehicle can use engine instead of an electric motor, hence its operating cost required will be less than any other ordinary vehicle.
- Due to the use of engine, speed and load carrying capacity can be increased for vehicle.
- Weight of vehicle has reduced as no. of batteries required is less and smaller in size.
- This vehicle can be assembled and disassembled by a single person.

- With the introduction of reverse switch, a person can make the vehicle move backwards without leaving from his/her seat.

11. FUTURE SCOPE

- This vehicle can be modified to provide more space by increasing suitcase size and motor capacity.
- Engine can be used to provide more power and torque if needed.
- Weight can be optimized by using more strength and light weight material.
- Thickness of chassis material can be reduced if high strength material is in use.
- If the vehicle is equipped with safety equipment's, then it can be used on public roads within certain limits.
- It can be made into four wheel drive if size of suitcase is increasing.
- We can use electric motor hub if there is only one wheel to transmit power to vehicle.
- A differential can be used to reduce turning radius.

12. CONCLUSION

Our project "Design and Fabrication of foldable vehicle" is the perfect application of theory and practical we have studied so far in engineering. The aim of this project was to design and build a coaxial, light weight vehicle which will consume less space for parking and can be carried along. This aim has achieved and a foldable suitcase vehicle with electric motor has manufactured and successfully tested.

A comprehensive literature review has conducted, covering technical information relevant to the project. An analysis has done by using ANSYS 15.0 software to measure impact effect on the vehicle to be manufactured. A formulated design approach was used to create the most efficient and robust configuration for fabrication of the foldable vehicle. The structural design was considered concurrently with component selection, aesthetics, and ergonomics to minimize mechanical, electrical and rider integration problems.

It can be used in college campuses and industrial areas to minimize the walking distance. As it is electric motor powered, it is easy to operate. The vehicle is compact, lightweight, has simple design and hence easily portable. Cost of manufacturing is moderate. Other vehicles can be manufactured having greater capacity as well as larger area for heavy duty works.

Thus, our project "Design and fabrication of foldable vehicle" is a successful attempt to overcome traffic congestion and parking problems.

13. ACKNOWLEDGEMENT

First and foremost, we express our gratitude towards our guide **Prof. Anita Wankar**, who kindly consented to act as our guide. We cannot thank her enough for her patience, energy, an utmost contagious positive attitude, and critical comments are largely responsible for a timely and enjoyable completion of this assignment. We appreciate her enlightening guidance; especially her pursuit for the perfect work will help us in the long run.

We are very much thankful to our **Prof. Siddharaj Allurkar (H.O.D. Automobile Engineering)** for his whole hearted support in study. We would like to thank to all our teachers at various levels of our education, from whom we have gained more than just academic knowledge. They have positively influenced and shaped our ideas and made us a better person. We are also grateful to all our friends and parents without their support this task was difficult. Finally we would like to thank all our lab assistants, Teachers and non-teaching staff members.

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