DESIGN OF SCOOTER FOR PHYSICALLY HANDICAPPED WITH FOLDABLE HOOD

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Technology

In

Industrial Design

By

Vishal Upadhyay
(Roll: 213ID1372)

Department of Industrial Design
National Institute of Technology
Rourkela-769008, Orissa, India

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Prof. B.B. Biswal

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CERTIFICATE

This is to certify that the work in the thesis entitled, "**Design of scooter for physically handicapped with foldable hood"** submitted by **Mr. Vishal Upadhyay** in partial fulfilment of the requirements for the award of **Master of Technology Degree** in the Department of Industrial Design, National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the work reported in this thesis is original and has not been submitted to any other Institution or University for the award of any degree or diploma.

He bears a good moral character to the best of my knowledge and belief.

Place: NIT Rourkela
Date:

Prof. (Dr.) Bibhuti Bhusan Biswal
Professor
Department of Industrial Design
National Institute of Technology, Rourkela

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For every new activity, human being needs to learn through other either by observation or by teachings and for increasing the capacity of learning and gaining the knowledge presence of GURU or Mentor is very necessary.

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Vishal Upadhyay

Abstract

In present scenario, transportation is one of the major requirements of the people for transportation of goods or self from one place to a different place. For a physically disabled or a debilitated person, transportation is a major hindrance and so the mobility of physically disabled people is among the great concern of the human civilization. It is really very hard to realize the problems and sorrows of a physically disabled or debilitated person who is dependent on others or is confined on a wheel chair with a limited mobility. In India, the contemporarily modified scooters used by the physically disabled people for transportation are not ergonomic and do not provide protection from adverse weather conditions which can be more dangerous for physically disabled people compared to the normal person while driving. It is very risky and uncomfortable to drive such modified scooters during the rain or in other adverse weather conditions. It is also difficult for physically disabled person to ride the three wheel scooter for a longer duration.

This project focuses at providing a feasible design solution in form of a user friendly three wheel scooter, which allows physically challenged or debilitated person with partial disability to commute themselves and perform their activities without anyone’s assistance. Problems were identified by the survey regarding the dimensions. Major issues like seat height, ground clearance etc, were utilized to develop the concepts and its selection. Then the detailed design of the selected concept was carried out using CATIA. The designed scooter will be ergonomically suiting disabled person in comparison to the conventionally modified scooters used by them. The improved design of the scooter was also incorporated with a foldable hood which will provide protection to the rider from adverse weather conditions and dust. This hood can be used to cover the scooter or uncover the user and the scooter as well. The seats of the conventional scooters are not suitable for the physically handicapped riders ergonomically. This scooter will also consist of the optimized seating for physically disabled person which provides greater comfort, making it more easy and comfortable to ride. Subjective analysis has been carried out for this purpose. After completing the CATIA model, a prototype model was build with rapid prototyping.

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CHAPTER 1

Introduction

1.1. Background and motivation

Disability may include impairments, limitations in performing the activities, and participation constraints. Impairment is a drawback in body performance or structure. Activity limitation could be a problem encountered by a person in corporal accomplishment of a task or action. Participation restriction could be a drawback intimated by an individual involvement in life conditions. Disability is principally caused by the impairments of various subsystems of the body which can be classified in physical disability and mobility impairments.

Any impairment that limits physical operation of limbs or organs can be a physical disability. Mobility impairment could be a class of disability that involves individuals with various types of disabilities. This kind of incapacity comprises of higher limb incapacity, lower limb incapacity, and incapacity in co-ordination with various organs of body.

Physical disability can be additionally termed as handicap, once physically debilitated individuals encounter cultural, social or physical barriers that hinder their access to completely different system within the day to day life that are easily accessible for other common people. As such, handicap is a loss of opportunities to participate equally with others. One among the areas where physically challenged individuals lose out is the transportation. Transport disability restricts physically challenged individuals from all sort of transport like private, public and personal transportation. These incapabilities also limit their ability to move with others within the society and take up jobs or business far from their home. Access to move can provide them freedom to live an independent and free life.

Census has unveiled in 2001 that over 21 million people in India (around 2.1% of population) are suffering from some kind of disability [1]. Out of the total disabled population in country, 9.3 million of them include females and 12.6 are males. Though the percentage of disabled is a lot more in rural than compared to urban areas, such fractions of the disabled females and males is about 42-43% and 42-43% respectively. Disability rate (i.e., the number of disabled per 100000 of population) for the country is about 2130. It is 2369 for males and 1874 for females.

Table 1.1 Number of disabled population and the type of disability [1]

	Population	Percentage (%)
Total population	1,028,610,328	100.0
Total disabled population	21,906,769	2.1
Disability rate (per lakh population)	2,130	--
Type of Disability		
(a) In seeing	10,634,881	1.0
(b) In speech	1,640,868	0.2
(c) In hearing	1,261,722	0.1
(d) In movement	6,105,477	0.6
(e) Mental	2,263,821	0.2
Source : Census of India 2001.		

For the people who have lower limb disability, movement from one place to a different place is a major problem. Access to public area units like public buildings and restrooms and city streets are the places where problems are faced by the physically disabled individuals.

Many difficulties are involved with the mobility of the physically challenged individuals within the society. It can be seen that physically disabled people essentially use some helpful devices like artificial limbs or legs, wheel chairs, three wheelers, etc for transportation. But these wheel chairs or three wheelers that are generally used by Indians are crude or are inefficient in design; not considerably appropriate for the country like India.

It is so because generally found manually operated wheel chair has a basic drawback that the user has to apply physical force to turn the wheels. This type of action is physically strenuous and may end up in muscle and joint pain and degradation, carpal tunnel syndrome and torn rotor cuffs; that may result in secondary injury or any other disability [2].

Fig 1.1 Conventionally modified scooters generally used in India [10]

Further, in India, the conventionally modified three or four wheel scooters used by the physically disabled people for transportation are not ergonomically designed and suited for the physically disabled person. In addition to this, the seats of such modified scooters which are modified for the physically handicapped users are not comfortable for them ergonomically. These seats do not provide lumbar support and other supports as well which needs to be considered for disabled users. Such three or four wheelers also do not provide any protection from adverse weather conditions which can be more dangerous for physically disabled people in comparison to the normal person while driving. It is very risky and uncomfortable to drive three wheelers at the time of rain or in other adverse weather conditions. It becomes even more difficult for physically disabled person to ride the three wheel scooter for a longer duration.

1.2. Objective

The aim of this project is to provide a feasible design solution in form of a user friendly three wheel scooter, which allows physically challenged or debilitated person with partial disability to commute themselves and perform their activities without others assistance. The scooter should be ergonomically designed for the physically disabled people and should comprise of a foldable hood that can provide protection from adverse weather conditions, sunlight & dust.

CHAPTER 2

Literature Review

2.1. Overview

In the field of designing the vehicle for physically disabled people, various works had already been done. Some of the works related to the designing of such vehicles had been mentioned below. Major works included the design of three wheelers.

2.2. Works done in the field of designing vehicles for handicapped

(Kumar et al., 2013) designed a three wheeler vehicle for physically handicapped people which can aid them for transportation. Although two concepts named as Sholay and Chariot were generated but the design was settled for the Sholay concept. After the detailed design was done in CATIA, the ergonomic issues of the model were carried out using Jack software. Then a working prototype model was build.

(Islam et al., 2012) proposed an improved design of three wheeler vehicle for physically disabled people, powered by solar energy. The conducted a survey for identifying the needs for designing the three wheeler. The proposed design was efficient and exceeded the facilities of conventional three wheelers. Solar panel for producing the electricity, battery system to conserve the power, cushion seat, etc. was incorporated in the design.

(Shareef et al., 2013) proposed the design of a concept car which is comparatively smaller than the conventional cars present. The designed car is basically a convertible car that can be converted into a bike, thus, reducing the amount of space required for parking.

2.3. Work done for chassis design

(Bhunte and Deshmukh, 2015) studied the investigations made on the analysis techniques of the frame of the automobile, including both static and dynamic analysis. Determination of various analysis around various conditions in chassis frames has been reported. They presented overview of the various techniques developed for analysing of automobile chassis frames and their result with the help of which further study and examinations on chassis will become simple.

2.4. Work done for aerodynamics of two wheeler vehicle

(Conti and Argento) developed a methodology to integrate various aerodynamic aspects in concept designing process. They pointed out the relevance of integrating aerodynamic attributes into the initial designing phase of the scooter. Features considered by them were aesthetic design, performances, safety and comfort.

2.5. Work done for designing of two wheeler seat

(Chandore and Deshmukh, 2014) presented a finite element study by simulating the vibration of cushion foam and the supportive structures of the seat, along with the human buttock soft tissues of the thigh in the seated position. They examined and analysed the various studies of other researchers that might facilitate redesigning or modification, assessment and examination of the seats of two wheeler riders for greater comfort while riding.

(Neville, 2005) critically reviewed the literature related to the basic principles of seating & positioning used with physically disabled kids and teenagers. Examinations from the published articles and expert opinions for determining the seating principles used with physically disabled kids and teenagers were used. An outline of the normal and abnormal seating postures was also examined.

2.6. Summary

Major works related to design of vehicles for physically disabled have been discussed. Various works related to different designing components, attributes and parameters like chassis design, seat design and aerodynamics of the vehicle have also been studied.

CHAPTER 3

Methodology and Materials Requirement

3.1. Overview

The method followed for designing the model of the scooter has been explained in this chapter. It explains the initiation and completion of the design process.

3.2. Methodology

Firstly, the problems of the physically disabled people are identified in order to determine the various features which need to be incorporated in the concept. Then various feasible concepts are generated which might be suitable for fulfilling the requirements. All the concepts generated are then compared to find the best feasible solution of the problem and finalizing the concept of the scooter model.

After finalizing the concept, general layout of the proposed concept is drawn that may depict the entire packaging system. Then the detailed design of the concept is carried out by determining the dimensions of the scooter. Detail design includes the design of chassis frame, suspension system, steering geometry, caster angle and ergonomic analysis. After the detailed designing is done on paper, the 3D model of the scooter is drawn by the help of CATIA software.

When the 3D model of the scooter is made, it is used for making the prototype of the concept in the rapid prototyping machine.

3.3. Material and software requirement

After drawing the sketches of the proposed model of the scoter, CATIA software is needed for drawing the model in 3D. For making the prototype of the model, rapid prototyping machine is required for the 3-D printing of the CATIA model of the scooter. Alkaline Butadiene Styrene (ABS) is required as the main and supporting material for printing of the prototype.

3.4. Summary

The entire designing process is discussed and explained. It includes, problem determining, concept generation, detail designing, making the CATIA model and then the prototype.

CHAPTER 4

Concept Design

4.1. Overview

Approach followed for generating different concepts are explained in this chapter. Various concepts are generated and then their comparison is done on the basis of their attributes in order to propose the design concept.

4.2. Approach for generation of concepts

In this stage the information available was studied and analysed, and the concepts were generated based on the requirements, and based on their advantages and disadvantages a concept was finalised. The process can be divided into two stages as given below:

- Concept Generation
- Concept Finalisation

4.3. Concept generation

In the project the ideas were generated through brainstorming and descriptive combination methods. These methods were categorized under the two categories namely:

- Function Board
- Life Style Board

4.3.1. Function board

The Function board mainly lays its focus on the functional needs of the product. Some of the fundamental functions which are expected to be considered in this product are:

- Ground clearance
- Height of the seat
- Reach of the seat to handle
- Leg space
- Hood

So, the concepts generated should have their main focus and attention on the above requirements to be incorporated in them.

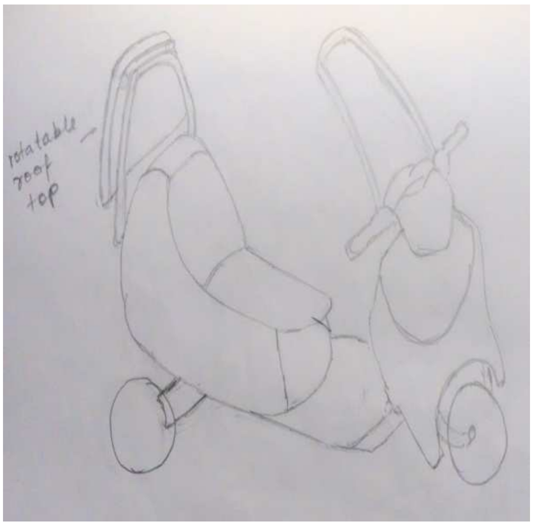
4.3.2. Life style board

Life style is basically a social classification between the categories which are differentiated by the behaviour, likes and dislikes. It is important to identify life style of the general users to address the targeted group. The life style board (Figure 3) describes a group of people who are linked with social life style. Under this life style people will feel free from physical barriers. In the images in this life style board physically challenged people are braking all the barriers and doing what they like the most, like extreme sports, long distance travelling and dancing making it clear that they want to lead a normal life like anybody else.

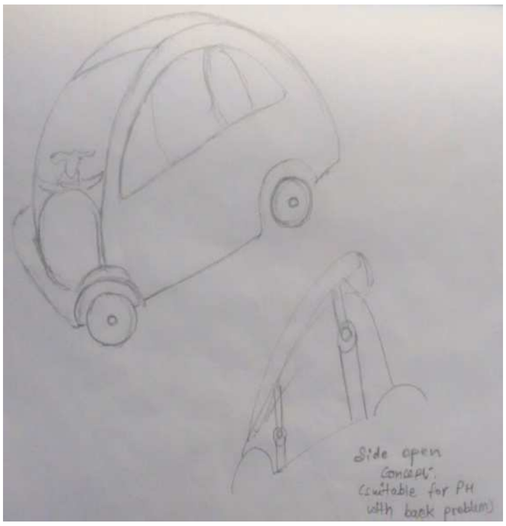
Fig 4.1 Lifestyle board [3]

With the consideration of all the available inputs and their analysis, the following six concepts were developed and the basic characteristics of each of the concept are described under

- Concept 1
- Concept 2
- Concept 3
- Concept 4
- Concept 5
- Concept 6

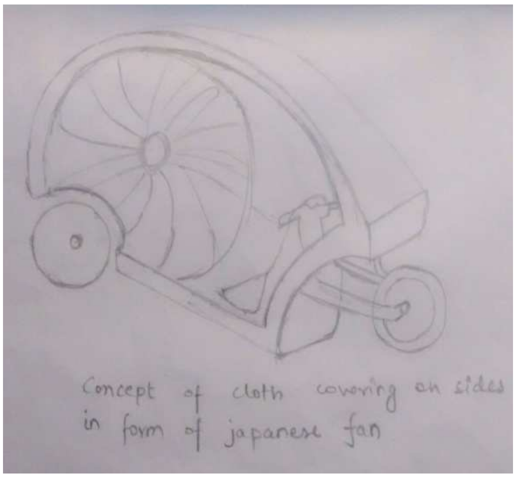


Concept 1

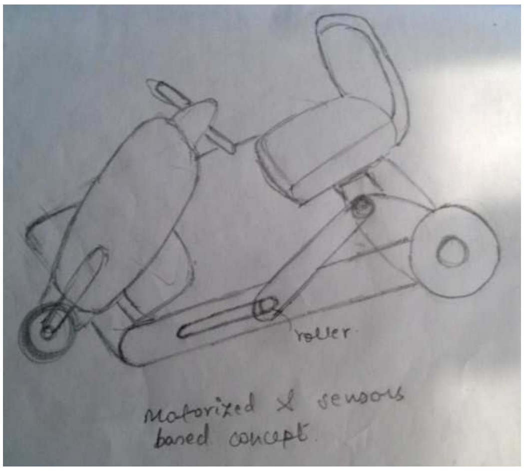


Concept 2

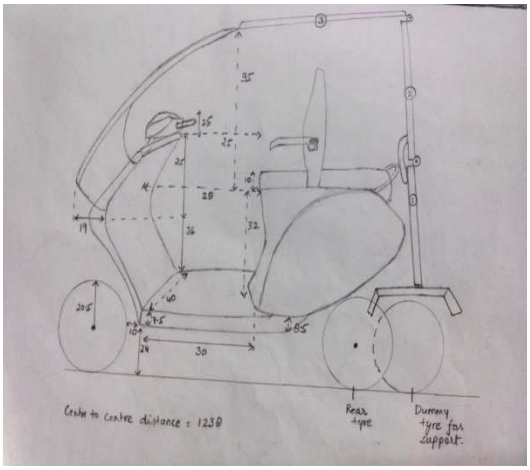
Concept 3



Concept 4



Concept 5



Concept 6

Fig 4.2 Concepts generated for designing the scooter

4.4. Attributes of the generated concepts

Concept 1

This concept provides good adjustment for the foldable hood to be placed upon and better leg space but the main shortcoming with this concept is the too low seating which will make the seating of the disabled person to be difficult.

Concept 2

This concept has very narrow seating arrangements. It will lead to lesser sitting and riding comfort and will restrict the movement of the limbs of the user.

Concept 3

This concept is very much similar to the conventional scooters. The major disadvantage of this concept is that it is suited for operating only with batteries as it does not have any scope for fuel tank. Further, it does not provide seating arrangement for the passenger other than the driver.

Concept 4

One of the main advantages of this concept is its easy designing. It is so because it does not require any major modification to be done on the chassis of the vehicle. The main problem associated with this concept will be too low seating arrangement which will provide difficulty to the disabled user to sit over the vehicle.

Concept 5

This concept provides better seating arrangements as it is incorporated with the electrical system which can regulate the seat height and the reach adjustments. This design is little bit complex as it requires inclusion of the sensor and electrical system. So it will increase the cost of the vehicle.

Concept 6

The design of this concept does not require any major modification in the pre-existing two wheel scooters. The ground clearance in this concept is lowered in comparison to the existing scooters, for providing easy better hold and sitting over the scooter. The caster angle for this concept is also better, i.e., increased so as to provide better reach to the handle.

The rear dummy tyres or the supportive tyres are placed rearer to the rear tyre of the scooter. It should be kept in mind that in the conventionally modified scooters, the dummy tyres are placed in between the front and rear tyre of the scooter. This concept also provides suitable adjustments for the placement of the hood which can be folded for covering the rider. The foldable hood is placed and supported over the rear dummy tyres. Hence this concept provides a better solution to the required objective.

4.5. Pugh matrix

Pugh Concept Selection Matrix is basically a quantitative technique that is used to grade or rank the multi-dimensional choices of an option set. It is often used in engineering for making design related decisions. The advantage of the Pugh matrix or the decision making matrix is that the subjective opinions concerning one alternative against another can be made more objective.

The decision matrix criteria's for this particular project has also been identified and listed in the PUGH table below:

Table 4.1 Pugh matrix for concept selection

Criteria	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Adaptability	-	-	+	-	-	+
Cost	+	-	+	+	-	+
Work content	+	-	+	-	-	+
Riding & handling	+	+	+	+	+	+
Aesthetics	-	-	-	+	-	+
Ergonomics	+	+	-	+	+	+
Total (+)	4	2	4	4	2	6
Total (-)	2	4	2	2	4	0
Remarks		Too compact	Only for battery	Too bulky	Sensors required	

4.6. Justification of proposed concept

From the above Table 1, the following conclusions can be drawn about the finalized concept 6 on various parameters:

4.6.1. Adaptability

It is better because it does not require any kind of major modification in the pre-existing three wheel vehicle.

4.6.2. Cost

It is better because of the amount of modification content required to be done and the mechanism of the wheel drive which is kept same for the rear wheel as is present in the conventional vehicle/scooters.

4.6.3. Work content & design ease

It does not require any major modification in the drive mechanism and the body, so the designing of the proposed concept 6 will be relatively easier.

4.6.4. Aesthetics

The design of the proposed concept is aesthetic and appealing. It is also an aerodynamic design considering the basic attributes.

4.6.5. Ease of drive

Steering reach for disabled riders is better than the conventionally modified scooters and ground clearance is also lowered, so it provides better riding conditions and easier handling.

4.6.6. Ergonomics

The proposed concept numbered 6 is better than the other concepts because of the lowered ground clearance which will provide ease for sitting over the scooter, better reach of the handle, and the lowered seat height.

Based on the above ratings and the attributes, it can easily be concluded that the proposed concept has more positives in comparison to the other five concepts. Hence it was decided to proceed ahead for designing the scooter based on the proposed concept numbered as 6.

4.7. Summary

This chapter has explained the concept generation phase of the designing process. Attributes of the various concepts generated have been explained and in accordance to the problem statement, a finalized concept has been selected. The justification has also been given for finalizing the concept.

CHAPTER 5

Layout Design

5.1. Overview

The general layout of the proposed concept for designing the scooter has been explained in this chapter. The entire packaging system and the various parameters of the scooters which needed to be outlined has been discussed.

5.2. General layout

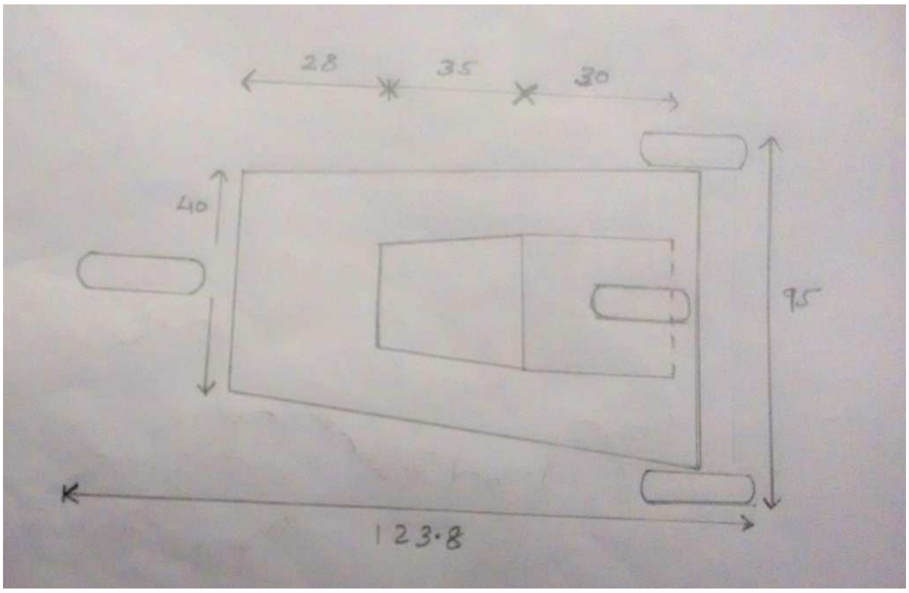


Fig 5.1 General layout of the proposed concept (in cm)

The design process was started by making the general layout of the concept. Before getting into the detailed features of the vehicle it was necessary to understand the overall dimensions of the vehicle on a larger scale. Vehicle construction is always considered as the inside out concept. This means that the vehicle is built around the systems that are packaged inside it.

Here the major packaging system is the disabled rider and the rear passenger. The chassis structure designed should be efficient enough to be able to package the entire body of the scooter and the passengers. The next packaging system is the additional wheel or the dummy wheel and its placement and the suspension system. The wheel and the suspension system should be in a manner such that they are able to follow the interior space requirement and for a better stability, they should be as close to the vehicle body as possible. Dummy tyre are placed behind the rear wheel which helps in supporting the hood and provides efficient riding comfort for rear passenger than compared to the conventionally modified three wheelers. Hood is supported on top of the dummy tyre.

The other essential issue which needs to be considered is the ground clearance. Ground clearance needs to be analysed in accordance to the national road standards because very low clearance may result in fouling of the vehicle and the ground will lead to damage of the vehicle which can also be very dangerous to the life of the rider. If the ground clearance is very high then it will affect the riding and handling of the vehicle.

Along with the packaging factor ergonomic requirements of the customer will also need to be considered. Fuel lid position should be in such a position where user can easily access without getting down of the vehicle.

It can be summarize that the general layout of the proposed concept consists of seat placement, steering geometry, leg space, dummy tyre placement, position of fuel tank, ground clearance.

Major design elements of the scooter which needs to be considered, analyzed and performed are:

- Layout Design
- Chassis and suspension
- Full body needs to be aerodynamic
- Seat should be ergonomically suited to the user
- Convertible hood for covering the rider and rear passenger

5.3. Summary

General layout of the design has been discussed. Various designing elements required to be considered have been explained.

CHAPTER 6

Chassis Design and Suspension System

6.1. Overview

This chapter explains the chassis and suspension system of the designed model of scooter along with the materials and the section of the chassis frame. Steering geometry of the model has also been explained.

6.2. Chassis

Chassis is basically an internal structural part or the framework which supports a manmade object in its construction, support and use. It is similar to animal's skeleton and serves the same function. It supports the transmission system, steering system and the wheels. Both the wheels in scooter, i.e., the front and rear wheel are indirectly connected to the chassis frame by means of a suspension system which is directly attached to the wheels.

6.3. Type of chassis frame

6.3.1. Backbone tube

It is a type of an automobile chassis which is similar to the body on frame type of design. It comprises of a stiffed or strong tubular backbone that connects the front and the rear suspension attachment. The body of the vehicle is placed on this structure.

Fig 6.1 Backbone chassis of the 1962 Lotus Elan [10]

6.3.2. Perimeter frame

It is very much similar to the ladder frame, but the major difference in both is that the middle sections of the frame sits outboard of the front and rear rails are just behind the rocker panels. As such it permits a lower floor pan, and thus lower overall vehicle. It was prevalent for designing cars. The perimeter frame also permits for the efficient and more comfortable lower seating positions and provides better safety during any side impact. The only drawback of this form of chassis is that it lacks stiffness.

Fig 6.2 Perimeter frame of Anadol FW11prototype [10]

6.3.3. Underbone type

This type of chassis involves structural tube framing with an overlay of plastic body. Underbone chassis or frame arrangement provides ease for mounting and dismounting of the vehicle body. The size of the engine generally used for the underbone frame is in between 50cc-150cc. This type of chassis is generally used in scooters and mopeds. The material used for constructing the underbone chassis is carbon steel because it provides stiffness and better strength to it.

An underbone scooter or bike may share its fuel tank position along with fitted body and splash guards, while other considerations such as the wheel size, engine position, and power transmission are similar to those of the conventional scooters or motorcycles.

Fig 6.3 MCX Raptor a motard type underbone [10]

6.3.4. Unibody or monocoque chassis

In unibody type of chassis the vehicle frame and the body are combined into a single strong frame. In a completely integrated body structure, the entire vehicle or the car works as a load-carrying unit which can handle all the loads experienced by the vehicle including the forces from the driving loads or the cargo loads. Sometimes it is also termed as monocoque structure, because the outer body of the car and the panels are made load-bearing including still ribs and the box sections to strengthen the body.

Fig 6.4 Monocoque or unibody chassis of 220px-Citroen [10]

6.4. Chassis material

The materials used for constructing the chassis frame mainly include

- Steel
- Aluminium
- Titanium
- Magnesium

6.4.1. Steel

Steel is easily available and it is also cheap. It is the main reason for which most of the cars or the other vehicles are made from steel. The cost and availability of the material and the requirements needed to process it are of a significant advantage for its commercial production. Apart from these factors, the physical properties of steel are also beneficial. Steel is almost three times stiffer than aluminium. In addition to this, steel better yield strength and allowable strength if it is carefully alloyed. Steel also resists fatigue failure considerably well. Due to this last fact, steel is found to be very useful even though the chassis flexes under load because such flexing need not result in the critical failure.

6.4.2. Aluminium

The density of aluminium is about 35% of that of the steel. As such it is used for more light weight construction of chassis is needed. Aluminium has 2.5 times stronger per unit mass as that of steel.

6.4.3. Titanium

Titanium is associated with space technology, and can be regarded as an ultimate material needed for that field. The density of titanium is about half of steel and somewhat over half the stiffness. There is a analogous condition regarding the yield and ultimate strengths. One of the major advantages of the titanium is that it resists corrosion and fatigue failure. Major issues regarding titanium are its cost which is very high and so it is not justified to use it for any conventional road vehicle.

6.4.4. Magnesium

Magnesium is the lightest metal that is used in a vehicle chassis and it has a density of about 25% of the steel. Lighter weight and less density of magnesium helps it to compensate for the fact that the strength and rigidity of magnesium is lower than that of aluminium, but with careful design magnesium can be used for building light and strong frame or structure. At present, the employment of magnesium in vehicles is limited to forge shapes for mounting braces and brackets, etc. Magnesium is an element that it is easy to get recycled and it has been used for many years for the construction of comparatively high strength and low weight wheels.

6.5. Chassis design of the proposed concept

The design process was started based upon the finalised concept of the scooter. The main requirement here is for providing a mounting frame or the structure for the following systems

- Wheel
- Handle
- Suspension System
- Body of the scooter
- Handle
- Wheels (front, rear and dummy wheels)
- Physically disabled rider and rear passenger

The space frame concept seemed to be the best fit for the proposed vehicle because

- Its material requirement is minimum
- Its structural behaviour is efficient or much better comparatively
- No requirement of mass production

Depending upon the above attributes it was decided to proceed ahead with the space frame concept. In the case of space frame choice of cross-section of the tubes used in frame is an important decision as it affects manufacturing, cost, weight and structural behaviour. The sections which are readily available for space frame in market were considered. The sections considered for the design were

- Hexagonal
- Rectangular
- Circular

All the stated three type of sections were analyzed and studied for the above mentioned criteria and the attributes are mentioned in the below table. After studying the below table it was decided to get ahead with the circular section. It is because even though the tubes structural behaviour is less compared to other sections its manufacturability is much better. The structural part can be stiffened by addition of further materials. But the manufacturability is also critical in this case. Hence, more weightage is given for the manufacturability and the decision has been taken accordingly.

Table 6.1 Section matrix

Section	Manufacturing Feasibility	Material Availability
Hexagonal	**Not good**	**Not much**
Rectangular	**Not good**	**Available**
Circular	**Good**	**Available**

After deciding the section of the frame of the chassis, the CAD modelling was initiated. The design was started from the base of the frame and then the top member which has a mounting with the vehicle on one side and the steering arrangement in the front was drawn. Finally the connecting bracket was drawn through which the vehicle body is connected.

The sketch of the chassis and the complete CATIA model of the chassis in the side view and the isometric view are shown below

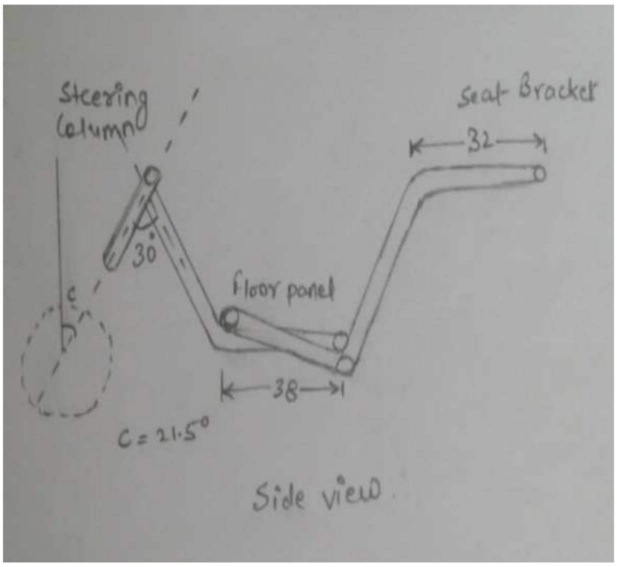
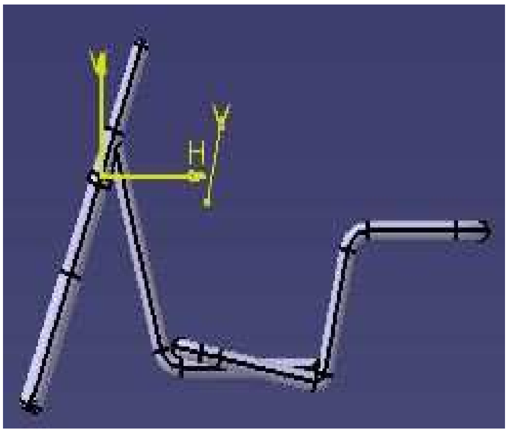
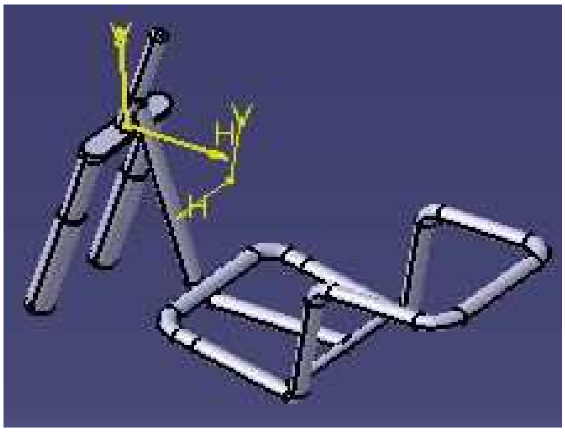


Fig 6.5 Sketch of the chassis structure of the proposed model





(a) (b)

Fig 6.6 (a) Side view of the chassis model in CATIA, (b) Isometric view of the chassis model in CATIA

6.6. Suspension system

It is a collection of springs and shock absorbers. It can be of two types: front suspension and rear suspension. It insulates both the rider and the vehicle from road shocks and also keeps the wheels in the closest possible contact with the ground and gives control of the vehicle to the rider. There are basically two types of suspension system

- Front suspension system
- Rear suspension system

6.6.1. Front suspension system

There are basically two types of front suspension system

- Telescopic type front suspension system
- Hydraulic type front suspension system

In present time, mainly telescopic forks are used for the front suspension in scooters and motorbikes. The forks consist of large hydraulic shock absorbers with internal coil springs. They allow the front wheel suspense up and down giving a comfortable ride. The bottom of the forks is connected to the front axle around which the front wheel spins. On typical telescopic forks, the upper portion, known as the fork tubes, slide inside the fork bodies, which are the lower part of the forks. The fork tubes must be made smooth in order to seal the fork oil inside the fork.

In the present work, telescopic type front suspension system is employed in the model because it is prevalent in present time and also comfortable for both the terrain and smooth roads while hydraulic type is suited only for smooth roads.

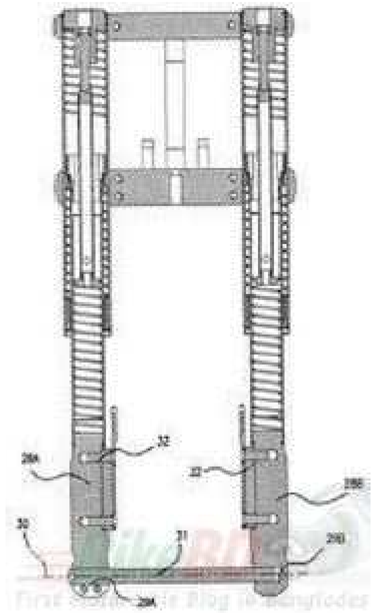


Fig 6.7 Telescopic type front suspension system [10]

6.6.2. Rear suspension system

There are two type of rear suspension being used

- Swing arm with spring loaded
- Hydraulic damper type

In the present work unit swing with spring loaded type rear suspension is employed as it is preferred nowadays for scooters. It is attached to only one side of the rear wheel, so it will allow the rear wheel to be mounted like a car wheel. It also guarantees the proper wheel alignment. The main drawback or the disadvantage of this type of suspension system is that the single sided swing arm type suspension needs to be stiffer than double sided swing arm, in order to bear extra torsional forces as such they are heavier than the double sided swing arm suspension.

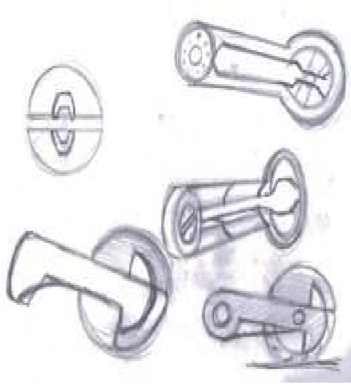


Fig 6.8 Sketches of the rear suspension system

6.7. Steering geometry

The main components to be considered in the steering geometry are

- Wheel base
- Steering axis angle (caster angle)

Wheel base influences the longitudinal stability of the scooter. Scooters with long wheel base will be difficult to balance in moving condition (cruiser bikes) and if scooter have small wheel base then it will become difficult to handle in stationary condition (city bikes).

So, wheel base is decided moderately in accordance with overall length of the proposed model. Wheel base of the designed model is determined as 1238mm

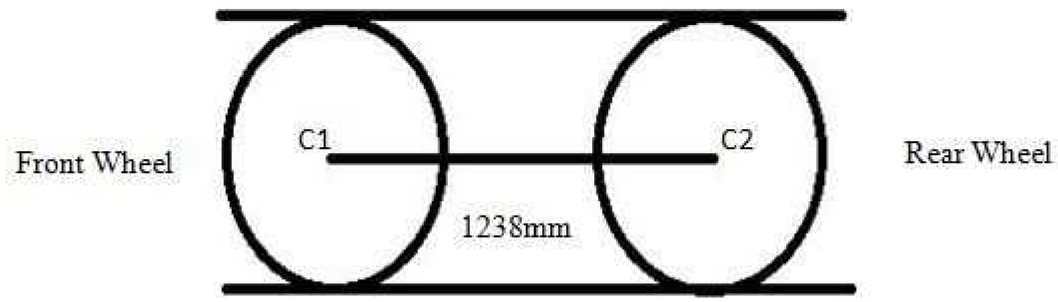


Fig 6.9 Wheelbase of the designed model

6.8. Caster angle

The caster angle is the angular displacement from the vertical axis of the suspension of a steered wheel in a car, bicycle or other vehicle, measured in the longitudinal direction. It is the angle between the pivot line (in a car or a two wheeler, an imaginary line that runs through the centre of the upper ball joint to the centre of the lower ball joint) and vertical. In reference to the bicycles, scooters and motorcycles, caster is generally referred as "rake and trail".

Generally, caster angle of 20-24 degree is used in scooters and small bikes. In this model, the caster angle was determined in accordance to the reach of the physically disabled person making it comfortable to ride. Caster angle of designed model was determined as 21.5 degree**.** This inclination of the caster angle is ergonomically suited from the observation and provides better riding comfort and also allows easy reach to the handle of the scooter for the physically disabled person.

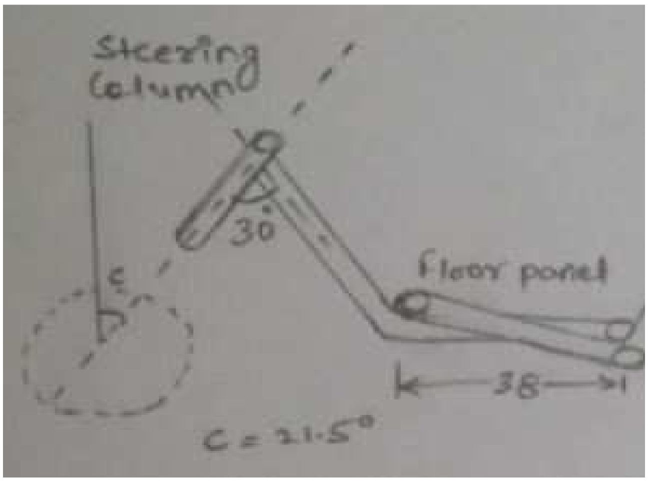


Fig 6.10 Cater angle (C)

6.9. Summary

The design of the chassis structure has been explained. Underbone type chassis has been designed for the scooter model. Front and rear suspension system incorporated in the model has also been explained. Steering geometry and the determination of caster angle has been discussed.

CHAPTER 7

Full Body Aerodynamics

7.1. Overview

Aerodynamics of any vehicle is an important factor which needs to be considered while designing it. The attributes of the designed scooter has been explained in this chapter.

7.2. Aerodynamics of the model

Aerodynamic force basically has two components lift and drag force. Lift force does not have any major influence on the model because of the less area available at bottom. The main factor needed to be considered is the drag force. A designer always tries to decrease drag in each automobile and it becomes too difficult in the case of two or three wheelers as the driver itself is the frontal area on which the drag force acts generally. So, the designed concept has a huge (in view of width and the height) front fairing aerodynamically which slashes the air into various streams and the windscreen.

From these streams two are deflected towards sides of the bike “1”, one to move above the driver’s head “2” and other towards the bottom “3”.

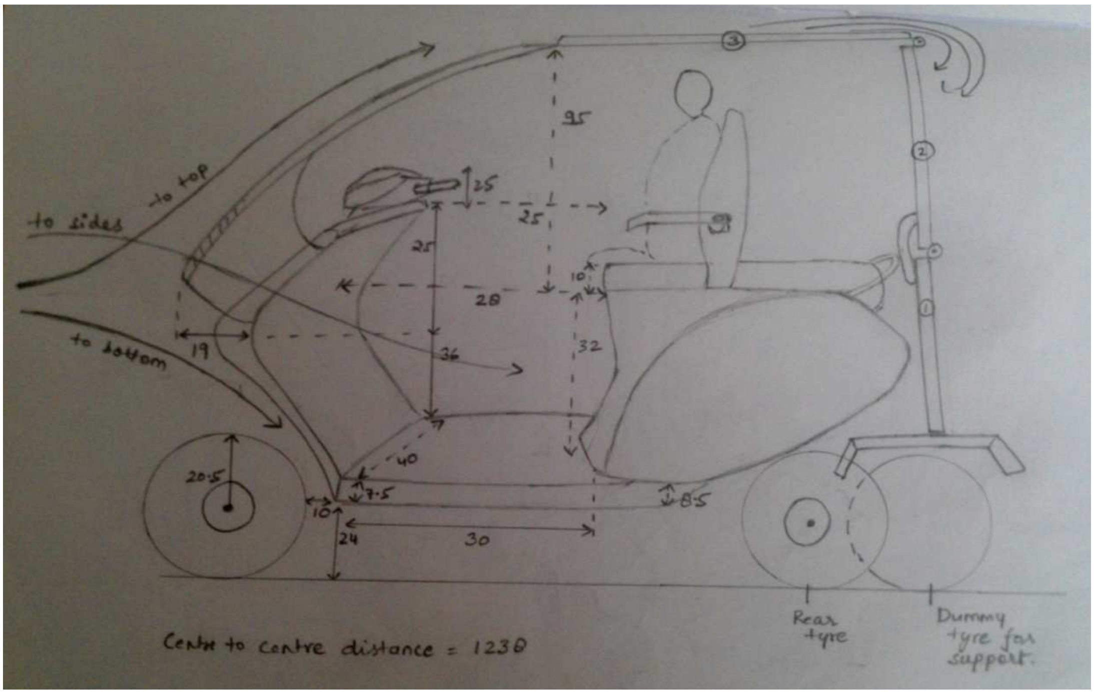


Fig 7.1 Design of the model showing the splashing of air current in various direction

Width of front fairing and the wind screen is designed such that the driver's legs can't exude throughout of it which gives smooth flow to the air stream.
Another force from wind is the side force. Under the effect of these force conditions, the weight of the scooter acts as an important factor and produces a torque which provides directional stability. As the centre of mass of the scooter is located near the engine, the turning of the scooter becomes easy and controlled. So, ideally it is a combination of some conflicting requirements and attributes as

- Minimal drag for performance and fuel economy.
- Low frontal Centre of Mass of passenger to reduce the induced weight transfer. Low and rearward side Centre of Mass of scooter to reduce the unbalancing moments, and give directional stability. A good shape and value of side area that minimizes the side force produced.
- The windscreen directs the air completely over the top of driver's helmet and the front end slices through it like a knife.

When the hood of the scooter is in covered condition, the hood is inclined towards the front at an angle of **5 degree**. So, it also provides aerodynamic push at the rear end, though its contribution is very small in percentage comparatively to the other aerodynamic forces.

7.3. Summary

Aerodynamic features of the designed model have been explained. The effect of wind current and its distribution after the impact have been discussed along with their advantages and drawbacks.

CHAPTER 8

Hood Design

8.1. Overview

The scooter is incorporated with a convertible hood that provides protection to the rider against the adverse weather condition like rain, dust, sunlight, etc. The concept of hood has been explained in this chapter.

8.2. Design of the convertible hood

In this work, design of the scooter is incorporated with a foldable hood which will provide protection to the rider from adverse weather conditions and dust. This hood can be used to cover or uncover the user and subsequently the scooter as well. This hood is supported on the top of the dummy tyres. The supportive dummy tyres supporting the convertible hood are placed rearer to the rear tyre, while in conventionally modified scooters, dummy tyres are placed between front & rear tyre. The distance between the centers of dummy tyre and rear tyre is determined as 25 cm. In the open condition, the hood is inclined at an angle of 5 degree toward the wind screen.

This foldable hood consists of three blocks:

Block 1: It is fixed over the mudguard of the dummy wheels. It also supports block 2 and block 3.

Block 2: This block is movable in the vertical direction and needs to be slided upwards for opening the hood.

Block 3: This block is also movable in the rotational manner. It is rotated and placed or supported over the mirror on the front side of the scooter.

This arrangement is supported via frame which is supported on the two additional tyres that are jointed for making the scooter stable for the physically disabled person. These two tyres are jointed in the conventional manner as they are attached to the modified scooters for the disabled person with the help of grill. But it is worth noting that in this design the additional tyres are attached at more distance from the front tyres, than in comparison to the conventional scooters for disabled person. This type of arrangement provides better sitting comfort to the rear passenger who can sit both sideways and in the front manner as well comfortably. Each block of the hood consists of an outer frame and the inner part is a thin film of woven fabric.

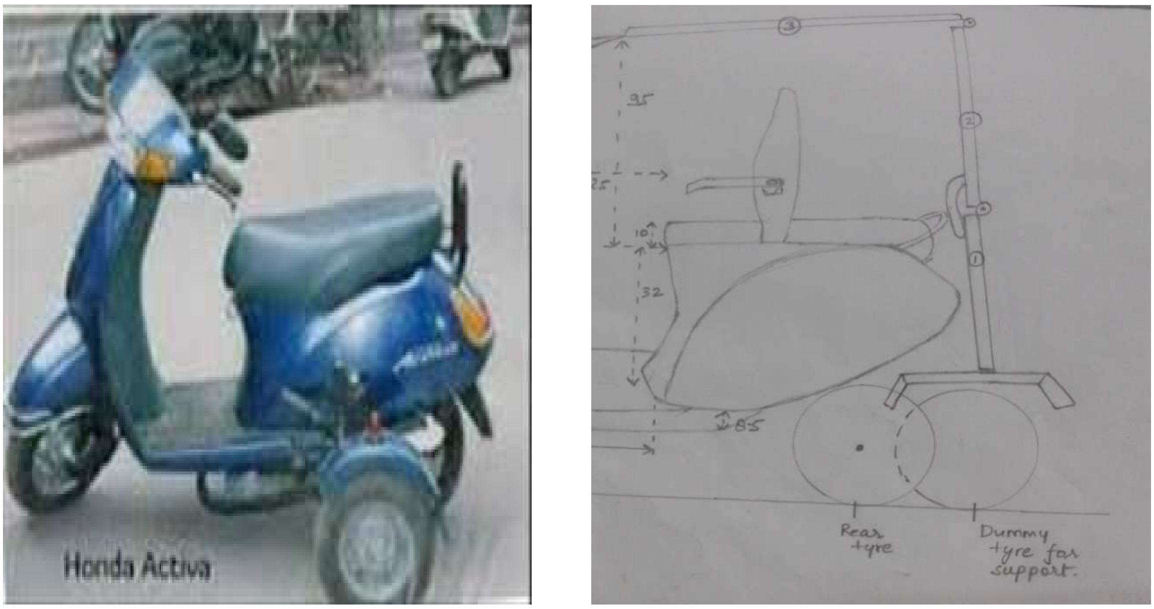


Fig 8.1 Comparison of the placement of dummy tyres between the proposed model and the conventionally modified scooters for physically disabled

8.3. Materials used for the hood block

The hood needs to be lighter in weight so that the physically challenged user can easily be able to open or close the hood. For serving this purpose, the frame of the blocks of the hood is made up of plastic fibre and the part of the hood inside the frame is made up of woven fabric.

8.4. Procedure for the opening and closing of the convertible hood

The foldable hood needs to be operated in a three step procedure

Step 1: The block 1 is fixed with support to the mudguard of the dummy tyre and has no movement in any manner but supports the two other blocks. Fig (a) shows the initial arrangement of the hood in the closed condition.

Step 2: The block 2 is movable in the vertical direction. It needs to be slided upwards as shown in fig (b) along with the third block when the hood needs to be opened and the rider needs to cover the scooter and subsequently himself/herself.

Step 3: The block 3 is also movable in the rotational manner. It is rotated and placed or supported over the mirror on the front side of the scooter.

Step 4: Block 3 gets fixed to the mirror plane after being placed on the mirror or the ind screen through a locking mechanism and thereafter the rider and the scooter gets covered up as shown in the fig (d).

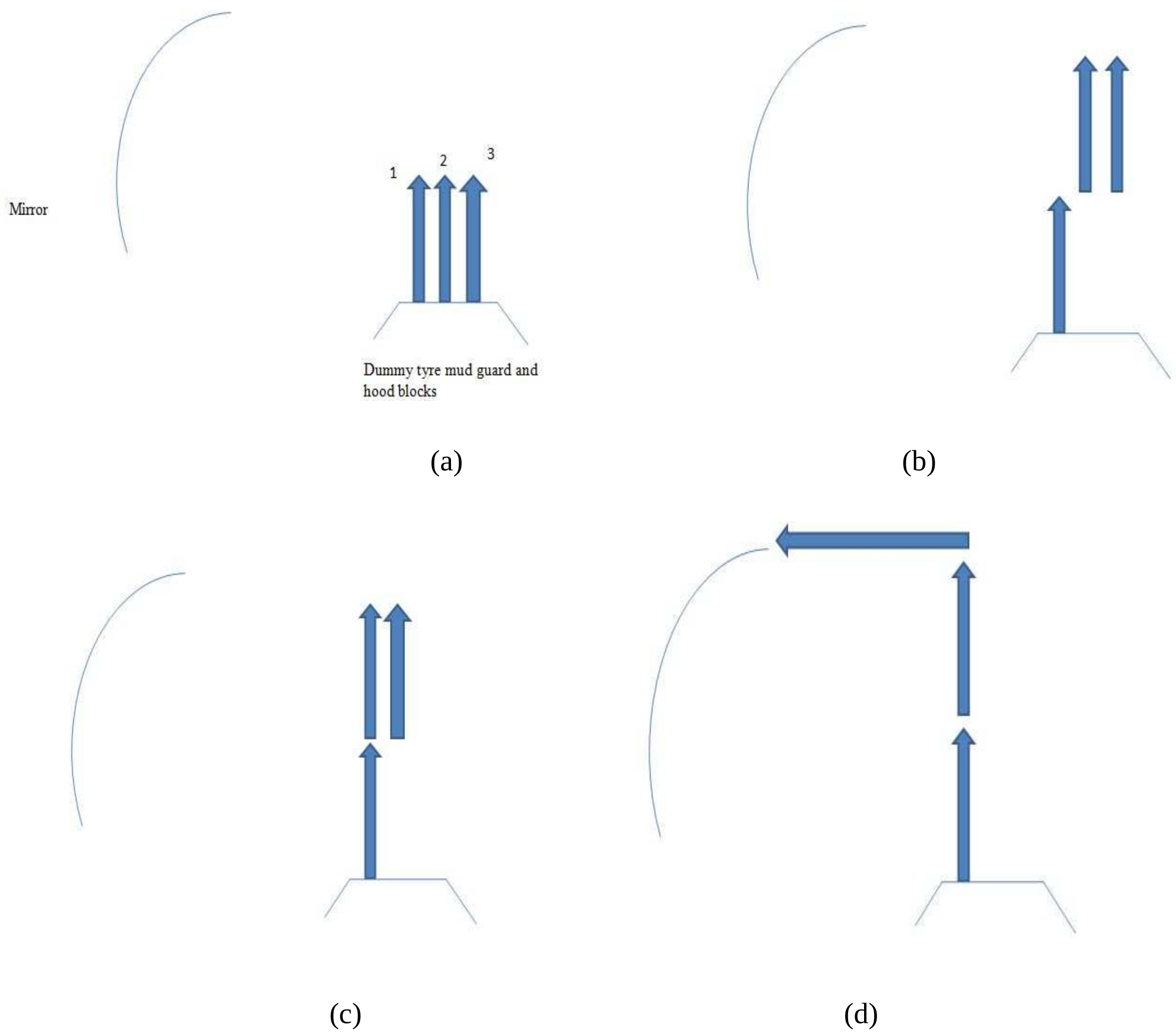


Fig 8.2 Step by step procedure of opening of convertible hood

8.5. Summary

The design of the convertible hood has been discussed. This chapter explains the design considerations for the foldable hood and also the step by step procedure to be followed by the user to open and close the foldable hood.

CHAPTER 9

Results and Discussions

9.1. Overview

In this chapter, various aspects considered in the design and determined while performing the detailed design of the proposed model have been discussed. These aspects include chassis design, aerodynamic attributes, and suspension system specification and so on.

9.2. Results and discussions

Chassis and suspension system has been designed thoroughly as one of the considerations in designing the proposed model of the scooter. The following technical specifications are identified, determined and are worth consideration:

Type of chassis – underbone type

Section of chassis used – circular

Material for chassis frame – steel

Front suspension used – Telescopic type front suspension

Rear suspension used – Unit swing with spring loaded type

Wheel base determined – 1238 cm

Width of scooter considering dummy tyres – 95 cm

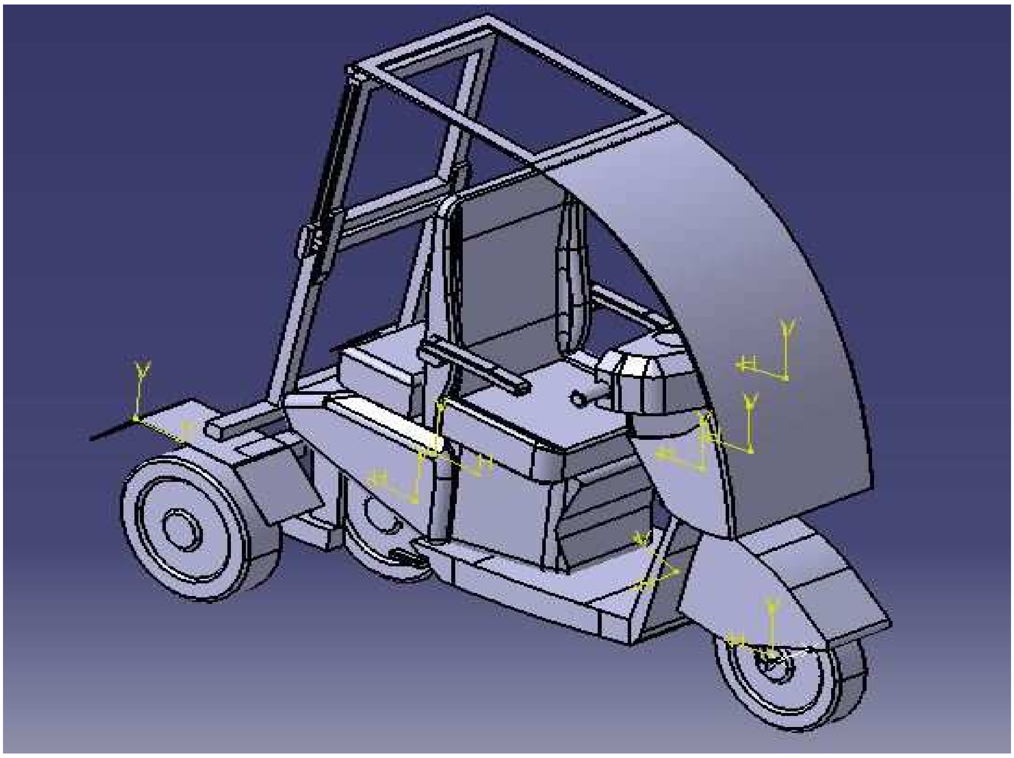
Caster angle – 21.5 degree

For aerodynamic attributes, the roof of the hood is inclined at an angle of 5 degree, providing additional aerodynamic push to the scooter. While designing the seat of the scooter, following attributes have been determined and incorporated in the proposed model of the scooter:

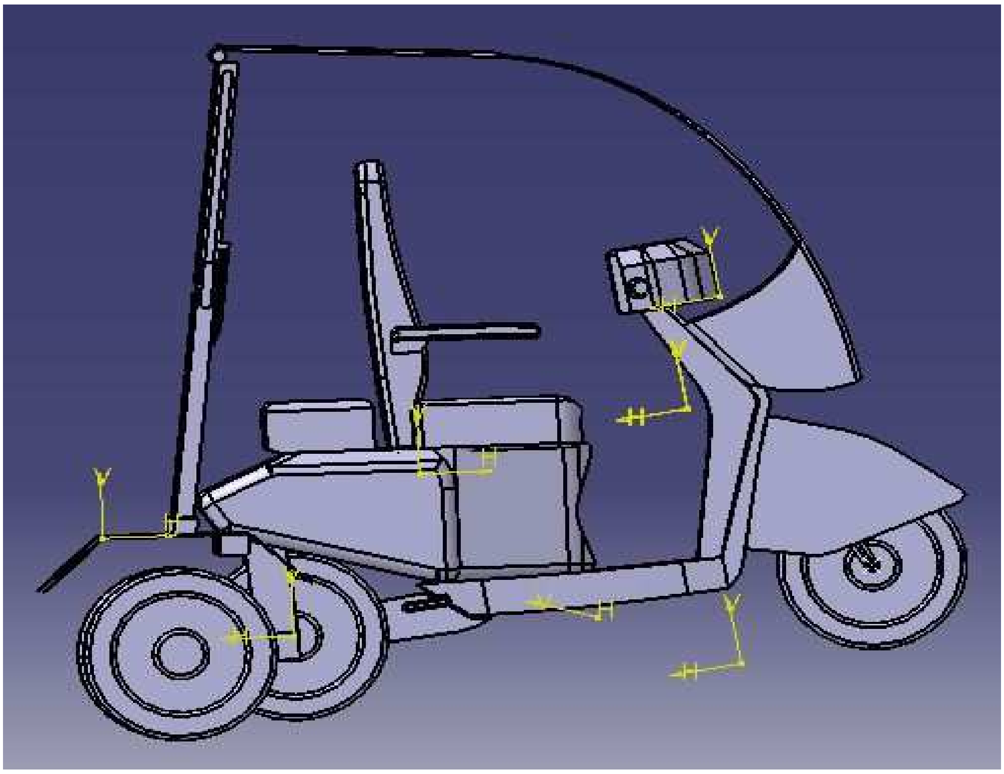
Bucket type seat is designed for the model

It can be rotated to 45 degree that helps in ingress and outgress to the rider

Foldable arm rest are provided having the rotation of 90 degree



(a)



(b)

Fig: 9.1. (a) Isometric view, (b) Side view of the scooter model in CATIA

9.3. Summary

All the important values and attributes determined have been discussed. These include, chassis and suspension system design: chassis material, chassis section, chassis type, steering geometry, wheel base etc.

CHAPTER 10

Conclusions and Future Scope

10.1. Conclusions

This paper has presented a a feasible design solution in form of a user friendly three wheel scooter, which will allow physically challenged or debilitated person with partial disability to commute on their own and perform their activities without others assistance. Major key issues considered identified in the present work were regarding the dimensions of the conventionally scooters which are generally used by the physically disabled people. Major issues like seat height, ground clearance etc, were utilized to develop the concepts and its selection. Then the detailed design of the selected concept was carried out using CATIA. The designed scooter will ergonomically suit the disabled person in comparison to the conventionally modified scooters used by them. The improved design of the scooter was also incorporated with a foldable hood which will provide protection to the rider from adverse weather conditions and dust. This hood can be used to cover the scooter or uncover the user and the scooter as well. The seats of the conventional scooters are not suitable for the physically handicapped riders ergonomically. This scooter will provide greater seating and riding comfort, making it more easy and comfortable to ride. Subjective analysis has been carried out for this purpose. After completing the CATIA model, a prototype model was build with rapid prototyping.

10.2. Future scope

In future some modifications could make the proposed design smarter and efficient. The modifications envisaged may be the following

1. Use of sensors and electrical system for opening of the foldable hood with manual labour
2. Improvising the rear passenger seat space by removing it to utilize the remaining space for carrying the luggage
3. Sliding leg support analogous to staircase can be provided at the base of the floor panel which can assist physically disabled person with high rate of lower limb incapacity for ingress and outgress over the scooter
4. Automization of the seat can be done with the help of sensors and electrical system for its adjustment, both in terms of height and reach to the handle.

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