DESIGN OF MOTORISED WHEELCHAIR

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By

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CERTIFICATE

This is to certify that the thesis entitled ***"Design of Motorized Wheelchair"*** *submitted by* ***T Shanmuk Anirudh (110ID0259) and Jyoti Pragyan Satpathy (110ID0625)*** *in partial fulfillment of the requirements for the award of the degree* ***BACHELOR OF TECHNOLOGY*** *in* ***INDUSTRIAL DESIGN*** *at* ***National Institute of Technology, Rourkela*** *is an original work carried out by them under my supervision and guidance.*

The matter embodied in the thesis has not been submitted to any other university/institute for award of any other degree.

Date: 07/05/2014

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ABSTRACT

First wheelchair model evolved long back in 18th century, but rapid development in this field initiated since mid of 20th century. Since then, many varieties of models had been designed, extending into broad range of products. This project involves the design of an ergonomically designed electric wheelchair for domestic use by Indian old aged people. Stair climbing functionality is embedded in the design through its structure and mechanism. The product mainly consists of 3 modules viz. seat, links and frame. Anthropometric measures are considered in the dimensioning of seat. The frame and wheels are designed and developed through the equations generated from the statistical data of dimensions of staircases in Indian houses. Focus is laid on different parameters such as form, functionality, technology and architecture of the product. The design is validated by developing Digital Mockups of individual parts are generated in CATIA and are assembled to form the final product. Necessary simulations of the product are generated in virtual environment of CATIA. The physical and focused prototype indicating the structure and functionality is developed using thermocol material. Here wheel carriers are made in RP (Fused Deposition Modelling) using ABS (Acrylo Butadiene Styrene) material. Wheelchair is embedded with some additional features like integrated commode facility, after gathering costumer requirements from different subjects.

CONTENTS

NOMENCLATURE

ω_w	=	rotational speed of the wheel
ω_m	=	rotational speed of the gear motor
Ω	=	rotational speed of the planet carrier
r_{PG1}	=	radius of the first planet gear
r_{PG2}	=	radius of the second planet gear
r_S	=	radius of the solar gear
r	=	radius of the wheel
h	=	step height
d	=	step depth
z	=	number of teeth
M	=	module of gear wheel
t	=	tooth thickness

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1 INTRODUCTION

A motorized wheelchair or electric-powered wheelchair is a wheelchair that is propelled by means of an electric motor rather than manual power. Motorized wheelchairs are useful for those who are not able to impel a manual wheelchair or who may need to employ a wheelchair for distances or over terrain which would be strenuous in a manual wheelchair. They may also be used not just by people with conventional mobility impairments, but also by people with cardiovascular and fatigue based conditions. Electric wheelchairs have enhanced the quality of life for many people with physical disabilities through the mobility they afford. The selection of power chair will rely on many factors; including the kind of surface setting the chair will be driven over, the need to settle thresholds and curbs, and clearance widths in accustomed environment. The most fundamental job of the chair is to take input from the user, usually in the form of a small joystick, and decipher that motion into power to the wheels to move the person in the preferred direction. The last few years have seen abundant improvements and models that give the user unmatched control of the wheelchair in terms of both user effort and vehicle aptitude

1.1 Problem Statement

A stair climbing powered wheelchair designed for elderly people at domestic places.

1.2 Objective of Work

The objective of this project is to analyze and prototype a motorized wheelchair based on extensive fact findings and research on existing models, technology used, market scenario and customer requirements. The course of our work begins with the planning phase involving initial research, literature review and background study. It is followed by concept generation phase that includes evaluating customer requirements, outlining specifications and generating concept designs. Next comes the system level design in which product architecture is defined and parts are modeled in CATIA. The fourth phase is detailed design phase where we focus on design for assembly and manufacturing and simulation in virtual environment. In the final phase, we progress towards prototyping and testing a feasible model.

2 REVIEW LITERATURE

The research and analysis of motorized wheelchairs dates back in time with several scientists and researchers evaluating the stair climbing mechanism. Ghani et al [1] investigate the control of a stair climbing wheelchair used for indoor purposes. This paper evaluates different stair climbing mechanisms viz crawler type, leg type, hybrid type and wheeled type. The model of a stair climbing wheelchair based on two wheels is generated using MSC Visual Nastran 4D (VN) design software. The humanoid model is developed using requisite anthropometric data. Various forces and torques acting on the wheelchair while climbing the stairs are evaluated. Preferably, the outer support assembly comprises wheels on either side of the chair. An inner support assembly, closer to the centerline of the chair, also supports the seat assembly. Franco et al [2] did work related to development of a stair climbing wheelchair that can move in structured and unstructured environments, climbing over obstacles and going up and down stairs. The wheelchair design is vividly elaborated. The wheelchair consists of a frame, seat and a linkage mechanism connecting the same. The frame consists of a chassis embedded with two motorized locomotion units, a support for two electrical gear-motors, two idle triple wheels units and a battery pack. The seat is a tubular structure that consists of a chair and a pivoting wheel. The linkage mechanism is responsible for relative motion between frame and seat during stair climbing operation. To successfully climb the stairs, it is required to move the seat backwards, then reorient it and finally lift up the pivoting wheel. When the seat is moved backwards, the center of mass of the wheelchair shifts to a safe position, and toppling is thus prevented. A four bar linkage is appointed for the same. The linkage mechanism is actuated by a mini-motor connected to a lead screw device. When the seat reaches the desired position the motor is turned off and no extra energy is required to maintain the position. The customer requirements were studied and evaluated after referring them from the DLF (Disabled Living Foundation) factsheet. The factsheet aptly outlines what the user needs, wheelchair features, preliminary considerations before buying a wheelchair, wheelchair controls, how to negotiate curbs, specifications of batteries and chargers, special features of motorized wheelchairs, accessories of different types of wheelchairs as well as about insurance and customer requirements. Murray., [3] has elaborated the background as well as recent developments in mobility assistive mechanisms while discussing the relative importance of stairs and wheels. These various types include mobility scooters, track based stair climbers, clustered wheel concept and caterpillar wheel based devices. A mechanism is proposed which is based on the use of four wheels. The rear wheels are autonomously driven and front wheels are freewheeling castors. This proposed concept is numerically modeled and power calculations for linear actuator are made. Stair ascent and stair descent operations are described along with figures and equations. The control system and the stair edge sensor system are also investigated. The stepping algorithm is discussed in detail. The influence of external factors like cost, weight, aesthetics, range of operation, safety, operational efficiency, comfort are evaluated. The track based stair climber is also analyzed similarly. Lockton [4] discusses the retro fitting of electric power into manual wheelchairs. The existing products and configurations are reviewed in a comparative table. Various product specifications are categorized and briefly described. These include control devices, drives, steering and position. Various configurations viz Twin-wheeled drive, rear-mounted, with differential steering, Single-wheeled drive, rear-mounted, with steering ahead of the wheel, single-wheeled drive, rear-mounted, with steering above the wheel, Single-wheeled drive, rear-mounted, with nutation steering and Single-wheeled drive, front-mounted, with handlebar/articulated steering are evaluated. The motors, mechanics, control technology and usability are investigated for the above mentioned combinations. Peizer et al [6] have investigated and summarized the evolution of wheelchairs over five years. Anthropometric parameters required to be considered for the design of seat ergonomically, a book on Indian anthropometric dimensions by Prof. D.K.Chakraborty is referred. Necessary measurements and data have been collected from Indian Anthropometric Design.

3 METHODOLOGY

3.1 Market Study

The methodology for this project began with market study of the product under consideration. This involved extensive evaluation of the various types of wheelchairs available in the market and a precise overview of the Indian market scenario.

3.1.1 Electric Wheelchair

The foremost electric wheelchair was invented by George Klein with the purpose to help the wounded soldiers of the World War II. With time, it has evolved into many designs and forms. The power chairs comprise a range of functions like reclining, tilting, seat elevation, chin controller, hand controller and many more. Some of the models are portable that is they can be disassembled and carried along while travelling. The electric wheelchair is characteristically categorized into three categories

- *The front wheel powered chair*: It is a power chair for indoor purposes. This is a four wheel driven chair and is most flexible among the lot.
- *The rear wheel powered chair:* It is a power chair facilitated for outdoors. Being rear wheeled, they are appropriate for rugged roads.
- *Mid wheel powered chair:* This electric wheelchair is apposite for indoors but it has sturdy steering functions.

3.1.2 The heavy duty wheelchair

The heavy duty power wheelchair has been shown in Figure 3.1. It is designed to be used for outdoor rationale and can be customized on the basis of individual necessities.. It can be used for travelling over coarse surfaces. These power chairs can be transferred only by the aid of lifts and ramps.

Fig 3.1 Heavy Duty Wheelchair (Source: www.americanwheelchairs.com)

3.1.3 Transportable wheelchair

This type of power wheelchair can be easily conveyed by virtue of its light weight and thus it can be disassembled fast and hassle free. Because of its compact size, it is apt for slender doorways and halls. One of the models is shown in figure 3.2

Fig 3.2: Transportable wheel chair (Source: www.behance.net)

3.1.4 Powerbase wheelchair

These power wheelchairs, shown in fig 3.3 are mostly unique because of their higher battery array. Being unfold able, it requires lifts during travel. It is suitable for both outdoor and indoor travel. This wheelchair ensures a smooth and stable traverse.

Fig 3.3: Power base wheel chair (Source: www.valleyhomemedicalsupply.com)

3.1.5 Mobi electric folding wheelchair

This wheelchair is operated like a habitual manual wheelchair. While the user pushes on the hand rims, force sensors in the rims perceive the user's physical effort and adjoin supplementary power to the wheels. Thus the physical movement is analogous to power steering in a car. A self-balancing technology is integrated that places the user in the centre of gravity while balancing on two wheels. The obliteration of the requirement for castor wheels leads to more condensed and maneuverable medium. The lithium ion batteries which power the electric servo motors are situated in the base of each of the hub less wheels and are rechargeable, giving the vehicle a range of approximately 20km with one charge. Wide and ergonomically viable push rims allow an easier grip. One of the models is illustrated in fig 3.4

Fig 3.4: Foldable wheel chair (Source: www.universaldesignstyle.com)

3.1.6 Sports wheelchair

These chairs are tailored for sports – such as basketball, or tennis or bowling, as shown in fig 3.

Fig 3.5: Sports wheel chair (Source: www.medarts.net)

3.2 Indian Market Analysis

- *Overview*

Approximately 20 million people in our country suffer from various disabilities. About 11 million of them are locomotors disabled. The pervasiveness of locomotive debility is uppermost in India–at 1,046 per 100,000 people in the rural areas and 901 per 100,000 people in the urban populace. Low literacy, unemployment and widespread social stigma are the causes of such disturbing figures. The best way to empower the masses to deal with disabilities is through organizing awareness programs and conveying employable assistances. Government agencies and NGO's are working in the direction of advanced policy and frameworks for the incapacitated. India's wheelchair market is a nascent market with double digit growth rate. The market is broadly classified into unorganized and organized segments as shown in table 3.1.

Unorganized Segment		Organized Segment		
Domestic manufacturers	Wholesalers			
It is estimated that about 80-100 players sell 100-150 wheel chairs in a year.	They are based in wholesale markets and are involved in importing wheelchairs from China.	Indian manufacturers e.g. Vissco, Janak, Sage and others.	Indian distributors of foreign companies e.g. Vin Grace	Subsidiaries of foreign companies importing and selling in India e.g. Otto bock, Karma Healthcare.

Table 3.1: Classification of Wheelchair market in India

- *Domestic Players and Market share*

  The domestic players belong to the unorganized segment. It comprises of domestic manufacturers, who are assessed to be about 80-100 players selling 100-150 wheel chairs in a year and unorganized segment players usually accommodate demands of indigenous and provincial markets. The market for wheelchairs in projected to be 120,000 units worth US $ 15 million, emergent at a rate of 10% over the past 3 years. The organized market is worth $ 6 million, budding at a rate of 10% annually. The key to usability of wheelchairs in India is customization. However there are only a few companies who offer to do customization in our country.

- *Future projections*

  Forthcoming demand of manual wheelchairs in organized segment is expected to reach a CAGR of 10% to reach $ 5 million in 2015 and that of motorized wheelchairs in is expected to register a CAGR of 5% to reach Euro 4 million in 2015.

- *Roadblocks*

  Access is the biggest obstruction for wheelchair users. Despite of the growing market of wheelchairs, utility for users still remains an issue. Healthcare entree for disabled is the principal trial in the India. Presently, in India, buildings, toilets, hospitals and other places are not locomotors disabled person friendly. Unpaved, poorly maintained sidewalks that are crowded by vendors are common across Indian cities which impede the movement of people bound to wheelchairs. However the scenario is rapidly altering e.g. some malls have taken initiative by constructing washrooms which are suitable for disabled masses.

3.3 Customer Requirements

- *A stable seating base*

  The convention says the seat should have a level base and be wide enough to house outdoor clothing if required. However it must not be so wide that the user is obligated to sit asymmetrically for support. Narrow seats cause discomfort and risk causing pressure sores. Poor sitting balance causes postural asymmetry or disparity in muscle tone, requiring a supportive seat unit with trunk and pelvic supports.

- *A vehicle that is easy to maneuver*

A few wheelchairs are designed primarily for indoor use and have a tendency to be smaller and more maneuverable. We have to make sure that the wheelchair can

- go through doorways and over thresholds;
- maneuver on floor planes
- make constricted turns from hallways into living rooms;
- move backwards on requirement, e.g. reversing out of the toilet;
- go down shop aisles

The powered wheelchair does not adjust instantly to a variation in direction because the castors need a split second to twirl round. Vehicles intended virtuously for outdoor use typically have very wide turning circles and wide/deep plodded tires for easier movement over uneven as well as lenient ground.

- *A stable vehicle*

All power-driven vehicles are stable on even ground. A user with a lower limb confiscation, particularly a high level or double amputation, should be cautious while choosing a wheelchair because the deficiency of weight at the front may distress the centre of gravity and could root the vehicle to tip backwards mainly when climbing kerbs. Stability can also reduce if the backrest of the wheelchair is reclined or is tilted backwards (tilt-in-space).

- *Freedom of travel*

Motorized vehicles permit the user to navigate long distances without too much individual effort. Even though many wheelchairs have a decent distance per battery ratio, to travel these distances more time is essential. It might take a minimum of four hours to cover 25km (16 miles) in a pavement-only vehicle.

- *A vehicle that is easy to transport*

Transport of a wheelchair requires flexibility (to reach catches and, plugs, for example);

strength (to lift the component parts); and standing/walking stability. Majority of motorized wheelchairs have a collapsible frame that can be pleated once the batteries have been detached. A few wheelchairs also contain separable motors. The frame might not fold down as efficiently as the frame of a manual wheelchair and will be bulkier to lift. If the backrest of the wheelchair folds down, they can be carried into the back of acar through ramps.

- *A vehicle that meets the Assistant's needs*

For easy handling by the assistant, controls are positioned on the right or left pushing handle of the wheelchair. Dual controls not only empower users to be autonomous when required, but also enable someone else to help when the need ascends. The comfort and mobility prerequisites of the wheelchair inhabitant are of paramount significance. In order for the assistant to undertake routine upkeep, such as pumping up tyres and putting the wheelchair on charge, and dismantling and assembling the wheelchair then he/she must be convoluted in the choice of the vehicle to ensure that the essential tasks are manageable.

3.4 Concept Development

Different mechanisms had been studied and researched upon, depending on different power drives and transmission mechanisms, such as mid-wheel powered, front wheel powered, track mechanism, clustered wheel concept and caterpillar wheel concept. Following different concepts had been generated. These figures have been illustrated in the figures 3.6, 3.7, 3.8, 3.9 and 3.10 respectively.

3.4.1 Concept 1

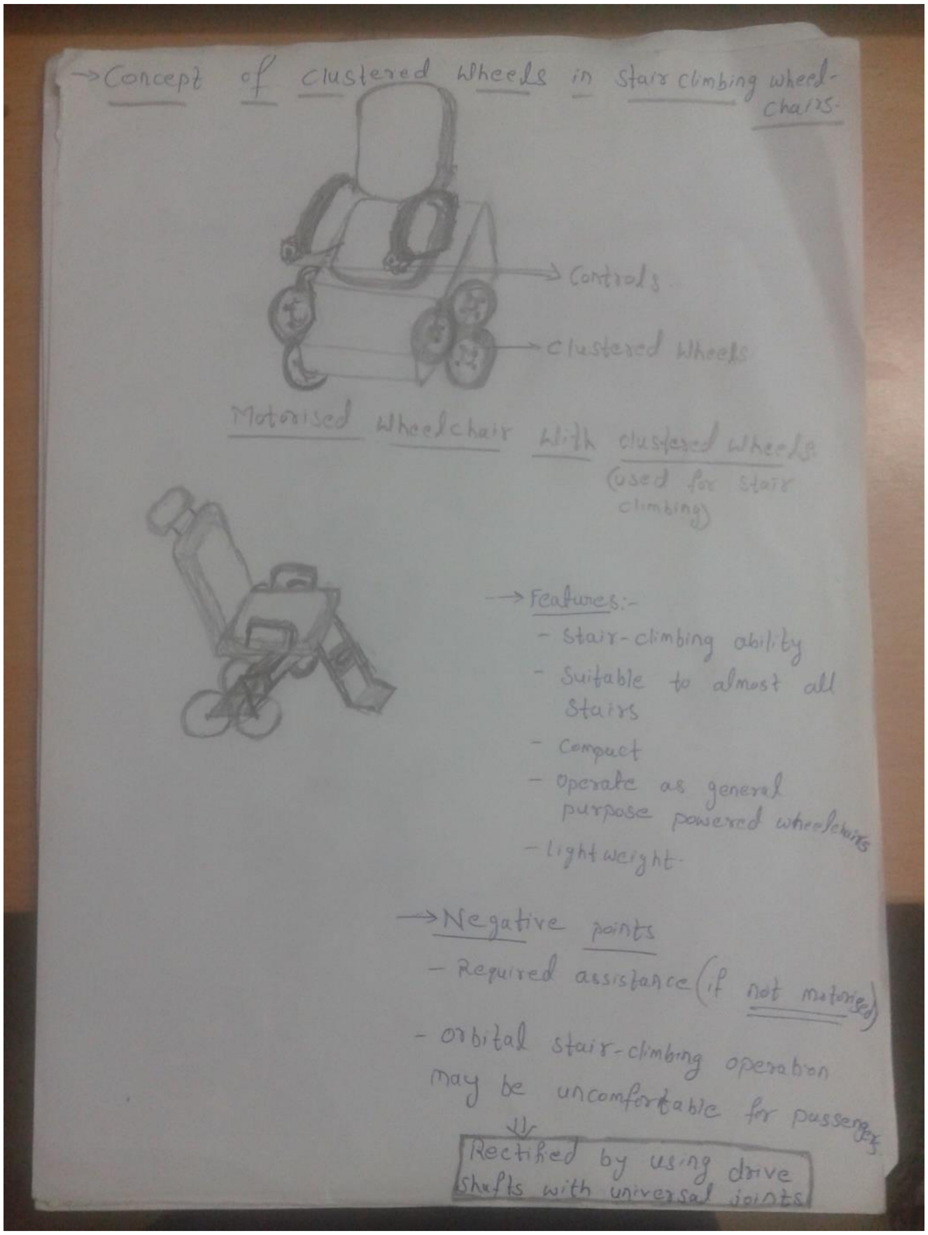


Fig 3.6: clustered wheel

3.4.2 Concept

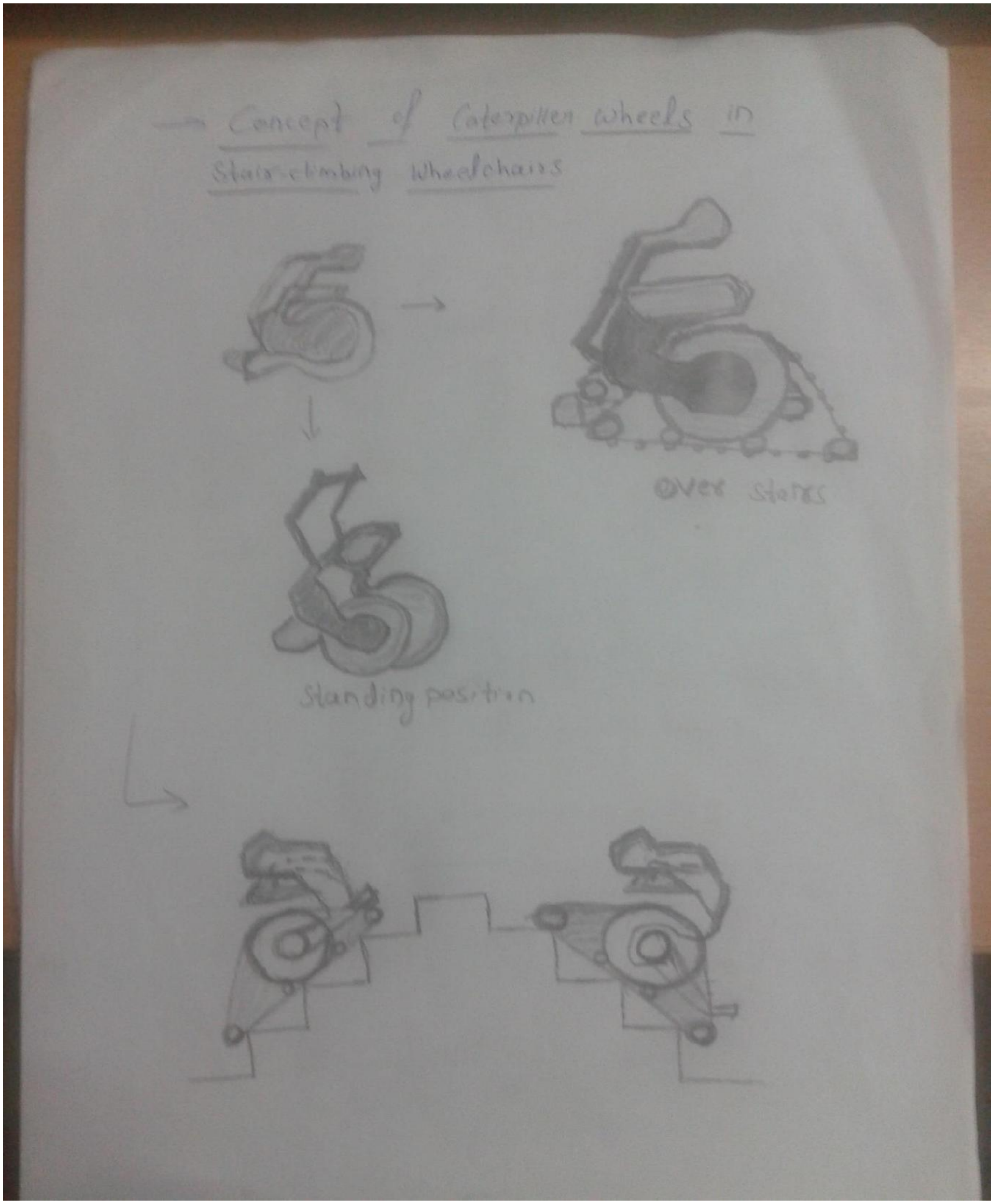
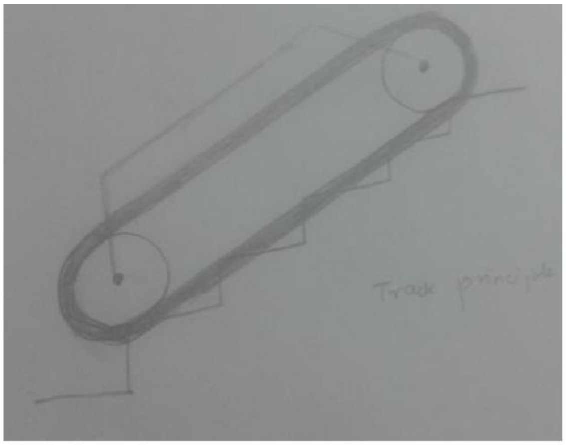


Fig 3.7: caterpillar wheels

3.4.3 Concept 3



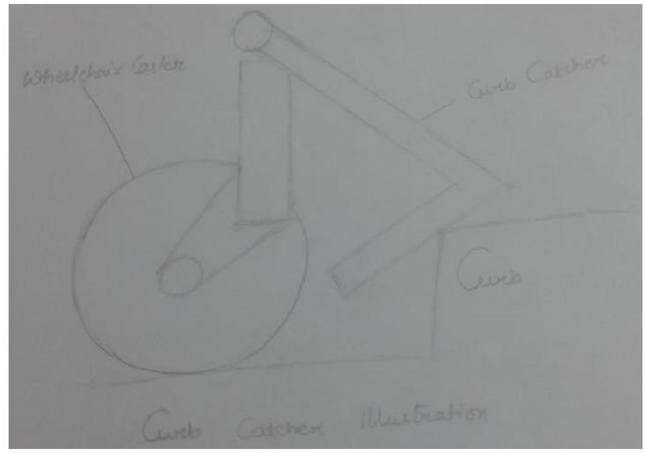


Fig 3.8: Track

3.4.4 Concept 4

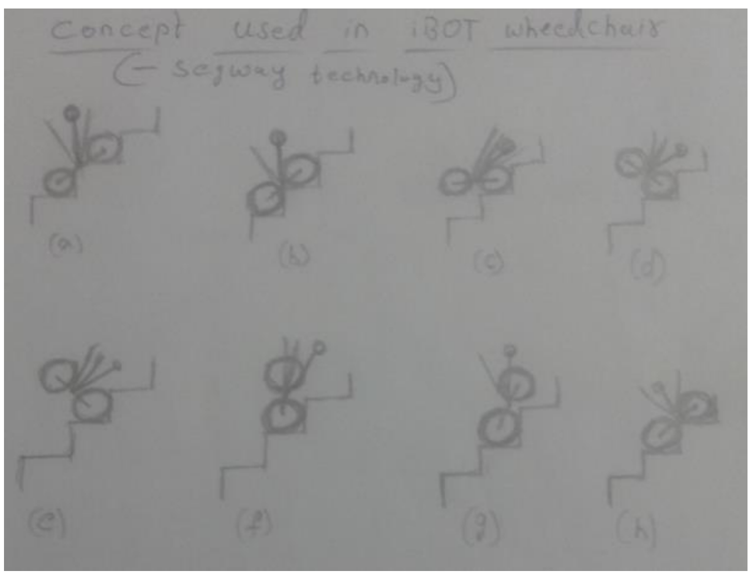


Fig 3.9: iBOT

3.4.5 Concept 5

It is the final selected concept. Wheelchair consists essentially of three elements: a frame, a seat and a linkage mechanism connecting frame and seat. Using only one motor and transmission system per locomotion unit, the wheelchair passively changes its locomotion, from rolling on wheels (“advancing mode”) to walking on legs one (“automatic climbing mode”), simply on the basis of local friction and dynamic conditions.

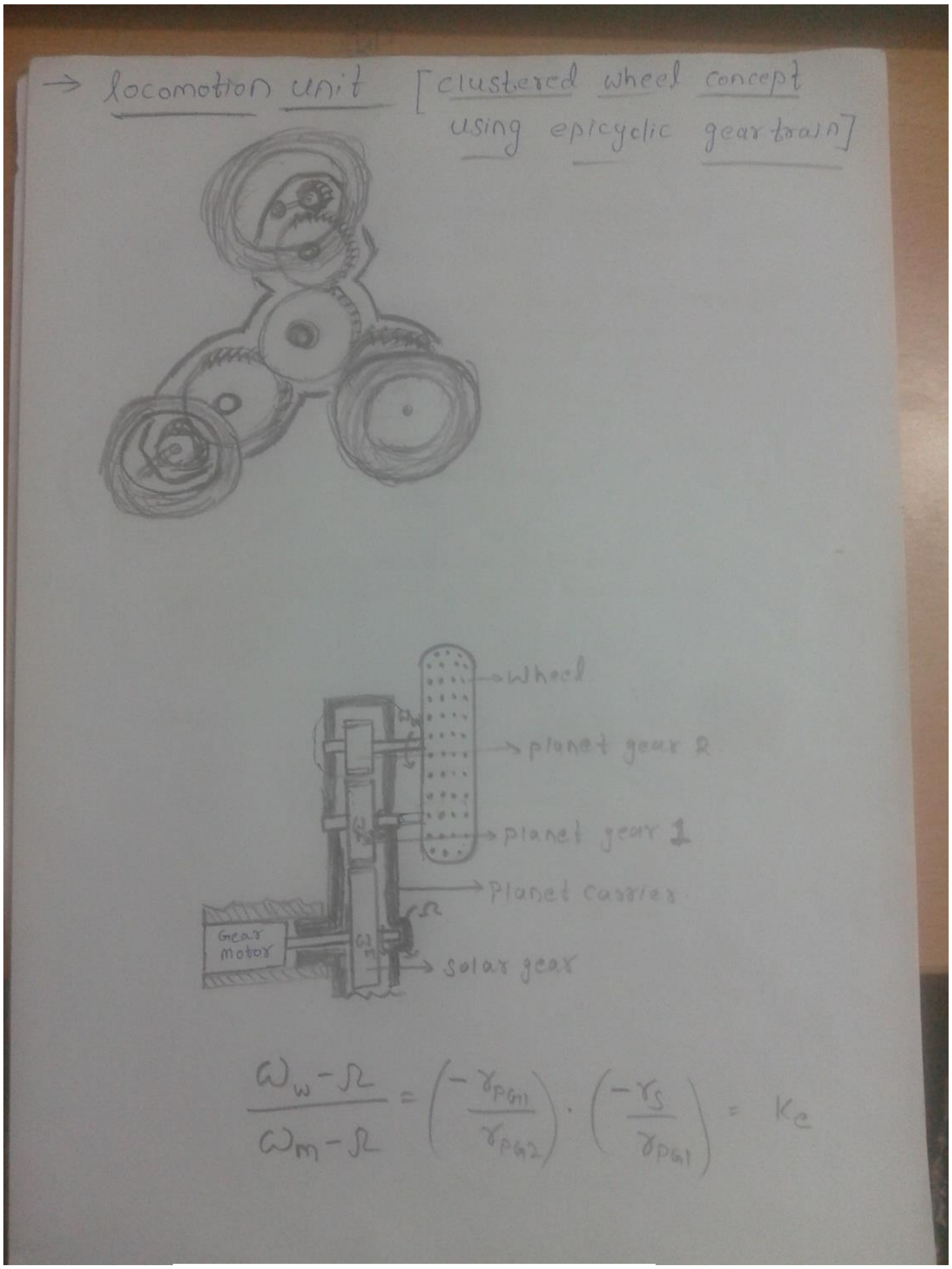


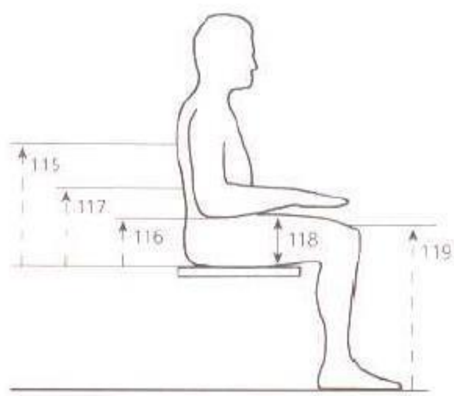
Fig 3.10: planetary gear drive

3.5 System Level Design

- Seat

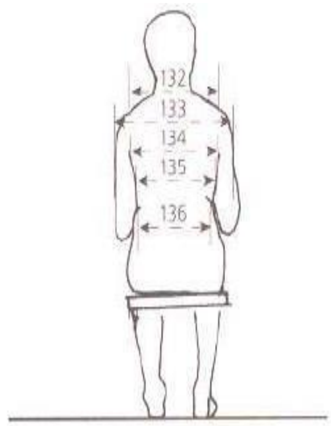
The seat is a tubular structure carrying a chair and a pivoting wheel. The seat consists essentially of two tubular structures, connected by means of crossbars, a chair support and a pipe that ends with a pivoting wheel. Connection points, in tubular structure, are hinges for the linkage mechanism. The seat can move relative to the frame: during stair climbing operations in fact the wheelchair is moved backwards and reoriented.

The seat is designed ergonomically, considering all the required anthropometric measurements. Parameters considered along with their measures are as shown below.



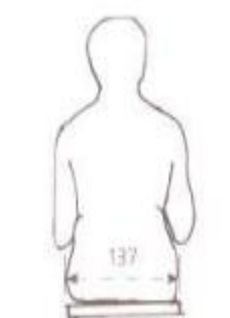
R.No.	Parameters	Definition (brief)
115	**Tip of shoulder blade**	Lower tip of the shoulder blade (scapula).
116	**Elbow rest**	Lower most part of the elbow.
117	**Waist**	Upper margin of the lateral iliac crests (where the belt is worn).
118	**Mid thigh**	Top of the middle thigh.
		Heights from floor
119	**Knee**	Uppermost point on the knee (at lower thigh).

Fig 3.11: Anthropometric Measurements



R.No.	Parameters	Definition (brief)
		Breadths
132	**Bi-acromion**	Maximum horizontal distance across the shoulders, breadth measured between the most lateral points on the superior surfaces of the acromion processes of the scapula.
133	**Bi-deltoid**	Maximum horizontal distance across the shoulders, breadth measured to the protrusions of the deltoid muscles.

Fig 3.12: Anthropometric Measurements



137	**Hip breadth**	Maximum horizontal distance across the hips.

Fig 3.13: Anthropometric Measurements

The CATIA model of the chair is as follows. Here lumber lordosis of spinal column of humans is also considered as shown in the design below.

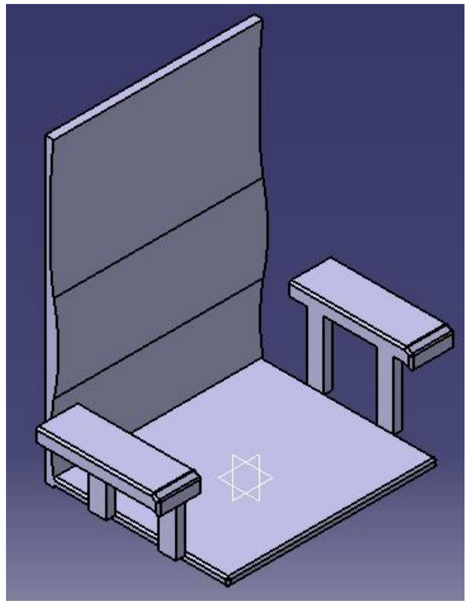


Fig 3.14: CATIA model of seat

This model is further modified in order to accommodate, a feature for attending a nature's call by the users. The users being elderly people, need not take the strain of transferring themselves to the commode. Here by considering the standard commode sizes, a slot of appropriate form and size is made to the base of seat. This is covered by a projection of a negative shape having 1 degree of freedom (rotation about an edge of seat). The figure is as shown below.

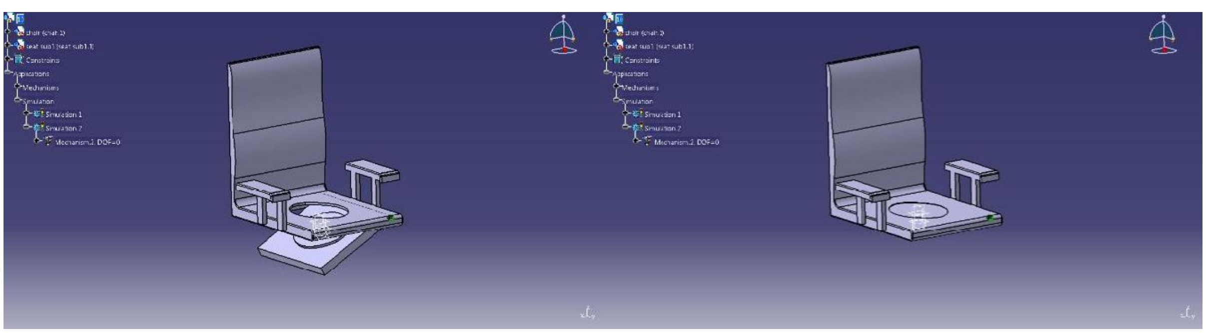
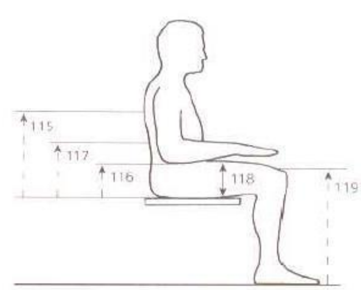


Fig 3.15: CATIA model of seat

- Frame

The frame consists of a chassis that carries two motorized locomotion units, a support for two electrical gear-motors, two idle triple wheels units and a battery pack. The chassis consists mainly of two tubular structures, connected by means of crossbars; two triangular tubular structures on the front support the triple wheel units. Connection points are hinges for the linkage mechanism. The triple wheel units consist of a spider, rotating around a central axis, with three idle wheels placed at its vertices. Wheel size was chosen on the basis of the consideration that large wheels can better absorb vibrations caused by uneven terrain, while small wheels reduce overall dimensions. Accordingly, larger wheels were selected for the locomotion unit and for the pivoting wheel, which are in contact with the ground most of the time, while smaller ones were chosen for the triple wheel units, in contact with the terrain only during the stair climbing operation.

The dimensions of the frame are calculated according to the space constraints. These space constraints are obtained from height of base of seat from ground and dimensions of chair. Seat height is based upon the anthropometric measurements of the parameter ‘Knee height’. According to the Indian anthropometric measurements, 95th percentile of knee height in sitting posture is 55cm. Assuming 15cm as clearance, a total of 70cm of gap is considered. Therefore, frame dimensions are decided upon the space constraints of (48X63X70) cm.



R.No.	Parameters	Definition (brief)
115	**Tip of shoulder blade**	Lower tip of the shoulder blade (scapula).
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118	**Mid thigh**	Top of the middle thigh.
		Heights from floor

Fig 3.16: Anthropometric Measurements

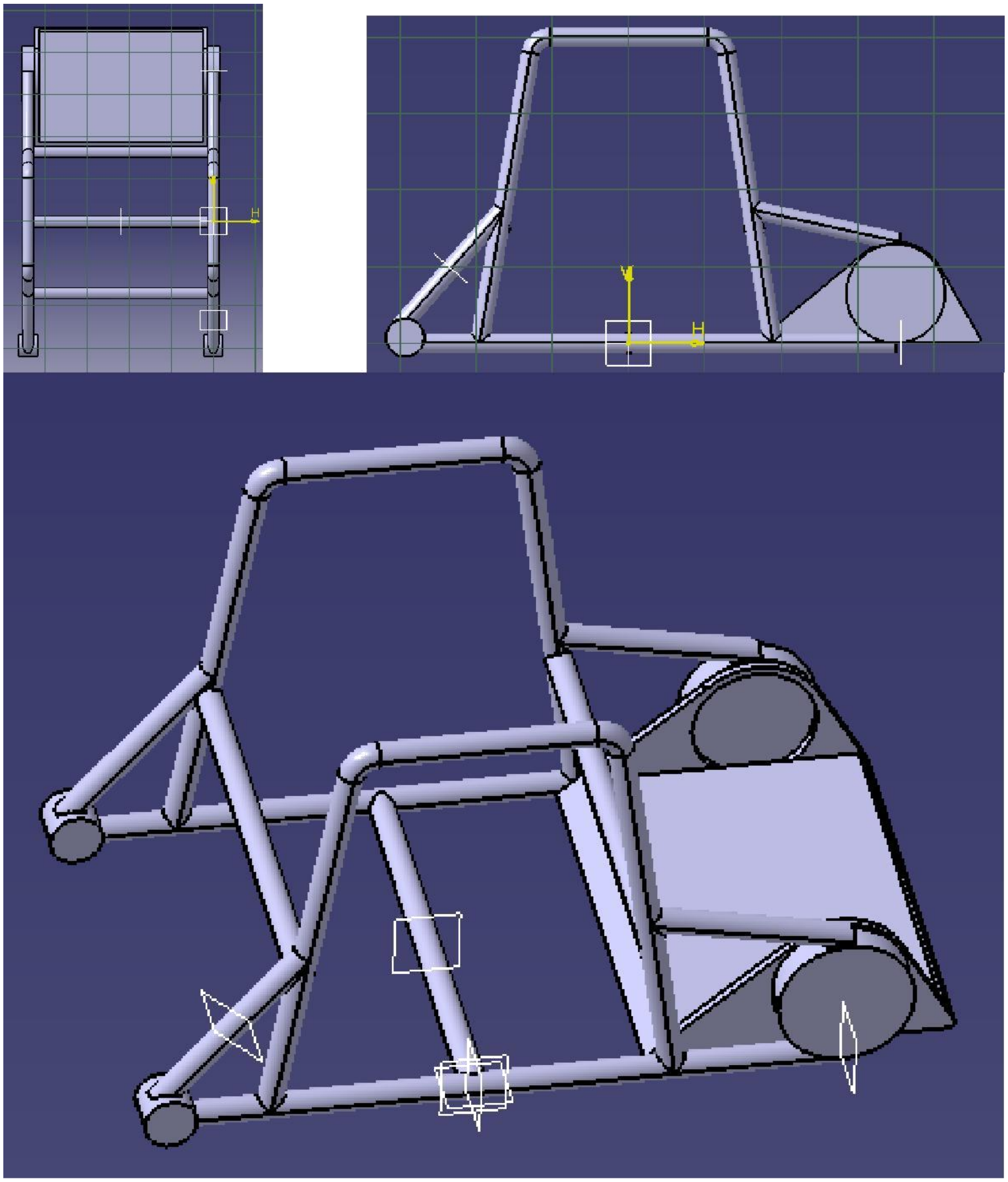

Fig 3.17: Frame

- Gear motor

A gear motor is used as locomotion unit and this motion is transmitted to the clustered wheels. This motor is mounted on a support provided by the frame as shown. The dimensions and specifications of gear motor are obtained from standard motors available. A gear motor of 750 watt power and 1:64 reduction gear ratio is used. It is as shown below.

Reduction ratio : 30, 40, 50, 60, 75	Approx. weight : 20.0kg
Reference page : Specification Chart→P26	

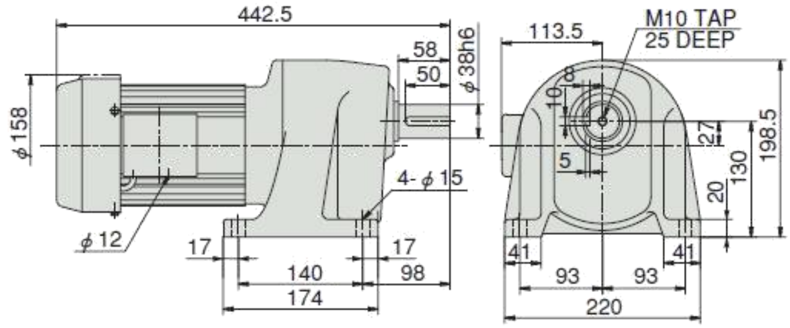

Fig 3.18: Gear Motor

- Wheels

Here a clustered wheel concept is being developed in order to accommodate stair climbing feature. Three wheels are arranged in a triangular array, such that centers of each of the wheels coincide with vertices of an equilateral triangle. Now the side of an equilateral triangle (s) and radius of the wheel (r) are calculated using certain equations, which are described below. In the following equations, step heights and depths are assumed to lie in the range between (152-203)mm and (254-330) mm respectively. These are taken from ergonomic standards. As the wheelchair being designed is intended for domestic use, steps would rather be even and so their heights and depths are approximately taken as 150mm and 250mm respectively. Also the evenness of these stairs led to the equilateral configuration of wheel arrangement.

Case 1: Radius of the wheel (r) > Step height (h); Free Body Diagram is as shown.

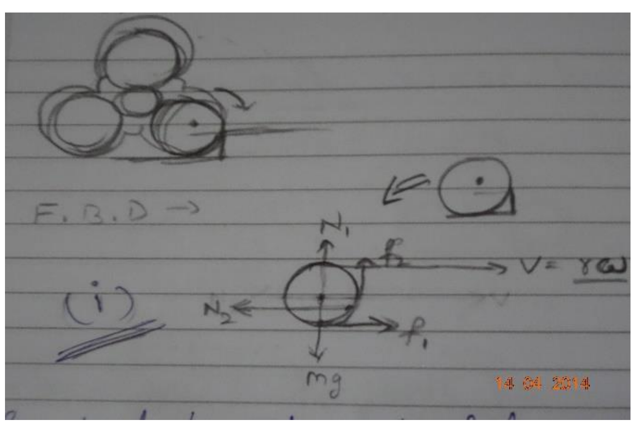

Fig 3.19: free body diagram of wheel

Here torque (1) to be applied during stair climbing is given by,

$$1 = [(\ 1 + \ 2) \times \ ] - [\ 2 \times (\ - h)]$$ -- (1)

Case 2: Radius of the wheel (r) < Step height (h); Free Body Diagram is as shown.

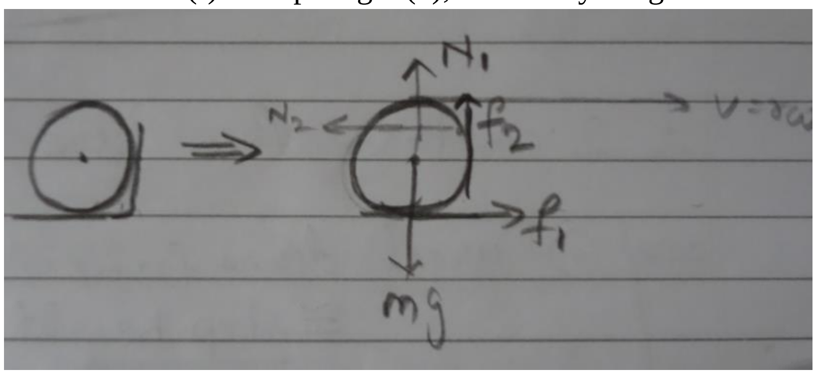

Fig 3.20: free body diagram of wheel

Here torque (2) to be applied during stair climbing is given by,

$$\tau 2 = [(\ f1 + \ f2) \times \ ] + [\ N2 \times (h - r\ )]$$ -- (2)

Now, from (1) & (2), we can observe $\tau 1 < \tau\ 2$. So case 2 is desirable, as locomotion unit shifts to the clustered wheels on increased torques, which is suitable for climbing. Therefore radius of each wheel (r) < step height (h).

$\Rightarrow\ r < 150$-- (3)

Now let'd' be the step depth; 'h' be the step height; 's' be the distance between centers of the wheels arranged in a triangular array. In the stage 1 of stair climbing, following is the situation.

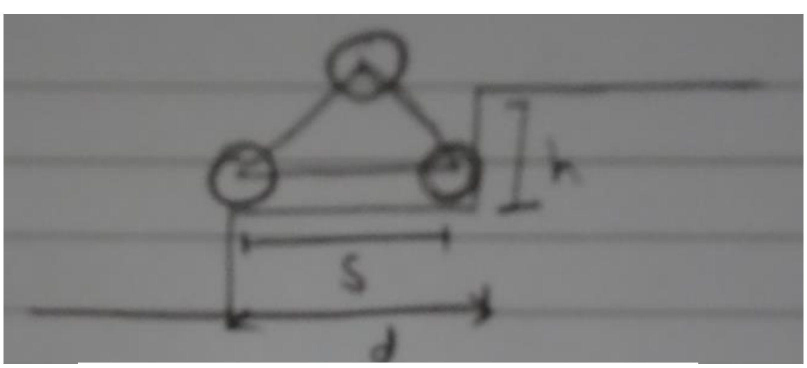

Fig 3.21: free body diagram of wheel carrier

From the above figure, we have,

$s + 2r \leq d$-- (4)

Now in the stage 2 of stair climbing,

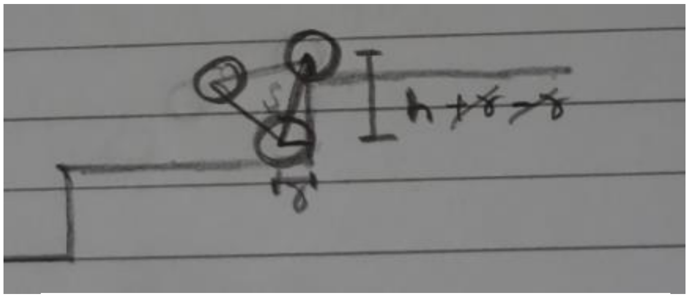

Fig 3.22: free body diagram of wheel carrier

From the above figure, we have,

$s^2 \geq r^2 + h^2$-- (5)

Here, we assume, h=150mm;d=250mm;

Therefore from, (3), (4), (5)

r = 50mm and d = 200 mm (Approximately).

The CATIA model of wheel is as shown below.

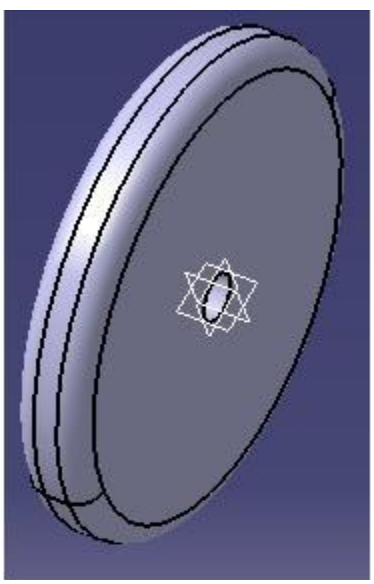

Fig 3.23: Wheel CATIA model

- Planetary Gear train

Transmission of motion from gear motor to the wheels is through this planetary gear train. The specifications of these gear wheels are obtained partly from existing commercial gears used in motorized wheelchairs and partly by customization.

Specifications of planet gear-1:	pitch diameter	=	30.5mm;
	Number of teeth (T)	=	10;
	Module (M)	=	3.05mm;
	Tooth thickness (t)	=	5mm;
Specifications of planet gear-2:	pitch diameter	=	15mm;
	Number of teeth (T)	=	5;
	Module (M)	=	3.05mm;
	Tooth thickness (t)	=	5mm;
Specifications of sun gear:	pitch diameter	=	130mm;
	Number of teeth (T)	=	42;
	Module (M)	=	3.05mm;
	Tooth thickness (t)	=	5mm;

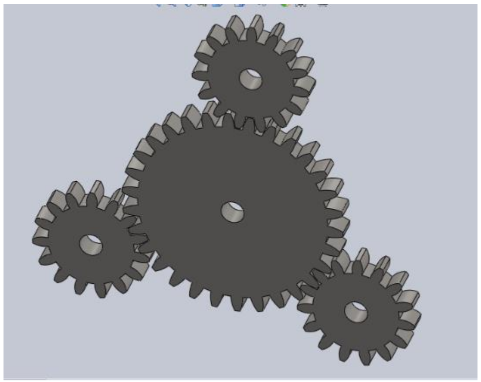

Fig 3.24: Solid works gear sub assembly model

- Planet Carrier

The shape and size of planet carrier depends on the arrangement of wheels in triangular array and also on the dimensions of gears. As calculated above, distance between centers of wheels (s) is 200mm. The figure is as shown below.

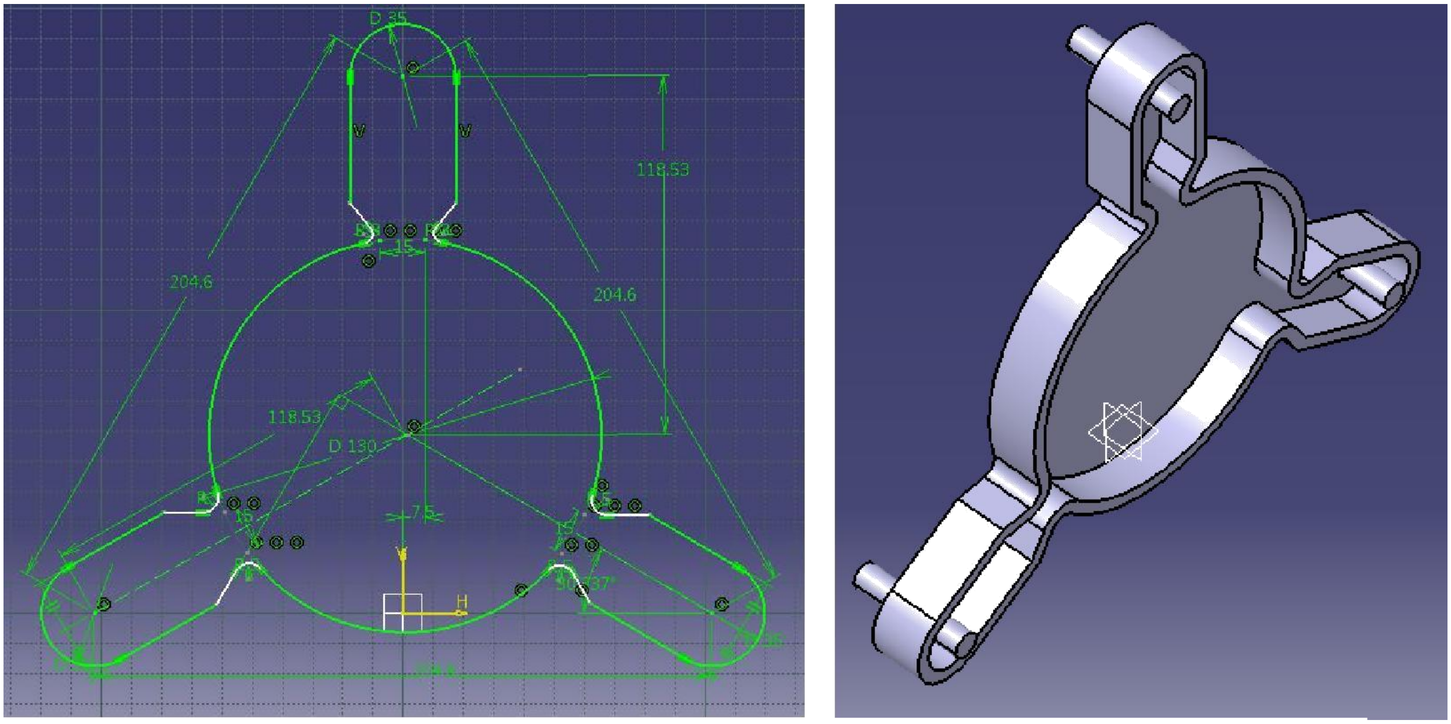

Fig 3.25: Carrier Drawing and Model

- *Linkage mechanism*

  In order to keep the base of the seat horizontal while climbing up or down the stairs, a linkage mechanism is provided connecting the seat and frame together. This mechanism is designed based on the second inversion of 4-bar linkage mechanism. It is similar to whit worth quick return mechanism. Here, a closed loop control is provided with mini servo motor being connected to the 2nd link. Strain gauges are used to feedback appropriate angle to be rotated to acquire stability and making no couple to act on the wheelchair. Here, mini motor keeps the seat in stable position bringing the Centre of gravity down. It is as depicted in figure 3.28.

  The linkage mechanism generates relative motion between the frame and the seat. During stair climbing operations it is required to accomplish three different tasks: moving the seat backwards, reorienting it and lifting up the pivoting wheel. When the seat is moved backwards, the centre of mass of the wheelchair is placed in a safe position, and overturning is thus prevented.

  Once the four-bar linkage mechanism was chosen, only its geometry had to be determined. The four-bar linkage are in an initial position (red) and in a generic position (green). A0 and B0 are hinges built into the frame, designated as (d), A and B are hinges fabricated in the seat, designated as (j). E is the centre of mass of the seat, each link of a four-bar linkage can be represented in a complex plane, as described using complex numbers.

As depicted, the locomotion unit is axially joined to the frame (0) but rotationally free by means of bearings. The locomotion unit consists of the following elements: gear motor (1), planet carrier (2), solar gear (3), first planet gear (4), second planet gear (5) and wheel (6). Using only one motor and a transmission system per locomotion unit, the wheelchair passively changes its locomotion, from rolling on wheels ("advancing mode") to walking on legs ("automatic climbing mode"), according to local friction and dynamic conditions.

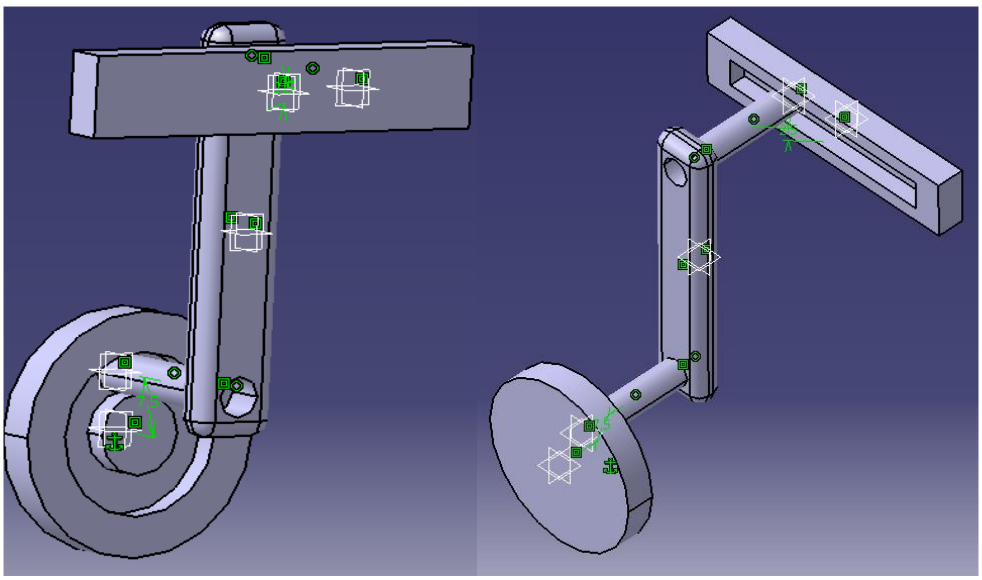

Fig 3.26: CATIA model of linkage sub assembly

- *Transmission mechanism*

  Initially the power from the battery flows to the gear motor, which is arranged together with battery in an enclosed box. Now the gear motor rotates along with the shaft attached, with appropriately reduced RPM according to the specified reduction ratio of motor. Here 'differential gears' are used to transmit the motion from rotating shaft to the wheels with the flexibility for left and right (exterior and interior) wheels to move at different speeds. This accommodates turning of the wheelchair when required.

The differential gear has three jobs:

- To aim the engine power at the wheels.
- To act as the final gear reduction in the vehicle, slowing the rotational speed of the transmission one final time before it hits the wheels.
- To transmit the power to the wheels while allowing them to rotate at different speeds.

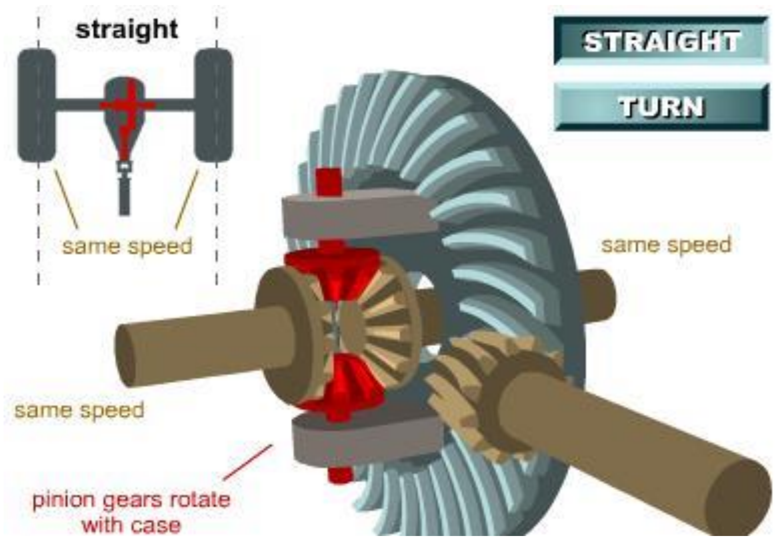

Fig 3.27: Transmission Mechanism

3.6 Detailed Design

The detailed design phase includes materials, manufacturing processes and digital mock up.

3.6.1 Materials

- *Frames*

  Power base chairs may have aluminum, stainless steel, cold-rolled steel, flat steel, tubular steel, or steel frames. The type of material used to construct the frame affects the weight of the frame, and therefore the overall weight of the wheelchair. The type of frame material also can affect the wheelchair's overall strength.

- *Upholstery*

  Upholstery for wheelchairs must withstand daily use in all kinds of weather. Consequently, manufacturers provide a variety of options to users, ranging from cloth to new synthetic fabrics to leather

- *Wheels/Tires*

  Tires vary in size (generally ranging from six to eight inches in diameter, although smaller sizes are also used) and composition (pneumatic, solid rubber, plastic, or a combination of these).

3.6.2 Digital Mock Up

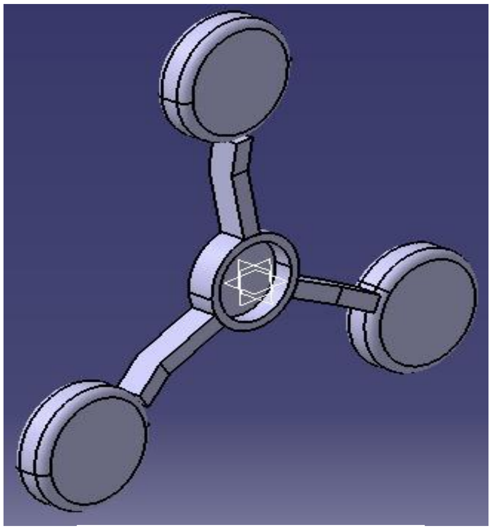

Fig 3.28: Idle Wheels

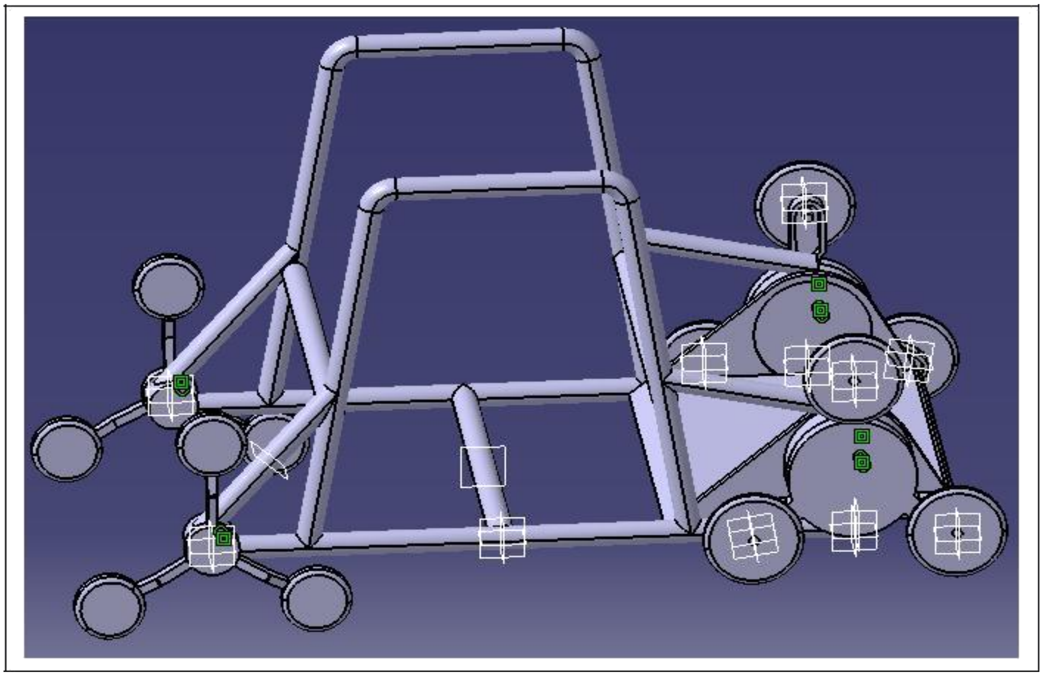

Fig 3.29: Frame Wheel Assembly

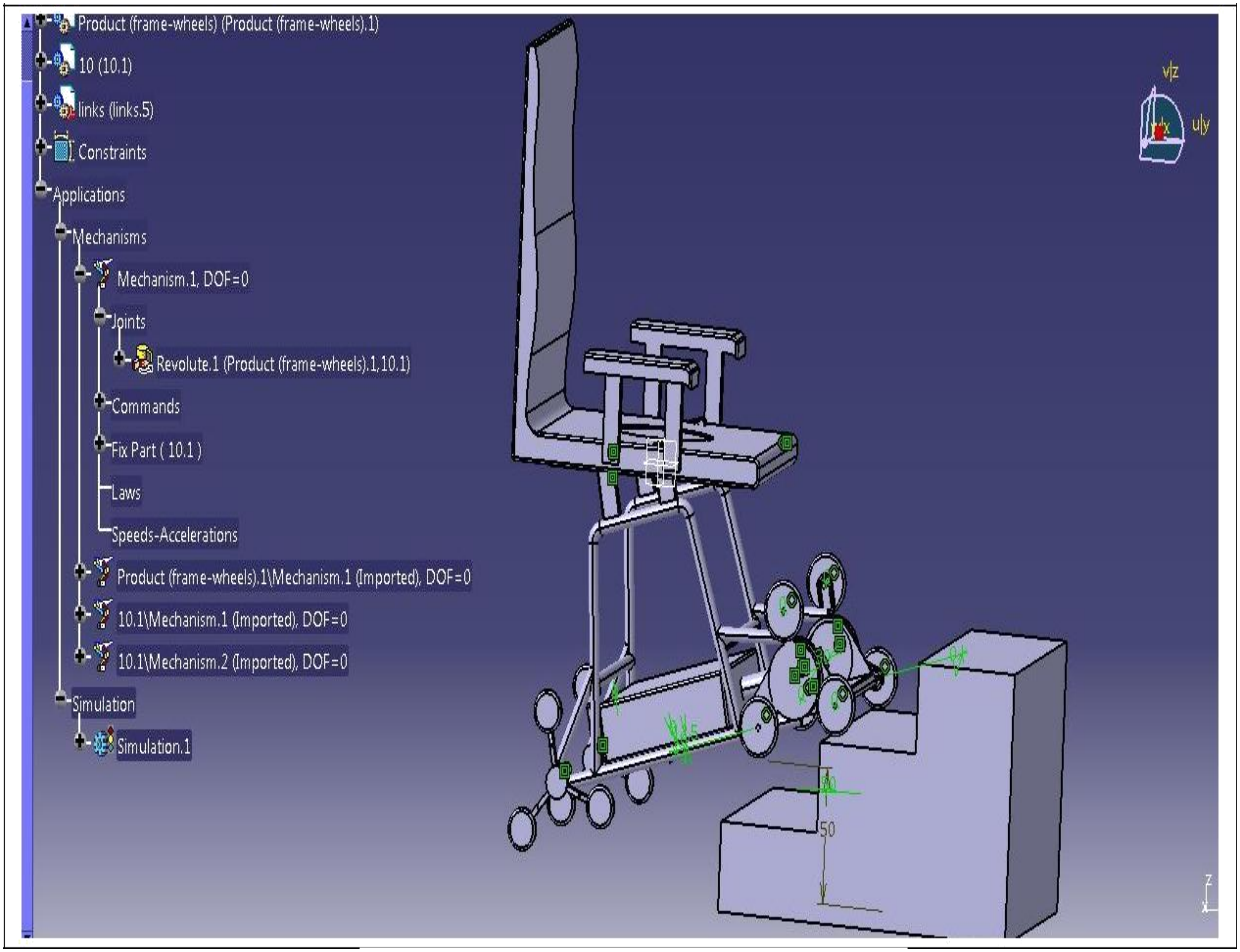

Fig 3.30: Final assembly of Product model

4 RESULTS & DISCUSSION

The digital and physical mock-ups are developed based on the discussed equations in the sections above. These are as shown in figures 4.1 and 3.31. Here the dimensions of the physical model are scaled to half of original dimensions as it is intended to serve as focused physical prototype depicting the structure and basic functionality. The dimensions of original complete model developed in CATIA are as given below.

Fig 4.1: Final assembly of Product (physical mockup)

a) Seat

• Backrest -	Length	=	685mm
	Width	=	480mm
• Base -	Depth	=	110mm
	Width	=	480mm
• Armrest -	Length	=	260mm
	Width	=	90mm
• Thickness of chair		=	50mm

b) Frame

- Diameter of tubular section = 25mm
- Height of frame = 400mm
- Width of frame = 440mm

c) Wheel Carrier

- Centre to centre distance = 200mm
- Wheel diameter = 100mm

d) Gear motor and battery box

- Length = 320mm
- Width = 430mm
- Thickness = 90mm

In the designed model, there are variations in proportional dimensional scaling. These are due to the different percentiles of anthropometric parameters considered in the design of individual features of chair. These percentiles to be considered are based on subjective perceptions arrived at by subjective analyses. Also the design of wheels and wheel carrier are suitable to limited range of staircase dimension variations. As the product is targeted for domestic use, the regularity in staircases are assumed.

The mechanism for engagement and disengagement of shaft to the sun gear and the wheel carrier are to be developed further, to accommodate the switching between stair climbing mode and moving on flat ground mode. This could be provided either manually or automatically by setting the maximum limit for torque in flat ground mode.

5 CONCLUSIONS

This project involves the design of an ergonomically designed electric wheelchair for domestic use by Indian old aged people. Stair climbing functionality was the main focus in its structure and mechanism. The product covered 3 modules viz. seat, links and frame. Seat dimensions were calculated following the Indian Anthropometric standards. The frame and wheels are designed and developed through the mathematical calculations based upon from the statistical data of dimensions of staircases in Indian houses. Form, functionality, technology and architecture of the product are also evaluated. Digital Mockups of individual parts were developed in CATIA and assembled to form the final product. The stair climbing mechanism is simulated in virtual environment. The physical and focused prototype indicating the structure and functionality is developed using thermocol material. The wheel carriers are developed by using Rapid Prototyping technique (Fused Deposition Modelling) using ABS (Acrylo Butadiene Styrene) material. Wheelchair is embedded with some additional features like integrated commode facility, after gathering costumer requirements from different subjects.

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