Design and Analysis of Stair Climbing Chair

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ABSTRACT – The first wheelchair was made in 1965 for Philip II of Spain by an unknown developer. With the time some scientists and engineers started thinking over the new modifications in the wheelchair. In this chapter a review is done on the stair climbing wheelchairs. This feature is added into the chair by mechanical structure change of design. We considered every parameter there is to add this functionality such as its architecture, form, functionality and technology of the product. The proposed design is first made in CATIA software. Individual parts are developed and finally embedded together to form the final product. The required simulations are done in CATIA virtual environment. The structure of proposed stair climbing wheelchair is motor powered with a belt connecting the wheels.

INTRODUCTION

The wheelchair is a very useful article for the people with spinal cord disability or for the people who are unable to walk themselves due to other reasons. The electric wheelchair is very popular these days. They are coming with the facility of holding eye-level discussion with normal standing people and shopping by balancing on two wheels, climbing curbs and stairs, traversing outdoor surfaces (e.g., grass, dirt trails), going up and down steep ramps, [1]. A stair climbing wheelchair is a chair fitted with wheels which is able to climb stairs with ease. These wheelchairs either allows manual propulsion to the person sitting by pushing the rear wheels by the handles behind the seat by another person, or electric propulsion by motors. These wheel chairs are used by the people who are unable to walk due to legs of spinal cord disability or due to some injury, illness. People who find walking and sitting difficult uses wheelchairs. Motorised wheelchairs are used by the people who are unable to drive it manually or if they have to cover large distances or if they have to climb upon sloppy land which can be fatiguing. These are not only used by the people with physical impairment but also by the people with cardio vascular problems and fatigue related problems.

STUDY ON CONVENTIONAL WHEELCHAIR

In the prescription of the wheelchair, dimensions and components of the wheelchair must be specifies which are arms, footrest, leg rest, casters, seat, back and wheels.

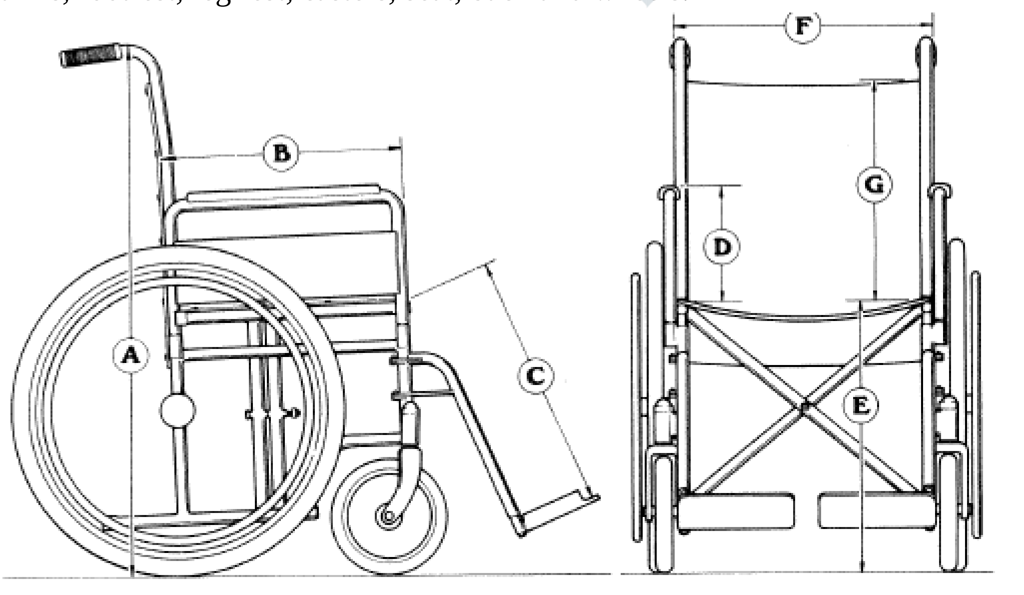

Fig 1: Conventional Wheelchair

The dimensions ranges which US manufacturers specified for adult wheelchair are- a) Total height : 36 - 37" ; b) depth of seat : 16 - 17" ; c) support of footrest (range of adjustment) : 16 1/2 - 22" ; d) height of armrest from seat rail (range of adjustment) : 5 - 12" ; e)height of seat from floor : 19 1/2 - 20 1/2" ; f) back width and seat : 14 - 22" ; g) distance from seat rail to back height : are according to the requirement

Proposed Design Structure

Seat: We can make our product for an average person only. When survey of people from a target population was taken, we found a mid-point that divides into two classes of people - one below and one above the "average" It is only logical to use the midpoint of the survey to decide a height of the chair. We determine a standard size to assign the upper and the lower limit of the changes required to make adjustment in size of wheelchair according to the standard data of variants of sizes. The design of workstations requires the application of anthropometric and ergonomic data [14].

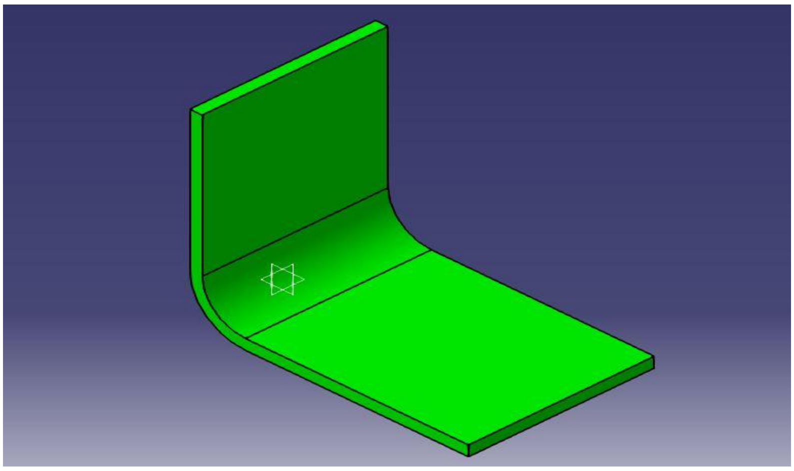

Fig 2: CATIA Design of chair

Dimension

(Base seat)

Length-16 inch

Breath-14inchg

Material; Plastic

Frame: Several things must be done by any good frame:

1. Expected life of our vehicle is very long because of it is very structurally sound . This means there is a guarantee of no breaking under normal conditions.
2. For safe handling maintain the suspension mounting locations and consistent under bump loads and high cornering.
3. Everything should feel solid and should have a long, reliable life that supports the body panels and other passenger components.
4. External intrusion must not bother occupant.

Cast iron for all the components in the frame is used, this increases its strength even further and allows us to use thinner sections – the result is a frame that is both stronger and lighter. The bar used has a tensile strength of 300MPA-350MPA.A square tubular is welded directly to other extends of frame. This structure provides not only the mounting areas for the body structure; hinges, latches and dashboard, but also incorporates side impact protection.

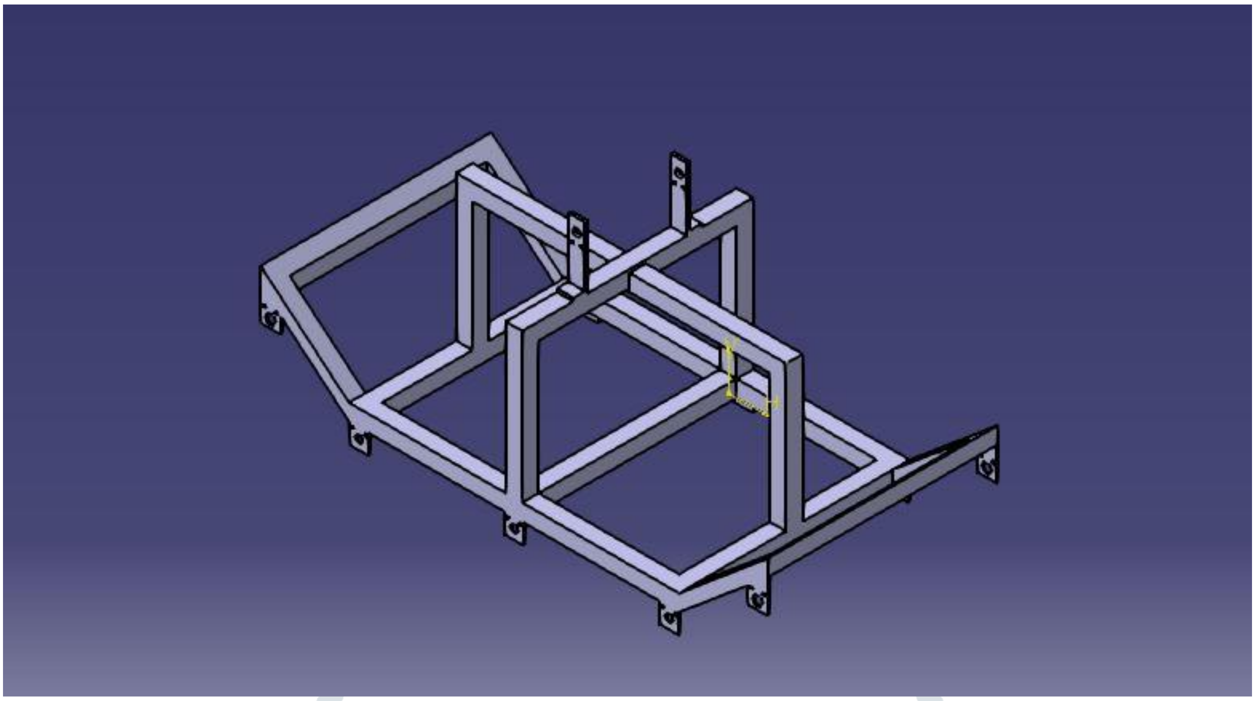

Fig 3: CATIA DESIGN OF FRAME

Dimension (excluding the outer balancing frame)

Length-20inch

Width-19inch

Side of square rod-1/2 inch

Outer balancing frame dimension

Length-7inch

Dimension of frame beneath the seat

Length-14 inch

Width-19 inch

Gear motor: A gear motor drives the wheel chair. It drives the clustered wheels. This motor is supported by the frame on which it is mounted. The standard motors with dimensions and specifications which are available in the market is used. A gear motor of 12watt power and 150 revolutions per minute is used to drive inner wheels also another geared motor of 12 V and 300 rpm. It is as shown below.

Wheel: When there is a force pushing the object to the surface wheel allows efficient movement of an object across a surface. Motion with low resistance (compared to dragging) is defined as follows (refer to friction):

1. At the sliding interface the normal force is same.
2. For a given distance of travel by wheels, sliding distance is reduced.
3. At the interface of wheel and the floor, the coefficient of friction is less

From the wheel-to-road interface additional energy is lost. This is due to a deformation loss which is termed as rolling resistance. The wheel lowers the energy loss (in comparison to dragging) because the net force developed is in the perpendicular direction which is at the point of contact between the wheel and the road, and zero work done generates. This depends on the nature of the material of the wheel, of the ground, the net torque exerted by the eventual engine, its inflation in the case of a tire, and many other factors. [11]

In our design, it has ten large four and half inch diameter wheels with and approx. one and half inch-wide breadth, located at the outer periphery on each side of the substructure. These wheels are used in robotics operation.

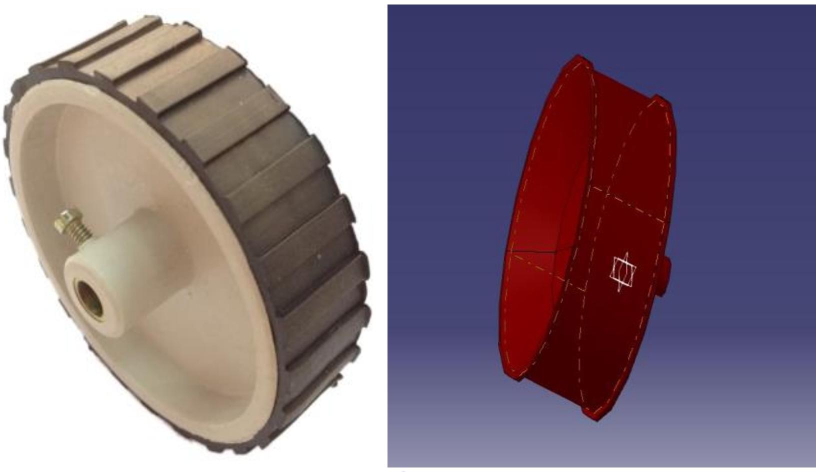

Fig 4: Wheel used in our project along with CATIA design

Dimension

Diameter- 4.3 inch

Width-1.6 inch

Conveyor Belt: Conveyors is durable and reliable components used in distributing forces over surface. Belt conveyors we used is fairly similar in construction of conventional used conveyor consisting of a flat metal chain running on the two wheels covered by a metal frame. When electric motor drives one of the sprockets upon which belt is looped around the belt slides over the solid sprocket wheels, and moves the product. The beds upon which belt is rolled over is replaced by the rollers in heavy applications. As the amount of friction developed by the heavy loading on the belts, the roller allows the weight to be conveyed. Belt conveyors with curved cross-sections which use tapered rollers and curved belting to drive products around a corner can now be manufactured.

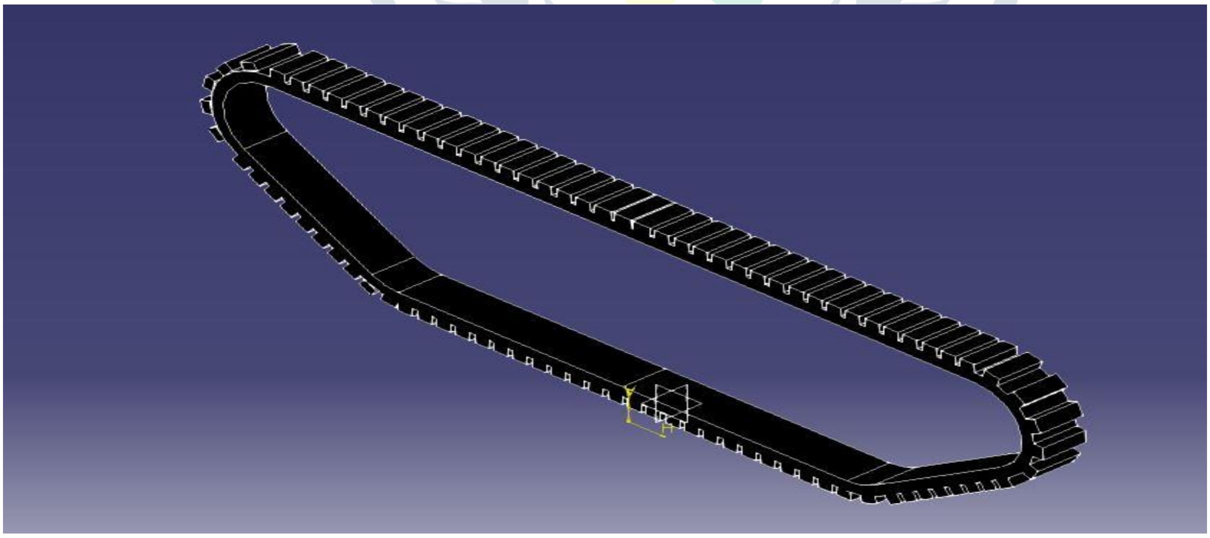

Fig 5: CATIA Design of our conveyor

Dimension

Length- 1920 belt

Width -40 mm

Material- PU rubber coated conveyor belt

Final Design of entire wheelchair: - The conveyor is connecting the motor with the wheels of the wheelchair via powered linkage using front and rear wheels. This mechanism allows the wheelchair to climb upon the stairs up and down and also in and out of a van. Control system based on wheels, motors and switch controllers have been embedded to operate the model which is made up of aluminium frame.

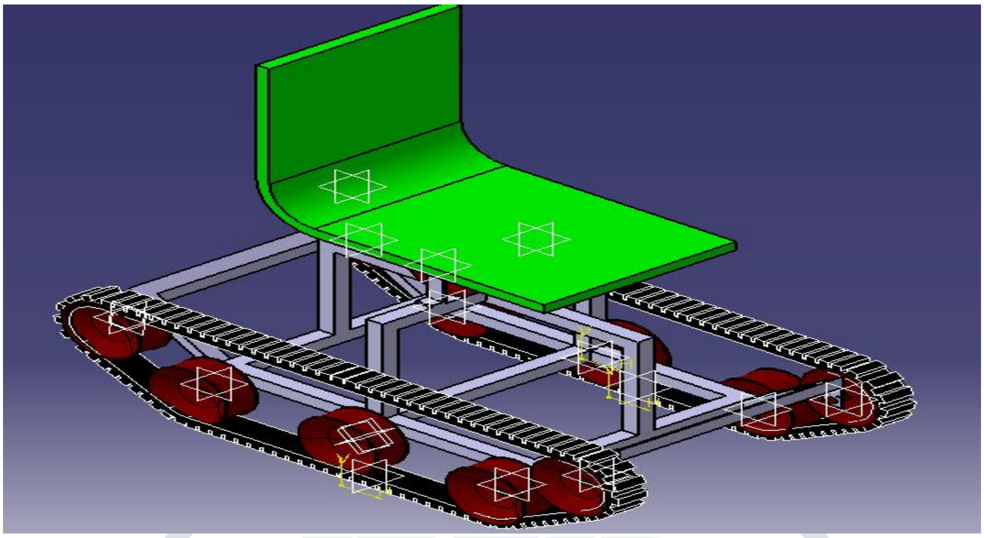

Fig 6: Final CATIA based design of wheelchair

Mass balancing of wheelchair: The design of the wheelchair has been done in such a way that the wheelchair gets balance due to the symmetry in the geometry of the body.

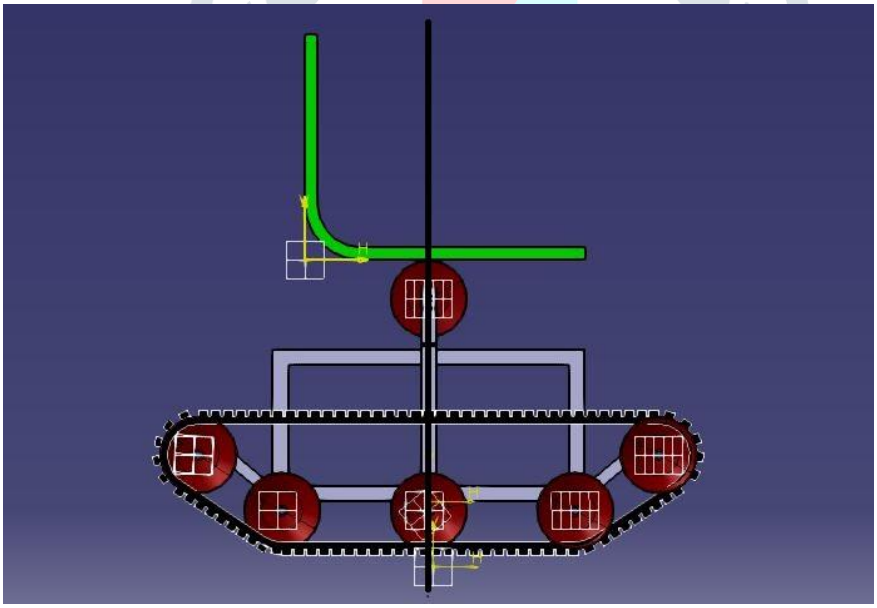

Fig 7: Side view of CATIA model of Wheelchair

Weight in both the sides of the black centreline drawn is same. Hence no further balancing is required. The centre of mass of the body sitting on the chair will also have its weight concentrated towards centreline only.

Therefore, weight at each side: 5.8/2 = 2.9 (with no load condition)

Chair Mechanism: When the wheelchair climbs the stairs, the centre of mass of the body sitting on the chair gets shifted to somewhere near the curve of the chair. In order to reposition the centre of mass, chair is rotated to the same degree, as the angle of inclination of the stairs. This is done by using two motorized wheels. The wheel is so designed that after rotating 22 degree, the chair will be stuck at the metal stand and will not rotate more.

Radius of the wheel 4.5 inch

Distance between wheel and frame below it 1.2 inch

Length of the chair from its midpoint 14.78 inch

Therefore, angle that the chair will make: sin ɵ = perpendicular/ hypotenuse

= (4.5+1.2)/14.78

ɵ = sin-1(0.385656)

ɵ = 22.1°

8.3. Power Transmitted by the Motors: Given, torque of the motor = 3.5 kg-cm

Revolution per minute of the motor = 60

Therefore, Power: 2π*torque*rpm/60 (1kg = 9.81 N and 1cm= .01 m)

= 2.157 watt

8.4. Dynamic Equilibrium (Neglecting Friction):

Torque = Force * distance between line of action of force and central axis of the body.

34.335 = Force * (4.5*2.54)

Force = 3.218 N

This is the force of one wheel

Forces produced by 10 wheels = 10*3.218 =32.18N

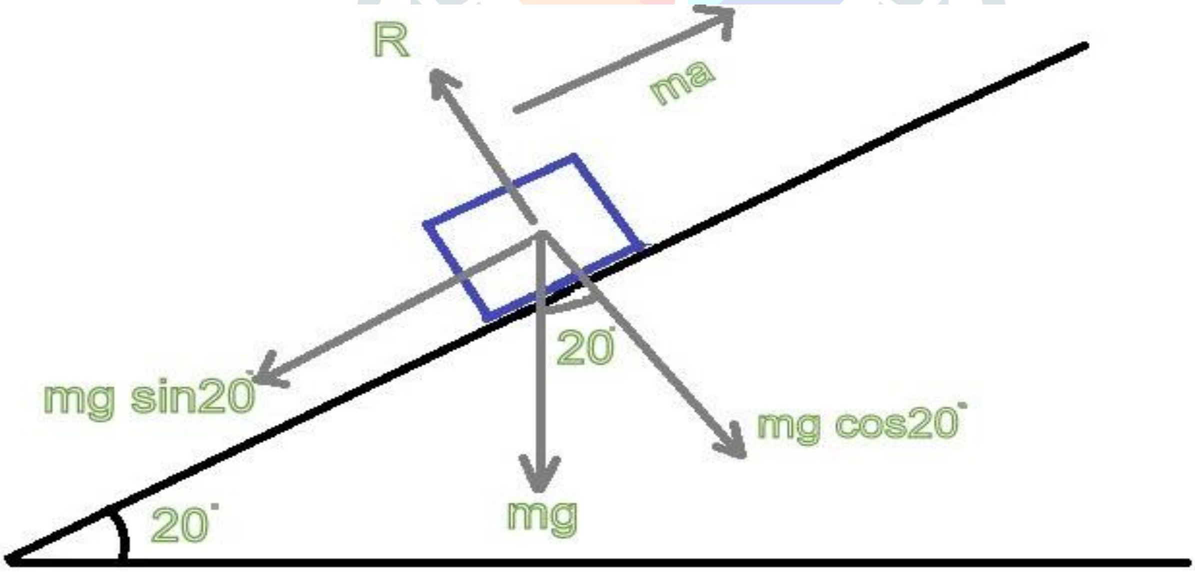

Fig 8: Basic FBD of Wheelchair (Neglecting Friction)

Now, force required to climb the wheelchair about the stairs is determined by splitting force into components.

mgsin20 and mgcos20

mgcos20 is of no use as no motion is taking place in this direction, and mgsin20 is the force against which the wheels have to work to climb the stairs.

Now, mgsin20 = 5.8*9.81*sin20 = 19.46N

So, we can see the value of mgsin20 is less than the force produced by wheels. Therefore, wheelchair can easily climb the stairs with the motors installed on the system.

More experimental works were done on the frames by changing the angles of front bend made for climbing the stairs. 2-3 times clamps were changed in trying to lose weight from the structure and reduce cost of manufacturing.

Result

Digital mock-up and physical motion of the stairclimbing wheelchair has developed on the calculation basis that has been shown in research & experimental work. Here the scaling for the dimensions has been done by taking original dimensions of the parts, but all the measures in original dimension were in inches. However, motor rpm and torque should be at list double the torque in the prototype and wheels to be chosen for the original construction of the wheelchair, should be stronger material than the prototype. Clamps to be chosen should be of some material like cast iron.

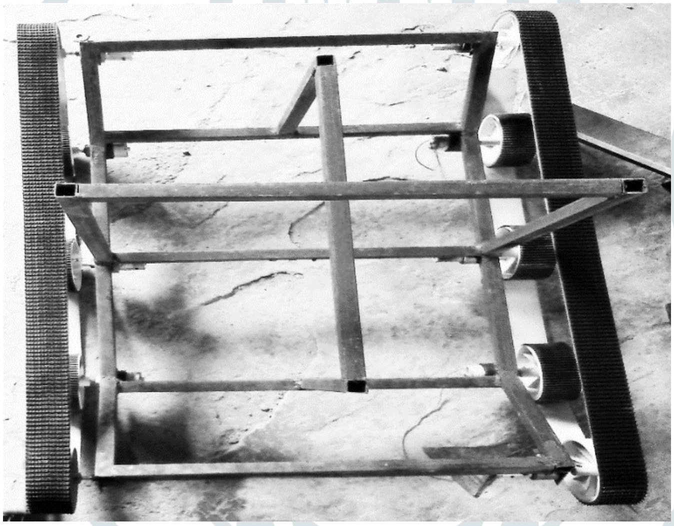

Fig 9: Final Live Model with frame, wheels, motor and conveyor

Dimensions that has been taken during CATIA design are:

a) Seat

Backrest - length = 685 mm

Width =485 mm

Base - Depth = 110mm

Width = 90mm

Armrest - Length = 260mm

Width = 90mm

Thickness of chair = 50mm

b) Hollow pipe dimension used in frame:

Cross section area= 25 mm*25 mm

Length = 900mm

Breadth = 600 mm

Angle of inclination of extended parts = 22.5°

c) Dimension of the supporting stands:

Height of larger stand = 730mm

Height of smaller stand = 600mm

In this model there are some variations in the proportional dimensions during scaling. These are due to the standard arability of the parts with standard dimensions in market which were used to add individual feature in the chair. These assumptions and decisions of dimension selections are subjective. Only for the limited range of staircase dimension variations these designs of wheels and the wheelchair is applicable. As it is mainly applicable for the domestic purposes, the assumption in regularity of staircase is taken.

The mechanism of chair rotation during stairs climbing need to developed more, in fact if possible, mechanism of chair alignment should be changed with further research and experimental work. By setting the maximum limit for torque in flat ground mode, the mechanism could be provided either manually or automatically.

Conclusion and Summary

This project is designed mainly for the Indian crippled and old aged people. In this project we made ergonomically designed stair climbing motorised wheelchair for home use. In its structure and mechanism stair climbing is its main functionality. The three modules covered the product are frame, links and seat. Indian Anthropometric standards helped us to calculate the seat dimension. Depending upon the statically data of stairs in Indian houses, we developed our mechanism and design of wheels and the frame. technology, functionality, form and architecture of the product are also evaluated. Part Design for mathematical modelling is done in CATIA and finally assembled product was formed. We developed a virtual environment of stair climbing mechanism. The physical and focused model structure is developed using Cast Iron material and the functionality of mechanism is carried out by incorporating geared motors and wheel. The belt conveyors are designed using Rapid Prototyping technique (Fused Deposition Modelling) using PU (Poly Urethane) material. The main drive of the wheelchair and the horizontal seating alignment can be controlled by the occupant using a 3-way switch. The final embedded system's control system has been demonstrated to be performing its tasks smoothly.

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