Design and Fabrication of Multipurpose Mobility Carriage for Crippled

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Abstract

The project mainly aims to design and fabricate a carriage for armless people for the easy transportation from place to place, also outdoors. The project focuses for the use of crippled people (Both armless as well as disabled). The cost efficiency of the design makes it affordable for the common man. The drive is provided by an electric motor. A rechargeable battery is used for the power supply. It uses track chain instead of traditional wheels, thereby enabling it to pass through different terrains as well as ability to climb stairs. The use of track chain also enables it to rotate 360º in standstill position. The controls can be operated either by using hands or by using legs, thereby enabling it to be used for people with different disabilities. The product in application will be economic and can be used in several cases where normal transportations are difficult.

Keywords: Mobility Carriage, Crippled, Caterpillar Track Mechanism

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I. INTRODUCTION

The earliest records of wheeled furniture are an inscription found on a stone slate in China and a child's bed depicted in a frieze on a Greek vase, both dating between the 6th and 5th century BCE. The first records of wheeled seats being used for transporting disabled people date to three centuries later in China; the Chinese used early wheelbarrows to move people as well as heavy objects. A distinction between the two functions was not made for another several hundred years, around 525 CE, when images of wheeled chairs made specifically to carry people begin to occur in Chinese art. The first known image of a wheelchair was carved into a stone in the 6th century. Although the Europeans eventually developed a similar design, this method of transportation did not exist until 1595 when an unknown inventor from Spain built one for King Philip II, who was the King of Spain during the 16th century. It was a very elaborate wheelchair that had both armrests and leg rests. In the 18th century the first wheelchair similar in design to those available today was developed. It had large front wheels and a single wheel in back. By the 19th and 20th century wheelchairs were constructed of wood and wicker design.

Wheelchair is used by people who have difficulty in mobility. Generally, people who use are,

- People who are crippled.
- Patients at the hospitals.
- Elderly people.
- People who are paralyzed.

There are many types of wheelchairs available in the market like manual or powered wheelchair and the choice of wheelchair depends upon the physical and mental ability of the user.

Manual wheelchair incorporates a frame, seat, one or two-foot plates (footrests) and four wheels: usually two caster wheels at the front and two large wheels at the back. An attendant-propelled wheelchair is generally similar to a self-propelled manual wheelchair, but with small diameter wheels at both front and rear. An electric-powered wheelchair, commonly called a "power chair" is a wheelchair which additionally incorporates batteries and electric motors into the frame and that is controlled by either the user or an attendant, most commonly via a small joystick mounted on the armrest, or on the upper rear of the frame. One-arm or single arm drive enables a user to self-propel a manual wheelchair using only a single arm. Reclining or tilt-in-space wheelchairs have seating surfaces which can be tilted to various angles. Mobility scooters share some features with power chairs, but primarily address a different market segment, people with a limited ability to walk, but who might not otherwise consider themselves disabled. A range of disabled sports wheelchairs have been developed for disabled athletes, including basketball, rugby, tennis, racing and dancing.

Wheelchair faces various limitations varying from lumps and bumps to the architectural barriers. Physical activity with wheelchair users has proven to be a lifesaver when it comes to longevity and being healthy overall. Several studies have shown that both children and adults benefit substantially from access to a means of independent mobility. If they become unable to walk or wheel themselves to the commode and help is not routinely available when needed, a move to a more enabling environment may be necessary.

II. Literature review

The 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. The project by Tadakamalla Shanmukh Anirudh et al. [1] 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. 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. According t review paper published by Mohammed Hayyan Al Sibai et al. [2], there are many forms for designing a smart wheelchair. Early smart wheelchairs were mobile robots to which seats were added. Currently, most of developed smart wheelchairs are built on by modifying commercially available power wheelchairs. Few smart wheelchairs are designed as “add-on” units that can be attached to and removed from the underlying power wheelchair. All these designs are sharing the same objectives which are: Easing the way the chairs are used, avoiding collisions as much as possible, increasing travel distance and decreasing travel time. A review of electric-powered wheelchair with stair-climbing current technology and its future tendency was discussed by Weijun Tao et al. [3] in 2017 to inform electric-powered wheelchair with stair-climbing researchers in the development of more applicable and popular products. The respective advantages and disadvantages of different types of electric-powered wheelchairs with stair-climbing are outlined for an overall comparison of the control method, cost of mechanical manufacture, energy consumption, and adaptation to different stairs. State-of-the-art technologies empower people with motor disabilities to carry out activities of daily living, thus enabling a better quality of life. In fact, studies have shown that, among people with motor disabilities, those having better mobility report 7 greater satisfaction with their quality of life than those having lower mobility. A team of students and mentors [4] from the University of Ljubljana, Slovenia, developed the concept and prototype for a hybrid robotic wheelchair that allows the user to traverse obstacles, such as stairs and ramps commonly found in urban and rural environments, by utilizing both wheeled and tracked propulsion. Additionally, the team’s prototype incorporates a wheel-drive system designed for enhanced maneuverability in indoor spaces. Dan Ding and Rory A Cooper [5] conducted a review to convey the depth and breadth of the research conducted on EPW (Electric-powered wheelchairs) control technology as well as provides insights into future directions. They reviewed the concepts and previous work on velocity control, traction control, suspension control, stability control, stair-climbing wheelchairs, and wheelchair navigation.

The major challenge faced by the existing designs of normal wheelchairs in the market is their inability to climb steps even with the help of a bystander. However, the existing step climbing wheelchair are designed only for that purpose and not economically designed for movement through flat normal surfaces. The proposed design of the wheelchair by Gabby John et al. [6] alleviates aforesaid disadvantages and is able to climb steps, move more easily through flat surfaces and rough terrains and more importantly it is economical. The proposed wheelchair employs caterpillar track mechanism. The centre of gravity is controlled by hydraulic shocks. This type of traction belt is responsible for contact with two steps at a time, thus enabling the wheelchair to move up or down over the steps. The forward, reverse and sideways motion of the proposed wheelchair is controlled with the aid of an electric motor and steering is operated by a mechanical pedal. This innovation made the wheelchair highly versatile and flexible in application.

III. Design, materials and working methodology

A. *Design Procedure*

The physical realizability and economic worth of the device were studied. Design parameters, specifications, and major design criteria were formulated. Ten potentially useful conceptual solutions were generated. All potentially useful solutions were thoroughly examined at the beginning of the preliminary design phase. Synthesis and comparative analysis led to the "best promising approach," which was modelled. After building sufficient confidence this approach was finalized. All components and systems were fully specified. Operating procedures were generated. A complete set of assembly and detail drawings were prepared. A cost analysis was conducted. Then, the prototype was fabricated and tested.

B. *Initial Design*

Many models were constructed and analysis was carried out before finalizing the actual frame which was to be adopted to the application. The frame was then analyzed using Autodesk Fusion360. The analysis shows that the design is not safe to use. The structural rigidity is poor and the frame is unstable. Even though the first design provided better safety and comfort to the occupant, due to its bigger size it is difficult to maneuver.

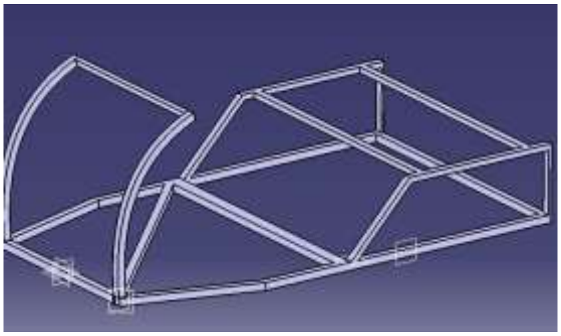

Fig. 3.1: CAD model of the frame

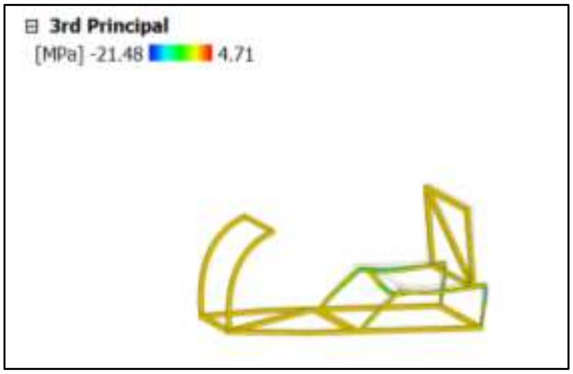

Fig. 3.2: Compressive Stress

C. *Final Design of the Prototype*

A second model was thus prepared analyzing the defects of the first model. The second model is rectangular in shape and is much compact. The MS equal angle was of dimension 20 x 20 x 3. The lower section of the frame which houses the motor, drive shaft, reduction gears are fabricated using MS angle of dimension 25 x 25 x 5 to impart better strength.

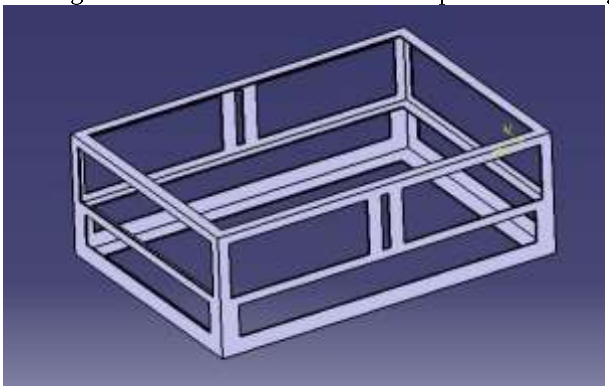

Fig. 3.3: CATIA model of the product

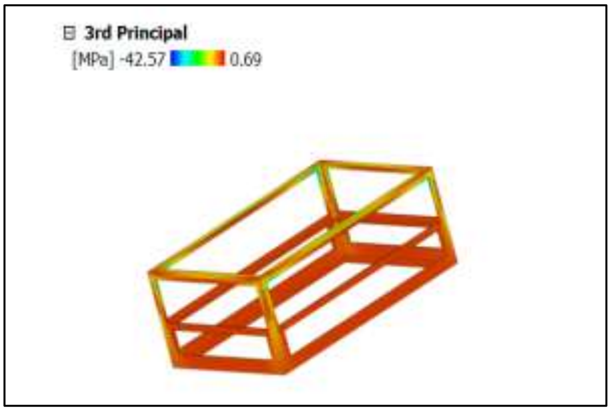

Fig. 3.4: Compressive stress

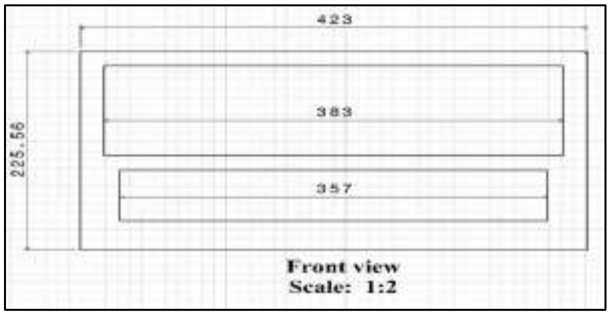

Fig. 3.5: Modified frame design: front view

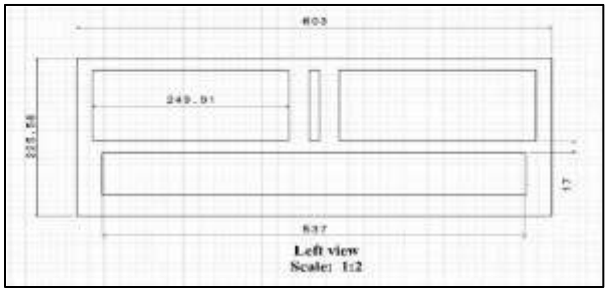

Fig. 3.6: Modified frame design: side view

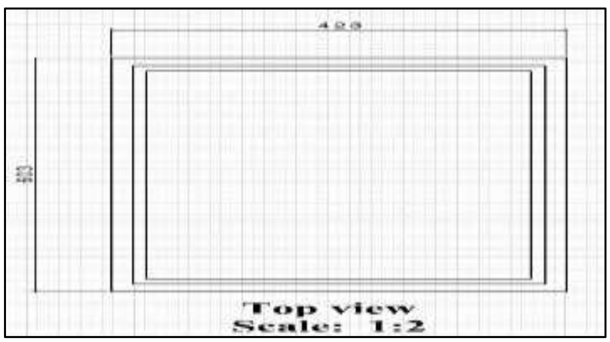

Fig. 3.7: Modified frame design: top view


Fig. 3.8: Completed prototype

D. Components Description

The major components involved in the design and the fabrication are

1) *Frame*

The frame is the supporting structure to which all the components are attached. The main function of the frame is to support the mechanical components and the seat. It also deals with the static and dynamic loads with undue deflection or distortion. These include weight of the components, occupant, vertical and torsional twisting transmitted by going over uneven surfaces, Transverse lateral forces caused by road conditions, Longitudinal tensile forces from starting and acceleration, as well as compression from braking. The frame was fabricated using MS Angle to reduce weight as well as cost.

2) *Undercarriage*

Undercarriage is the component that serves as the driver and has the left and right track drive. The undercarriage used in this project was modelled using materials available in the market. It consists of the sprocket, track link, track shoe, final drive unit, track frame. Final drive unit is set in the undercarriage that consists of gear units where transmit the power from the engine and increasing the torque.

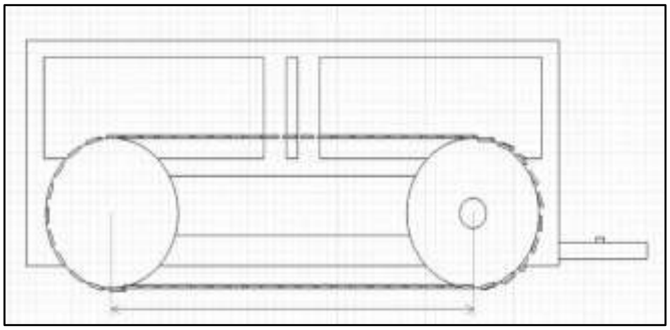

Fig. 3.9: Side view of undercarriage

3) *Spur Gear*

Spur gears, illustrated in Fig. , have teeth parallel to the axis of rotation and are used to transmit motion from one shaft to another, parallel, shaft. Of all types, the spur gear is the simplest and, for this reason, will be used to develop the primary kinematic relationships of the tooth form.

4) *Sprocket and Chain*

Sprocket is one of machine element which profiles wheel with teeth and using a chain in order to transmit the power. It is distinguished from a gear which directly contacts to a counter gear and differs from pulley which has smooth surface and using a belt to transmit the power. A chain is a series of links which assembly with sprocket in transmission of power without slip.

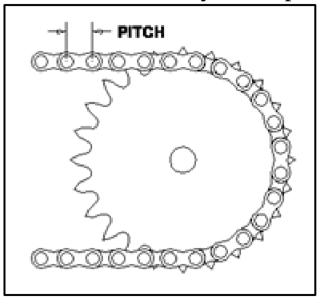

Fig. 3.10: Chain movement over the sprocket

5) *Power Transmission System*

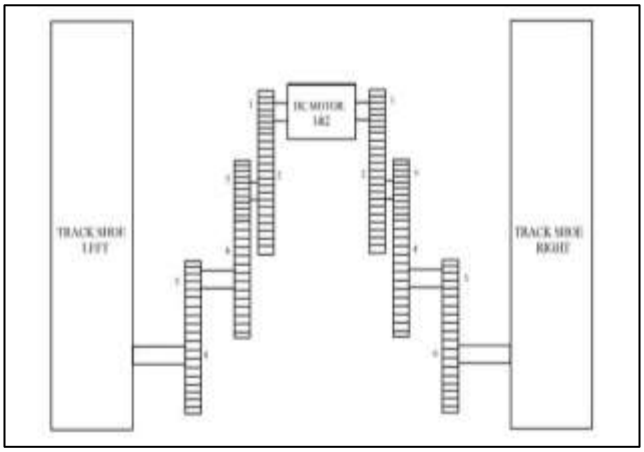

Fig. 3.11: Sketch of the power transmission mechanism

The transmission arrangement consists of 2 pairs of spur gears. The DC motor shaft is attached to a 14-tooth spur gear, which is coupled with 74-tooth spur gear. The shaft holding the 74-tooth spur gear has a 17-tooth spur gear which is mated to 17 tooth spur gear. It is then mated to a 47-tooth spur gear, and the shaft holding the same has another 12-tooth spur gear mated to another 62 teeth spur gear. This is then coupled with the sprocket. Thus, the final drive ratio is obtained as:

$$\frac{Driven}{Driving} = \frac{74}{14} X \frac{47}{17} X \frac{62}{12} = 76:1$$

Thus, having such a high gear ratio ensures that the wheelchair will not move unless the motor is powered thereby ensuring braking at all times when the motor is not operational. This eliminates the requirement of an additional braking system. Also, the high ratio ensures torque multiplication thereby permitting us to use a low power consuming DC motor. The high gear ratio facilitates torque multiplication ensuring that sufficient torque is available at the wheels and also, reducing the output rpm so that the wheelchair can move smoothly at a slow speed.

6) Chair

The chair is one of the main parts of the wheelchair. The chair is fitted on to the frame of the wheelchair. There is a tilting mechanism which connects the chair to the frame. There is need for the tilting mechanism because the person sitting on the wheelchair may feel like slipping from the seat. So with help of the seat tilting mechanism the person sitting on the wheelchair can adjust the seat to the higher angle making the seat nearest to parallel to the ground so that he may sit comfortably on the wheelchair while it is climbing a slope.

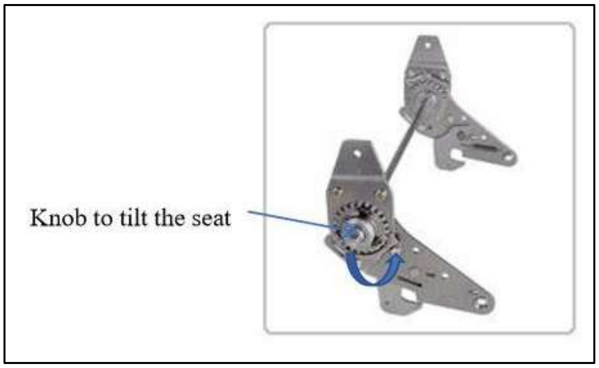

Fig. 3.12: Seat tilting system

The figure shows the seat tilting mechanism where the knob is rotated to tilt the seat to the higher position. The person sitting on the wheelchair can rotate the knob to change the position of the seat when he wants to climb a slope. With this the CG of the wheelchair will be directed towards the ground.

7) DC Motor and Electrical Circuit

The motor used for the application is a 12V, 120W 3200 rpm DC motor generating a torque of 0.458 mN.m.

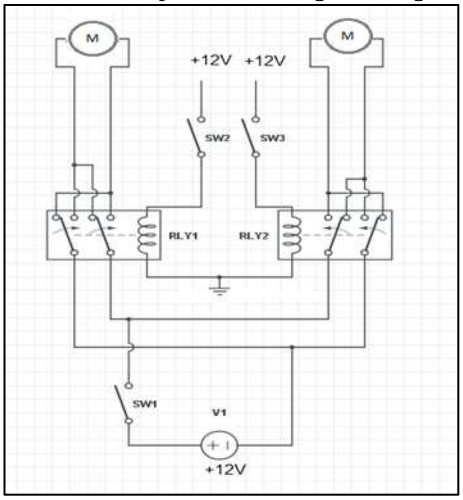

Fig. 3.13: Electrical circuit

The electrical circuit for the project is shown in the above figure.

The main components include the electrical relays, switches and the 12v DC supply battery. The circuit was constructed in MATlab.

E. *Working of the Circuit*

Initially when the master switch SW1 in turned ON, both the motors will get the supply and the motors would start spinning in the forward direction and the wheelchair moves forward. Now if we want to turn the wheelchair left/right the switches SW2/SW3 are used. When the switch SW2 is pressed then the relay connected to the corresponding switch will invert the polarity of the motor and it will rotate in opposite direction thereby allowing the wheel chair to turn and similar will be the case for SW3. Such a setup also allows the standstill rotation in 360^0. Now suppose if in any case we wish to move the wheelchair backward then both the switches need to be pressed simultaneously.

F. *Fabrication*

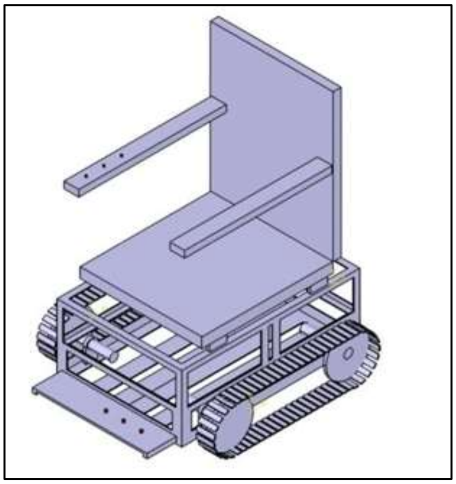

Fig. 3.14: CAD model of the wheelchair

The angle section was cut into required lengths as per the drawing and it was then welded properly in correct positions to make the frame. The chain and sprocket were used to make the track. The Track shoe is made by cutting a plate that has a thickness of 2 mm and a length of 50 mm and a width of 15 mm. Plates that have been cut was installed in the cracks of the iron cylinder has been connected with the chain sprocket. The shafts were machined to fit as per requirement. The shaft is supported at the mounting points using ball bearings inside Plummer block. The gears were then attached to these shafts. The gears were either keyed or welded. The motor and the battery were connected and the motor was fitted onto the center shaft. The transmission from the motor to the sprocket is as shown in figure. The seat tilting mechanism was fitted to the chair and then it was fitted to the frame. The wiring for the motor and the battery were made.

IV. CALCULATIONS

Torque required on a flat surface
Normal force (F_n) = force applied= mg = 100*9.81 = 981N
Since there are four sprockets to support the entire wheelchair
Friction force (F_f) = μ(F_n/4) = 0.7*(981/4) = 171.67 N
Torque required = F_f*r_w =171.67*0.085 = 14.59 N-m
Torque required on slope
Slope angle (α) = 30^0
Total mass (including setup) = 100kg = 100*9.8 = 981N
Normal force acting (F_n) = mgcosα = 100*9.81*cos (30^0) = 849.57N
Frictional force (F_f) = μ(F_n/4) = 0.7*(849.57/4)= 148.67 N
Opposing force (Of)= mgsinα = 100*9.81*sin (30^0) = 490.5 N
Torque required = (F_f + F_o) r_w = (148.67+ 490.5) 0.085 = 54.32N-m
Motor torque generated
Power of motor (P) = 2πNT/60
120 = (2π x3100 x T /60) *0.8 (i.e., 0.8 = gear transmission efficiency)
T = 0.4620 Nm
Torque available at wheel = T * 76 = 35.112 Nm
Therefore, Total torque available at the wheels while using two motors = 2 x 35.112
= 70.224 Nm

The Sprocket and chain used were the ones which were commercially available.

It was necessary that the sprocket had sufficient diameter so as to provide adequate ground clearance for the wheelchair. The length of the chain was determined using the following formulae:

$P = 2\ r_2 \sin(180/Z2)$

$L_p = 2*c/15 + (Z_1+Z_2)/2 + P(Z_1-Z_2)/(4\pi^2*c)$

Where,

P = Pitch of chain

Lp = Pitch length of chain

L = Length of chain

c = centre distance

Z1 = no. of teeth on driver

Z2 = no. of teeth on driven

The requirements of the chain-sprocket arrangement is as shown in the table 4.1.

Table - 4.1
Specifications

Criteria	*Value*
Centre distance	*460mm*
Pitch of chain	*12.7mm*
No: of links of chain	*55*
Radius of driven sprocket	*85mm*
Radius of driver sprocket	*85mm*
Length of chain	*1070mm*
No of teeth on driver	*45*

V. DETAILED OPERATION OF THE MECHANISM

The power is generated using a DC geared motor. This motor is coupled with a gear box. Due to this the high speed, low torque input of the motor gets converted to low speed high torque output. The geared box is coupled with the centre shaft which gets high torque but low rpm.

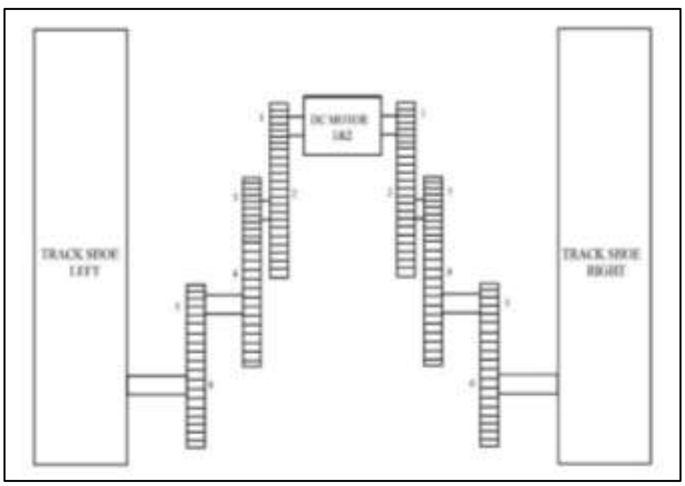

Fig. 5.1: Power transmission mechanism

Two sets of sprockets are used. In both the sets all the sprockets are of 43 teeth. The sprockets are coupled with the transmission system and track chain.

Both the sprockets receive same high torque as the motor is on the centre shaft. This torque is transmitted to both the sprockets using gears drive system. Since the sprockets are same there will be no change in the torque transmitted and also the speed will remain same. The mechanism can be seen in the in the above figure.

VI. RESULTS AND DISCUSSION

After assembly of the wheelchair, it was tested on a normal surface. Afterwards the load was gradually increased. After successful pull up to 50 kg, people with weight around 70 kg were made to sit on the wheelchair. The torque generated by the motor was sufficient to move the wheelchair. However, the limit on a plane surface was found to be 120 kg. The wheelchair was able to move through rough patches and minor obstacles in its path without many problems.

The wheelchair was then tested on a slope where the limit was around 90 kg.

The wheelchair was also tested on stairs. But here the limitation is that for the initial step the wheelchair needs to be lifted for further climbing and thus making it impractical in many cases.

Table - 6.1
Test result of the wheelchair on flat surface

Loading Condition	*Load on Wheelchair*	*Result*
On flat surface	*50*	*Successful*
	60	*Successful*
	80	*Successful*
	100	*Successful*
	110	*Successful*
	120	*Unsuccessful*

Table - 6.2
Test result of the wheelchair on slope surface

Loading Condition	*Load on Wheelchair*	*Result*
Slope (30°)	*50*	*Successful*
	60	*Successful*
	80	*Successful*
	100	*Successful*
	110	*Unsuccessful*

VII. CONCLUSION

Electric-powered wheelchairs are practical and efficient assistive devices for people with movement disabilities. However, architectural barriers, such as curbs, ramps, and stairs, present a major challenge for users of electric wheelchairs. We have presented the concept of a hybrid wheelchair with efficient mobility and maneuverability in both indoor and outdoor environments using a caterpillar track wheels. The design of the wheelchair is compact and hence is able to move about in almost all the terrains that we find at institutions, offices, industries and also at some homes. The design is made very safe and there is no chance of failure of the frame and wheels under normal conditions. According to the tests conducted, the wheelchair has a capacity of carrying a load of 100 Kg on flat surface. It has the ability to ascend 30 º degree elevations carrying a weight of 100 Kgs. However, there are limitations to our approach that will need to be addressed in future development of this mobile device. Currently, the vehicle is fully controlled by the user without any automatic systems. Also, in the current state of our wheelchair design, the user still needs to possess sufficient cognitive, neuromuscular, sensory, and perceptual capabilities to safely control the wheelchair in a complex environment with the switches provided.

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