Design & Fabrication of Staircase Climbing Wheelchair using Conveyor Belt Mechanism

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Abstract - *From 18 century many types of wheelchair had been designed, by developing its functionality. This project involves an ergonomically design and fabrication of an stair climbing functionality will be upgraded by changing its structure design and mechanism. The important parts of this product are conveyor belt, frame and driving mechanism climbing wheelchair for regular use by old disabled people.. The design of frame will be done by considering various loads, stresses at various positions. The main factor of wheelchair is laid on the angle of stair and center of gravity of whole system. Understanding the different issues regarding the functionality of wheelchair and introducing a advanced design that will be an as help for the medical field and a helping hand for disabled people.*

Keywords: - staircase climbing, track belt, base area, low cost

1. Introduction

Wheelchair is a device used by disabled people to improve their personal mobility. There are multiple types of wheelchairs present in the market like hand-operated or automatic wheelchair and the selection of wheelchair depends upon the physical and mental condition of the user. Wheelchair has some demerits against architectural difficulties on its way. As per PWD 1995 act it is compulsory to provide a hospitable environment in every public property but many buildings in India are constructed without considering convenience for disabled people and wheel chair users.

Many rural as well as urban of India have addressed the problem by providing substitutes for the constructional barriers like building ramps at entrance, wheel chair ramps, lifts etc. yet a wheelchair user had to face few architectural difficulties .In this study we will attempt to design a wheelchair prototype which can reduce the problem faced by a wheelchair users.

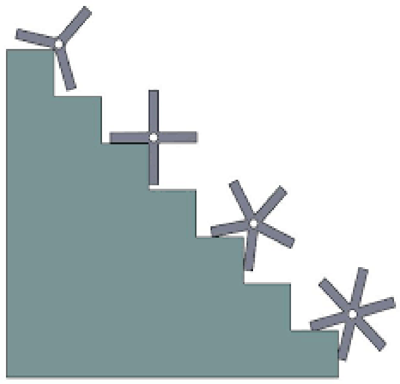
Stair climbing wheelchairs currently available for sale in market are costly for the users and are not easy to afford An automatic Stair-climbing wheelchair can be a good solution for the user and can enhance the mobility to access most of the buildings.

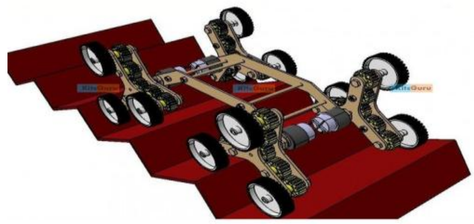
2. Literature review

This project has been made by lot of people around the globe and also in India but the mechanism behind it is what our innovation is.

The Mechanism which are available as –

1. Lobe Type Mechanism
2. Tri-Wheel Type Mechanism





Lobe Mechanism was made in Japan and it was found that it had some limitations where the lobe could climb only a particular kind of steps of particular dimensions only. Taking this into consideration was first what we did before designing the mechanism. This mechanism becomes a disadvantage because the person using the wheelchair cannot carry different types of lobes all the time and by himself won't be able to attach it. The three wheel mechanism has same problems and so the mechanism which we are making it to solve is an experiment to solve the previous problems faced.

In order to provide functionality required for climbing of stairs a mechanism suitable of climbing stairs should be provided, two approaches are presented in this thesis, proposed use of an articulated wheel cluster technology and a practical track based mechanism. Another aspect is the provision of a balance mechanism giving acceptable stability margins. During the stair climbing the providing of required stability all times is of prime important in regard to safety, and hence in the public necessity of all form of stair climbing devices. In case of wheelchair constant seat angle is required.

Climbing of stairs represents two prime problems, firstly the a negotiating of each step, and secondly providing steadiness for overall mechanism while on the stairs. In case of able-bodied person a balance is provided in form of legs and an unambiguous balance mechanism is provided by the brain in synchronicity with various sensory systems. The legs are provided with high speed & high power output actuators in form of muscles. The brain acts as the combination of visual data and tactile / pressure sensory data from the legs and balance sensors associated with the ears / brain, this provides a closed control loop.

3. Problem statement

The problems which are facing disabled people in daily life that are needed to be focused:

a) The commercial available wheel chairs do not have functionality for climbing staircase.

b) If the disabled person wants to reach higher floor during lift failure, it's inconvenient for person to move upstairs with the conventional wheel chair.

c) Some advanced wheelchairs are expensive to middle class peoples.

4. Objectives

The main of project is to design the prototype and it is as follow

a) Propose a design of wheelchair that will increase the mobility and functionality in climbing of stairs.

b) Making the total prototype as cost-effective ad as less expensive as possible.

c) Forming of a wheelchair structure that would carry up to 100 kg

5. A Proposed Diagram

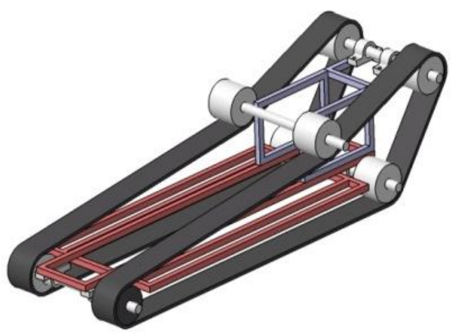


Figure. 3d model of mechanism

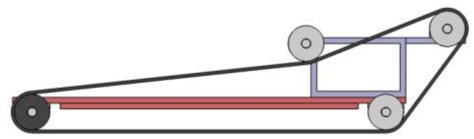
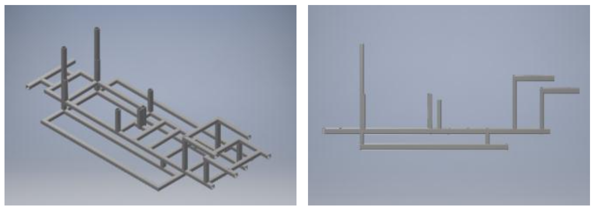


Fig. side view of mechanism

6. Selection of material and components

6.1. CHASIS:

It is made from the hollow rectangular section of mild steel. The mild steel is low in cost and the avaibility of this in market is also high. As to fulfill our objective we choose mild steel material for chassis.



CARBON STEEL:-

Composition: - Carbon→ 0.20 % - 0.30%

Manganese→ 0.30% - 0.60%

Properties- Tensile strength 44.54 kgf/mm^2

Yield stress 28 kgf/mm^2

Hardness 170 BHN

6.2. Selection of motor

The motor is use to provide the motion for the chair while climbing. The main objective is that to use the mechanism to anywhere not for the fixed area. As we need high torque during climbing we selected the geared DC motor also it reduces the problem of spark generation as compare to the AC motor.

Stair dimensions

Land: 254.0 mm

Rise: 177.8 mm

$$Slope\ of\ stair\ (\theta) = \tan^{-1}\left(\frac{177.8}{254}\right) = 35^{\circ}$$

$$Total\ mass\ acting\ (including\ setup) = 100kg = 100 * 9.8981N$$

$$Normal\ force\ acting\ (F_n) = mgcos\theta$$

$= 100 * 9.81 * \cos(35^\circ)$

$= 803.58\ N$

$Frictional\ force\ F_f = \mu F_n$

$= 0.2 * 803.58$

$= 160.7\ N$

$Opposing\ force\ (Fo) = mg\sin\theta$

$= 100 * 9.81 * \sin(35^\circ)$

$= 562.67\ N$

$Torque\ required = (F_f + F_o) r_w$

$= (160.7 + 562.67) 0.18$

$= 130.20\ Nm$

6.3. Gear box

The gear box is used to maintain speed and increase the torque transmitted. It also reduces the failure of motor during high shock. Here we use gear box of worm gear type having same number of teeth at input as well as output shaft.

6.4. Shaft

Torque calculation

$Power\ of\ motor = P = 1500\ watt$

Power transmitted by shaft,

T →Torque transmitted

$$P = \frac{2\pi NT}{60}$$

Where

, N→ Rpm of motor shaft =2000-6000

T →Torque transmitted

$$1500 = \frac{2\pi \times 6000 \times T \times 10^3}{60}$$

T= 2.38 x 10³ N-mm

Torque transmitted by sprocket

We know that,

No. of teeth (Gear), N1 = 18

No. of teeth (sprocket), N2 = 18

Ratio = R = 1 : 1

Torque on sprocket = 1 × T

$= 1 \times 2.38 \times 10^3$

$= 2.38 \times 10^3$ N-mm

Diameter of Sprocket

$Periphery = \pi \times diameter.Of\ sprocket$

$18 \times 6.25 = \pi \times D$

$$D = \frac{18 \times 6.25}{\pi}$$

D= 35.52mm

Diameter of shaft

Torque transmitted,

T = Force × radius

$2.38 \times 103 = F \times 18$

$F = 132.22N$

$$F = \frac{132.22}{9.81}$$

$$\boldsymbol{F = 13.47\ Kg}$$

Torque transmitted by shaft,

$$T = \frac{\pi}{16} \times \tau \times d^3$$

Select permissible shear stress (τ) from design data book.

$\tau = 70\ N/mm^2$

Therefore, $2.38 \times 103 = \frac{\pi}{16} \times d^3 \times 70$

D = 5.574 mm

Taking factor of safety = 1.6

$D = 1.6 \times 5.574 = 8.919 = 9\ mm$

We select dia. Of shaft = 20mm. for safety factor

6.5. Pulley: In this project we used two types of pulleys

A) Driving pulley: Here we have used Aluminium material which have medium strength alloy with good mechanical properties such as corrosion resistance and weldability.

B) Idler pulley: We have plastic polymer which is light and can be easily driven. This pulleys are used for giving support only to the belt .

6.6. Power source: Here we used 4*12v rechargeable DC battery to supply required current to drive high torque motor and related accessories

Specification:

1. 4 batteries of 12volts each
2. Cycle use :14.4V - 15V
3. Standby use: 13.5V – 13.8V
4. Charging time: 6 – 8 hours with standard charger.

6.7. Accelerometer: To accept directional instructions from the which is connected directly to controller for easy prototyping. The accelerator includes spring auto return to center it helps to avoid the stress of the operator.

6.8. Gripped Conveyor Belt: The second important component for our design is gripped conveyor belt. The pulleys will be connected using a pair of conveyer belts. The conveyer belt will be having grips to provide friction force and tractive force will be generated by the motors driving the pulleys. This combination of mechanism will help the chair to traverse and hold the inclined plane easily. A pair of pulleys is projected few a inches higher than rest to provide assistance in the climbing of stairs [4].

6.9. Selection of the bearing:

Here pedalastic bearing are selected for radial load of transportation along with the self weight of plate including friction being 10 kg. during 90% of time & 30 kg load during remaining 10%. The shaft rotates maximum at 50 rpm. We have to determine the value of dynamic load rating for5000hrs of operation with not more than 10% of failure

$W1 = 10\ kg$

$W2 = 30\ kg$

$N = 50\ rpm$

$Therefore\ no. of\ revolution\ during\ 90\%\ of\ time$

$L1 = 0.9\ x\ 50\ x\ 60\ x\ 5000$

$L1 = 13.5\ x\ 106\ min$

$Number\ of\ revolution\ during\ 10\%\ of\ time$

$L2 = 0.1 * 50 * 60 * 500$

$L2 = 1.5 * 106\ min$

$$Basic\ dynamic\ load\ rating = C = \frac{\left(L_1 W_1^{\ 3} + L_2 W_2^{\ 3}\right)^{\frac{1}{3}}}{10^6}$$

$$C = \frac{\left((13.5 * 10^6 * 10^3) + (1.5 * 10^6 * 30^3)\right)^{\frac{1}{3}}}{10^6}$$

$$C = [2160000 + 15360000]^{\frac{1}{3}}$$

$$C = [54000]^{\frac{1}{3}}$$

$$C = 37.79\ kgf$$

6.10. Selection of bolt:-

Bolt is to be fastened tightly also it will take load due to rotation. Stress for C-25 steel ft =420 kg/cm^2 . Std nominal diameter of bolt is 8mm. From table in design data book, diameter corresponding to M8 bolt is 8.160mm

Let us check the strength :-

Also initial tension in the bolt when belt is fully tightened.

P =30 kg = 300 N is the value of force applied by hand

Also,

$$P = \frac{\pi}{4} d_c^{\ 2} x\ f_t$$

$$Ft = (300 * 4)/(3.14 * 12\ x\ 0.84)$$

F_t= 3.76 N/mm^2

The calculated ft is less than the maximum ft hence our design is safe.

6.11. Design of welded joint

Checking the strength of the welded joints for safety. The transverse fillet weld all the angle and the edge, The maximum load which the weld can carry for transverse fillet weld is

$$P = 0.707\ x\ S\ x\ L\ x\ f_s$$

Where, S = size of weld , L = contact length = 30mm (5 mm for starting & stopping of weld)

The load of shear along with the friction is 45 kg = 441N

Hence, $441 = 0.707\ x\ 5\ x\ 30\ x\ f_s$

Hence let us find the safe value of 'f_s'

Therefore, $f_s = \frac{441}{0.707\ x\ 5\ x\ 30}$

f_s = 4.15 N/mm^2

Since the calculated value of the shear load is very smaller than the permissible value as f_s=56 N/mm . Hence welded joint is safe.

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7. Machining Operation:-

OPERATION SHEET

Component 1 – Frame

Material – M.S angle section

SR. NO.	OPERATION	M/C TOOL	TOOL / GAUGE	TIME (min)
1	Cut the angle as per drawing	m/c saw	Steel rule	15
2	Grind the cutting edges and bring it in Section	Bench vice	file	10
3	Drill the holes as per drawing	Radial drill machine	Twist drill	15
4	Weld the members together	Electric arc welding machine	Chipping hammer, try square	20

Component 2–Shaft

Material – Mild steel Round bar

SR NO.	OPERATION	MACHINE	TOOL/ GAUGES	TIME (min)
1.	Facing	3–jaw chuck, lathe	Single point cutting tool	30
2.	Straight turning	3-jaw chuck, lathe	Single point Tool, verniercaliper	60
3.	Polishing	Lathe	Polish paper	15

Component 3 – Pulley

Material – Aluminium

SR NO.	OPERATION	MACHINE	TOOL/GAUGES	TIME (min)
1.	Facing	3 – jaw Chuck, lathe	Single point cutting tool	54
2.	Straight turning	3 -jaw chuck, lathe	Single point Tool, Vernier calliper	54
3.	Double V-groove	3- jaw Chuck, lathe	Vernier caliper	54
4.	Centre Drilling	3 -jaw chuck, lathe	Vernier caliper	54

8. Working

DC motor –gearbox – chain drive – side shaft – main shaft or down pulley – cross pulley – front pulley ideal

A 48 V, electric supply is given to DC motor which converts electric supply to motive power. Further this motor power is transmitted to gearbox through chain drive. The gearbox is a WORM REDUCTION GEARBOX which uses a WORM shaft and a BRONZE wheel. The gearbox reduces the input speed and increases the torque enormously. The output from the gearbox is transmitted to the side shaft through chain drive. Further the drive is given to the main shaft again through chain drive. The main shaft is the bottom shaft which bears most of the module's weight. Further the drive is given to the cross pulley through chain drive. The cross pulley is the pulley installed on an inclination for climbing the stairs. For making the wheelchair climb the chair is tilted to a prefixed angle to adjust the CG during climbing. The angle of cross pulley is also set according to the stairs. For climbing the chairs the angle of cross pulley aligns with the stairs and the teeth of the belt grips the stairs and elevates upwards. Once the cross pulley climbs the stairs, the main shafts approaches the stairs and climbs the stairs. While descending stairs the base module first descends the stairs followed by the cross pulley. At the end of stair the angle of the module helps in descend.

Actual image of project

9. Conclusion

The different mechanisms were reviewed and the most appropriate were studied in detail. Their advantages and limitations were compared and the tank mechanism was found to be most suitable to fulfill the various requirements. Modeling was carried out using INVENTOR software and the results achieved were encouraging. Hence, this mechanism was used for the further development of prototype. A test model was developed and modifications were made for design for manufacturing and assembly after thorough experimentation on the model. Based on these modifications, the actual prototype was developed. The chair mechanism and the electrical controls were also mounted. The prototype was tested on level surface as well as on staircase. It is seen that the tank mechanism works effectively as it was expected.

10. FUTURE SCOPE

Since olden times man is always trying to gain more and more luxury. Man is always trying to develop more and more modified technique by improving the aesthetic look and economic consideration. But we can ignore the topic of aesthetics since it is about helping the crippled people. But us being engineers and having the capability to think and plan, we brought up this following idea. But due to and due to lack of funds required, we could mention the following modifications can be done for the project to make it even more efficient.

1. Upgrading quality of belt, The Belt is also an important component because when belt grips to the stairs, the more it can climb easily and get down as well. Caterpillar tracks are costly and not available at most places as they are used in tank tracks.

2. By using hydraulic mechanism to shift and maintain the CG, So that centre of gravity easily maintained while ascending and descending of wheelchair on staircase. It affects the stability of system and also it reduces the load on motor.

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