DESIGN OF STAIR-CLIMBING WHEELCHAIR USING TRI-WHEEL MECHANISM

Mechanical Engineering

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Abstract : The objective of this work is to develop a mechanism for climbing up and down over stairs for physically disabled people. The mechanism involved is a tri-wheel mechanism for climbing up and down stairs. The modeling is done in SolidWorks designing software. Tri-wheel mechanism is a unique mechanism for climbing stairs. The analysis is carried out by considering three different materials and the best material is suggested for fabrication. (1)The mechanism involved is a tri-wheel mechanism which is unique and simple in design for climbing stairs. The shaft is designed based on theoretical force analysis and the wheelchair is designed. The design of components is done using Solid Works software. Stress, strain, and deformation analysis are done by considering three different materials and best material is suggested. The tri-wheel mechanism is simple for fabrication and it reduces the total cost of fabrication of wheelchair. These results will help to design of shaft based on human weight. With the help of tri-wheel mechanism stair-climbing wheelchair, we can move easily up and down on stairs without building ramps in hospitals, by this construction area and money can be reduced for building hospitals.

KeyWords - Stairs, Tri-Wheel Mechanism, Wheel Chair, Ramp.

I. INTRODUCTION

The main Purpose of technology is to provide comfort to the people. Many countries are currently experiencing what is referred to as an "Aging population". The average human age is increased and accordingly the Number of old people is also increased. A common problem in every country that Older people are facing difficulty in mobility. In this regard, traditional wheelchairs and powered wheelchairs continue to play a vital role.

Though some people are born with disability, many people become disabled due to injuries and health problems. Perhaps, people with disabilities (PWD) depends non-disabled people including family members for their mobility. Wheelchairs are one of the key assistive devices for PWD across the world. Generally, wheelchairs are grouped into five categories, namely: Manual wheelchairs, Attendant-propelled chairs, rigid frame wheelchair, folding frame wheelchair and motorized wheelchair/ power chair/ electric-powered wheelchair. Among them, electric-powered wheelchair is more suitable for PWD as it reduces their dependence on their assistants.(9) The Disabled people difficult to travel from one place to another by ordinary wheelchair even though they get help from others. So most of the times the physically disabled people will remain in homes due to lack of facilities like elevators and uneven roads. Due to the above activities, it may affect their physiology and psychology (1)

A wheelchair is a wheeled mobility device. There have been a number of innovations in this field since then.Wheelchairs could be broadly classified into (1) manual wheelchairs and (2) powered wheelchairs.Manual wheelchairs require human physical power to move. The device is propelled either manually or via various automated systems. Wheelchairs are used by people for whom walking is difficult or impossible due to illness, injury, or disability.

Objectives of Automated Wheelchair

Automated wheelchairs that are equipped with sensors & data processing unit are termed as Smart Wheelchair. Our goal is to design and develop a system that allows the user to interact with Wheel chair.(15) The society nowadays concentrating on physical disabled and old people to provide solution by developing and constructing elevators, but it is not possible everywhere. So Stair-climbing wheelchair plays an important role in the life of disabled people.

This work is mainly based to overcome the disadvantages of existing stair-climbing wheel chair by incorporating tri-wheel mechanism. The tri-wheel mechanism is optimized and added to a wheelchair. The tri-wheel mechanism allows the wheelchair to climb easily up and down stairs and also to move freely on Un Even road, etc. It improves the safety and comfort of the wheelchair.

II. Literature Review

This chapter provides a study on assistive devices, focusing on mobility assistive devices and patient lift/transfer devices. It gives a bird's eye view on various commercially available wheelchairs & lift/transfer systems and a thorough literature review of researches happening in this area majorly focusing on caregiver assisted transfer devices and self-transfer devices. Manual wheelchairs require human physical power to move. There are two types of standard manual wheelchairs, self propelled wheelchair and attendant propelled wheelchair.

Eye and Voice Controlled Wheel Chair

Swati Jajee, Prof. Sanjivkumar Jalde (6) Proposed work basically depends on two systems . In Eye Control system is used to guide and control the wheelchair for disabled persons based on movement of eye. This method concept can be used for persons

with loco-motor disabilities. In this system involves three stages:image detection, image processing and sending of control signals to wheelchair. The eye movement is detected by using camera mounted on head. The output signals are then send to the motor driving circuit which will control motor actions. 2). In Voice control method Electronic system configuration, a sensor system, a dependent-user recognition voice system has been planned in this wheelchair In this way we have obtained a wheelchair which can be driven with using voice commands and with the possibility of avoiding obstacles and downstairs or hole detection. K. Velusamy, Kishore Kumar et al(7) design a wheel chair which will control by Voice of the Person. They used the Speech recognition technology.It provide a new way of human interaction with machine. Therefore the problem can be realized and optimized with use the smart phone device as an intermediary or interface. In this project interfaces has been designed therefore to develop a program for recognize speech also controls the movement of chair.

Gunda Gautam, Gunda Sumanth et al (8) work on wheel which uses the optical-type eye tracking system to control powered wheel chair. In this method eye movement are translated to screen position using the optical type eye tracking system. When user looks at appropriate angle, then computer input system will send command to the software based on the angle of rotation of pupil i.e., when user moves his eyes balls up (move forward), left (move left), right (move right) in all other cases wheel chair will stop. Once the image has been processed it moves onto the second part, our microprocessor. The microprocessor will take a USB output from the laptop and convert the signal into signals that will be sent to the wheelchair wheels for movement.

Girish Sudhir Modak, Dr.Manmohan M. Bhoomkar (2) design a stair climbing wheel chair mechanism by using Conjugate Profile Generation. It is observed that the axle is perfectly moving. They conduct trials by using thermocol prototypes. P. Swapna, Dr. B. Sharmila et. al (3) worked on Electric Powered wheel chair, In which they provide propulsion system of powered wheelchairs typically consists of a pair of motors, one for each drive wheel, and a drive train consisting of gears, belts that couples the motor's shaft to the wheel shaft. Most wheelchairs uses the permanent magnet DC motors (PM motors), with two 12V lead acid batteries providing a 24 V supply. Parmar Mehu, Patel Purvi et al (4) develop a wheel chair which operate by Motion of Head. In which the different parts used in typical wheelchairs can be replaced by drive shaft motor, sensor control, DC motors, rotating shaft. Thus makes it more accurate and has a capability to communicate with human being. Palkar Aman Manohar, Dr. Ghanshyam Das et. al.(5) develop a wheel chair which work on Planetary wheel mechanism has a great of advantages among the stair-climbing wheelchairs, which not only has a simple and compact structure, flexible movement, good stability, small fluctuation range of gravity centre, but also combines the advantages of moving on the ground and climbing stairs. Therefore planetary wheel mechanism is chosen as the walking in our design. The number of planetary wheels can be two, three or more than three, in order to realize the requirements of small volume, light weight, consideration of overturning moment and wheel cluster centre fluctuation.

Prof. Prathibha Sudhakaran ,Derick Dcunha et al (10) work on track chain wheel chair for disabaled person. As the conventional chair is used ful for smooth road, but it can not run on outdoor environments such as farms, picnic spots, off-roading or even grass fields provide additional challenges. These problem are overcome by using tracks to the wheelchair in-spite of just wheels. Adding tracks the wheelchair cannot just drive through any terrain, but also climb stairs. The chair has the ability to level at up to 45 degrees and can provide a manual lift of 6 inches.

Braking System in Wheel Chair

Mr. B. Elamvazhudi1 K. Saranraj et al (11) work on breaking of wheel chair. They provide stability to the person who travels in the wheel chair. Their work provide prototype of an Electro mechanical wheelchair. R.S.Nipanikar , Vinay Gaikwad, et al (12) worked on automated Wheel. Voice system and ultrasonic and infrared sensor systems has been integrated in this wheelchair. An automatic wheelchair which can be driven using voice commands and with the possibility of avoiding obstacles by using infrared sensors. Accelerometer also provided to this wheel chair for the movement.

Rakhi A. Kalantri, D.K. Chitre (13) works on the principle of acceleration, one acceleration sensor, provides two axis, acceleration sensors whose output vary as per the acceleration applied to it, by applying simple formula they calculate the amount of tilt. Output of tilt will decide to move in which direction. Sensor gives x-axis & y-axis o/p independently which is fed to ADC & then µC & depending on the pulse width it decides to move or not. On chair Obstacle sensors will be installed. Total 4 sensors will be installed for detection of wall/obstacle in the forward, backward, left & right direction. We are trying to build a controlled wheelchair; the system will understand and obeys natural language motion. S.D. Kumar, Avinash Jangir et al (14) Wheelchairs are being used for movingpatients in hospital as well as handicapped people. Wheelchairs are move by human efforts so this problem has been overcome by the automated power wheel Chair. In this they provide Power to wheel chair by battery which is free from pollution. It can applicable to Hospital etc. for disabled Person.

Anupam S. Bhojkar, Hrishikes D.Gaikwad et al (15) design wheel chair attach hand bike. The hand bike made up of electric bike motor, rechargeable battery, a controller electric throttle, and mechanical brakes. This type of wheel chair are light weight and safe. This motorized hand bike that can be attached to a manual wheelchair which helps the disabled people to easily ride on roads and reduces the pain on their shoulder.

III. DESIGN AND MODELING

III.1. Tri-Wheel Mechanism

The tri-wheel function will be same as the normal wheel. As external force applied it will climb the stairs due to the rolling action of wheels.

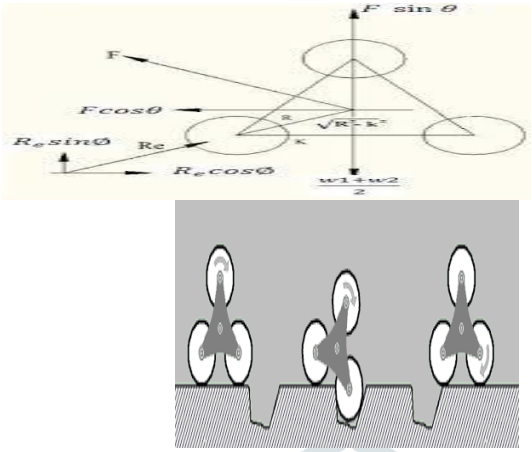


Figure 1: Tri-Wheel Working Mechanism

This wheel design is so simple, it consists of three wheels, each wheel is mounted on different shafts and shafts are mounted the almost like vertices of triangle. These set of wheels can negotiate different types of surfaces like surface with sand and mud. It allows traveling over obstruct surface like rocks, holes, in rolling action and the third wheel remains idle. Whenever there is an an obstruction occurs, the lower front wheel will stop to move forward, but the driving axle remains in motion and the top wheel will now come into action as a wheel usually lands on top of obstruction and rest of assembly will move over the obstruction. The same procedure will repeats until the required distance get covered.

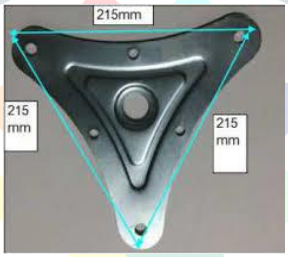


Figure 2: Quasi Planetary Wheel Frame

In this work, we are replacing the tri wheel assembly in place of normal wheels for stair climber to move up and down comfortable and easily over obstacles like bumps holes, and stair on the way.

III.2. Wheel Frame

The design of wheel frame is such that which can hold the tri-wheels comfortable on each side of the shaft. The wheel frame, first it is made of straight wheel frame and became more complicated while climbing so it is modified to quasi-planetary wheel frame to create more frictional force and provide smooth power transmission for climbing stairs. This quasi- planetary wheel frame is suitable to transmit exact velocity ratio. The wheel frame setup is designed to provide higher efficiency. The maintenance is less because of simple design parts and failure occurs in the bolt, washer, nuts,etc.

III.3. Force Analysis

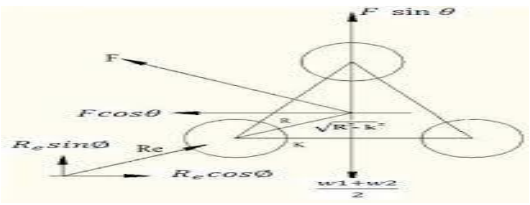


Figure 3: Force Analysis of Wheel

Force analysis deals with what are the different types of forces acting on the components or system. It is done mainly to determine the dimensions of the components. The various parameters involved are the weight of the human body, weight of wheelchair, the force applied on lever, reaction force.

Where,
W1= weight of the human body to be carried
W2= weight of the wheelchair
Re = reaction force on one side
F = force applied (on one lever)
R = 18 cm
k= 14.5 cm
Applying equilibrium conditions:
Equilibrium condition on moments

$$[\frac{w1+w2}{2} - F\sin\theta].k = F\cos\theta\sqrt{R^2 - k^2} \quad (1)$$

Equilibrium condition of forces on the x-axis:

$$R_e\cos\emptyset = F\cos\theta \quad (2)$$

Equilibrium condition of forces on the y-axis

$$R_e\sin\emptyset + F\sin\theta = \frac{w1+w2}{2} \quad (3)$$

III.4. Maximum Load Calculations

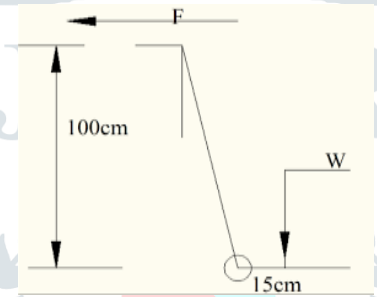


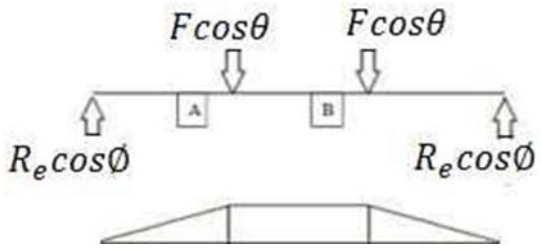
Figure 4: Maximum Load Calculations

F×100=W×15
W= (100/15)×F
When we assume F to be 98N, we get W=653.5N
Where F = Force applied on the lever, W= weight of the object measured in Newton.

III.5. Bending Moment and Stress Analysis

When an external force or moment acting on an element causing the element to bend, the bending moment is the reaction force induced in the component. It is done to know the maximum moment or force where the element can sustain.The parameters involved are different types of forces acting on it. The horizontal bending moment is calculated based on horizontal bending moment analysis diagram, a vert analysis diagram and the resultant bending moment is calculated considering both horizontal and vertical bending moment diagram. The shaft diameter is calculated by initializing parameters weight of wheelchair, lever force and resultant bending moment.
Let the length of the shaft= l m
Span of forces = a (distance between A and B)

III. 6. Horizontal Bending Moment Analysis



The horizontal bending moment diagram represents the horizontal forces acting on the shaft.

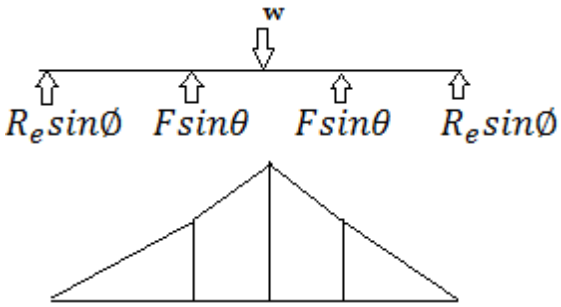
Bending Moment at point A

$$B.M \text{ at } A = R_e\cos\emptyset.X\left[\frac{1}{2} - \frac{a}{2}\right] \text{ clock wise}$$

Bending, moment at point B

$$\text{B. M at B} = R_e \cos\emptyset . X\left[\frac{1}{2} - \frac{a}{2}\right] \text{ counter clock wise}$$

III.7. Vertical Bending Moment Analysis



The vertical bending moment diagram represents the vertical forces acting on the shaft.
The critical section is identified to be the middle section
Maximum Moment at point B:
(Mb) max = Resinφ. (L/2) + Fsinθ. (A/2)
σmax = (Mb) max/ Z
Where, d= diameter of shaft
If, W1 = 67 kg, W2 =20kg, a =33cm, l=38cm, _ = 455, n=60 and Re = 75 N
Therefore, by the above analysis and estimates following moment is obtained as
(Mb) max = 6550 N mm
By Solving we get shaft diameter as d = 25.4 mm

III.8. MODELING OF STAIR CLIMBER WHEELCHAIR COMPONENTS

Stair climbing components like wheelchair frame, seat, armpad of the arm, gripper, caster fork, tri-wheels, footrest and backrest are designed using Solid works modeling tool.

Figure 7: Modeling Parts of Wheelchair: (a) Wheel Chair Frame (b) Assembly of Tri-wheel (c) Assembly of Wheel Chair

IV. FABRICATION OF WHEEL CHAIR

The following processes were used in the fabrication of wheelchair:
Gas cutting: Gas cutting uses oxygen and fuel gases to cut the different lengths required design. The parameters to be considered are the temperature of gases for steel pipes.
Pipe bending: Human powered 60^0 for pipe handle.
Plasma arc cutting: Plasma arc cutting is used for cutting four tri of an accelerated jet of hot plasma.
Arc welding: Arc-Welding is used to join trolley parts together which create an electric arc between base material by using a welding power supply to melt the metals at the welding point.

V. RESULTS AND DISCUSSIONS

Quasi-planetary wheel frame is elected for more friction for climbing stairs out of different wheel frames like straight wheel frame, curved wheel frame etc,.Theoretical calculation is done for calculating the shaft diameter by considering different parameters. Solid Works is used for designing tool.

VI. CONCLUSIONS

The stair-climbing wheelchair is designed with the help of the tri-wheel mechanism which has a compact structure and can move on the flat or inclined terrain, stairs, and obstacles. The quasi-planetary wheel frame is selected as a tri-wheel frame to create more frictional force and provide smooth power transmission for climbing stairs. This design eliminates the steps of shifting patients from wheelchair to stretcher and vice versa as nurturing of disabled people becomes difficult. Our design will thus be an efficient mobility aid for the medical field.
The mechanism and safety of patient are our main purpose while designing the conceptual model of stair climbing wheelchair. Stair climbing wheelchair avoid excessive exertion of patient as well as it make sure that the patient does not get injure.

The shaft is designed based on loads assuming and the dimensions are calculated.
The optimization of design has been designed to make the wheelchair more convenient and comfortable.
Assembling simulation is carried out in Solid Works in order to avoid interference between different parts of the wheelchair.
Analyzed by considering different material properties and suggest the best material (Stainless steel) for manufacturing.

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