Design, Fabrication and Control of Multi-Posture Smart Wheelchair

Wah Engineering College

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It is hereby declared that the work presented in this project report, titled “Design, Fabrication and Control of Multi-Posture Smart Wheelchair” is an original work of the students submitted to the Department of Mechanical Engineering, Wah Engineering College (University of Wah). The work has been accomplished under the supervision of Prof. Engr. Dr. Adnan Tariq by following:

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CERTIFICATION

This is to certify that project entitled "Design, Fabrication and Control of Multi-Posture Smart Wheelchair" which is submitted in partial realization of the requirement for the award of degree, Bachelor of Mechanical Engineering is a record of the candidate's own work carried out by them under my Supervision. The matter embodied in this report is original and has not been submitted for the award of any other degree.

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ACKNOWLEDGMENT

All the praises are for Almighty, Allah who bestowed us with the ability and potential to complete this task. We also pay our gratitude to Almighty Allah for enabling us to complete this Research Report within due course of time.

We took this opportunity to record our deep sense of gratitude and appreciation to our supervisor **Prof. Engr. Dr. Adnan Tariq** (Dean of Wah Engineering College) for his constant encouragement and inspiring guidance, and our co-supervisor **Engr. Dr. Waseem Shehzad** (Assistant Professor, Mechatronic Engineering Department, Wah Engineering College) and **Engr. Haider Ali** (Lecturer, Mechanical Engineering Department, Wah Engineering College) who were ready to lend a hand and facilitate us and eliminate all hurdles which abstracted our way during the completion of our project.

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Words are very few to express enormous humble obligations to our affectionate parents for their prayers and strong determination to enable us to achieve this job.

DEDICATION

Dedicated to our Parents and Teachers.

ABSTRACT

Physical disability resulting in the total/partial loss of movement capabilities is a traumatic experience for affected individuals resulting in physical and psychological challenges. The freedom and quality of life of both the elderly and disabled individuals are severely affected due to limbs' dysfunction. This puts their families under a huge nursing burden on a regular basis. Considering the living styles in Pakistan, it becomes tedious to transfer the patient from ground to top/other floors through stairs. Such situations require state-of-the-art technological solutions that would help the people having disabilities or require rehabilitation while facing an injury to live a mobile life thus reducing the related frustration and dependence on nursing staff/relatives. Therefore, this project addresses the problem through designing and fabrication of an intelligent multi-posture electric wheelchair with stair climbing ability. The wheelchair is convertible to three postures (bed, sitting, and standing position) with input from a numeric button for easy control of patients. For the motion of the wheelchair, a pair of electric motors integrated in the wheel hubs are used. However, chain sprocket mechanism has been attached with motors to help the wheelchair climb up the stairs. The onboard, microprocessor based, motion control system will translate the user input (direction and speed) to independent motor control signals for smooth drive through the narrow hallways and passages.

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1 INTRODUCTION

1.1 Chapter Overview

This Chapter discusses the basic concept of wheelchair and its main components.

1.2 Introduction to Wheelchair

Wheelchairs are crucial and widely used for people with disabilities to move around. When disasters like earthquakes or accidents occur, some are injured and left unable to move. This makes daily activities difficult and can even lead to health problems like high blood pressure and weak bones due to prolonged sitting. To help with this, there's a need for a device that allows them to change their position and move easily. Basic wheelchairs have evolved to let patients move themselves, and electric-powered wheelchairs take it a step further, allowing patients to control the chair with commands.

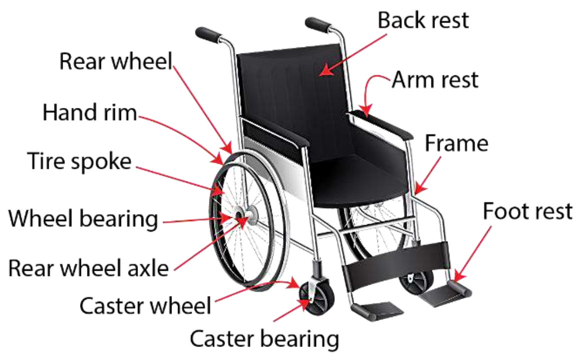


Figure 1-1: A simple Wheelchair with components

Changing positions was also a challenge for patients. They needed someone to help them move from their wheelchair to the bed when they wanted to rest, or from the bed to the wheelchair for things like checkups. Sometimes, patients even had to stand up for therapy reasons, which can be helpful for their health. But they could not stand on their own because of gravity and their medical condition. So, there was a need for a special structure that could move the patient using external power source. This structure could turn into a bed or a stretcher when the patient needed to relax. It could also help patients stand up when they are unable to do it by themselves, allowing them to try different positions for exercise.

There have been various modifications in the wheelchairs to help mankind. Especially aids for the blind and old age people. Using the gestures of hand, eyes, and through verbal communication to give the instructions to the wheelchair are the hot topic nowadays. Controlling the wheelchair through the brain signals is at the epitome. Special additions like using artificial intelligence to the wheelchair for the risk-free motion for the people with disability.

Intelligent electric stair climbing wheelchairs have a lot of advantages over traditional wheelchairs, especially when climbing up the stairs. The following are some of the primary advantages:

- **Freedom to Climb Stairs:** The main advantage of a smart electric stair climbing wheelchair is its freedom to climb stairs. These wheelchairs use cutting-edge technology to make it simple for individuals to ascend or descend stairs, such as motorized tracks or wheels that can grasp the stairwell. This function allows wheelchair users to access locations that would otherwise be inaccessible, increasing their mobility and independence.
- **Increased Safety:** Safety is a top priority in the design of stair climbing wheelchairs. When ascending or descending stairs, they contain elements like stabilizers and sensors that are embedded right into the stairs themselves. These safety features reduce the possibility of mishaps or falls, giving users and their cares peace of mind.
- **Versatility and Accessibility:** In addition to being able to navigate stairs, stair climbing wheelchairs also offer exceptional maneuverability in a variety of settings. They can readily navigate a variety of terrains, including ramps, uneven ground, and curbs. This adaptability improves consumers' overall mobility and gives them access to a larger range of locations.
- **Reduced Physical Demand:** Both the user and their care may experience physical strain while manually transferring from a wheelchair to steps. The requirement for manual transfers is removed by an intelligent electric stair climbing wheelchair, relieving the user's burden and lowering the possibility of injury to both parties. For people who need assistance or who have weak upper bodies, this feature is especially helpful.
- **Independence and Empowerment:** Smart electric stair climbing wheelchairs encourage a sense of empowerment and improved independence by allowing users to freely navigate stairs. Users are able to move around freely in their surroundings, enter public areas, and engage in activities without needing help from others. The quality of life for wheelchair users

may be considerably improved by this increased autonomy.

The wheelchair market's future prognosis is positive, with various growth prospects on the horizon. Technological improvements will continue to play an important role in market shaping. Advanced materials, sophisticated sensors, and connectivity features will improve wheelchair performance and functionality, enhancing user experience and promoting independent mobility. The global wheelchair market has a bright future, with prospects in homecare and health care institutions. The global wheelchair market is predicted to reach $10.1 billion by 2028, growing at a 5.7% CAGR between 2023 and 2028.The growing older population, rising spinal cord injuries, and rising obesity rates are the key drivers of this market.

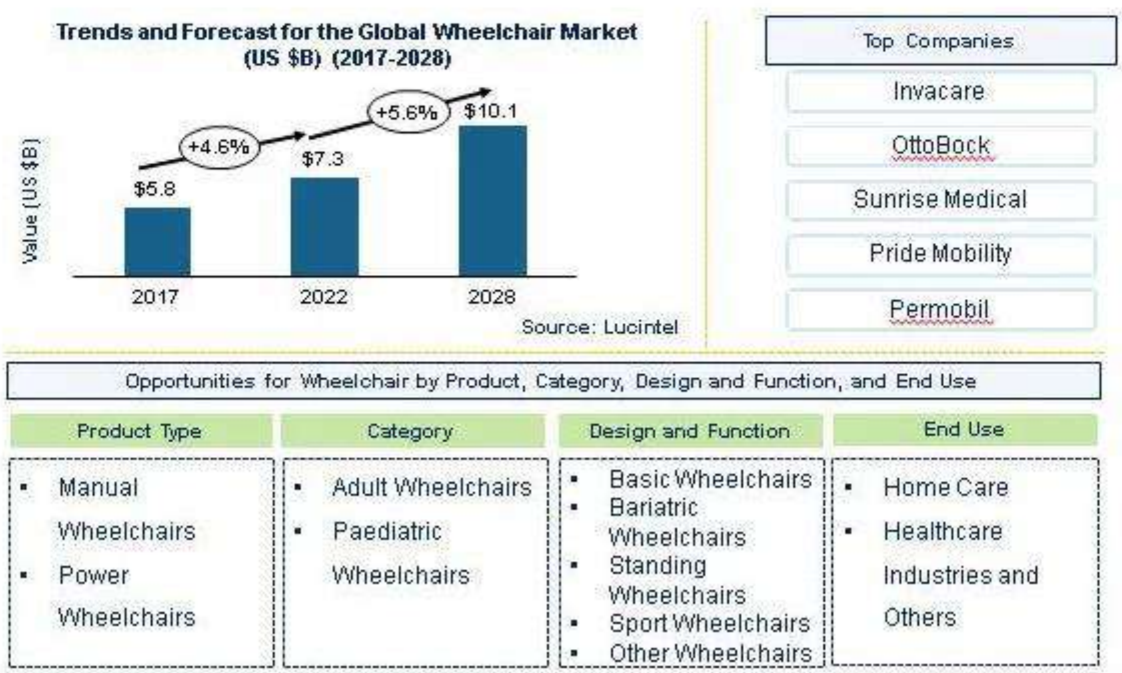


Figure 1-2: Wheelchair Market

We have proposed and developed a wheelchair able to move and being controlled through numeric inputs and convertible to three postures i.e., bed, a sitting and standing. This wheelchair will be able to carry a person of 100 kg. The standing angle of seat portion was 64 degrees horizontally to make it safe for getting tipped over. The sitting area was made comfortable to reduce the chances of developing pressure sores on the sensitive area of human body. The mobility of wheelchair was conducted through two DC powered motor one on each side of wheelchair and convertibility of back seat, sitting portion and leg portion and DC motor used for stair climbing was achieved through electrically operated linear actuators. For making an easily understandable input panel for user, the controller for all the functions of mobility and posture convertibility was controlled through Arduino microcontroller in collaboration with motor module for each motor and linear actuator.

The basic structure of wheelchair was built up with the circular hollow cross- section pipes of mild steel material. The provided design structure has enough weight reduction further weight reduction of structure may compromise the strength ability to bear load. Method of Tig welding is performed over the mild steel pipes with Argon as burning gas and mild steel filling wire to help fill holes and pores at joints, after that regular polishing was done to provide a fine and elegant looking structure.

1.3 History of Wheelchair

The first user-propelled wheelchair is attributed to Stephen Farfler, a paraplegic watchmaker who built it in 1665 when he was just 22 years old. This wooden wheelchair was heavy and difficult to push, but it represented a significant advancement in the development of wheelchairs [1].

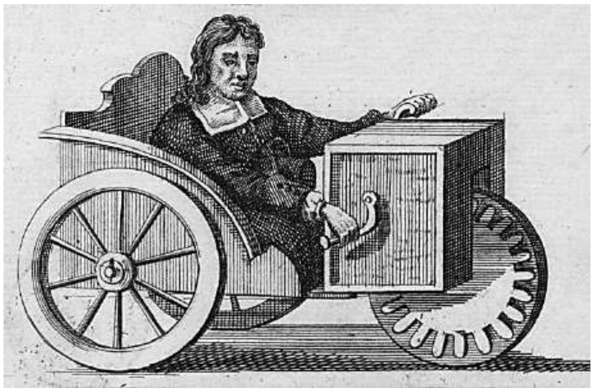


Figure 1-3: Stephan Farfler (German Scientist) - Three-Wheeled Device

In 1783, John Dawson of Bath, England, designed a wheelchair with large rear wheels and a small front wheel. This wheelchair was used to transport people to therapeutic waters in Bath. It became the most popular wheelchair sold in the early 19th century. Like many wheelchairs of that time, the Bath chair relied on attendants for propulsion [2].

During the industrial revolution of the mid-19th century, wheelchair production in the United States flourished. Bicycle and carriage makers began producing wheelchairs, replacing wooden wheels with metal ones equipped with rubber tires. Axles and frames were made of more durable metals. Comfort features such as padded parts, improved armrests, and leg rests started to appear as upgrades to base models [3].

Nias (2019) In 1932, engineer Harry Jennings designed a folding wheelchair with a tubular steel frame for his disabled friend Herbert Everest. They founded Everest & Jennings in 1933, which became a dominant player in the wheelchair industry. The "X" bracket folding frame wheelchair made it easier to transport the once heavy and cumbersome wheelchair. This innovation revolutionized wheelchair design and continues to influence it today [4].

In 1952, Canadian inventor George Klein led a project funded by Canadian Veterans Affairs and various veteran’s organizations to develop the first practical electric wheelchair. Everest & Jennings marketed the chair in 1956, marking the beginning of the power wheelchair era. The project aimed to restore mobility to the many soldiers paralyzed and unable to push a manual wheelchair after World War II [5].

Wade (2019) In the 1980s, with the introduction of lightweight materials and fixed frames, wheelchairs took on more artistic designs. Wheelchairs with bold lines, dynamic designs, and eye-catching colors were appreciated not only for their improved performance but also for their artistic beauty. Designers like Bob Hall created custom masterpieces such as the Hallmark in 1984 and the Hall's Racing Wheelchair, which was displayed at the Museum of Modern Art in 1986. These chairs became highly sought-after in their time. A wheelchair is used by people who have trouble in movability. Mostly people who use wheelchairs are paralyzed people patients at the hospitals aged people [6].

1.4 Problem Statement

Every year, about 500,000 people worldwide suffer spinal cord injuries. The main causes of injuries are traffic accidents, mishaps, falls and other accidents. These injuries may lead to disabilities and then which will make the life of the victims difficult. In order to have these disabled one run the race of normal people, technology should play its role and give necessary aids. One of the common disabilities with legs gave rise to development of the wheelchair, however, constant sitting on the wheelchair may lead to pressure sores, progression of deformities, and increased stress in the patients. Also, when they are to be shifted from bed to wheelchair and vice versa an attendant is required all the time.

1.5 Project Objective

In order to address the above problem, we have proposed a wheelchair able to convert into three postures, able to climb up the stairs and able to move with input from the numeric buttons and joystick. The following are the objectives of our project.

1. Design and fabrication of wheelchair that can change its postures into multiple positions (like sitting, standing and stretcher position)
2. Design and fabrication of wheelchair that has capability to climb up the stairs.
3. Design and installation of digital controller for changing the modes of wheelchair.

1.6 Project Background

This project is a follow up of a final year project of BSc. Mechanical Engineering, Wah Engineering College, to make several design changes required to that attempted effort. It has already been completed in three phases. The first phase included the design of a wheelchair with multi-posture conversion ability, the second was related to stair climbing and third was mainly focused on the motion and feedback control of the wheelchair using electric motors and controllers. However, in this project we are working on combining the stair climbing and posture conversion feature of the wheelchair.

1.7 Motivation to Work

Working on a smart multi-posture wheelchair is a noble and innovative idea that has the potential to bring about significant positive impact. The main reason behind this work is to help people who have limitation in mobility to lead independent lives, allowing them to engage in various activities both social and professional, leading toward better physical health and overall, well-being of all users. We also want to manufacture smart stair climbing wheelchairs as a product due to its potential to attract stakeholders and generate revenue. There is a consistent and growing demand for wheelchairs due to the aging population and the prevalence of mobility challenges caused by various factors such as accident. This sustained demand can motivate manufacturers and suppliers to invest in producing and selling wheelchairs.

1.8 Roadmap of the Document

There are five Chapters in this thesis. These are organized as follows:

Chapter 1 presents an introduction to wheelchairs.

Chapter 2 presents the literature survey on wheelchairs.

Chapter 3 describes the design for the multi-posture and stairclimbing wheelchair.

Chapter 4 describes the manufacturing process to be applied to manufacture the wheelchair.

Chapter 5 describes the control component and coding for controlling movement of wheelchair.

Future Recommendation is the part of document after chapter 5. The References cited in the thesis document appears at the end.

2 LITERATURE REVIEW

2.1 Chapter Overview

This Chapter describes the literature review of wheelchairs. This chapter involves summary of research paper, article related to various aspects of wheelchair.

2.2 Literature Review

Degonda (1999) introduced a wheelchair which is used for the disabled persons. It consists of a framework which is divided into two portions. The first frame portion is armed with the two main wheels are driven by a separate motor. And the second frame portion utilizes one wheel to contact the ground at the opposite end of the seat. A spring device is joined between two frameworks to supply and discharge the energy [7].

Montiglio (1999) created a wheelchair which can be converted into different sizes. This type of invention relates to a new wheelchair that is adjustable in different length, width and height. It can be adjusted to different users of different sizes or to a child growing up. This wheelchair has a T-shaped rear frame [8].

Kauffmann (2000) designed an affordable wheelchair which helps the patient move and supporting in standing and sitting positions. The electric machine is used in this apparatus to lift the person from sitting to standing position and bring down the person from standing into sitting position [9].

Johnson (2001) developed a standing wheelchair comprises of a basic frame, a pair of front wheels that drive the wheelchair, the seat assembly which is pivoted at the front top of the frame which further includes the seat portion that can move between seat position and standing position at lift angle up to 63 degrees with horizontal. The seat assemblies can be removed, and other types of seat designs can be adjusted. Footrest is grounded or stabilized as seat move to standing mode. The wheelchair is given in Figure 3 [10].

Figure 2-1: Johnson Model for Wheelchair

K. Cox (2002) created a step-climbing wheelchair involving a seat and frame with spoked wheels on either side. There is a little wheel toward the end of each spoke. A pitch sensing gadget and PC controlled pitch deposition modifying skids on front and back corners of the edge keep the wheelchair seat level during step climbing [11].

B. Carsten (2002) worked on an invention which identifies engine-driven stair climbing gadgets, specifically wheelchairs for impaired people. The wheelchair was connected to the step climber but could be removed [12].

Figure 2-2: B. Casten Model for Wheelchair

Trancosa (2003) used hydraulic mechanism in wheelchairs for lifting the patients. A person on the wheelchair drives a switch get together to raise the jack from sitting to stand position. This wheelchair has solitary bar that has a lower central edge and an upper central casing so that a lift position between lower central edge and upper central casing the lifting forces from sitting to standing position [13].

Masaki Fukuchi et al (2004) in this paper, worked on a robot whose shape is more human, they designed this robot to climb stairs and move on flat ground [14]. Tanaka (2005) electroencephalogram EEG technique is used for the robotization of the wheelchair. Using the EEG signals from the brain the motion of the wheelchair was carried out. There is a distinctive sort of interfaces and interchanges among human and machines which can be meant control the wheelchair [15].

Figure 2-3: Tanaka Model for Wheelchair

R. Quigg (2005) worked on a step climbing wheelchair comprising a chair, a frame which supports the Seat, a set of wheels on which the wheelchair moved during ordinary tasks, and a couple of indistinguishable track assemblies on which the wheelchair moved when plummeting and rising [16]. Schaffner (2006) focused on the motion of wheelchairs using electric motors with better suspension. The forward wheel is connected to the frame of the wheelchair with supporting the suspension flexible spring and suspension being connected to the frame with the rear wheels. A joystick is used for controlling the movement of the wheelchair [17].

R. Morales et.al (2006) discussed that there is a great demand for an economical and efficient way of climbing stairs with a convenient wheelchair. With user safety as a primary concern, the objective of this report is to provide a lightweight and affordable wheelchair for climbing stairs. The wheelchair is given in Figure 6 [18].

Figure 2-4: R Morales Et.al Model for Wheelchair

W. Franco & R. Oderio et al (2008) also used wheeled type mechanism. They used delta wheels as the stair climbing mechanism. They also used an actuator for self-balancing seat mechanism. This chair can move on regular and irregular terrains. They conducted all kinematic, dynamic and structural analysis. They also added electronic sensors and environment recognition to it [19].

Negishi & Masaaki (2008) focused on developing a wheelchair for disabled people. It has a battery for providing power to motor. The motor helped it to climb the stairs. They used cam and follower mechanism for balancing chairs during climbing on the stairs, but the manufacturing cost is high and it gave a lot of jerks to the user during the climb. A joystick was used for controlling the movement of the wheelchair [20].

R. Morales & Gonzales (2009) used wheeled type mechanism for climbing wheelchair on stairs. They used four rubber wheels in an automatic robotic system. They used actuator for balancing seat during climbing on staircase. They started to work to increase the abilities of the curve planner in order to reduce the time wasted in crossing obstacles [21].

Giuseppe Quaglia Et.al (2009) analyzed in this paper is about Pram, a concept of a wheelchair for climbing stairs capable of moving in structured and unstructured environments, climbing obstacles and going up and down stairs. The four-bar linkage moves and rotates the chair to prevent the wheelchair from tipping and to ensure a comfortable position for the passenger during various operations. The kinematic synthesis of the binding mechanism is analyzed by an algebraic method [22].

Salmiah Ahmed Et al (2010) developed the wheelchair with three modes: stair climbing mode, electronic wheelchair mode and manual mode. The walking mechanism was first designed, along with the theoretical design and calculation that were used to decide on the structure and size; then the design of the transmission system was followed. A seat back adjustment system has been designed to adjust the center of gravity before going up and down the stairs. At the same time, a locking system has been installed to make the wheelchair more secure [23].

S. Yu et al (2010) defined a different type of mechanism. He used a different type of arrangement of tires with different size and used belt for moving chairs on stairs. He improved the ability of a wheelchair to climb stairs. They improved the terrain adaptability of wheelchairs on the peak of stairs [24]. Y. Sugahara et al (2010) worked on a four-bar linkage wheeled type mechanism. He used gear mechanism for balancing the wheelchair during the process of climbing on stairs. He did not fabricate a wheelchair. He made a prototype on experimental results. Experimental results come from different equations and analysis on software [25].

Chen (2011) focused on the electric wheelchair. The suspension system is installed on this electric wheelchair. This wheelchair provides good stability or comfort while driving through curved surfaces or raised surfaces [26]. G. Quaglia et al (2011) designed a stair climbing wheelchair capable of climbing over obstacles and going up and down stairs using delta wheels and a four-bar linkage mechanism. The four-bar linkage moves and rotates the chair to prevent the wheelchair from overturning and to guarantee a comfortable [27].

Jost (2012) recommended that a mechanized wheelchair incorporates an edge, a battery support get together that Supports a battery box and is associated with the casing, first and second power drive congregations arranged on every sidelong side of the wheelchair, first and second back wheels driven by the power drive gatherings, first and second caster wheels driven by the power drive gatherings, and first and second caster wheels that are urgently associated with said casing [28]. L. Fang et al (2012) used a mechanical control system for the stair climbing case. Planetary wheels are used during the climbing of staircase and the Linear Actuator is used for the seat balancing purpose [29].

Lin Zhang Et.al (2012) designed a manual wheelchair that can move both on level ground and upstairs. In the project, instead of using the normal wheels, we used the Penta wheel. The steel bar is Penta in shape and each bar is also tilted 72 ° to each other. When climbing, one wheel which is the free wheel will be in contact with the ground and another wheel will be in contact with ladder

[30]. R. Rajasekar et al (2013) focuses on the development of a compact wheelchair control strategy for climbing stairs to maintain stability and balance when climbing stairs in confined spaces for the elderly and disabled. The challenges are to control the front and rear motors and the lean angle to ensure system stability and keep the climbing process smooth [31].

Figure 2-5: R. Rajasekar et.al Model for Wheelchair

S.K Choudhary (2013) focused on the control of the wheelchair for climbing stairs with inertia uncertainties and external disturbing torques a new method of synchronous control is proposed combining with cross-coupling techniques. For this, a special controller is designed, capable of improving the performance of the system under conditions of uncertainty and torque disturbances and ensuring the synchronization of the system [32].

Juanxiu Liu et.al (2015) the main objective is to improve the lives of people with disabilities by providing them with an independent and comfortable living environment. This document aims to design a wheelchair for people with disabilities. The proposed project is mainly focused on upgrading the wheelchair with lowered stairs. The wheelchair is designed with CATIA software and the group's wheel drive mechanism is used [33].

G. Quaglia et.al (2016) the functional design and kinematic synthesis of a recent version of an electric wheelchair stair lift. The proposed device represents the latest evolution of the "Wheelchair" project and introduces several improvements over previous models. With a suitable cam profile, it is possible to compensate for the oscillations that enter the wheelchair during the ascent sequence and allow the user to obtain a translational path [34].

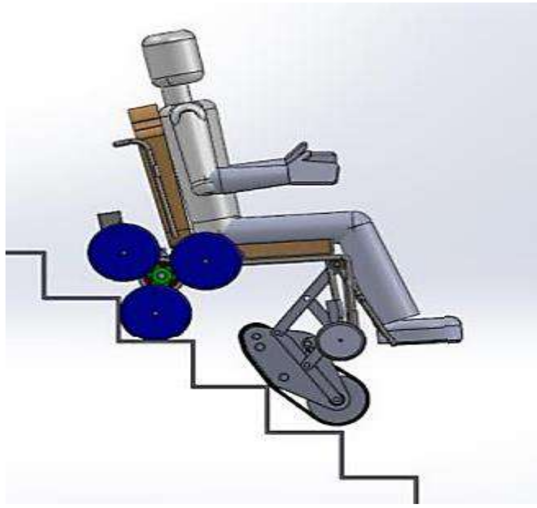


Figure 2-6: G. Quaglia.et.al Model for Wheelchair

Ugale (2017) proposed a new design that is comfortable for those who use it generally. The main objective of this project is to use the software design to predict the actual working of converting nature of the wheelchair into stretcher so that actual model could be manufactured. This would provide ease for patients having physical disabilities [35].

Matteo Nisi et.al (2018) worked in this research to develop a mechanism for climb up and down stairs for people with physical disabilities. The mechanism involved is a three-wheel mechanism for going up and down stairs. Modeling is done in SolidWorks design software and analysis is done in ANSYS software. The three-wheel mechanism is a unique mechanism for climbing stairs. The analysis is performed considering three different materials and the best material for manufacturing is suggested. The axle is designed based on theoretical strength analysis and the wheelchair is designed [36].

Blake (2018) proposed and developed a standing aid for the person to move from wheelchair to bed. The proposed design consists of sliding mechanism to move person away from caster wheels and lift mechanism to lift the pelvis area help them in standing on the ground and then they can move to toilet or do other tasks leaving wheelchair. CAD model was developed and then actual model for testing the feasibility is manufactured [37]. Dawar (2019) designed standing wheelchair for the disabled people majority of them are paralyzed from lower part of body, but upper part of body can work effectively so that they can stand independently and do their normal routine work moving around in that posture. They wanted to achieve this posture transform ability in cost effective way that can be mobilize able as well. The structure can lift load up to 90Kg with the help of gas spring actuator and five bar lifting mechanism [38].

J. Anjaneyulu et.al (2019) described stair climbing wheelchair using lever operated swivel feet with postural transition mechanism. The design principle of this wheelchair is to utilize the latent capacity of the user's upper body, with appropriate mechanisms to allow extended functionality of the normal wheelchair without the need for heavy and expensive motors or electric mechanisms. An arm mechanism allows the user to walk steps and stairs independently without any external power source. The developed wheelchair consists of manual wheels with casters for flat locomotion, offering capacities equivalent to a normal manual wheelchair [39].

Kai Sasaki et.al (2020) offered an approach to climbing stairs for a four-wheeled vehicle. The idea and approach for the climbing the stairs are described and results of the experiments are presented by the authors. Tracked vehicles and vehicles with special and complex mechanisms are commonly used to climb continuous steps of the stairs. In contrast, this article looks at a four wheeled vehicle with further degrees of freedom, the mechanism of which is not so complicated [40].

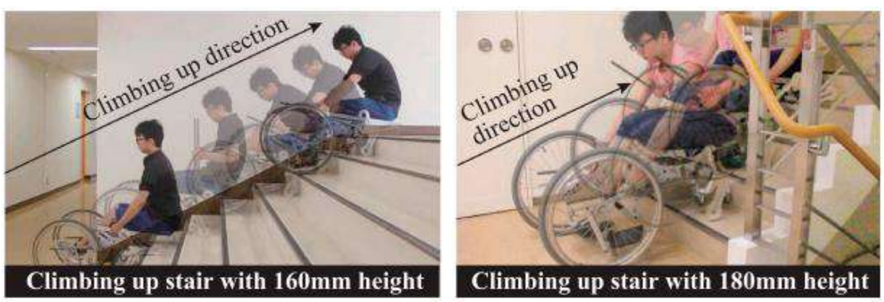


Figure 2-7: Kai Sasaki et.al Model of Wheelchair

The cost of different type of wheelchairs in Pakistan are given below.

Table 2-1: List of wheelchairs from different companies with their cost

Wheelchair Type	**Company Name**	**Price (Rs)**
Manual Wheelchair	Lifecare Enterprises	32000
Powered Wheelchair	Tango 3	90000
Stair Climbing Smart Wheelchair	Entra Stair Climbing Wheelchair	250000
Posture Smart Wheelchair	Power Wheelchair – NSL123	175000

2.3 Literature Gap

The following table gives the literature gap for our project.

Table 2-2: Table for literature gap

Sr. No	Paper Title	Author	Year	Multi-posture			Stair Climbing	Manual	Automated
				Sitting	Standing	Bed			
1.	Motorized Standing wheelchair	Jay A. Johnson et al.	2001	✓	✓	✗	✗	✓	✗
2.	The "Hands-free" Wheelchair Control System	Torsten Felzer and Bernd Freisleben	2002	✓	✗	✗	✗	✗	✓
3.	Kinematic model of a new staircase climbing wheelchair and its experimental validation	R. Morales V. Feliu	2006	✓	✓	✗	✓	✗	✓
4.	Wheelchair, a mechanical concept for a stair climbing wheelchair	Giuseppe Quaglia	2009	✓	✓	✓	✗	✗	✓
5.	Intelligent Joystick for controlling power wheelchair Navigation	Yassine Rabhi et al.	2013	✓	✗	✗	✗	✓	✗
6.	Design and Fabrication of Staircase Climbing wheelchair	R Rajasekar et. al	2013	✗	✗	✗	✓	✓	✗
7.	Mechanically operated wheelchair convertible stretcher	Ninad M. Borkar	2016	✓	✗	✓	✗	✓	✗
8.	Conceptual Design of Stair Climbing Wheelchair using Catia	Chinmaya Sukhwal	2016	✓	✗	✗	✓	✓	✗
9.	Design and fabrication of convertible wheelchair	Nirmal Mistry et al.	2018	✓	✓	✓	✗	✗	✓
10.	Voice controlled automatic wheelchair	Sumet Umchid et al.	2018	✓	✗	✗	✗	✓	✗
11.	Design of Stair-Climbing wheelchair using tri-wheel mechanism	Pothamsetty Kasi v Rao	2018	✓	✗	✗	✓	✗	✓
12.	Wheelchair Cum Stretcher For a Disabled Person	Sk. Muzeeb et al	2020	✓	✗	✓	✗	✓	✗
13.	Stair-climbing wheelchair with lever propulsion control of rotary legs	Kai Sasaki	2020	✓	✗	✓	✓	✓	✗
14.	Design and Fabrication of a Multi-Tasking Convertible wheelchair for Disabled Persons	Batch 2018	2022	✓	✓	✓	✗	✓	✓
15.	Design and Fabrication of a stairclimbing wheelchair	Batch 2018	2022	✓	✗	✗	✓	✓	✗
16.	Design and Fabrication & Control of a Multi-posture smart wheelchair	Our Project	2023	✓	✓	✓	✓	✓	✓

2.4 Gap Analysis

Following gap points can be inferred from the literature,

1. No work has been carried out in Pakistan regarding posture convertibility and stair climbing ability feature in single wheelchair.
2. The wheelchair available in Pakistan are of high cost and no one has both stair climbing and multi-posture ability.

To cover for the above points, our project accounts for the development of the economical wheelchair with the abilities of both stair climbing and posture conversion.

2.5 Methodology

The methodology for the project is given in figure 2-8.

2.6 Summary

This chapter presented the literature review for the advancements in wheelchairs. The gap was identified and for a given gap, a model of the wheelchair was presented in order to cover for the gap. At the end a methodology for the project was provided.

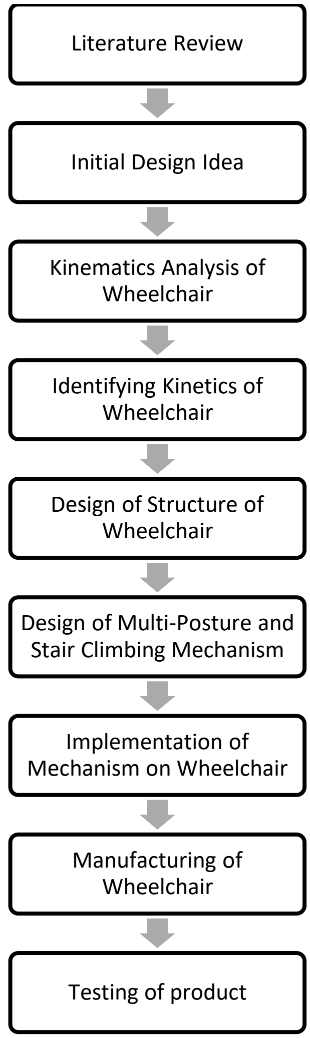


Figure 2-8: Methodology

3 DESIGN OF WHEELCHAIR

3.1 Chapter Overview

In this chapter an initial design idea and design calculation of wheelchair are given below

3.2 Initial Design Idea

The basic structural design for a wheelchair was drawn up in a notebook, then after some fine-tuning exercises, the design was created using the Creo Parametric software. All components were 3D modeled and then assembled on software to create full geometry. The members of the construction have a thickness of 0.9 mm and a diameter of 25mm. Seat Linear actuator is extended to bring the model into the standing position which shifts it up to 70 degrees from horizontal at its longest extension.

The linear actuator that is related to leg-rest, when operated then a wheelchair also converts its posture to another one. When actuator that is coupled with an armrest has been fully extended, the structure is transformed into a stretcher.

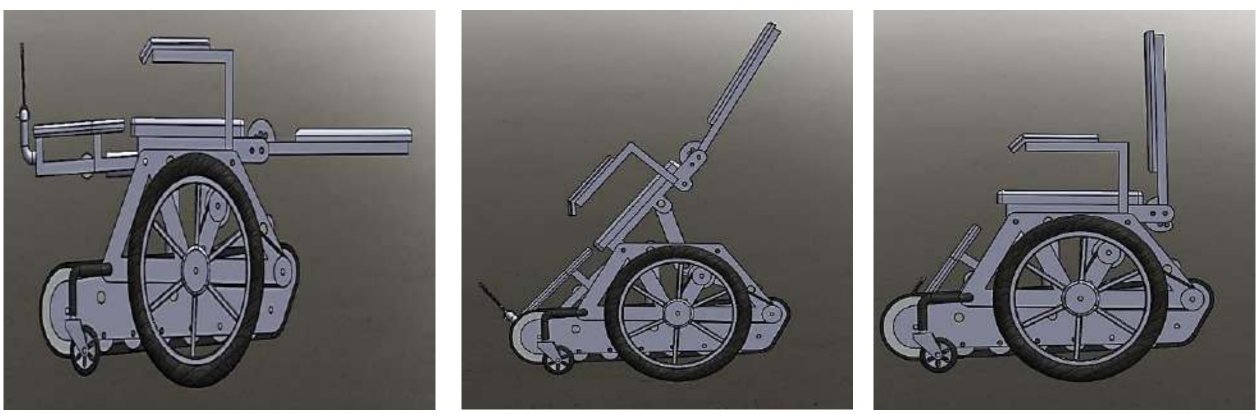


Figure 3-1: Different Postures of Wheelchair

For Stair climbing operation a Track-Chain mechanism was deployed with the help of linear actuator so when a wheelchair encounters stair a Track-Chain mechanism was deployed, and it will start to climb up to stair.

3.3 Required Design for Wheelchair

The following are the components for the design of a posture convertible and stair climbing wheelchair.

1. Design of Structure
2. Design of Stair Climbing Feature
3. Design of Multi-Posture Mechanism

The components of wheelchair are listed below and shown in Figure 12.

a. Structure that holds the weight of physically challenged people.
b. For Posture Conversion
    1. Linear Actuators (4 used: one for backrest, footrest, standing, track mechanism)
c. For Stair climbing
    1. Track Mechanism
    2. Shaft
    3. Bearing
d. For Mobility Purpose
    1. DC gear motors (attached on each side of rear wheel)

3.3.1 Design of Structure of wheelchair

The main components, as seen from the figure, are the seat, back rest, footrest, and legs of a chair. The seat, however, is a rectangular plate which has been replaced with a series of rods joined together with a space in between and a cushion is placed over it for sitting purpose. The load bearing by the seat is given in figure as below.

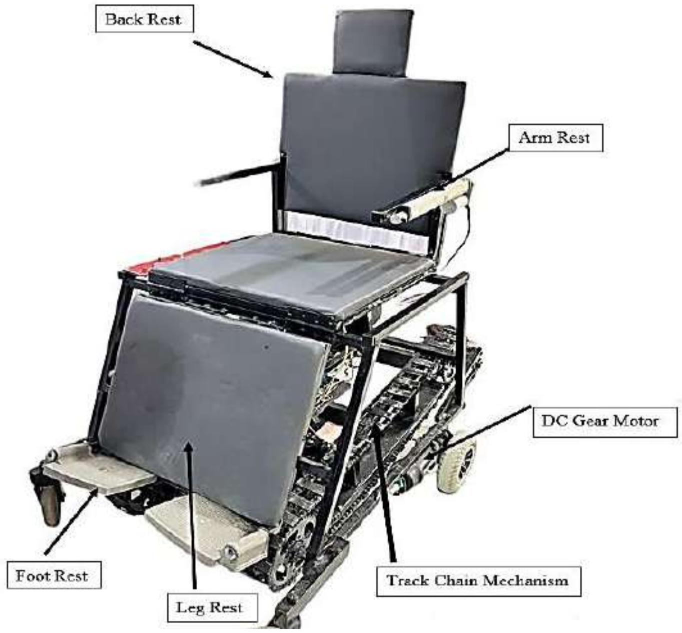


Figure 3-2: Main Components of Wheelchair

This design of a wheelchair is intended to support a maximum mass of 100 kg.

Mass of common person = m = 100 kg

Convert this, mass of person in terms of Force (N) **=** W = mg = **980N**

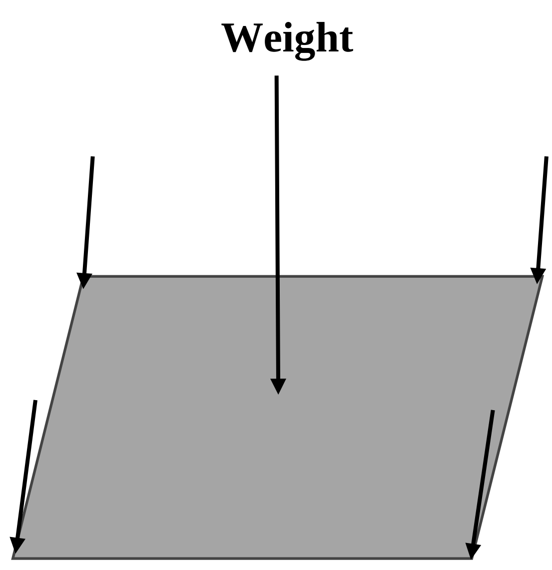
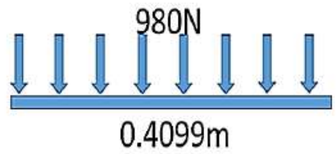
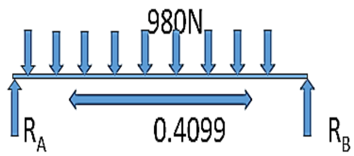


Figure 3-3: Forces on the wheelchair seat

The seat of a wheelchair can be considered as a horizontal beam, and the weight of the person sitting on it can be treated as a uniformly distributed load along its length. As the seat is square in shaper therefore the length is equal to width of the wheelchair which is given below.

Seat Length = Width of seat = L = 0.4099 m





In X-direction no forces act, because no external forces act on a beam, it is typically due to a state of equilibrium or a balanced condition The forces act only along Y-axis (F_y), Therefore:

$$\sum F_y = 0$$

$$R_A + R_B - 980 = 0$$

Where;

R_A = Reaction force at support A

R_B = Reaction force at support B

$$\sum M = 0$$

Where M = Bending Moment of Beam

For bending moment take one point zero and revolve around it.

Clockwise= -ve

Anticlockwise= +ve

$$(R_B \times 0.4099) - 980 = 0.4099/2$$

$$R_B = 490\ N$$

Then R_A is calculated as follows;

$$R_A + R_B = 980$$

Putting value of R_B in above equation;

$$R_A = 980 - 490$$

$$R_A = 490 \text{ N}$$

Now calculating maximum bending moment for the beam;

$$M_{max} = \frac{1}{2}(w \times l)$$

$$M_{max} = \frac{1}{2}\,(490\ \times \frac{0.4099}{2})$$

$$M_{max} = 50.21\ N/m$$

σ_y = Yield strength of mild steel
c = maximum distance from the neutral axis
I = moment of inertia of component

$$\sigma_y = \frac{M_{max}}{I/c}$$

Taking the cross section of the rod as Hollow Square rod.

$$Allowable\ stress = \frac{\sigma_y}{FOS}$$

$\sigma_{allowable}$ = 50.21 / 2 MPA
σ_b = 25.105 Pa

By Flexure Formula;

$$\sigma_y = \frac{M_{max}\ c}{I}$$

Section Modulus=Z=I/c=315.5 mm^3

The section modulus of 25.4x0.9mm hollow square rod is:

Z=I/c=410 mm^3

In a wheelchair, the member that acts as a column is typically the vertical support structure that connects the seat or base of the wheelchair to the wheels or the ground. This vertical member provides stability and helps to bear the weight of the user. It is commonly referred to as the wheelchair frame or frame column.

Columns are designed on buckling;

$$P_{Cr} = \frac{\pi EI}{L_e^2}$$

Where;

E = Modulus of elasticity

I = Moment of inertia

P_{cr} = Critical load

L_e = Effected length

L = Original length

Now both ends fixed at column so;

$$L_e = \frac{L}{2}$$

$$= 0.51\ m$$

Modulus of Elasticity for mild steel = 194GPa

$$L = 4099\ m$$

As we know that moment of inertia for Hollow Square rod is given by;

$$I = \frac{D4 - d4}{12}$$

Putting the values in the above formula; where the value of D = 17 and d = 12:

$$I = 5232.083\ mm^4$$

$$P_{Cr} = \frac{\pi(1.95 \times 10^5)(5232.083)}{0.51^2}$$

$$P_{Cr} = 12316\ KN$$

Now calculating buckling load for the column;

$$F_b = 490 \cos(26.5)$$

$$F_b = 440.4\ N$$

Note:

Whether the column in a wheelchair is safe to utilize, we need to compare the applied load (buckling load) with the column's capacity (ability to resist buckling). In this case, the applied buckling load is 440.40N, and the column's capacity or ability to resist buckling is given as 12316 KN (12,316N).

Comparing the applied load to the column's capacity, we find that the applied buckling load (440.40N) is significantly lower than the column's capacity (12,316N). This indicates that the column has a sufficient margin of safety. Based on this comparison, we can conclude that the column in the wheelchair is safe to utilize, as the applied buckling load is well below its capacity to resist buckling.

3.3.2 Design of Stair Climbing Feature

The components that are required for stair climbing mechanism are designed and calculated below;

1. Design of Shaft
2. Design of Bearing
3. Chain Drive Mechanism

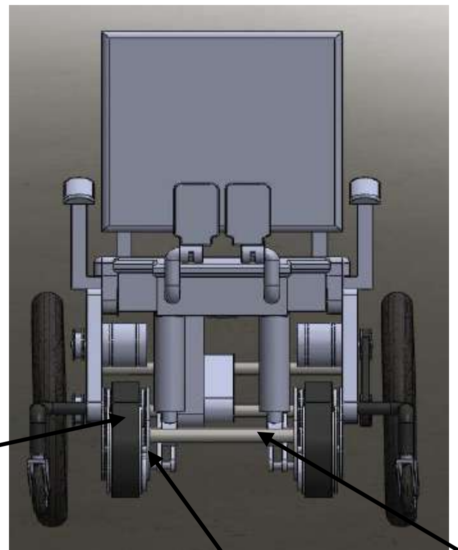


Figure 3-4: Design for Stair Climbing Feature

The wheelchair is designed to climb the stairs at Wah Engineering College. The angle of inclination of stairs will define the force for the wheelchair. The angle of inclination can be found by using a simplified diagram for stairs as given below.

Table 3-1: Standard Stair Dimensions

Standard	Going (mm)	Riser (mm)
AS1657	215-355	130-225
BCA Recommendations	240-355	115-190

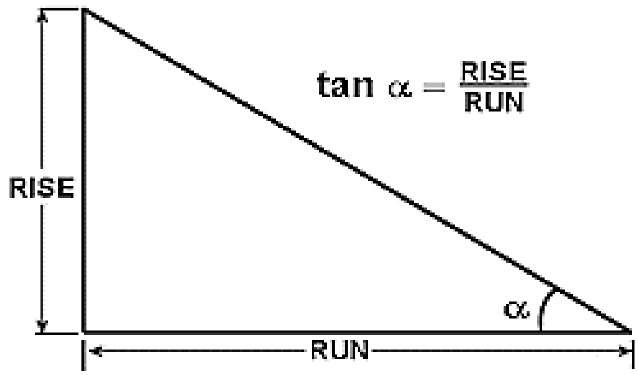


Figure 3-5: Calculation of Angle of Stair

Angle Range = $20^{o} - 45^{o}$

The dimension of stairs of Wah Engineering College (WEC) are given below;

Riser of stair = 152.5 mm

Tread of stairs = 304.8 mm

Slope of stairs (θ) is calculated as follows;

$$\theta = \tan^{-1}\frac{152.5}{304.8}$$

$$\theta = 26.5^{\circ}$$

For the person of weight 981 N, the required force to move wheelchair on ground is calculated below;

Now calculating force required for sliding of wheelchair on the ground.

$$F_{req} = \mu \times mg\cos\theta + mg\sin\theta$$

Put (θ) = 0

$$F_{req} = 392.4\ N$$

Now calculating force required for rolling of wheelchair on the ground;

$$F_{req} = \mu_r N$$

Put μ_r = 0.04 (Rolling friction for mild steel on concrete)

$$F_{req} = (0.4)(981)\cos 0^{\circ}$$

$$F_{req} = 39.24\ N$$

$$39.23 < 392.4$$

Therefore, when moving on the ground in a sliding case (sliding without rolling), the F_{req} is generally higher compared to the ground rolling case. This is primarily because sliding involves a higher degree of friction between the wheelchair's wheels and the ground, which leads to a higher F_{req} of motion. In contrast, in the rolling case, the wheelchair's wheels can rotate freely, reducing the friction and subsequently lowering the F_{req} of motion so, system will roll instead of slip.

For the person of weight 981 N, the required force to move up the stairs can be calculated from figure and equations given below.

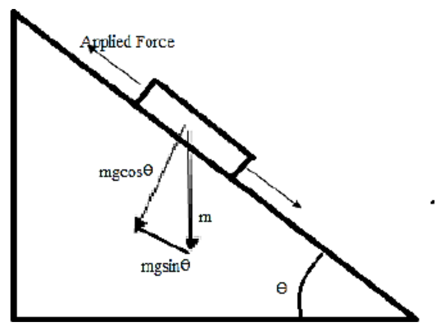


Figure 3-6: Inclined Surface

Normal component of force is calculated by;

$$N = mg\cos\theta$$

$$N = 981\cos 26.5^{\circ}$$

$$N = 877.9\ N$$

Force along the surface is calculated by;

$$F = mg\sin\theta$$

$$F = 981\sin 26.5^{\circ}$$

$$F = 437.72\ N$$

As stairs are made of concrete while on the other hand the track mechanism is made of mild steel so;

Considering the coefficient of friction for mild steel on concrete is (μ) = 0.4

$$F_{req} = \mu N + F$$

$$F_{req} = (0.4)(877.9) + (437.72)$$

$$F_{req} = 788.88\ N$$

Calculating required force for rolling on stairs;

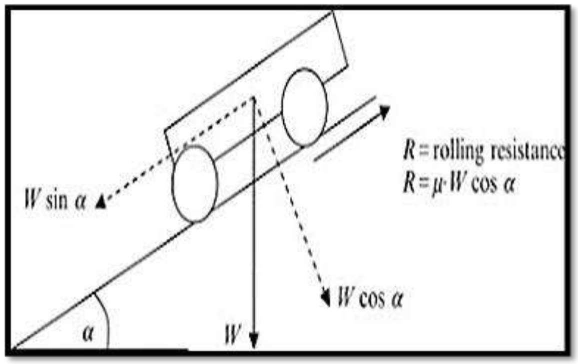


Figure 3-7: Rolling Resistance

$$F_{req} = \mu N \cos\theta + mg \sin\theta^{\circ}$$

Considering the coefficient of friction for mild steel on concrete is (μ) = 0.4

$$F_{req} = (0.4)(877.9)\cos 26.5 + (981)\sin 26.5^{\circ}$$

$$F_{req} = 755.5\ N$$

$$755.5 < 788.8$$

Therefore, when moving along a surface, the F_{req} of the convertible wheelchair would be higher compared to the rolling case. This is because the wheelchair may encounter increased friction due to the slope, leading to a higher F_{req} of rolling instead of slipping.

3.4 Motor Power Required

Power calculations are crucial for designing, manufacturing wheelchairs that can safely and effectively climb stairs. They inform the selection of batteries, control systems, and overall design to ensure that the wheelchair performs optimally while considering energy efficiency, user safety, and stability.

Where’s;

P = Power Required

N = Number of Revolution

T = Torque Required

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

$$P = \frac{2\pi(48)(61.8)}{60}$$

$$P = 312.6\ W$$

3.4.1.1 Shaft Design

Shafts are used in wheelchairs for several critical purposes that contribute to the overall functionality, maneuverability, and comfort of the wheelchair. It is located under the seat for track mechanism.

Power=312.6 watt

2 Motors are used so it becomes double

Power =624.398 watt

Where's;

P= Power required for wheelchair for Stair climbing

T= Torque required for Stair climbing

N= Number of Revolution

M_{max} = Maximum Bending Moment

d= Diameter of Shaft

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

Re-arranging above equation;

$$T = \frac{P \times 60}{2\pi N}$$

Putting values of;

Power of Motor = P = 624.398 W

Number of Revolution = N= 69.86 rpm

$$T = \frac{624.398 \times 60}{2(3.14)(69.86)}$$

$$T = 85.39\ Nm$$

Now calculating equivalent torque;

$$T_{eq} = \sqrt{M^2 + T^2}$$

$$T_{eq} = \sqrt{50.212^2} + \sqrt{85.39^2}$$

$$T_{eq} = 99.059\ Nm$$

The equivalent torque is equal to;

$$T_{eq} = \frac{\pi}{16}\ .d^3.t$$

Re-arranging above equation and putting value of (t) = 215Mpa = 215 × 10^6

$$d^3 = \frac{16}{\pi t}(T_{eq})$$

Putting value in above equation;

$$d = 13\ mm$$

3.4.1.2 Bearing Design

Single Deep Groove Ball Bearing is used in this wheelchair. The two bearings was mounted at the back side of chair. The two bearings was attached with both ends of shaft (for track mechanism). It also support rotation of the wheelchair parts at different angles.

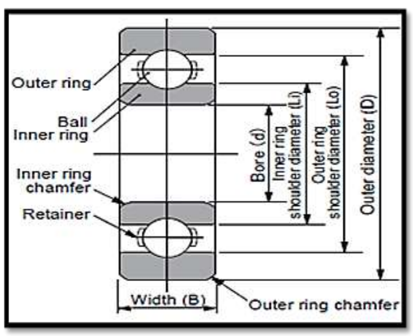


Figure 3-8: Bearing Nomenclature

Bore dia= d

$Outer\ dia = D$

$Width = B$

$W_R = radial\ load$

$P = W_R = 637.5N$

$$L_{10h} = 3000\ h\ (life\ expected)$$

$$L_{10h} = \frac{60 \times 48 \times 3000}{10^6} = 86.4\ million\ years$$

$$C_{rr} = P(10h)^{\frac{1}{3}}$$

$$C_{rr} = 2818.28$$

$$d = 12\ mm$$

So, suitable bearing from Catalogue is **6201** as its C_{rr} = 6.82KN and dia = 12mm

3.4.2 Multi-Posture Mechanism

Multi-posture wheelchairs are designed to provide individuals with disabilities or mobility impairments with the ability to adjust their seating positions in various ways, promoting comfort, health, and independence. These wheelchairs offer several adjustable features that allow users to change their posture throughout the day, helping to prevent medical complications, improve well-being, and enhance overall quality of life.

The Multi-Posture ability of wheelchair is achieved by Linear Actuators.

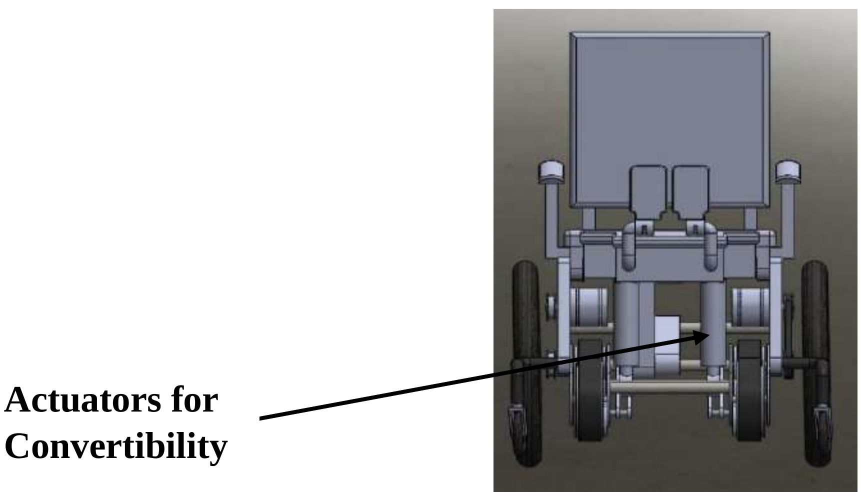


Figure 3-9: Multi-Posture Mechanism for Wheelchair

The function of the linear actuator in wheelchair is to provide adjustability, comfort, pressure relief, postural support, functional independence, and adaptation. It enables users to adjust their seating postures in accordance with their unique needs, fostering maximum comfort, health, and well-being.

The Hydraulic linear actuators are used for our project which have Weight lifting capability up to 900N, and in total four linear Actuator are used to achieve multi-posture and stair climbing ability.

Figure 3-10: Linear Actuator

3.5 Chain Drive Mechanism

Chain drive mechanism is a way of transmitting mechanical power from one place to another. Chain mechanism having three basic parts.

1. Chain
2. Driver Sprocket
3. Driven Sprocket

Figure 3-11: Chain Drive Mechanism

The relative number of teeth between the driven sprocket and the driver sprocket determines the speed and torque of the driven shaft. Ratio of the teeth can be selected to increase or decrease speed or torque to the driven shaft.

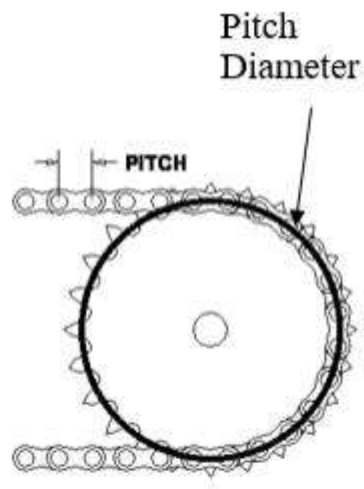


Figure 3-12: Specification of Chain Sprocket Assembly

Pitch = p = 12.8 mm

No of teeth = z

$$Pitch\ Dia\ of\ Driver\ Sprocket = D_1 = \frac{p}{\sin(\frac{180}{z})}$$

No of teeth of Driver Sprocket = z = 14

$$D_1 = \frac{12.8}{\sin(\frac{180}{14})}$$

$$D_1 = 58\ mm$$

Now calculating pitch diameter (D_2) for Driven Sprocket;

$$Pitch\ Dia\ of\ Driven\ Sprocket = \frac{p}{\sin(\frac{180}{z})}$$

No of teeth for Driven Sprocket = z = 36

$$D_2 = \frac{12.8}{\sin(\frac{180}{36})}$$

$$D_2 = 147\ mm$$

Length of chain is calculated by;

$$Lenght\ of\ Chain = \ No\ of\ Links \times p$$

$$lenght\ of\ Chain = 100 \times 12.8$$

$$Lenght\ of\ Chain = 1280$$

Table 3-2: Chain Mechanism Result

Sr No	Category	Details
1	Teeth of driver sprocket	14
2	Teeth of driven sprocket	36
3	Length of chain	1280 mm
4	Pitch Diameter of Driver sprocket (D1)	58 mm
5	Pitch Diameter of Driven sprocket (D2)	147 mm
6	Pitch of chain linkages	12.8 mm

3.6 Total weight

Table 3-3: Components Weight Distribution in Wheelchair

Weigt of Frame	8 kg
Weigt of Track-Chain Mechanism	15 kg
Weight of Battery	3 kg
Weight of Linear Actuators	4 kg
Weight of Motors	1.75 kg
Weight of Sprocket Pulleys	250 g
Weight of (Nut, Bolts, Washer, Tensioner and Holding camps)	2 kg
Weight of Tires	1.25 kg
Wight of (Wooden Box, Seat)	1.5 kg
Weight of (Bearing, Bearing blocks)	4.5 kg
Total Weight of all Components	**41 kg**

3.7 Calculation Summary

Table 3-4: Overall Calculation Results

Slope of Stairs	26.5°
Force required for sliding over stairs	970.9 N
Force required for rolling over the stairs	889 N
Motor Speed	60 rpm
Power required	310.6 W
Torque Required for Stair Climbing	61.8 Nm
Bearing Number	6201
Motor Horsepower	0.41 hp
System overall Weight	41 kg

4 MANUFACTURING OF WHEELCHAIR

4.1 Chapter overview

This chapter describes the manufacturing process of wheelchair.

4.2 Manufacturing Process

The operations followed during the manufacturing of convertible wheelchair is given by:

1. Welding
2. Grinding and Polishing
3. Drilling
4. Turning

4.3 Steps of Manufacturing Process

1. Manufacturing of Frame
2. Manufacturing of Chain-Track Mechanism
3. Installation of Rear and Caster Wheel
4. Installation of Dc Gear Motor
5. Installation of Linear Actuator
6. Installation of Battery

4.3.1 Manufacturing of Frame

Mild steel has been chosen as the material for constructing the frame of the wheelchair due to its desirable characteristics of being lightweight and strong. The selected pipes for the frame have a thickness of 19 gauge, which are suitable for adequately supporting the weight of an average person, estimated to be around 100 kg. The frame is fabricated using welding techniques, specifically ARC welding and grinding methods to ensure proper construction and durability.

Figure 4-1: Wheelchair Frame

4.3.1.1 Back Seat

Mild steel material was selected for the construction of the wheelchair back seat. Specifically, 18-gauge mild steel pipes were utilized to manufacture the seat structure. The inclusion of a back seat provide support to the back and head of the person using the wheelchair. To ensure structural integrity, welding was employed to connect all the joints securely.

4.3.1.2 Seat Portion

The wheelchair seat was constructed using mild steel material, specifically 18-gauge mild steel pipes. The primary component of the wheelchair is the seat, which provides the area on which a person sits. The joints of the wheelchair were connected using welding techniques.

4.3.1.3 Foot Portion

The foot portion of the wheelchair was constructed using 18-gauge mild steel pipes, which provided beneficial support for the person's legs. The joints were securely connected through the application of welding techniques.

4.3.2 Manufacturing of Chain Track Mechanism

For the purpose of climbing up and down stairs using a wheelchair, an effective mechanism is required to provide the necessary traction and stability. In this scenario, a track chain mechanism is employed instead of using a belt and pulley system. This choice is made due to concerns related to slippage and other associated issues with the belt and pulley mechanism.

Here's a simplified explanation of a components involved in track-chain mechanism used for stair-climbing purpose:

- **Tracks:** Instead of conventional wheels, these devices have tracks similar to those found in tanks. The tracks consist of interlocking links connected by pins and bushings, forming a continuous loop.
- **Drive Sprockets and Chain:** The device incorporates motorized drive sprockets that engage with the tracks. These sprockets have teeth that grip the track links, allowing them to move the tracks. Chain is a series of interconnected links that form a flexible and durable loop. The primary purpose of a chain is to transfer rotary motion and power from one sprocket to another.
- **Idler Wheels:** Similar to the track-chain mechanism in vehicles, stair-climbing devices have idler wheels that help guide the tracks and maintain tension. The idler wheels are strategically positioned to ensure proper alignment and contact with the stairs.
- **Pulleys:** Designed to support the movement of a belt or to transfer power, a pulley is a wheel mounted on an axle or shaft.
- **Gearbox:** A mechanical device known as a "GEARBOX" transfers power from a motor to a drive component. When transferring speed and torque from a rotating power source to another device, it makes use of gears and gear trains.
- **Shaft:** Shaft receives power from the chains and sprockets. Shafts are utilized to transport power.
- **Bearing and bearing Housing:** Modular assemblies known as bearing housing are created to enable the installation of bearings and shafts simple and to safeguard bearings. Bearings are "components that aid in the rotation of objects." The shaft that spins inside is supported by them.

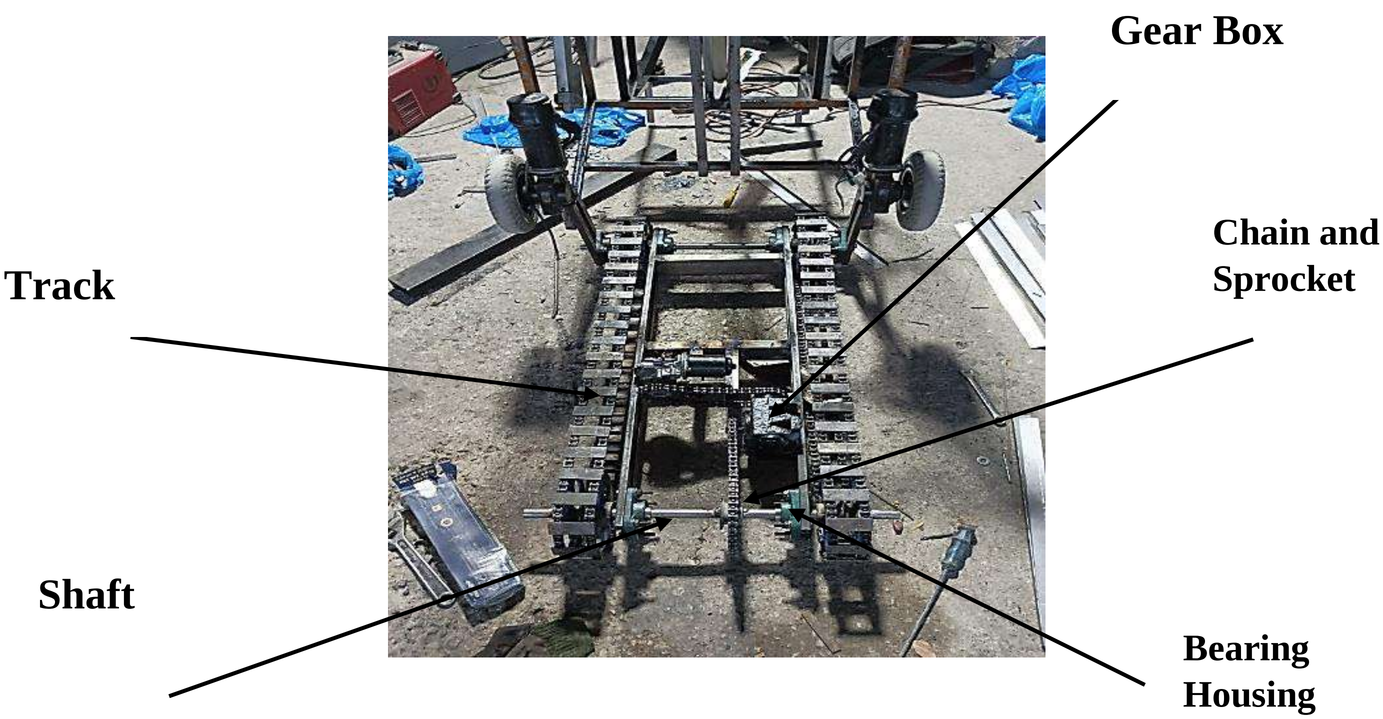


Figure 4-2: Chain Track Mechanism

When a stair-climbing device encounters a staircase, the track-chain mechanism comes into action:

- **Ascending:** To climb the stairs, the drive sprockets rotate and engage with the track links. As the sprockets turn, they move the tracks, which pull the device upward. The idler wheels guide the tracks along the stairs, ensuring smooth movement and stability.
- **Descending:** When descending stairs, the drive sprockets rotate in the opposite direction. This controls the tracks, allowing the device to move down the steps while maintaining control and balance. The idler wheels continue to guide the tracks to ensure a controlled descent.

Stair-climbing devices that utilize a track-chain mechanism are specifically designed to provide stability, safety, and efficient movement on stairs. They are often used by individuals with mobility impairments or in situations where navigating stairs manually would be difficult or unsafe.

4.3.3 Installation of Rear and Caster Wheels

Rear wheels play a critical role in wheelchairs by providing propulsion, stability, maneuverability, and control. The caster wheels are in smaller size, swiveling capability, and position at the front of the wheelchair contribute to safe and efficient mobility, allowing users to navigate various environments with greater ease and confidence.

For our wheelchair design the Rear wheels used are in diameter 8'', while the Caster wheel are in 6'' diameter. They caster wheel are attached to main frame by means of welding, and the rear wheel are attached to motor connected with frame by means of nut and bolt. The rear and caster wheels are shown:

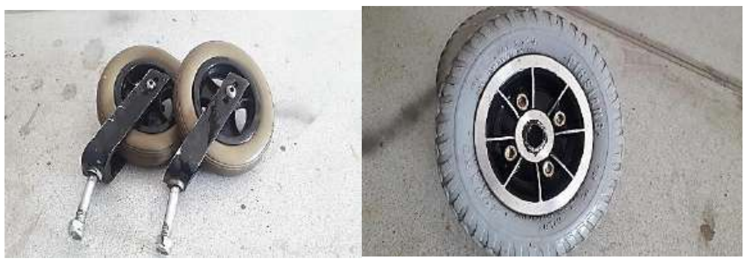


Figure 4-3:Rear and Caster wheels

4.3.4 Installation of Dc Gear Motor

The power, control, and efficiency needed for wheelchair propulsion are provided by DC gear motors. They are a common option in wheelchair design because of its small size, strong torque production, capacity to manage speed, and dependability, which enables users to move effectively and comfortably.

The Dc Gear Motor used in our project have power of 350 watts and 120rpm and have voltage of 24 Volts. They are connected to main frame by nuts and bolts.

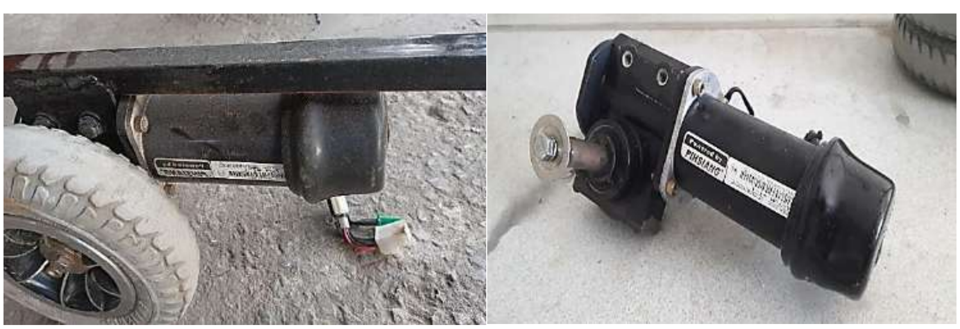


Figure 4-4: DC Gear Motor

4.3.5 Installation of Linear Actuators

The function of the linear actuator in wheelchair is to provide adjustability, comfort, pressure relief, postural support, functional independence, and adaptation. It enables users to adjust their seating postures in accordance with their unique needs, fostering maximum comfort, health, and well-being.

The Hydraulic linear actuators are used for our project which have Weight lifting capability up to 900N, and in total four linear Actuator are used to achieve multi-posture and stair climbing ability.

Figure 4-5: Linear Actuator

4.3.6 Installation of Battery

The aim of a DC battery is to supply the wheelchair with the electrical power required for mobility, allowing users to control the wheelchair's motor(s) and other electrical parts. It provides wheelchair users with a dependable and effective power source thanks to its portability, recharge ability, long running time, safety, and compatibility with charging systems.

The lithium-ion battery was used for providing necessary electrical power to components and it have voltage of 24volts. It was installed to rear portion of back seat of wheelchair.

Figure 4-6: Battery

4.4 Assembly

The initial step in the assembly process involved welding the backrest, seat, leg-rest, and base frame together to create the overall structure of the wheelchair. Following this, the rear and caster wheels were mounted on the structure, and the drive motor was attached to the rear wheels. Linear actuators were then connected in appropriate locations to enable the multi-posture feature and deploy the Track-Chain mechanism, which facilitates stair climbing. To enhance patient comfort, a soft cushion was placed on the structure. The wheelchair is powered by a DC battery.

Subsequently, the assembly focused on constructing the Track-Chain mechanism. This involved attaching sprockets to a shaft through welding. The shaft was supported by bearing housing to ensure smooth rotation. The chain was then placed on the sprockets, allowing it to rotate when the sprockets rotate. The Track-Chain mechanism also included a drive motor coupled with a gearbox. The gearbox, in turn, was connected to the drive sprocket using sprockets and chains. As the motor rotates, the gearbox reduces its RPM, providing low RPM but high torque for stair climbing. Small pieces of mild steel were welded to the chains to maintain contact with the stairs and provide grip for the stair climbing feature.

Figure 4-7: Assembly of Wheelchair

5 CONTROL OF WHEELCHAIR

A control system for a wheelchair is designed to provide the user with the ability to maneuver and control the movement of the wheelchair. The control system typically consists of various components and interfaces that allow the user to operate the wheelchair safely and effectively.

Here are some key elements of a typical wheelchair control system:

5.1 Arduino Micro Controller

An Arduino microcontroller can be used as a central control unit to enhance its functionality and provide additional features. The Arduino microcontroller is a small, programmable device that can interact with various sensors, actuators, and other electronic components to perform specific tasks.

By utilizing an Arduino microcontroller in a wheelchair, it becomes possible to enhance its control capabilities, add safety features, implement autonomous functions, or integrate with other smart devices or systems. The flexibility and programmability of the Arduino platform make it a popular choice for prototyping and developing custom wheelchair control systems tailored to individual needs.

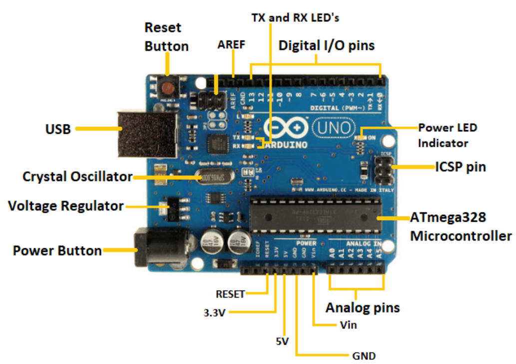


Figure 5-1: Arduino UNO

5.2 PWM Driver

In a wheelchair, a PWM (Pulse Width Modulation) driver is used to control the speed and direction of the electric motors that drive the wheelchair. PWM is a technique that involves rapidly switching a digital signal on and off at a fixed frequency. By varying the width or duration of the "on" state compared to the "off" state, the average power delivered to the motor can be adjusted, thereby controlling its speed. By varying the width or duration of the "on" state compared to the "off" state, the average power delivered to the motor can be adjusted, thereby controlling its speed.

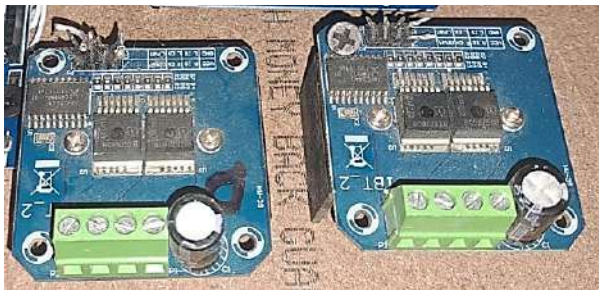


Figure 5-2: PWM Driver

5.3 Relay Motor Drives

Relay motor drives are another type of motor control mechanism used in wheelchairs to control the speed and direction of electric motors. A relay motor drive utilizes electromagnetic relays to switch the motor's power supply on and off. They offer a reliable method of controlling the motor's speed and direction, ensuring smooth acceleration, deceleration, and reversals based on the user's input.

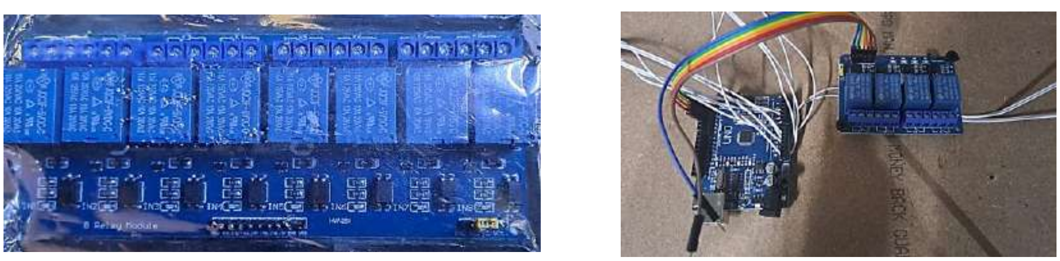


Figure 5-3: Relay Motor Drives

5.4 Joystick

A joystick is a common control interface used in wheelchairs to enable users to maneuver and control the movement of the wheelchair. The joystick consists of a lever that can be moved in different directions, typically in a 2D or 3D configuration. The joystick's sensors and control system work together to interpret the user's input and generate the appropriate commands for the wheelchair's movement.

Figure 5-4: Joy Stick

5.5 Buck Converter

A buck converter, also known as a step-down converter, is a type of DC-DC converter commonly used in wheelchairs to efficiently regulate the voltage and current supplied to various components, such as the motor or control system. It steps down a higher input voltage to a lower output voltage while maintaining a constant current output.

By using a buck converter in a wheelchair, the higher input voltage from the power supply can be efficiently stepped down to a lower, regulated voltage required by various components. The buck converter ensures that the components receive a consistent and appropriate voltage, improving their performance and efficiency while preserving battery life.

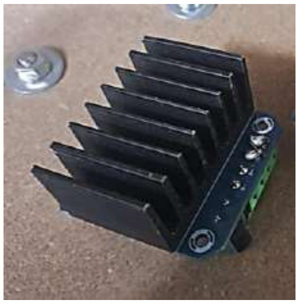


Figure 5-5: Buck Converter

6 CONCLUSION:

Physical disability resulting in the total/partial loss of movement capabilities is a traumatic experience for affected individuals resulting in physical and psychological challenges. Considering the living styles in Pakistan, it becomes tedious to transfer the patient from ground to top/other floors through stairs. Such situations require state-of-the-art technological solutions that would help the people having disabilities or require rehabilitation while facing an injury to live a mobile life thus reducing the related frustration and dependence on nursing staff/relatives. This project addresses the problem through designing and fabrication of an intelligent multi-posture electric wheelchair with stair climbing ability. Initially raw designs for structure of wheelchair were sketched and then a modified CAD model was proposed. For designing that kind of wheelchair, the objective is to ensure that it can effectively accommodate individuals with disabilities weighing up to 100 kg. Material used for the manufacturing of structure is Mild Steel. Subsequently, linear actuators are integrated to enable posture conversion (three postures: bed, sitting, and standing position). On the other hand, there is track mechanism used for the stair climbing purpose and the angle of inclination is 26.5^0. After finding the F_{req} in both cases, while moving on the ground or moving up the stairs, it results that when moving up the stairs, the F_{req} of the multi-posture wheelchair would be higher compared to the rolling case (moving on a ground). This is because the wheelchair may encounter increased friction due to the slope, leading to a higher F_{req} of rolling. So from this, it is clear that motor required for stair climbing have the enough power for proper functionality. For the motion of the wheelchair, a pair of DC gear motors (power of 350 watts and 120rpm and have voltage of 24 Volts) are used. In the end, it is concluded that our wheelchair has the capability to overcome the above mentioned problems faced by the physically challenged people.

7 FUTURE RECOMMENDATIONS

Here are some future recommendations for the development and improvement of Multi-Posture Smart Wheelchairs:

a) Flexibility in stair climbing mechanism, so due to this wheel chair can easily climb up or down the stairs (as dimensions of tread and riser would not similar everywhere)

b) Total cost can be minimized by using light efficient motors, replacing linear actuators with some pneumatic or hydraulic devices.

c) Integrate advanced sensor technologies, such as pressure sensors and body movement detectors, to enable the wheelchair to automatically detect changes in the user's posture and adjust accordingly.

d) An integrated monitoring system should be implemented to track the battery status of the wheelchair. This system will generate a warning when the battery level falls to a low range of approximately 5-10%.

e) To enhance safety, the wheelchair can be equipped with an anti-locking system. This system is to prevent the wheels from locking up during sudden braking or when encountering slippery surfaces. It utilizes sensors and advanced algorithms to detect wheel rotation and traction conditions.

8 REFERENCES

[1] Ruscoe, G. (2019, 1 24). HISTORY.PHYSIO. Retrieved from History of the Wheelchair: https://history.physio/history-of-the-wheelchair/

[2] "A History of the World – Object : Bath Chair". BBC. 2012-09-02. Retrieved 2012-11-19

[3] Johnson, Nelson (2012-02-01). Boardwalk Empire: The Birth, High Times, and Corruption of Atlantic City (Kindle ed.). Independent Publishers Group. p. 28

[4] Nias, K. (2019, 1 3). Science Museum. Retrieved from HISTORY OF THE WHEELCHAIR: https://blog.sciencemuseum.org.uk/history-of-the-wheelchair/

[5] "X-brace construction for collapsible invalids' wheel chairs

[6] Johnson, Jay A., Paul T. Wade, and Qinghuan Yu. "Motorized standing wheelchair." U.S. Patent 6,231,067, issued May 15, 2001.

[7] Borkar, Ninad M., Saurabh A. Apte, Tejas N. Deshmukh, and Sampada M. Apte. "Mechanically Operated Wheelchair Convertible Stretcher." *International Journal of Mechanical Engineering and Technology* 7, no. 2 (2016).

[8] Mistry, Nirmal, et al. "Design and fabrication of convertible wheelchair." (2018).

[9] Oshima, Toru, and Noboru Momose. "User-friendly acceleration/deceleration control of electric-powered wheelchair." *Journal of Robotics and Mechatronics* 18, no. 1 (2006): 18-25.

[10] Hashizume, Satoshi, Ippei Suzuki, Kazuki Takazawa, Ryuichiro Sasaki, and Yoichi Ochiai. "Telewheelchair: The remote controllable electric wheelchair system combined human and machine intelligence." In *Proceedings of the 9th Augmented Human International Conference*, pp. 1-9. 2018.

[11] Huang, Shao-Shih. "Electric wheelchair frame." *United States of America Patent US* 7 (2007): B2.

[12] Putra, Renaldo Herdiano, et al. "Design and stress analysis on electric standing wheelchair." *2017 International Electronics Symposium on Engineering Technology and Applications (IES-ETA)*. IEEE,2017.

[13] Hirudkar, Akshay, et al. "Automatic stretcher cum wheelchair." *International Research Journal of Engineering and Technology (IRJET)* 4.03 (2017).

[14] Tsunoda, M., Premachandra, C., Sarathchandra, H. A. H. Y., Perera, K. L. A. N., Lakmal, I. T., & Premachandra, H. W. H. (2019). *Visible Light Communication by Using LED Array for Automatic*

Wheelchair Control in Hospitals. 2019 IEEE 23rd International Symposium on Consumer Technologies (ISCT). doi:10.1109/isce.2019.8900977

[15] Dey, P., Hasan, M. M., Mostofa, S., & Rana, A. I. (2019). *Smart wheelchair integrating head gesture navigation. 2019 International Conference on Robotics,Electrical and Signal Processing Techniques (ICREST).* doi:10.1109/icrest.2019.8644322

[16] Vernekar, Prasanna, et al. "Gesture Controlled Wheel Chair and Convertible Wheel Chair into Stretcher." *2020 International Conference for Emerging Technology (INCET)*. IEEE, 2020.

[17] Aktar, Nasrin, Israt Jaharr, and Bijoya Lala. "Voice recognition based intelligent wheelchair and GPS tracking system." *2019 International Conference on Electrical, Computer and Communication Engineering(ECCE)*. IEEE, 2019.

[18] Parthasarathy, Shruthi Abinaya, et al. "Design and development of arduino based multipurpose wheelchair for disabled patients." *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*. IEEE, 2020.

[19] Rajesh, Adarsh, and Megha Mantur. "Eyeball gesture controlled automatic wheelchair using deep learning." *2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*. IEEE, 2017.

[20] Nisi, M [2017]. *Design of a self-leveling cam mechanism for a stair climbing wheelchair*. Department of Mechanics and Aerospace Engineering, Corso Duca degli Abruzzi, Turin, Italy.

[21] Tao, W, et.al. [2017], *Electric-powered wheelchair with stair-climbing ability*. State Key Laboratory of Fluid Power and Mechatronic Systems, College of Mechanical Engineering, Zhejiang University, Hangzhou, China.

[22] Montes, H. et al. [2018]. *Assertive Wheelchair Caster Unit Improvement Of Step Detecton Method*, Department of Mechanical Eng., Toyo University, Kawagoe, Japan.

[23] Nisi, M., [2017]. *Design of a self-leveling cam mechanism for a stair climbing wheelchair* Department of Mechanics and Aerospace Engineering, Corso Duca degli Abruzzi, Turin, Italy.

[24] Prof. Patil, V.C. et.al [2018]. *Design and manufacturing of automated staircase climbing wheelchair prototype by using belt drive.* Mechanical engineering, G. S. Moze College of engineering, Savitri Bai Phule Pune University, India.

[25] Rao, K.V [2018].*Design of stair climbing wheel chair using tri wheel mechanism.* , Department of Mechanical Engineering, Konner Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India.

[26] Anjeneyulu, J .et.al [2019] .*Design and analysis of a stair climbing wheel chair*. Sreenidhi Institute of Science and Technology, Hyderabad, India.

[27] Sasaki, K. [2020].*Stair climbing wheel chair with lever propulsion control of rotary legs.* University of Tsukuba, Tsukuba, Japan.

[28] Masaki, F et al. [2004], *Stair climbing for humanoid robots using stereo vision* Intelligent Systems Research Laboratory Sony Corporation Tokyo, Japan.

[29] Marissa, L. J et al. [2005], *Design of a stair climbing hand truck* Degree of Bachelor of Science in Mechanical Engineering at the Massachusetts Institute of Technology US.

[30] R. Morales, V. F, et.al [2006], *Design and analysis of stair climbing wheel chair* .School of Industrial Engineering University of Castilla-La Mancha 13071 Ciudad Real, Spain.

[31] Alfredo.R. et al. [2007], *Design and manufacturing proposal for a stair climbing wheel chair without an external power source* Degree of Bachelor of Science in Mechanical Engineeringat the Massachusetts Institute of Technology US .

[32] Giuseppe, Q, et.al. [2009].*Drive mechanism for stair climbing wheel chair using penta wheel.* Department of Mechanical Engineering, Politecnico di Torino, Turin, Italy.

[33] Salmiah, A. et al [2010], *Controlling and modeling of wheel chair on two wheels*. Department ofAutomatic Control and Systems Engineering, the University of Sheffield, UK.

[34] Giuseppe, Q., et.al, [2011].*A research paper on stair climbing wheel chair*. Riccardo Oderio Politecnico di Torino, Department of Mechanics, Turin, Italy.

[35] Zhang.L, et.al [2012].*An optimization design for stair climbing wheel chair.* Department of Mechanical Engineering Blekinge Institute of Technology Karlskrona, Sweden.

[36] Rajasekar, R. et al [2013]. *Design and fabrication of stair climbing wheel chair.* Department of Mechanical Engineering, Sri Sai Ram Institute of Technology, Chennai, Tamil Nadu, India.

[37] Choudhary, S.K. [2013].*Synthesis, Modeling Analysis and Simulation of stair climbing wheel chair.* International Journal of Mechanical Engineering and Robotic Research. India.

[38] Juanxiu, L.Y.W, et.al [2015] *High-Order Sliding Mode-Based Synchronous Control of a Novel Stair-Climbing Wheelchair Robot.* School of Automation, Nanjing University of Scienceand Technology, Nanjing, China.

[39] Quaglia, G. et.al. [2016] *Kinematic Analysis of an Electric Stair Climbing Wheelchair.* Master in Mechanical Engineering, Politecnico di Torino. PhD in Applied Mechanics, Mechanical System and Structures. Italy.

[40] Vel, C.S. [2016]. *Conceptual design of stair climbing wheel chair using CATIA*. Tech. Technical University Chennai, Ind

Annex A

➢ Arduino Code

```
/*
  AnalogReadSerial

  Reads an analog input on pin 0, prints the result to the Serial Monitor.
 Graphical representation is available using Serial Plotter (Tools > Serial Plotter menu).
  Attach the center pin of a potentiometer to pin A0, and the outside pins to +5V and ground.

  This example code is in the public domain.

  http://www.arduino.cc/en/Tutorial/AnalogReadSerial
*/
int m1=0, m2=0,i;
// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
  pinMode(A0, INPUT);
  pinMode(A1, INPUT);

  pinMode(2, OUTPUT);
  pinMode(3, OUTPUT);
  pinMode(4, OUTPUT);
  pinMode(5, OUTPUT);

  pinMode(9, OUTPUT);
  pinMode(10, OUTPUT);
  digitalWrite(2, HIGH);
  digitalWrite(3, HIGH);
  digitalWrite(4, HIGH);
  digitalWrite(5, HIGH);
}

// the loop routine runs over and over again forever:
void loop() {
  // read the input on analog pin 0:
  int Val1 = analogRead(A0);
  int Val2 = analogRead(A1);
  // print out the value you read:
  Serial.println(m1);
  Serial.println(m2);
```

```
Serial.println("-----------------");

if (Val1 > 600)
{
 m1 = map(Val1, 601, 1023, 0, 150);
analogWrite(9, m1);
analogWrite(10, m1);
  digitalWrite(2, LOW);
  digitalWrite(3, HIGH);
  digitalWrite(4, HIGH);
  digitalWrite(5, LOW);
}
else if (Val1 < 450)
{
analogWrite(9, 130);
analogWrite(10, 130);

digitalWrite(2, HIGH);
digitalWrite(3, LOW);
digitalWrite(4, LOW);
digitalWrite(5, HIGH);

}
else if (Val2 > 650)
{

analogWrite(9, 150);
analogWrite(10, 150);
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, LOW);
}
else if (Val2 < 400)
{
analogWrite(9, 150);
analogWrite(10, 150);
digitalWrite(2, LOW);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, HIGH);
}

else if (Val2 > 400&&Val2 < 650&&Val1 > 450){
    delay(500);
  i=0;
```

```
  m1=0;
  m2=0;
    analogWrite(9, 0);
analogWrite(10, 0);
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, HIGH);
}
  delay(1);       // delay in between reads for stability
}
```