DESIGN AND DEVELOPMENT OF REMOTE CONTROLLED FORK LIFTER USING MECANUM WHEELS

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2023

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A Project Report Submitted to the Department of Mechanical Engineering in partial fulfilment of the requirements for the degree of Bachelor of Science in Mechanical Engineering

Faculty of Mechanical Engineering
National University Technology,
Islamabad

July, 2023

BSME HARIS, AWAIS, SAMEER 2023

CERTIFICATE OF APPROVAL

It is certified that the project titled "Design and Development of remote controlled fork lifter using mecanum wheels" carried out by Haris Ijaz, Reg. No. F19602030, M. Awais Abbasi, Reg. No. F19602023 and Sameer Nawaz, Reg. No. F19602048. Under the supervision of Dr.Liaquat Ali Khan, Associate Professor, National University of Technology (NUTECH), Islamabad.

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ACKNOWLEDGMENT

We would like to express our sincere gratitude and appreciation to all those who have supported and contributed to the successful completion of this final year project. First and foremost, we extend our heartfelt thanks to our project supervisor Dr. Liaquat Ali Khan, for their invaluable guidance, constant support, and insightful feedback throughout the project journey. Their expertise and encouragement have been instrumental in shaping the project's direction and outcomes. We are deeply thankful to the faculty members of Mechanical Engineering for their continuous encouragement, provision of resources, and fostering an environment conducive to learning and innovation. Lastly, we are deeply indebted to our families for their support, understanding, and motivation throughout our academic journey.

ABSTRACT

This project proposes the design and fabrication of a remote-controlled forklift system equipped with Mecanum wheels. It focuses on developing an innovative solution for efficient material handling and transportation in industrial settings. Traditional forklifts are limited in maneuverability and struggle to navigate tight spaces. Mecanum wheels, on the other hand, offer omnidirectional movement capabilities, allowing the forklift to move laterally, diagonally, and rotate on the spot. This unique wheel configuration provides increased flexibility and agility, enhancing the efficiency of material handling operations. The project involves the design and development of a robust mechanical structure capable of supporting heavy loads while ensuring stability and safety. Additionally, the forklift is equipped with a lifting mechanism capable of raising and lowering loads with precision. The control system is implemented using a wireless remote control, enabling operators to maneuver the forklift remotely. To achieve these objectives, the project follows a systematic approach, including the conceptual design phase, detailed engineering design, and fabrication. SOLIDWORKS software is utilized to create accurate 3D models of the forklift and its components. Subsequently, the fabrication process involves the construction and assembly of the mechanical structure, installation of the Mecanum wheels, and integration of the control system. For the structure we used rectangular hollow bar of mild steel having 1.6mm thickness. The lifting mechanism is composed of ball screw coupled with wiper motor, Mecanum wheels are installed at precise location that are coupled with heavy dc gear motors, and for wireless remote control system we used Arduino Mega and Nano, ibt-2 motor drivers, Hc-12 transceivers, relays and batteries.

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LIST OF ACRONYMS

NUTECH	National university of technology
FYP	Final Year Project
BSME	Bachelor of Science in Mechanical Engineering
HOD	Head of Department
CAD	Computer aided design
RF	Radio frequency
DC	Direct current
RFID	Radio frequency identification

Chapter 1

INTRODUCTION

In today's fast-paced industrial landscape, the efficient movement of goods and materials within confined spaces is a critical aspect of optimizing productivity and reducing operational costs. Traditional forklifts have long served this purpose, but as technological advancements continue to reshape industries, there arises a need for innovative solutions that can address complex logistical challenges with greater precision and flexibility. This project, "Design and Development of a Remote-Controlled Forklift Using Mecanum Wheels," aims to explore and create a novel material handling system that capitalizes on Mecanum wheel technology to redefine the capabilities of forklifts in dynamic environments.

Mecanum wheels, known for their unique omnidirectional movement characteristics, have garnered increasing interest in robotics and automation. Unlike conventional wheels, Mecanum wheels allow for seamless lateral, diagonal, and rotational movements, enabling a forklift to maneuver through tight spaces, negotiate obstacles, and navigate intricate pathways with unprecedented agility. By harnessing this innovative technology, the project seeks to revolutionize the way material handling is conducted in environments such as warehouses, manufacturing plants, and distribution centers.

1.1 Overview

The project's primary objective was to design and develop a remote-controlled fork lifter that leverages Mecanum wheels to enable versatile movement and precise positioning. This entails a comprehensive exploration of mechanical design principles, electronic components, control algorithms, and user interfaces. The interdisciplinary nature of the project required the integration of mechanical engineering, electronics, and software development to achieve a seamless and cohesive solution.

Throughout this project, a series of key milestones has been achieved, including:

Conceptualization and Design:

The initial phase involved a detailed analysis of the requirements and challenges associated

With material handling. The Mecanum wheel system and lifting mechanism was carefully selected and integrated into the forklift's design, considering factors such as load-bearing capacity, stability, and power consumption.

Mechanical Construction:

The construction phase focuses on fabricating the physical forklift prototype, incorporating the Mecanum wheel mechanism, load-bearing structure, and lifting mechanism. Attention to detail in this phase is crucial to ensure safety, durability, and efficient performance.

Electronics and Control System:

The integration of electronic components, and motors constitutes the heart of the project. Developed a sophisticated control system that enabled remote operation and precise movement.

Programming and Interface:

The forklift's control interface was designed to provide users with intuitive control over the Mecanum wheels and the lifting mechanism. This involves software development, user experience design, and seamless RF communication between the remote control and the forklift.

Testing and Validation:

Rigorous testing validates the functionality, stability, and safety of the remote-controlled fork lifter. Real-world scenarios and simulated environments were employed to assess the system's performance under various conditions.

1.2 Statement of Problem

The main problem is of maneuvering of fork lifter in constrained space in industry. Absence of remote controlled feature in current fork lifter. Increasing efficiency of material movement by reducing travelling distance. In a two dimensional space, a body has three degrees of freedom, being capable of translating in both directions and rotating about its center of gravity. However, most conventional vehicles do not have the ability to control every degree of freedom independently, because conventional wheels are not capable of moving in a direction parallel to their axis.

To solve this problem we have proposed a project with utilization of Mecanum wheel and remote control system. Mecanum wheel is a unique wheel that allowing a vehicle to move at any degree translation when moving at a certain speed and rotation direction.

1.3 Specifications of proposed solution

This project is a prototype that is designed for a lifting load of 20kg. The overall length of fork lifter frame is 26in, width is 20in and lifting height is also 20in. The length of forks is 13in, height of 10in, width and thickness is 2.5in and 6mm, the distance between forks is 6.5in and tilt angle of forks are kept 5 degree. The lifting mechanism is operated with the help of ball screw that is coupled with a 12v dc worm type gear motor that has a torque of 6N-m. The Mecanum wheels are directly coupled with 24v dc planetary type gear motor that has the capacity of producing 3.5N-m torque. Two battery of 12v each is installed at the back end that supply power to motors and also work as counterbalance. For wireless control system we have used hc-12 module with Arduino Mega and Arduino Nano that has a range of 1km and 433 MHz to 473 MHz frequency.

1.4 Purpose of the project/research

Main purposes of our project are stated below:

- To integrate Mecanum wheels into the forklift design to enable omnidirectional movement.
- By utilizing Mecanum wheels, the forklift will have improved agility and maneuverability in confined industrial spaces.
- To reduce air pollution by replacing fuel engines with batteries.
- To save work time by speed up the fork lifter movement.
- The project will develop a user-friendly remote control interface that allows operators to spontaneously control the forklift's movement, lift, and lower functions. The interface also incorporate joysticks and buttons that ensure efficient and safe operation.
- It should be able to lift and transport various types of loads commonly found in industrial environments.
- To overcome accidents caused by fork lifter in work place by reducing human interface.

1.5 Applications of the project/research

Some of the applications of our project are explained below:

Warehousing and Distribution Centers:

In busy warehouses and distribution centers, the ability of the remote-controlled forklift to move laterally and navigate tight spaces can significantly improve efficiency. It can help in quickly transporting and stacking goods on shelves, optimizing storage space, and reducing the need for excessive maneuvering.

Manufacturing Facilities:

Manufacturing plants often require precise movement of raw materials and products across different areas. The Mecanum wheel forklift can easily transport materials to assembly lines, storage areas, and other sections within the facility, enhancing workflow and reducing production bottlenecks.

Retail Environments:

Retail stores can benefit from the forklift's agility in restocking shelves, rearranging displays, and handling inventory efficiently. The remote control feature allows for easy operation even in crowded or customer-accessible areas.

Logistics and Transportation Hubs:

In logistics and transportation hubs, the forklift can efficiently move items to and from trucks, trains, and shipping containers. Its omnidirectional movement capability can help save time.

Research and Development:

Research institutions and laboratories often deal with sensitive equipment and materials. The forklift's precise control can aid in moving delicate instruments without causing disruptions.

Indoor sensitive environments:

In indoor environments where the temperature is too low or too high, that can damage human skin in long terms. The remote controlled fork lifter can handle equipment's in those environments like ice cream storage facilities etc.

1.6 Project Plan

The project was planned according to the following goals:

- Literature review
- Parametric study
- Mathematical modeling
- Designing
- Simulation
- Fabrication

- Automation
- Testing

1.7 Report Organization

This project report has been organized in a way that it is easy for the reader to get a clear insight of the project. The first chapter contains the introduction of project in detail. The first chapter includes an overview of the project, specifications selected for the proposed solution, statement of the problem, domain configuration, purpose, and applications. The first chapter gives the whole idea of what this project is all about. The second chapter is dedicated to a literature review regarding related research on the proposed project. In this section, detailed study is provided about previously submitted research papers on this topic. A complete analysis has also been done for what pros and cons of the previous projects and research have and what is required to be implemented for our project. The third chapter contains information about project design and implementation. In this chapter, there is complete detail about fork lifter design and simulation being done. In fourth chapter, complete hardware details have been explained. This chapter is about fork lifter fabrication hardware and automation hardware. Fifth chapter includes all the results i.e. experimental and theoretical of both the hardware and software, hardware results refer to the testing of fork lifter on hard smooth surface, while software results have the details of structural analysis of fork lifter, limitations related to this project have also been mentioned while future recommendations are also part of chapter five. Sixth chapter includes the conclusion in which a thorough ending has been made over complete project, regarding design, simulation and fabrication.

Chapter 2

LITERATURE REVIEW

2.1 Related Technologies

In industrial settings, various technologies are employed for the loading and transportation of materials to optimize efficiency, safety, and productivity. Some of the key technologies used for material loading and transportation in industries include:

2.1.1 Conventional fork lifters

A conventional fork lifter is an industrial truck used for loading and transportation of materials within the industrial area. Due to manually operate by steering and use of common tires, consume time and space as compared to wireless operated fork lifter that has Mecanum wheels.

Figure-2.1 conventional fork lifter

Some of specifications of conventional fork lifter are given below:

- It is equipped with hydraulic cylinders and a pair of forks that can be raised and lowered to carry and place materials at different heights. But the hydraulic system is complex, costly and takes time for maintenance.
- It consists of vertical rails, rollers, and chains that guide the forks as they move up and down.
- Conventional forklifts are equipped with tires that require space for turning and it is difficult for it to operate in tight spaces.
- Conventional forklifts often require larger turning radii and wider aisles for efficient operation. This can limit the effective utilization of available space in warehouses and storage areas.
- Forklifts have controls for steering, lifting, lowering, tilting the forks, and controlling forward and reverse movement.

2.2 Related Projects

2.2.1 Design and fabrication of fork lifter with multi direction wheels:

The main objectives of this project were:

1. To design and develop a wheel mechanism to achieved multi directional movement.

2. To design a Mecanum wheel with regular concave rollers and rollers of different material other than regular plastic material to achieve better grip on surface to study performance of vehicle movement.

3. To fabricate low cost and low weight (10 Kg) forklift to study the performance. [1]

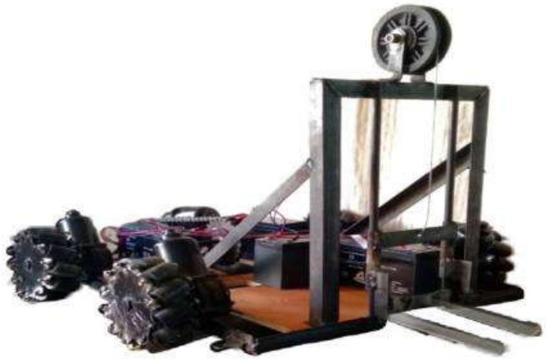

Figure-2.2 fabricated prototype

2.2.2 Design, Development and Modelling of Forklift:

The main objective of this project is to fabricate a Mechanical forklift for material handling in industries. In this paper a robotic vehicle is fabricated which runs to carry material from one place to another by using Radio Frequency Technology. This paper discusses how to integrate Radio frequency identification (RFID) technology into a forklift truck to make it wireless to increase visibility and human safety. [2]

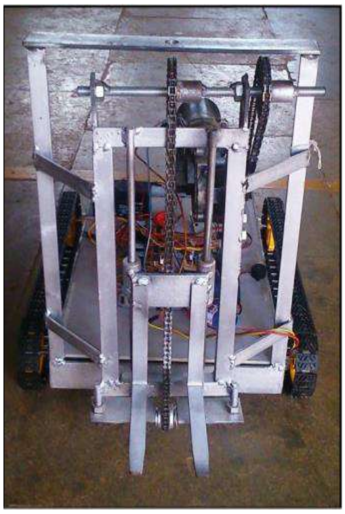

Figure-2.3 prototype model

2.3 Related Studies/Research

Some of the related studies to Mecanum wheels and remote control fork lifter are mentioned below:

Utkarsh Namdeo, Pranjul Mishra, worked on the applications of zero turning mechanism in fork lifter using the Mecanum wheels. The purpose of their work was to analyze the optimum material for forks and minimize the space required for movement of fork lifter. The have no zero turn using Mecanum wheels and analyzed suitable material for fork lifter frame. The designed machine has the ability of moving in any direction, and controlled through wireless [3].

Lobo Allwyn , Khebude Karan , Adsul Ganesh , Bhosale Prathamesh , Khade Omkar , Naik Abhijeet. Their worke based on the design and fabrication of fork lifter for small scale work in industry. They have fabricated a Mechanical forklift that assures the comfort of the operator or worker and to reduce time required for manual lifting and handling. It lifts the maximum load of 200 Kg at maximum height 1250mm. This increases efficiency of productivity & it provide safety of operator while handling of the material. Their work recommend future modification in their design by operated the forklift automatic [4].

Hsu PE, Hsu YL, Chang KW, Geiser C, use the concept of Mecanum wheels in wheelchairs for disable persons. The vehicle uses four Mecanum wheels to facilitate movement in all directions, including sideways, and zero radius of rotation. Their wheelchair requires much less space than ordinary electric wheelchairs in turning and sideways maneuvers. Based on this moving vehicle, mobility assistance functions are designed for three different operators: the wheelchair user, caregivers, and the wheelchair itself in autonomous behaviors [5]

Prof.P.L.Sarode, Altamash Sayyed, Kapilkumar Patil, Latesh Varude, Pratik Pande, Shubham Patil, worked on the design and creation of the Multi directional wheels which offers a means to implement Omni-directional translational motion in a vehicle platform. To demonstrate technical contradiction that solve here shows the working of electric multi-direction forklift which is able to move single degree of freedom independently. Their proposed work focus on movement of forklift in confined spaces by using Mecanum wheels, environment friendly by using a wireless remote control system instead of engine that cause pollution. They also worked on the directional stability for the given load condition and its sustainability [6].

2.4 Their Limitations and Bottlenecks

One limitation of earlier work on the development of automatic forklifts using Mecanum wheels is that they typically focus on the movement and navigation of the device, rather than its ability to perform specific tasks. Another limitation is that the earlier work typically focused on the movement of the device in static environments, such as warehouses, and may not be suitable for more dynamic environments. The earlier works also have limitations on the load capacity and the speed of the forklift.

There is a potential for further research in this area to improve the capabilities of automatic forklifts using Mecanum wheels, particularly in terms of their ability to perform specific tasks and navigate in dynamic environments.

2.5 Summary

The application of Mecanum wheels in material handling equipment, such as forklifts, has gained significant attention in recent years due to the unique maneuverability they offer. This literature review explores the existing research and developments in the field of remote-controlled forklifts using Mecanum wheels, focusing on design considerations, control strategies, and practical applications.

Chapter 3

PROJECT DESIGN AND IMPLEMENTATION

3.1 Design of the Project

A forklift has two weights (load, counterweight), each located on the end of a beam balanced on a fulcrum, similar to a playground seesaw. A load is located on the forks and balanced by the forklift's weight with a counterweight.

Key Specifications:

- Design of wheel (Forces, Movement)
- Center point
- Forklift Load capacity
- Fork operating mechanism
- Stability of fork lifter

3.2 Methodology used

The project is divided into following phases:

- Parametric study
- Mathematical modelling
- CAD model and simulation
- Fabrication and automation

3.3 parametric study

Drive mechanism for Mecanum wheels:

As Mecanum wheels are Omni-directional wheels that can move in any direction. In our project we set 10 direction for Mecanum wheels which are forward, reverse, left, right, clockwise, counter clockwise and diagonal. The wheel number starts from left front and ends at right rear.

Table-3.1 Mecanum wheel drive mechanism

vement	**eels rotation**
ward	wheels moving forward
erse	wheels moving backward
ht	forward 2,3 backward
t	backward 2,3 forward
gonal	heels lock and 2 wheels move
ckwise	forward 2,4 backward
ınter clockwise	backward 2,4 forward

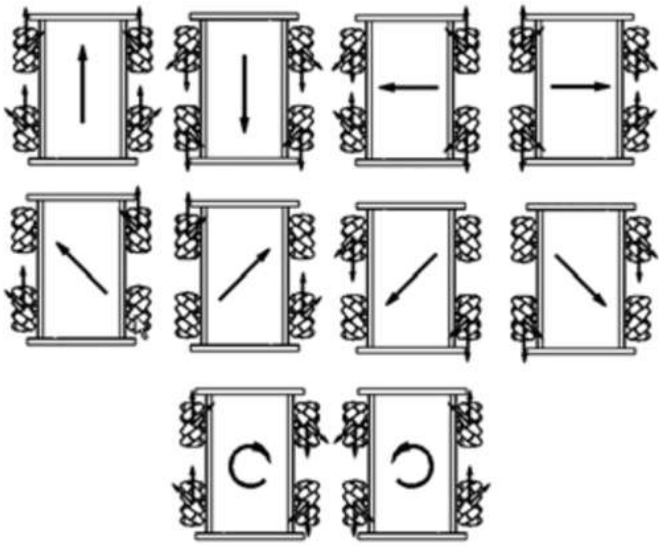

Figure-3.1 working principle of Mecanum wheels

The figure shows different direction of fork lifter in which it can move and the force vector on each Mecanum wheel and its rotation for various movements.

Table-3.2 Mecanum wheel specifications

ler material	J
eel hub material	bon steel
ring	bon steel oil
eel diameter	ım
eel width	ım
of roller per wheel	
ximum bearing load	g/4pcs

Required design specifications

The project is designed according to the following specifications:

Table-3.3 required design parameters

ameter	**ue**
ss to lift by fork lifter	g
tor of Safety	
ıd to lift by fork lifter with F.S	N
al mass to carry	g
al load to carry	N

ving speed of fork lifter	n/s
ing speed	2m/s

Fork Assembly design Parameters:

Fork assembly is designed for specific lifting load by keeping stability and accuracy.

Table-3.4 fork assembly parameters

Symbol	**'ameters**	**ue (mm)**
	ıgth of fork	mm
	ckness of fork	n
	ght of fork	mm
	dth of fork	5mm
	tance b/w forks	mm
	ss of fork	5kg
	ıd of fork	38N
	k tilt angle	

Chassis Design parameters:

Chassis is designed by keeping the stability and safety of fork lifter during operation. Chassis specifications are given below:

Table-3.5 chassis parameters

nbol	**'ameters**	**ue (mm)**
	ıgth of chassis	mm
	ing height	mm
	ıssis material thickness	n
	ss of chassis without fork assembly	2kg
	nt load due to chassis mass	9N
	tery mass with counter mass	g
	tery load with counter load	N

3.4 Mathematical modelling

Free body diagram of fork lifter:

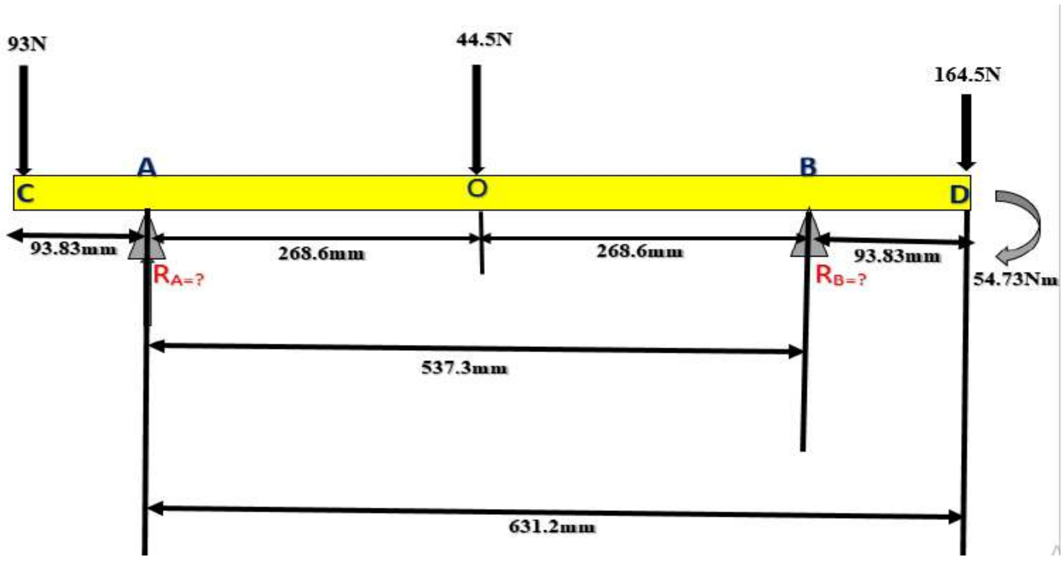

Figure-3.2 free body diagram of fork lifter

The figure shows forces and reaction forces acting on wheels and forks in specific direction and the bending moment occurs due to these forces. It also shows the overall dimension of fork lifter. A and B are the rear and front wheels, while C and D are rear end of fork lifter and fork tip. R_A and R_B indicates the reaction forces at rear and front wheels.

Bending moment due to acting load on fork

$$M = P * \frac{l}{2} = 328.8 * \frac{0.330}{2} = 54.73Nm$$

Reaction Forces

$$\boldsymbol{\Sigma Fy = 0}$$

$$RA + RB - 93 - 44.5 - 164.4 = 0$$

$$RA + RB = 302N$$

$$\boldsymbol{RB} = 301.1N$$

$$\boldsymbol{RA} = 0.9N$$

Bending moment

$$\boldsymbol{\Sigma \mathrm{MA} = 0}$$

$$-0.5373 \times \mathrm{RB} + 0.63117 \times 164.44 + 44.5 \times 0.2686 - 93 \times 0.09383 + 54.73 = 0$$

$$164.4 \times 0.42 - 44.5 \times 0.268 - 93 \times 0.63 = 0$$

$$70 - 11.6 - 58.4 = 0$$

Shear force

Shear force at point C = -93N

Shear force at point A = -93+1 = -92N

Shear force at point O = -92-44.5 = -136.5N

Shear force at point B = -136+301 = 164.5N

Shear force at point D = 164.66N

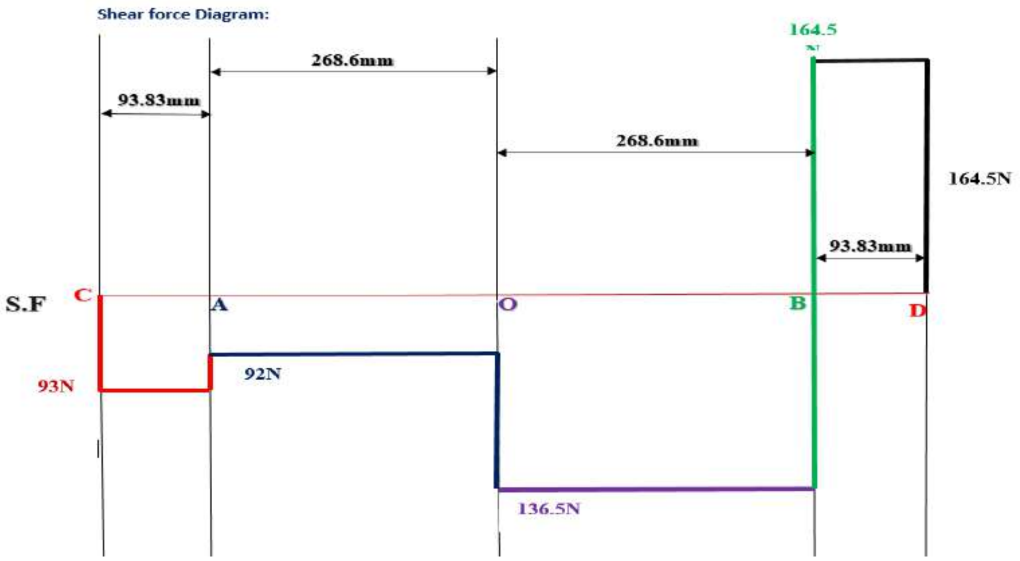

Figure-3.3 shear force diagram

Torque required for each wheel:

We are using dc motor with following specifications:

- Current = 1.5A
- N = 280 rpm
- Stall torque = 3.5N-m
- Stall current = 10A

$$\text{Motor power} = \text{VI}$$

$$24 * 1.5 = 36W$$

$$P = 2\pi NT/60$$

$$T = \frac{2160}{1760} = 1.22Nm$$

Therefore approx. torque on each wheel will be 1.22Nm.

Force Calculation:

The force calculation for Mecanum wheel forward, reverse and diagonal force are obtained by:

$$F_F = \frac{4*T}{r} = \frac{4*1.22*1000}{14} = 348N$$

$$F_R = \frac{4*T}{r} = \frac{4*1.22*1000}{14} = 348N$$

$$F_D = \frac{2T*1.414}{14} = \frac{2*1.22*1000*1.414}{14} = 246N$$

3.5 Summary

In this chapter we have carried out the design specifications and implementation. Mathematical modeling and parametric study is the most important part of any project which is explained in this chapter. The torque requirements from motors and forces on Mecanum wheels are also calculated and explained.

Chapter 4

TOOLS AND TECHNIQUES

4.1 Hardware used with technical specifications

In this project there are two types of hardware used.

1. Fabrication hardware
2. Automation hardware

Both types of hardware are explain below with their technical specifications.

4.1.1 Fabrication hardware

The fabrication include the following components;

Mild steel:

Mild steels is used for the frame/chassis of the fork lifter because of it good machinability, easy to weld, high strength and it is economic.
For our frame we used (1×2.5 in) rectangular hollow bar of gauge 16 which has thickness of 1.6mm.

Figure-4.1 Rectangular bar of mild steel

Forks:

Forks are mount at front of fork lifter which function is to load and unload material from ground to some specific height or from height to ground or some other place. Forks can be operated with various techniques but the one we used is ball screw with gear motor at the top. We have designed our fork lifter assembly for a load of 20 kg by keeping the stability and accuracy.

Ball screw:

A ball screw is a mechanical component used in linear motion systems to convert rotational motion into linear motion. It is a type of screw and nut mechanism with rolling elements, usually small steel balls that circulate between the screw and the nut.
The reasons for using ball screw instead of other options is because of its precision and efficiency. The ball screw we used in our project has the following specifications:

Table-4.1 ball screw dimensions

erial	h alloy steel

al length	.4 mm
rking length	.4 mm
h	m
meter	mm

Mecanum wheels:

Mecanum wheels are omni-directional wheels that can move in any direction without changing its axis of rotation. It consist of several roller attached at 45-degree around the central hub. The reason for using mecanum wheels is its Omni-directional movement, easily move in congested spaces, simplicity of control, and smooth movement.

Figure-4.2 Mecanum wheel

Ball bearing:

The ball bearings are attached with forks frame that move vertically inside the vertical hollow bar, used for support and stability and smooth movement of forks during lifting and transportation of materials.

DC Wiper motor:

Wiper motor is coupled with ball screw for lifting mechanism. The wiper motor has worm type gear system that lower the speed and increase the torque. The wiper motor has a torque of 6N-m, two speeds 40rpm and 60rpm, runs on 12v battery, and is capable of lifting up to 30kg load.

Figure-4.4 wiper motor

DC Gear Motor:

Dc gear motor that has planetary type gear system are coupled with Mecanum wheels, each wheel has one motor. The gear motor runs on 24v, 10A current and has speed of 200rpm. The torque produced by each motor is 3.5N-m.The motors are capable of carrying 60kg load with speed and accuracy.

Figure-4.5 Dc gear motor for wheels

Battery:

We used 2 batteries each of 12v and 20A, the reason for using 2 batteries is because our gear motors operate on 24V. A separate connection is given to wiper motor from single battery of 12v. The motor drivers are also operated from these batteries. The batteries also work as counter balance as they have total weight of 15kg.

4.1.2 Automation Hardware:

Arduino mega:

The Arduino mega is a microcontroller board based on the ATmega 2560 microcontroller. The Arduino mega accumulates the 4 motor drivers, 1 relay module and Hc12 wireless module. The microcontroller is coded in Arduino IDE software and operate on 5v-12v battery, for which we used 3 cells of 3v each. The Arduino mega receives input from remote through Hc12 receiver and gives output to motors according to requirements coded in microcontroller.

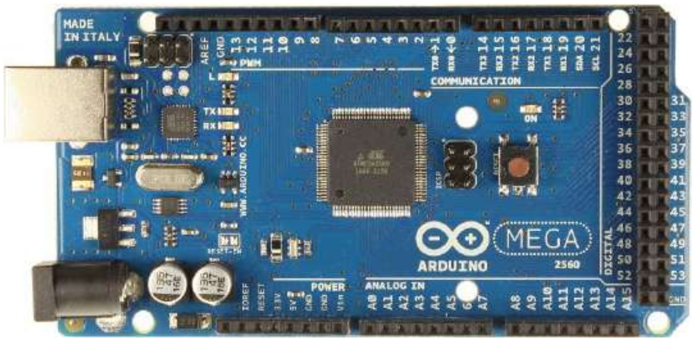

Figure-4.6 Arduino mega

Arduino Nano:

Arduino nano is used in remote as control unit. It takes input from joystick and buttons and transmit it to Arduino mega through Hc12 wireless module. It operates on 5v battery.

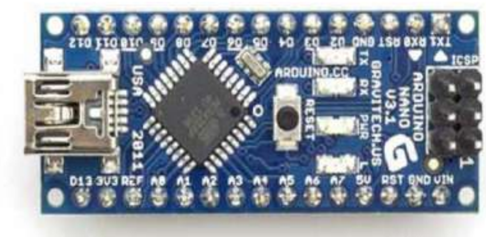

Figure-4.7 Arduino nano

Ibt-2 motor driver:

The IBT-2 is a high-power motor driver which is used for the speed and position control of the 24V gear motors used. Reason for using this module is that it operates with the motors that works at higher current values. It can operate at the peak operating current of 43Amps. Maximum operating frequency is 25 kHz, while the input voltage ranging from 6V-27V.

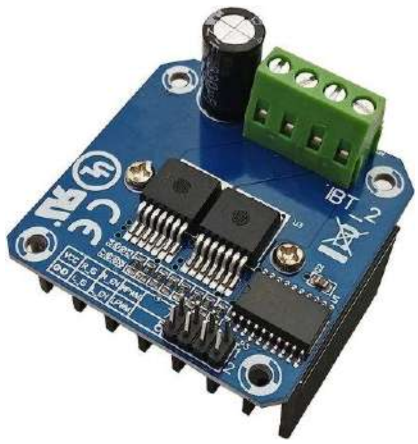

Figure-4.8 Ibt-2 motor driver

Relay module:

The heart of the relay module is an electromechanical relay. This relay consists of a coil and a set of contacts. When a low-power control signal from a microcontroller is applied to the coil, it generates a magnetic field that pulls the contacts, either opening or closing the high-power circuit.

Relay module of 2 channels is used for operating wiper motor. The relay module operates on 12v voltage and 10A current.

Figure-4.9 Two channel relay module

Hc-12 wireless module:

The HC-12 is a wireless transceiver module commonly used for wireless communication in Arduino and other microcontroller. We used 2 Hc-12 modules 1 as a transmitter in remote and 1 as a receiver with Arduino mega. It operates on a frequency of 433MHz and works in a range of 1km. The reasons for using Hc-12 is its long communication range, multiple channels, adjustable power setting and transparent mode.

Figure-4.10 Hc-12 wireless module

Remote:

Remote control system consist of 2 joysticks that control all the directions of Mecanum wheels, 2 buttons for lifting and lowing of forks, an Arduino nano, wireless transmitter, a voltage regulator for speed control, an ON/OFF button and a battery for powering Arduino nano.

Jumper wires:

Jumper wires are basically the electric wires which are used to connect the electric circuits. By attaching a jumper wire on the circuit, it can be short-circuited and short- cut (jump) to the electric circuit. Three type of jumper wires were used that are male to male, male to female and female to female.

4.2 Software(s), simulation tool(s) used

Different software's have been used in this project for various purposes, which are explained below;

1. SOLIDWORKS is used for design of fork lifter parts and assembling.
2. ANSYS is used for stress analysis and simulation.
3. Arduino IDE is used for automation.

4.2.1 SOLIDWORKS:

Complete machine parts are designed and assembled in Solid Works, this CAD design then being used for the structural analysis in ANSYS to check the sustainability of the forks under the effect of various forces.
Following are the main parts that have been designed using SOLIDWORKS, parts are first designed and then assembled.

- Chassis

- Forks
- Mecanum wheels
- Ball screw
- Motors
- Battery
- Brackets.

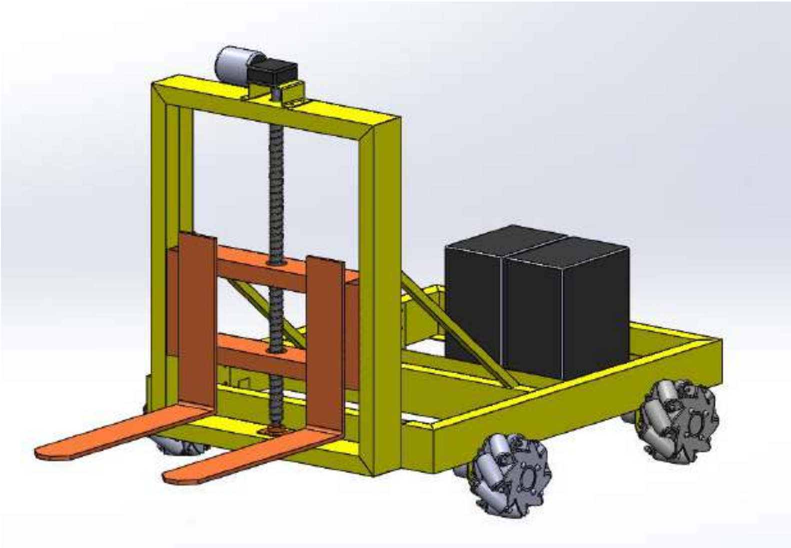

Figure-4.11 CAD model of fork lifter

4.2.2 ANSYS Simulation:

ANSYS software is used for simulation of forks. Following steps are done for stress analysis and total deformation of forks under various forces.

- Select static structural analysis
- Import solidworks geometry
- Select material
- Meshing
- Apply boundary conditions
- Solve for stress analysis and total deformation.

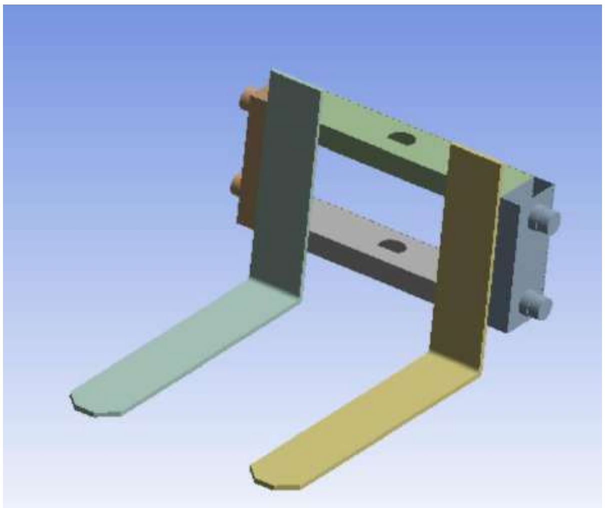

Figure-4.12 Imported forks geometry in ANSYS

The figure shows forks assembly imported from SOLIDWORKS into ANSYS for simulation to find stresses and bending moments.static structural analysis was carried out for geometry.

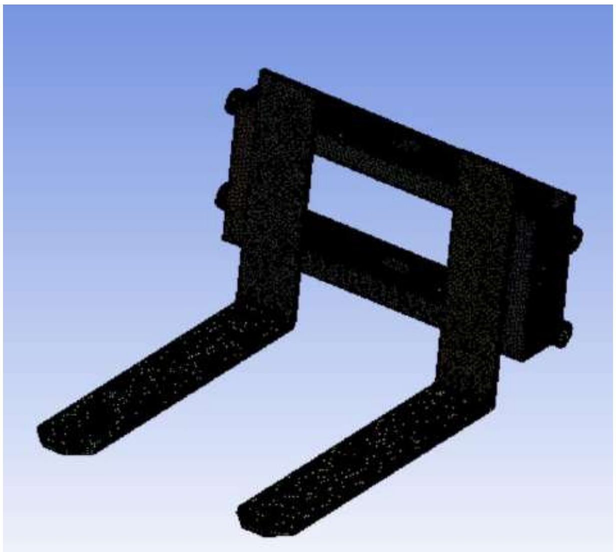

Figure-4.13 Forks assembly mesh

The figure shows meshed geometry in ANSYS. The mesh size is 2mm and meshing type triangular.

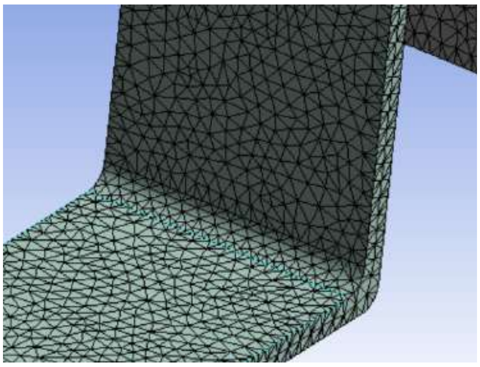

Figure-4.14 zoom in mesh size

4.2.3 Arduino IDE:

Arduino ide software is used for coding in C language. Separate codes are compiled for Arduino nano and Arduino mega. The code for Arduino nano is based on input signals from joystick, buttons and voltage regulator and output through Hc-12 wireless module.

The coding for Arduino mega is based on input data from remote through Hc-12 wireless modules, process the data and then give output according to the input data to motor drivers and relay module. The code is then uploaded to microcontrollers through USB cable.

4.3 Summary

This chapter dealt with the tools and hardware used in this project. Hardware tools included the fabrication tools and automation tools, whereas software tools included use of CAD (computer aided design) by the means of SOLIDWORKS and simulation tool that is ANSYS. These hardware and software tools are explained with complete design specifications in this chapter. Use of these hardware and software tools made sure the completion of this project in an effective manner. With the help of CAD software, the complete machine is being designed while simulation tool allowed the simulation of the project to get an insight of the stress analysis, structural analysis.

Chapter 5

PROJECT RESULTS AND EVALUATION

5.1 Presentation of the findings

In this chapter we have discussed in detail the findings of both hardware and software.

5.1.1 Hardware results

Mecanum Wheel Integration:

Successfully integrated mecanum wheels into the fork lifter chassis, allowing for omnidirectional movement. The mecanum wheels enabled the fork lifter to move forwards, backwards, sideways, and diagonally with ease.

Chassis and Frame:

Designed and fabricated a sturdy and stable chassis to support the weight of the fork lifter, the mecanum wheels, and the payload. The chassis design ensured proper weight distribution and stability during movement.

Fork Lifting Mechanism:

Developed and implemented a reliable fork lifting mechanism that could raise and lower loads with precision. The mechanism was operated using motors and controlled remotely.

Remote Control System:

Designed a user-friendly remote control system that included joysticks or buttons for controlling the movement of the fork lifter. The remote control effectively communicated with the fork lifter's microcontroller.

Electronics Integration:

Integrated the necessary electronics components, including microcontrollers, motor drivers, communication modules, and power supply systems, to ensure seamless operation of the remote-controlled fork lifter.

Testing and Calibration:

Conducted extensive testing and calibration to ensure accurate movement, lifting, and control. Evaluated the load capacity, stability, and responsiveness of the fork lifter under various conditions.

5.1.2 Software results

Microcontroller Programming:

Developed firmware for the microcontroller (Arduino mega and Arduino nano) to interpret commands from the remote control and translate them into motor movements. The programming allowed for independent control of the mecanum wheels to achieve omnidirectional motion.

Wireless Communication:

Established reliable wireless communication between the remote control and the fork lifter's microcontroller. The software ensured that commands were transmitted and received accurately and consistently.

Movement Algorithms:

Implemented algorithms for calculating motor speed and direction based on the input from the remote control. These algorithms enabled the fork lifter to move smoothly and precisely in any direction.

Lifting Control:

Programmed the fork lifting mechanism to raise and lower loads in a controlled manner. The software allowed for adjusting the lifting height and ensuring safe handling of the payload.

Testing and Optimization:

Conducted software testing and optimization to fine-tune the control algorithms, ensure consistent performance, and address any software-related issues that arose during testing.

SOLIDWORKS result:

Figure-5.1 Fabricated fork lifter prototype

The figure shows final fabricated prototype according to SOLIDWORKS design, mathematical modelling and specified parameter.

ANSYS result:

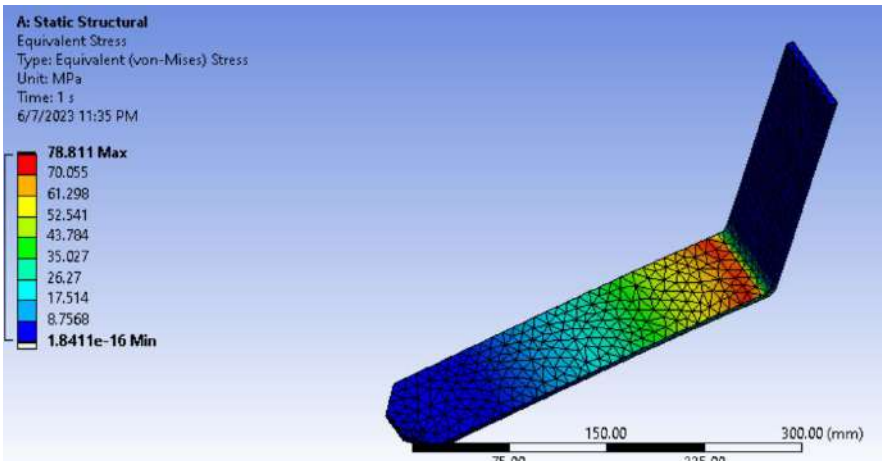

Figure-5.2 Stress results of fork

We can see from figure that the maximum stress is produced where the fork is bend. The red color shows the maximum stress value which is 78.8MPa, while the blue shows minimum stress which is mostly on the tip of fork. The stress produced under the exerted force of 196N (20kg) and is in safe limits as the allowable stress for selected material is 250MPa.

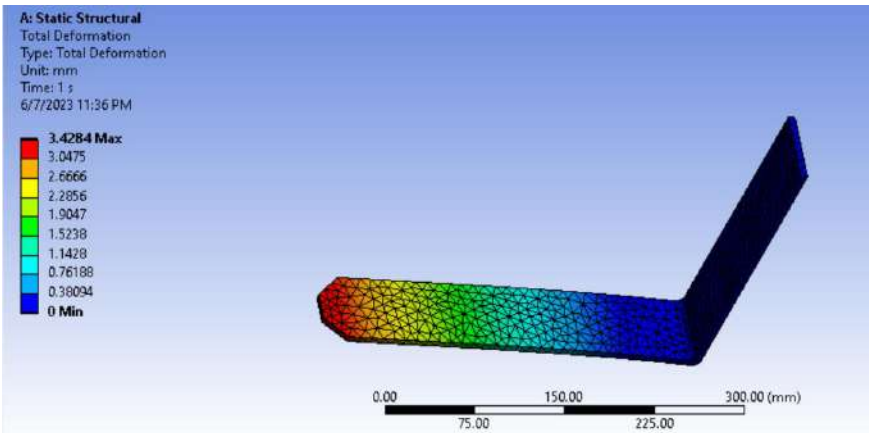

Figure-5.3 Total deformation result

Figure shows the total deformation occur as a result of applied force. The red shows maximum deformation which is 3.4mm occurs at the free end or tip of fork, while minimum deformation occur at the fix end. The fork are taken as cantilever beam.

5.2 Verification of design functionalities

These hardware and software results collectively contribute to the successful design and development of a remote-controlled fork lifter using Mecanum wheels, providing enhanced mobility, maneuverability, and operational efficiency.

5.3 Discussion of the findings

The project's hardware and software findings collectively indicate a successful implementation of a remote-controlled fork lifter using Mecanum wheels. The project team's multidisciplinary skills in mechanical design, electronics integration, software development, and control systems have come together to create a functional and efficient solution for achieving precise mobility and load handling. The positive outcomes of this project serve as a testament to the team's engineering expertise and problem-solving capabilities.

5.3.1 Comparison with initial Project Specifications

The fork lifter has been subjected to certain changes as compared to the initial design specifications, and these changes have been made when the fabrication started because fabrication has its own issues and the availability of components in market as compared to the mathematical modeling or the CAD design. First the total weight of the machine is reduced from 120kg to 60kg as the available Mecanum wheels were able to carry maximum load of

60kg. Similarly the lifting load is reduced to 20kg from 70kg. The parameters are also revised according to load changes. Our main focus was on;

- Torque requirements
- Power requirements
- Overall weight of fork lifter
- Lifting load

Mathematical modeling suggested that any further increase in the weight of the machine would also ask for the increase in the horsepower and torque requirement which means motors would have to be change to meet the design specifications.

5.3.2 Reasoning for short comings

The reasons for these short comings is the availability of Mecanum wheels as we have used 3in wheels which has the capacity of 60kg and by increasing the load on wheels the wheels diameter also increase which cause an increase of 2-3 times in price. Same is the case for lifting mechanism. We have used ball screw with dc wiper gear motor that has the capacity of lifting 20kg load as for 70kg load we has to change our lifting mechanism which was costly and again increases load on wheels and frame. The torque and power requirements also change with these changes which mean more heavy motors will be required.

5.4 Limitations

Our fork lifter has certain limitations according to various conditions.

- This fork lifter could not be used on rough surfaces as it has soft rollers which may tear on rough surface.
- Wiper motor has the ability of lifting 20kg load more than this wiper motor will fail to operate.
- The fork lifter is not capable of operating on unbalanced surfaces.
- The project takes more time for development and automation because of the complexity of Mecanum wheels.
- The dc gear motors requires high power, it may effect operation time while charging.
- The wireless communication range of remote controlled system is limited to 1km.
- Operating a remote controlled fork lifter with Mecanum wheels require skills and training.
- Complex mechanism of Mecanum wheels and lifting mechanism might require specialized maintenance and repairs.

5.5 Recommendations

Following are the future recommendations for someone who wants to carry this project:

- Integrate sensors or cameras to enable autonomous navigation and obstacle avoidance. This would allow the fork lifter to navigate and operate in complex environments without constant manual control.
- Implement load tracking and management features, such as weight sensors and load balancing algorithms, to optimize lifting and ensure safe operation even with varying payloads.
- Add remote monitoring capabilities through IoT connectivity, allowing operators to monitor the fork lifter's status, battery level, and performance remotely using a mobile app or web interface.
- Enhance safety features by integrating collision detection sensors, emergency stop mechanisms, and predictive algorithms that can anticipate potential safety risks.
- Tailor the design and features of the fork lifter for industrial applications, adhering to industry-specific standards and requirements for safety, reliability, and efficiency.

5.6 Summary

This chapter explained the results of the hardware and software. Hardware results includes the practical experimentation and working of the fork lifter on the field. While software results include the structural analysis of the fork lifter under the effect of the varying loads and stresses.

Chapter 6

CONCLUSION

In conclusion, the project "Design and Development of a Remote-Controlled Forklift Using Mecanum Wheels" has successfully demonstrated the feasibility and effectiveness of employing Mecanum wheel technology in the field of material handling and robotics. Through meticulous design, precise engineering, and rigorous testing, we have achieved the creation of a versatile and agile forklift capable of seamless omnidirectional movement.

The utilization of Mecanum wheels has proven to be a game-changer, enabling the forklift to navigate complex environments with exceptional maneuverability, including lateral and diagonal movements. This innovation holds great potential for enhancing efficiency and safety in industries that demand precise and flexible material transportation.

Throughout the project, we encountered and overcame various challenges, ranging from mechanical and electrical integration to programming and control algorithms. These experiences have not only expanded our technical skills but also reinforced the importance of interdisciplinary collaboration in realizing ambitious engineering endeavors.

Looking ahead, the remote-controlled forklift presented in this project lays the foundation for further advancements in autonomous material handling systems. By incorporating advanced sensor technologies, machine learning algorithms, and human-machine interfaces, we can envision a future where intelligent forklifts seamlessly operate in dynamic environments with minimal human intervention.

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Appendix – A

Transmitter code:

```
#include <SoftwareSerial.h>
#include <Wire.h>
SoftwareSerial HC12(12, 13); //tx,rx

#define rvx A6
#define rvy A5
#define lvx A4
#define lvy A3
#define rsw 10
#define lsw 9
#define potentio A2
#define lift_up 7
#define down 6

int variable1;
int variable2;
int variable3;
int variable4;
int variable5;
int variable6;
int variable7;
int variable8;
int variable9;

void setup() {
  HC12.begin(9600);
  Serial.begin(9600);
  pinMode(lvx, INPUT);
  pinMode(lvy, INPUT);
  pinMode(rvx, INPUT);
  pinMode(rvy, INPUT);
  pinMode(potentio, INPUT);
  pinMode(lsw, INPUT_PULLUP);
  pinMode(rsw, INPUT_PULLUP);
  pinMode(lift_up, INPUT_PULLUP);
  pinMode(down, INPUT_PULLUP);
}
void loop() {
  variable1 = analogRead(rvx);
  variable2 = analogRead(rvy);
  variable3 = digitalRead(rsw);
  variable4 = analogRead(lvx);
  variable5 = analogRead(lvy);
```

```
  variable6 = digitalRead(lsw);
  variable7 = analogRead(potentio);
  variable8 = digitalRead(lift_up);
  variable9 = digitalRead(down);

  HC12.print(variable1);
  HC12.print(",");
  HC12.print(variable2);
  HC12.print(",");
  HC12.print(variable3);
  HC12.print(",");
  HC12.print(variable4);
  HC12.print(",");
  HC12.print(variable5);
  HC12.print(",");
  HC12.print(variable6);
  HC12.print(",");
  HC12.print(variable7);
  HC12.print(",");
  HC12.print(variable8);
  HC12.print(",");
  HC12.print(variable9);
  HC12.println("");

  delay(100);
}
```

Receiver code:

```
#include <SoftwareSerial.h>
#include <Wire.h>
SoftwareSerial HC12(12, 13);//tx,rx
//IBT2 sensors
#define front_left_forward 2
#define front_left_backward 3
#define front_right_forward 4
#define front_right_backward 5
#define rare_left_forward 6
#define rare_left_backward 7
#define rare_right_forward 8
#define rare_right_backward 9
#define liftup 10
#define liftdown 11


int speedset=0;
```

```
int rvx=500;
int rvy=500;
int rsw=0;
int lvx=500;
int lvy=500;
int lsw=0;
int potentio=0;
int uplift=0;
int down=0;

String input;
int d1; //setup to reference delimiter locations so its easier to follow
int d2;
int d3;
int d4;
int d5;
int d6;
int d7;
int d8;
const char delimiter = ',';
void setup() {
  pinMode(front_left_forward, OUTPUT);
  pinMode(front_left_backward, OUTPUT);
  pinMode(front_right_forward, OUTPUT);
  pinMode(front_right_backward, OUTPUT);
  pinMode(rare_left_forward, OUTPUT);
  pinMode(rare_left_backward, OUTPUT);
  pinMode(rare_right_forward, OUTPUT);
  pinMode(rare_right_backward, OUTPUT);
  pinMode(liftup, OUTPUT);
  pinMode(liftdown, OUTPUT);

Serial.begin(9600);
HC12.begin(9600);
}
void loop() {
if(HC12.available())
{
input = HC12.readStringUntil('\n');
if (input.length() > 0)
{
//Serial.println(input);
d1 = input.indexOf(delimiter);
//Serial.println(d1);
rvx = input.substring(0, d1).toInt();
d2 = input.indexOf(delimiter, d1+1);
//Serial.println(d2);
```

```
rvy = input.substring(d1+1, d2).toInt();
d3 = input.indexOf(delimiter,d2+1);
//Serial.println(d3);
rsw = input.substring(d2+1, d3).toInt();
d4 = input.indexOf(delimiter, d3+1);
//Serial.println(d4);
lvx = input.substring(d3+1, d4).toInt();

d5 = input.indexOf(delimiter,d4+1);
lvy = input.substring(d4+1,d5).toInt();

d6 = input.indexOf(delimiter,d5+1);
lsw = input.substring(d5+1,d6).toInt();

d7 = input.indexOf(delimiter,d6+1);
potentio = input.substring(d6+1,d7).toInt();

d8 = input.indexOf(delimiter,d7+1);
uplift = input.substring(d7+1,d8).toInt();

down = input.substring(d8+1).toInt();


delay(10);
}
}
speedset=map(potentio, 0,1022,70,255);
if (lvx <= 300){
  analogWrite(front_left_forward, speedset);
  analogWrite(front_left_backward, 0);
  analogWrite(front_right_forward, speedset);
  analogWrite(front_right_backward, 0);
  analogWrite(rare_left_forward, speedset);
  analogWrite(rare_left_backward, 0);
  analogWrite(rare_right_forward, speedset);
  analogWrite(rare_right_backward, 0);
  Serial.println("forward");
}else if (lvx >= 700){
  analogWrite(front_left_forward, 0);
  analogWrite(front_left_backward, speedset);
  analogWrite(front_right_forward, 0);
  analogWrite(front_right_backward, speedset);
  analogWrite(rare_left_forward, 0);
  analogWrite(rare_left_backward, speedset);
  analogWrite(rare_right_forward, 0);
  analogWrite(rare_right_backward, speedset);
  Serial.println("backward");
}else if(lvy <= 300){
```

```
    analogWrite(front_left_forward, speedset);
    analogWrite(front_left_backward, 0);
    analogWrite(front_right_forward, 0);
    analogWrite(front_right_backward, speedset);
    analogWrite(rare_left_forward, 0);
    analogWrite(rare_left_backward, speedset);
    analogWrite(rare_right_forward, speedset);
    analogWrite(rare_right_backward, 0);
    Serial.println("right slide");
  }else if (lvy >= 700){
    analogWrite(front_left_forward, 0);
    analogWrite(front_left_backward, speedset);
    analogWrite(front_right_forward, speedset);
    analogWrite(front_right_backward, 0);
    analogWrite(rare_left_forward, speedset);
    analogWrite(rare_left_backward, 0);
    analogWrite(rare_right_forward, 0);
    analogWrite(rare_right_backward, speedset);
    Serial.println("left slide");
  }else if(rvy <= 300){
    analogWrite(front_left_forward, speedset);
    analogWrite(front_left_backward, 0);
    analogWrite(front_right_forward, 0);
    analogWrite(front_right_backward, 0);
    analogWrite(rare_left_forward, 0);
    analogWrite(rare_left_backward, 0);
    analogWrite(rare_right_forward, speedset);
    analogWrite(rare_right_backward, 0);
    Serial.println("secondary diagonal forward");
  }else if(rvy >= 700){
    analogWrite(front_left_forward, 0);
    analogWrite(front_left_backward, speedset);
    analogWrite(front_right_forward, 0);
    analogWrite(front_right_backward, 0);
    analogWrite(rare_left_forward, 0);
    analogWrite(rare_left_backward, 0);
    analogWrite(rare_right_forward, 0);
    analogWrite(rare_right_backward, speedset);
    Serial.println("secondary diagonal backward");
  }else if (rvx <= 300){
    analogWrite(front_left_forward, 0);
    analogWrite(front_left_backward, 0);
    analogWrite(front_right_forward, speedset);
    analogWrite(front_right_backward, 0);
    analogWrite(rare_left_forward, speedset);
    analogWrite(rare_left_backward, 0);
    analogWrite(rare_right_forward, 0);
```

```
    analogWrite(rare_right_backward, 0);
    Serial.println("primary diagonal forward");
  }else if (rvx >= 700){
    analogWrite(front_left_forward, 0);
    analogWrite(front_left_backward, 0);
    analogWrite(front_right_forward, 0);
    analogWrite(front_right_backward, speedset);
    analogWrite(rare_left_forward, 0);
    analogWrite(rare_left_backward, speedset);
    analogWrite(rare_right_forward, 0);
    analogWrite(rare_right_backward, 0);
    Serial.println("primary diagonal backward");
  }else if (rsw == 0 && lsw == 1){
    analogWrite(front_left_forward, speedset);
    analogWrite(front_left_backward, 0);
    analogWrite(front_right_forward, 0);
    analogWrite(front_right_backward, speedset);
    analogWrite(rare_left_forward, speedset);
    analogWrite(rare_left_backward, 0);
    analogWrite(rare_right_forward, 0);
    analogWrite(rare_right_backward, speedset);
    Serial.println("right rotation");
  }else if (lsw == 0 && rsw ==1){
    analogWrite(front_left_forward, 0);
    analogWrite(front_left_backward, speedset);
    analogWrite(front_right_forward, speedset);
    analogWrite(front_right_backward, 0);
    analogWrite(rare_left_forward, 0);
    analogWrite(rare_left_backward, speedset);
    analogWrite(rare_right_forward, speedset);
    analogWrite(rare_right_backward, 0);
    Serial.println("left rotation");
  }else{
    analogWrite(front_left_forward, 0);
    analogWrite(front_left_backward, 0);
    analogWrite(front_right_forward, 0);
    analogWrite(front_right_backward, 0);
    analogWrite(rare_left_forward, 0);
    analogWrite(rare_left_backward, 0);
    analogWrite(rare_right_forward, 0);
    analogWrite(rare_right_backward, 0);
    Serial.println("stop");
  }
  delay(5);
  if (uplift == 0 && down ==1){
    analogWrite(liftup, speedset);
    analogWrite(liftdown, 0);
```

```
  Serial.println ("liftup");
}else if (uplift == 1 && down ==0) {
  analogWrite(liftup, 0);
  analogWrite(liftdown, speedset);
  Serial.println("liftdown");
}else {
  analogWrite(liftup , 0);
  analogWrite(liftdown, 0);
  Serial.println("no lift");
}
delay(10);
}
```

DESIGN AND DEVELOPMENT OF REMOTE CONTROLLED FORK LIFTER USING MECANUM WHEELS

ORIGINALITY REPORT

11%	8%	2%	6%
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