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Design and Fabrication of Battery-Operated Remote Controlled Mini Forklift

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ABSTRACT: Recent changes in industrial technology have increased the demand for autonomous forklifts that can operate remotely. Unmanned forklifts eliminate the effort required to train qualified operators and reduce accidents caused by driver fatigue. Currently, forklifts are based on hydraulic or gasoline engines, which have a negative impact on the environment. Increasing awareness of environmental threats has led companies to replace conventional forklifts with electric forklifts. The cost of unmanned electric forklifts is high and poses a burden for developing countries, especially when used in small warehouses. Therefore, this paper presents a new method for the development of a semi-automatic and environmentally friendly stacker suitable for small warehouses using remote controllers. This stacker is designed with a belt & pulley mechanism and can take a maximum of 19.6122N. It stands out with its lightness and corrosion resistance. The 2D & 3D models of mini forklifts were developed using SOLIDWORKS software. The loading capacity of the forklift was designed using ANSYS simulations.

KEYWORDS: Remote operated, green forklift, Compact storage capacity, DC motor operated, left-right movement, belt drive, stackers.

I. INTRODUCTION

Forklifts play an important role in moving goods, improving efficiency and safety in industries such as warehouses, manufacturing, and logistics. Recent technological advances have led to a shift from traditional internal combustion engine stackers to battery-powered systems and increased remote control capabilities with the changing nature of the economy. Conventional forklifts, widely used in warehousing, manufacturing, logistics and other industries, often use combustion engines as power, resulting in environmental pollution and high operating costs. It is also important for the operator to use forklifts in hazardous areas or with limited security. There is an urgent need for new solutions that will solve these problems by providing products that are sustainable, effective, and safer than other alternatives.

Recent technological developments have led to the transition from traditional internal combustion engine stackers to battery-powered stackers and the rise of remote-control systems in response to changes in the economy. To solve emissions and noise pollution problems, there is a growing need for other sustainable solutions such as battery-powered forklifts that can provide environmentally friendly solutions and reduce carbon monoxide emissions. The remote-control device allows operators to operate the forklift from a safe location, further improving safety and reducing the risk of accidents. In addition, mini forklifts are designed to facilitate work in closed areas and small equipment and offer promise and diversity. This research is designed for the design and fabrication of a battery-powered remote control mini forklift. Goals include measuring loading performance, and control accuracy.

II. RELATED WORK

The development of mini forklifts has received significant attention in recent years, reflecting the expansion in product processing and industrial automation. Various studies and research projects differ from forklift technology and focus on innovation, electronic equipment, and control systems.

Research in the field of battery-powered stackers has been extensive due to the need for business solutions. Recent research has shown the advantages of lithium-ion batteries over lead-acid batteries in terms of higher energy

consumption, shorter charging times and longer operating life. These advances have proven significant in reducing the environmental impact and operating costs of forklifts, making them the first choice in everyday use.

Integrating remote control technology into forklifts shows great potential in improving workplace safety and productivity. Research shows how wireless communications and advanced technology can be used to operate remote-controlled forklifts from a safe location. This reduces the risk to the user in hazardous areas such as chemical plants or construction sites and allows better control of forklift operations.

Recent advances in automation and intelligent control systems have increased the efficiency and safety of forklift operations. By combining technologies such as artificial intelligence and machine learning, researchers have developed methods that can improve planning, improve prevention, and improve business performance. Although fully automated forklifts are still emerging, these smart controls have been incorporated into remote controls to improve their performance.

III. LITERATURE REVIEW

Forklifts are an important tool for transporting equipment in industry; They help move and store goods in warehouses, distribution centres, and manufacturing facilities. Conventional forklifts generally rely on an internal electric motor for power and manual operation for control. However, recent technological advances have encouraged the development of more efficient, safer, and environmentally friendly batteries, including batteries for electric and remote-controlled forklifts.

The development of forklift technology is characterized by the development of batteries and remote control. The change is driven by the need to increase business efficiency, improve workplace safety and reduce environmental impact. Battery-powered stackers have many advantages over traditional competitors, including lower cost, quieter operation, and less maintenance. In dangerous or stressful situations remote-controlled forklifts, on the other hand, give workers greater control and accuracy, especially in hazardous or tight areas.

Research on battery technology for forklifts has focused primarily on the development and optimization of lithium-ion batteries. These batteries have more power, faster charging times and longer lifespan than lead-acid batteries. Research demonstrates the feasibility and effectiveness of lithium-ion batteries for power stackers, highlighting their ability to make equipment use more efficient and durable. The integration of remote controls into forklifts has become a new promise to improve workplace safety and efficiency. Remote-controlled forklifts allow workers to control the vehicle from a safe location, reducing the risk of injury and damage. Advanced technology and wireless communications provide control and efficiency, especially in environments where human personnel may be difficult or dangerous.

Research in this area addresses issues such as battery management, wireless connectivity, and remote-control interface design. Although significant progress has been made in the development of batteries using remote-controlled mini forklift, there is still time for further research and innovation. Key areas may include optimizing battery performance, improving remote control, and integrating smart automation tools. Addressing this gap will not only improve the development of forklift technology but also support the continued development of handling equipment in various workplaces.

IV. METHODOLOGY

4.1 DESIGN CONCEPTUALIZATION:

During the conceptualization phase, we worked together to create ideas for the micro forklift, considering our specific requirements and limitations. We prioritize functionality, quality, and customer satisfaction by exploring design options through architectural design and CAD models. Our focus on innovation and sustainability leads to the development of cutting-edge designs based on our unique practices.

4.2 DESIGN PHASE:

Requirement Analysis: The forklift must have a load capacity of 2 kg, a lift height of 30 cm, and be operable via a wired control system

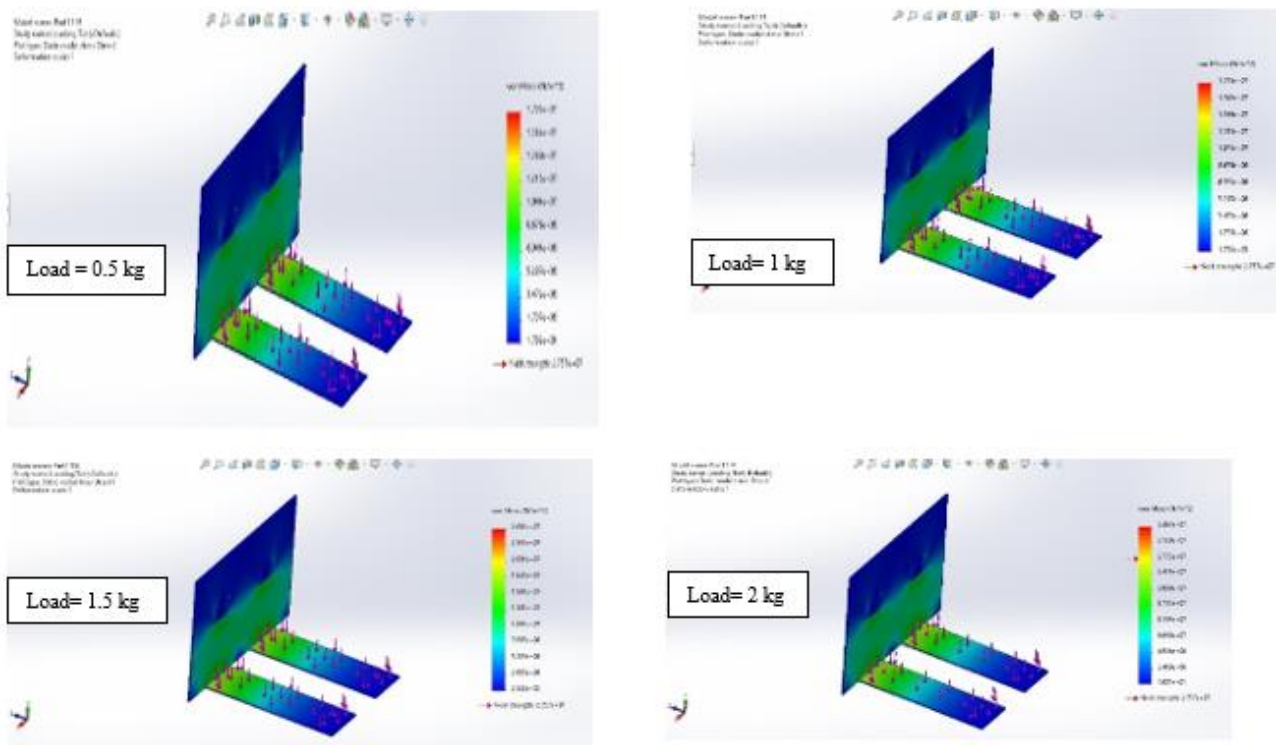


Fig 1: load analysis of carriage of forklift in SolidWorks

Conceptual Design: Preliminary sketches and 3D models were created using SolidWorks. These models helped visualize the forklift's dimensions and functionalities.

A detailed CAD model of the mini forklift was created using SolidWorks software. The CAD model includes components such as chassis, DC Gear motor, lift motor, lift support, motor mount, belt and pulley mechanism, wheels, support rod, & lifting bed. Most designs are optimized for geometry and optimized for functionality and performance.

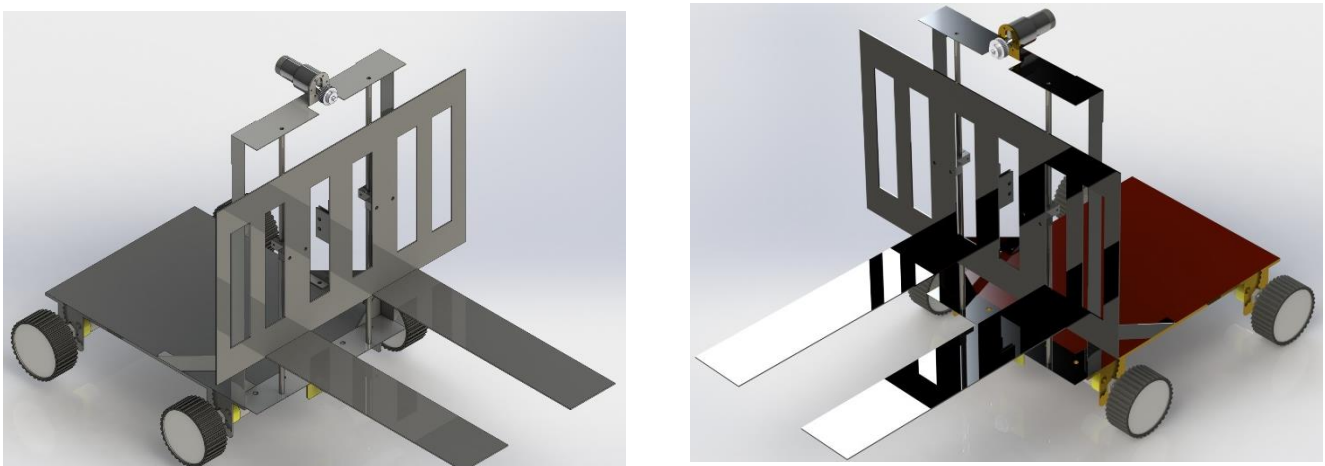


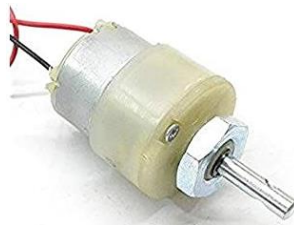
Fig.2 Isometric view of CAD model of forklift

4.3 COMPONENT SELECTION:

Components for the mini forklift were selected based on criteria such as performance, durability, compatibility, and cost-effectiveness. Motors with sufficient torque and speed capabilities were chosen to drive the wheels and lift mechanism. Lithium-ion batteries were selected for their high energy density and long cycle life Control systems, including remote control hardware, such as SPDT switch were chosen for compatibility with the selected components.



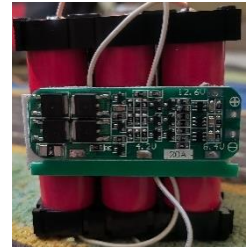
12V 60rpm Johnson gear motor



12V 60rpm DC gear motor



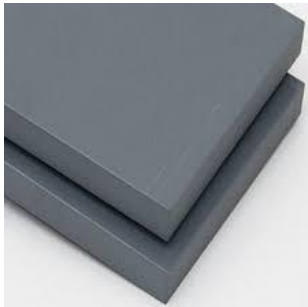
SPDT Switch



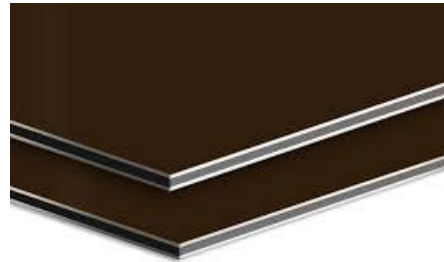
12V-12Amp Battery pack

4.4 FABRICATION TECHNIQUES:

Making the mini forklift prototype involves a combination of processes such as grinding, cutting, drilling and 3D printing. The chassis and equipment are made of aluminium and PVC materials, selected for their lightness and rigidity. 3D printing is used to create complex components such as pulleys.



PVC Sheets

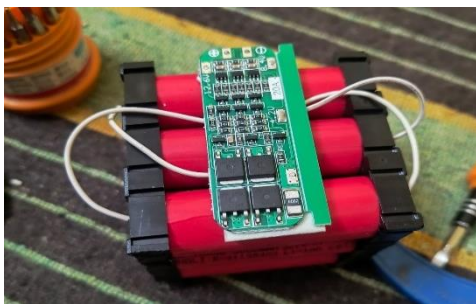


Aluminium Sheets

4.5 BATTERY PACK ASSEMBLY

12V, 12Ah Li-ion battery pack using a 5000mAh cell. First, we start by collecting the necessary materials consisting of 9 batteries, 3S BMS, nickel strips, welding machine, insulation materials, battery holders, blocks, and multimeter machine. We set up the cells in a 3S3P configuration and used a spot welder to connect the cells in rows by welding a nickel strip between the positive and negative terminals. We then assemble the wire string by connecting the nickel strips to the positive and negative ends of the wire string.

After insulating all connections with Kapton tape to prevent short circuit, we connect the BMS balance to the connection of the cell and its main terminals to the positive and bad terminals on the battery pack. We test the battery pack by measuring the total voltage and the voltage of each series battery with a multimeter to make sure they are equal. This careful process results in a reliable 12V, 12Ah lithium-ion battery pack.



Li-ion Battery	Specifications
Battery Type	Li-ion 18650 Battery Pack
Nominal Output Voltage	11.47 V
Maximum Output Voltage	12 V
No. of Battery Cell	9 × Li-ion 3.7 V 5A
Cycle Life	≥ 500 (80%)
Charging Temperature	0 - 45°C
Discharging Temperature	20 - 60°C
Capacity (mAh)	15000 mAh
Discharge Rate	3C

Fig.3: 12V 12amp Battery pack

4.6 CONTROL SYSTEM DEVELOPMENT

The control system development for a wired-controlled mini forklift involves design and implementation of a reliable system to control the movements and operations of the forklift through direct-wired connections. This section describes the steps taken to create the control system without the using microcontrollers and motor drivers.

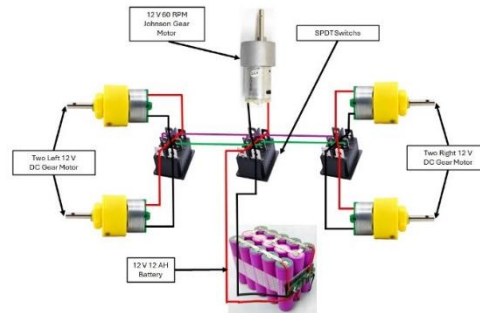


Fig 4: Forklift Control Circuit Wiring Diagram

COMPONENTS:

- Control Switch: A mechanical switch or wired joystick used to send electricity directly to the motors.
- Motor: 12V DC motors are used to drive the wheels and lift the carriage.
- Power Supply: 12V, 12Ah Lithium-ion battery powers the motor and control system.

HARDWARE INTEGRATION:

Connections:

- Joystick/Control Switch to Power supply: Connect the output of the switch to the power supply.
- Power supply: Connect the battery to the wheel motors and lifting motor.
- Assembly:
 - Securely install the joystick/control switch on the forklift or in a hand control.
 - Connect the wires between the joystick, and motors according to the wiring diagram.
 - Make sure connections are secure and insulated to prevent short circuits.

CONTROL LOGIC (HARDWARE-BASED):

Forward/Backward Movement:

- Use SPDT (Single Pole Double Throw) switches to control the direction of the driving motors.
- Each SPDT switch will control the polarity of the voltage applied to the motors, allowing forward and backward movement.
- Left/Right Turning:
 - Additional SPDT switches can control the left and right rotation by reversing the polarity of one motor while keeping the polarity of the other motor constant.
- Lifting Mechanism:
 - Uses SPDT (single pole double throw) switch to control the lifting motor, allowing it to move up or down.

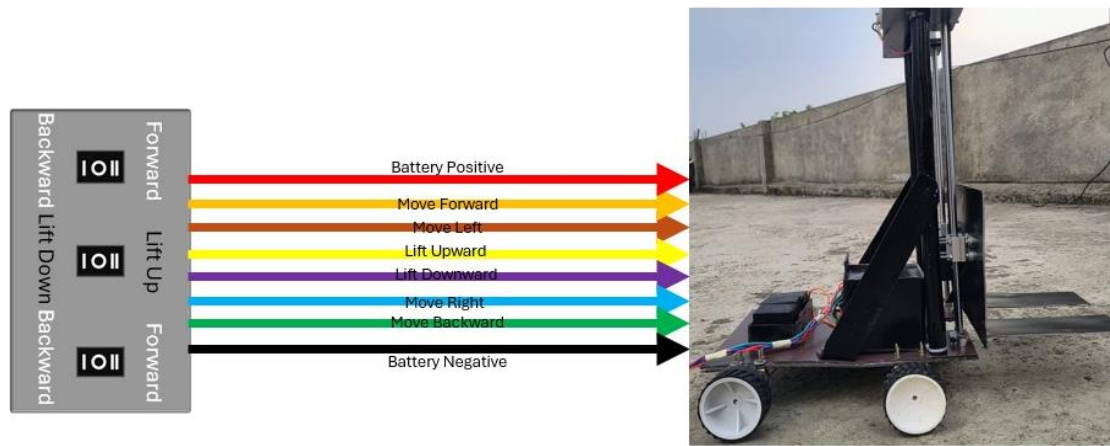
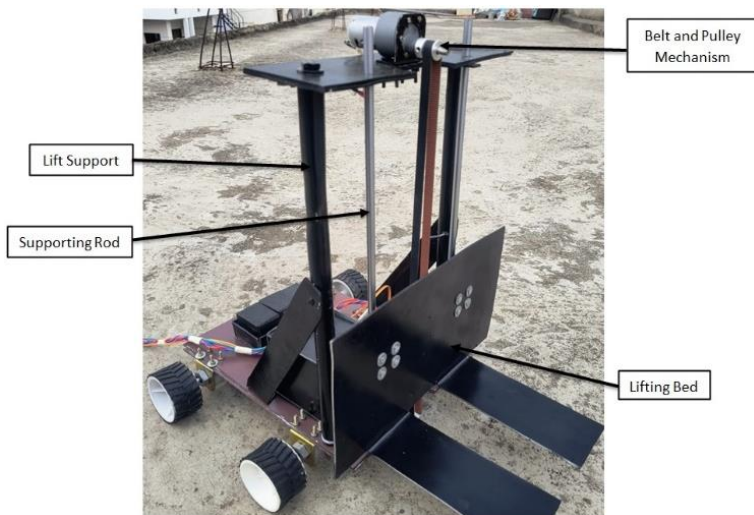


Fig 5: Control logic

CALIBRATION AND TESTING:

Calibration:

- Joystick/Switch Calibration: Ensure that the switches and joystick give the correct signal when turned on. If necessary, adjust the wires to correct the problem.
- Motor Calibration: Measuring individual motors to ensure they respond correctly to changing signals. Adjust the wiring to balance the speed and responsiveness of each motor.
- Initial Testing
- Tests performed in a controlled environment to ensure that the forklift responds correctly to the switch inputs.
- Test all functions, including forward/backward movement, rotation, and lifting, to ensure proper control.
- Debugging:
- Monitor the system for any problems such as slow responses, poor motion, or electrical failures.
- Improve the wiring and mechanical setup based on test results to eliminate any problems.



- Final assembly labelled as follows:**
- Belt and pulley mechanism.
 - Lift support
 - Lifting bed
 - Supporting rod
 - Battery box
 - On-off-On switch
 - Remote control
 - Linear bearing
 - Dead load
 - 12V DC gear motor with mount
 - DC motor wheel
 - Shaft support.

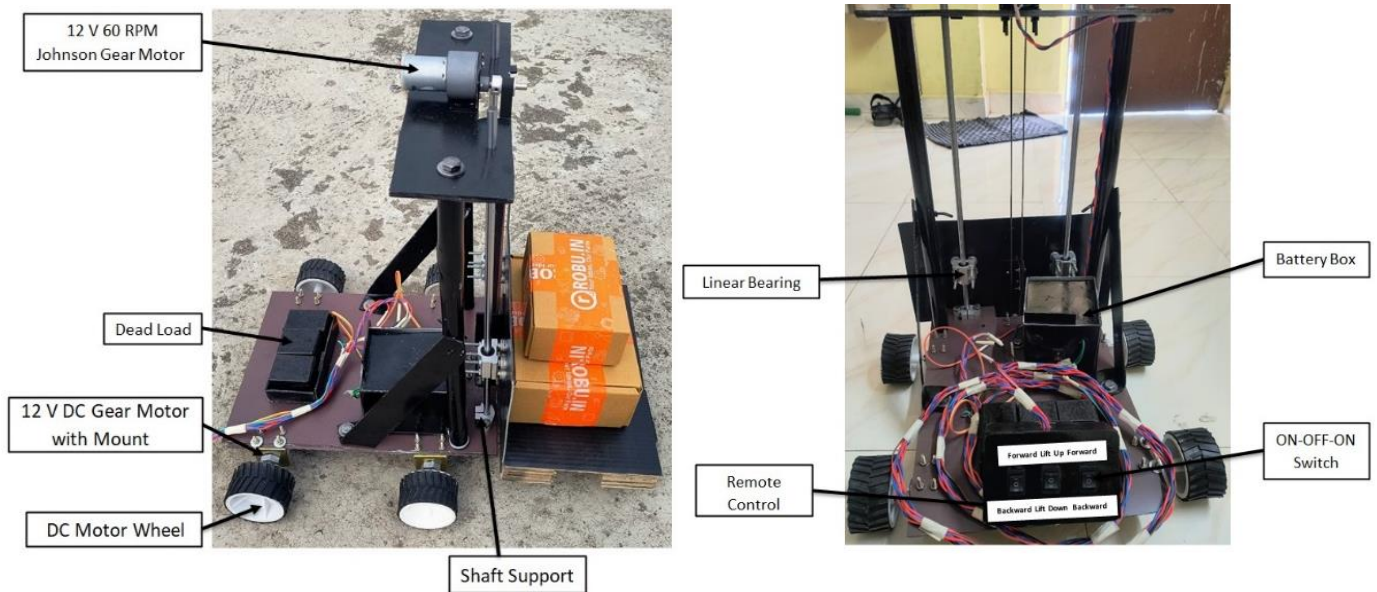


Fig.5: Labelling of parts of forklift

V. RESULTS

This section presents the test results obtained from testing of battery-operated, remote-controlled mini forklift. These tests are designed to measure the performance, durability, and safety of forklifts in a variety of applications.

1) PERFORMANCE TESTING:

Objective: To evaluate the performance of the mini forklift, including load capacity, lifting speed, & manoeuvrability.

Load Capacity:

- Procedure: The forklift was tested by adding weight from 0.5 kg up to the maximum design load of 2 kg.
- Results: The forklift was successfully lifted and transported loads up to 2 kg without any mechanical issues. The lifting mechanism works well in all load ranges.

Load (kg)	Lift Time (s)	Observations
0.5	12.33	Smooth operation, no strain
1	14.62	Smooth operation, minimal strain
1.5	15.42	Noticeable motor strain, stable
2	16.98	Maximum load, stable operation

2) LIFTING SPEED:

- Procedure: Measure the time required to lift a 500gm load to the maximum height of 30 cm.
- Results: As the height increases, the lifting speed decreases slightly, but the performance of the forklift remains the same.

Height (cm)	Lift Time (sec)	Observations
0-10	6.01	Smooth operation, no delay
10-20	6.36	Smooth operation, a little delay
20-30	6.57	Maximum time taken to achieve height

3) MANOEUVRABILITY:

- Procedure: The forklift's ability to navigate through an obstacle course with various turns and straight paths was evaluated. The distance travelled by forklift in all these above activities is 3 metres.
- Results: The forklift demonstrated good manoeuvrability, able to execute turns and navigate tight spaces effectively. The remote control provided precise inputs, and the response time was satisfactory.

Test	Completion Time (s)	Observations
Straight Path	13.60	Smooth, controlled speed
Zigzag Path	19.35	Good manoeuvrability, precise control
Tight Turns (2)	22.75	Slight delay in sharp turns

4) BATTERY DEPLETION:

- Process: Operate the forklift until the battery is almost dead and observe its behaviour
- Result: As the battery voltage decreases, the power of the stacker gradually slows down and the chemical also slows down against the speed of the lifting mechanism. The system features a low voltage cut-off feature to prevent battery damage during startup.

5) COST ANALYSIS:

Sr. No.	Part Name	Material	Component	Cost
1.	Chassis	Aluminium Alloy	Base	150
2.	Motor Mount	MS Steel	Drive	20×5
3.	12 V DC Gear Motor	-	Drive	150×4
4.	12 V Jhonson Gear Motor	-	Lift	400
5.	Lift Support	Polyvinyl Chloride PVC	Lift	50
6.	Lifting Bed	Polyvinyl Chloride PVC	Lift	50
7.	GT2 Timing Pulley	Aluminium	Lift	200
8.	Timing Belt	Rubber	Lift	150
9.	Linear Bearing	Aluminium	Lift	200
10.	Supporting Rod	Carbon Steel	Lift	350
11.	Horizontal Shaft Support	Steel	Lift	200
12.	DC Motor Wheel	Plastic + Rubber	Drive	200
13.	Battery	Lithium Ion	Drive	1000
14.	Dead Load	MS	Drive	50
15.	Nut and Bolt	Stainless Steel	Drive	300
16.	Free Pulley Mounting	-	Drive	50
Total				4050

VI. CONCLUSION

The research project "Design and Fabrication of Battery-Operated Remote Controlled Mini Forklift" is designed to create a functional and efficient mini forklift that can be controlled and operated by a battery power source. The main goal of the project is to create a forklift that can control its load capacity, perform smooth and precise manoeuvring, provide sufficient battery for use, and include safety features that will prevent accidents.

1. Design and Fabrication:

- This forklift has been successfully designed using CAD software and is designed to handle heavy yet strong materials. The chassis is mainly made of aluminium and the non-loading parts are made of high plastic.
- The integration of 12V DC motors into driving and lifting systems has proven to be very beneficial.

2. Performance Testing:

- The stacker meets the required capacity, can bear up to 2 kg and operates stably and reliably.
- Manoeuvrability testing proved that the forklift can be controlled from many directions and can make accurate movements via remote control.

3. Durability Testing:

- The forklift ensures stable and consistent operation in loading and unloading more than 100 times at maximum height.
- Stress tests with loads slightly above the design limit demonstrate the strength of the design, but also demonstrate the need to comply with special limits to avoid long-term damage.

The project achieved its goals by creating a high-performance and reliable battery-powered remote control mini forklift. The forklift's ability to carry its own load capacity, combined with its manoeuvrability and battery durability, makes it an ideal solution for lighting equipment.

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