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DESIGN AND FABRICATION OF POWER KIT FOR WHEELED CARTS

PROJECT REPORT

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ABSTRACT

Carts are a common means of transportation for a variety of goods and materials, but when loaded with a heavy load, they can be difficult for a person to manually pull. This can be especially challenging for elderly individuals. In this project, a power kit is designed and fabricated that can be attached to any cart to make it easier to pull. The power kit has an adjustable width and height to fit different sizes of carts. The power kit consists of motors, sensors, battery, an electronic controller, adjustable height and width mechanism and a micro controller. It is activated by pressing a button and controlled by mobile app. In order to design and fabricate the power kit, a systematic approach has been followed that included gathering data and information from relevant sources, prototyping and testing different designs and iteratively improving the design based on the results of our testing. Different factors are considered during design such as cost, safety, reliability and ease of use in our design. The resulting power kit will be able to successfully move carts of different sizes in our testing. Various tests would be done to ensure that the kit would functional and met the project objectives. The power kit has the potential to improve the transportation of goods and materials and to facilitate greater independence and mobility for users. In addition to its practical applications, the power kit also has the potential to make a positive impact on the environment. By reducing the reliance on manual labor to pull carts, the power kit can help to reduce the physical strain on workers and potentially reduce the risk of injury. Overall, the design and fabrication of a power kit for carts represents a practical and innovative solution to the problem of manually pulling heavy carts. It has the potential to improve the transportation of goods and materials and to facilitate greater independence and mobility for users.

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CHAPTER 1 - INTRODUCTION

1.1 Introduction

The shopping cart has long been an essential tool in retail environments, revolutionizing the way customers navigate and transport their purchases. Over the years, shopping carts have evolved from simple hand-carry baskets to wheeled carts, offering convenience and ease for shoppers. However, as shopping habits and customer expectations continue to evolve, there is a growing need for innovative solutions that can enhance the functionality and usability of these carts.

Throughout history, shopping carts have undergone various improvements to meet the changing needs of shoppers. The introduction of wheels significantly improved maneuverability, allowing customers to effortlessly navigate through stores and transport larger quantities of items. The first shopping cart was invented by Sylvan Goldman in 1936 when he combined a seat with shopping basket and moved the mechanism by attaching four wheels at the base [1]. The concept of first shopping cart is shown as figure below:

Figure 1-1: Invention of first Shopping Cart

Subsequent enhancements such as increased cart capacity, adjustable handles and child seating areas further improved functionality and customer convenience [2]. Despite these advancements, issues still persist when it comes to handling heavy or fully loaded shopping carts. Pulling and controlling these carts manually can become physically demanding, leading to discomfort and inconvenience for shoppers [3] as shown in figure below:

Figure 1-2: Pushing and Pulling Issues

Recognizing this challenge, project focuses on designing and fabricating a power kit that can be attached to existing shopping carts, providing an automated solution for cart propulsion. By integrating motorized components and smart control systems, our power kit aims to simplify the movement of shopping carts, making them easier to handle, especially when fully loaded. The power kit offers features such as adjustable speed control, braking mechanisms, and wireless connectivity for intuitive operation. Additionally, the design accommodates carts of various sizes and incorporates safety measures to ensure a secure shopping experience.

This project aims to contribute to the ongoing evolution of shopping cart technology, providing a practical solution that improves the overall shopping experience for customers and enhances the efficiency of retail operations. The subsequent chapters of this report delve into the detailed design, fabrication, and evaluation processes, highlighting the key findings and insights gained throughout the course of this project.

1.2 Background Knowledge

Carts are a common means of transportation for a variety of goods and materials. They are used in many different settings including retail stores, warehouses and construction sites. While carts can be very useful for transporting items, they can also be difficult to pull when loaded with heavy loads [4]. This can be especially challenging for elderly or for those with mobility issues as shown in figure below:

Figure 1-3: Manual Shopping Cart

To address the problem of manually pulling heavy carts, various solutions have been proposed. One solution is to make carts motorized, either by adding an electric motor to the cart itself or by attaching a motorized unit to the front or back of the cart. However, motorized carts can be expensive and may not be practical in all situations. They also require maintenance and may not be as reliable as non-motorized carts [5] as shown in figure below:

Figure 1-4: Motorized Shopping Cart

Another solution is to use a power assist system that can be attached to a cart to make it easier to pull. Power assist systems can be activated by the user and provide a boost of power to help move the cart [6]. These carts are smarter but they are too much costly. The smart is shown in figure below:

Figure 1-5: Smart Shopping Cart

In summary, the problem of manually pulling heavy carts is a common challenge that has been addressed by various solutions, including motorized carts and power assist systems. Manual shopping carts present various physical challenges, as mentioned earlier, such as the physical effort required to pull them and the potential strain or fatigue it can cause, especially for individuals with limited mobility. On the other hand, motorized shopping carts offer a solution to this physical burden by providing a motorized propulsion system. However, motorized shopping carts come with their own set of issues, notably the cost associated with their purchase, maintenance, and repairs. The implementation of motorized shopping carts requires a significant investment for retailers, as they are more expensive than traditional manual carts. Moreover, the maintenance and repair of motorized carts, including battery replacement and motor issues, can be costly and time-consuming. Therefore, while motorized shopping carts alleviate physical challenges, their cost implications need to be considered by retailers and users alike.

1.3 Motivation

The use of carts for transportation is prevalent in many sectors in Pakistan, including retail, warehousing, and construction. However, manually pulling heavy carts can be a physically demanding and time-consuming task, and it can be especially challenging for elderly or for those with mobility issues [7]. In addition to the physical strain, manually pulling carts can also be inefficient and may not be the most cost-effective solution in certain situations [8].

To address these problems, the opportunity is to design and fabricate a power kit that could be attached to carts to make them easier to pull. The motivation for this project was to provide a practical and innovative solution to the problem of manually pulling heavy carts and to improve the transportation of goods and materials in Pakistan. By using DC motors as the power source and incorporating sensors and an electronic controller, it is aimed to create a functional and reliable power kit that could be easily attached to carts of different sizes and successfully move them.

In addition to improving the efficiency and speed of cart transportation, the potential for the power kit to have a positive impact on the environment. By reducing the reliance on manual labor to pull carts, the power kit can help to reduce the physical strain on workers and potentially reduce the risk of injury. It can also reduce the carbon footprint of cart transportation as the use of electric motors can be more energy efficient than manual labor [9].

Overall, the motivation for this project was to address a common problem in Pakistan and to provide a practical solution that could improve the transportation of goods and materials. The power kit has the potential to make a positive impact in a variety of settings where carts are used for transportation including retail stores, warehouses, and construction sites. By designing and fabricating a power kit that can be easily attached to carts of different sizes, hope to make it easier for people to transport their items and to facilitate greater independence and mobility for users. In future, the power kit will be a useful and valuable addition to the tools and technologies available for cart transportation in Pakistan.

CHAPTER 2 - LITERATURE REVIEW

There has been a significant amount of research on the use of carts for transportation and on ways to improve the efficiency and ease of use of carts. In particular, there has been a focus on developing motorized carts and power assist systems that can be attached to carts to make them easier to pull.

2.1 Shopping Cart Sizing

There are different types of carts which are used in different places in the world. The carts have different shapes of base. Some carts have rectangular base while mostly carts have inclined base in which the width of cart changes continuously. The given below describes the different configuration of shopping carts and amount of load which it can support [10]. The purpose of data collection is to determine the size of variety of carts and load which they have to support for proper working.

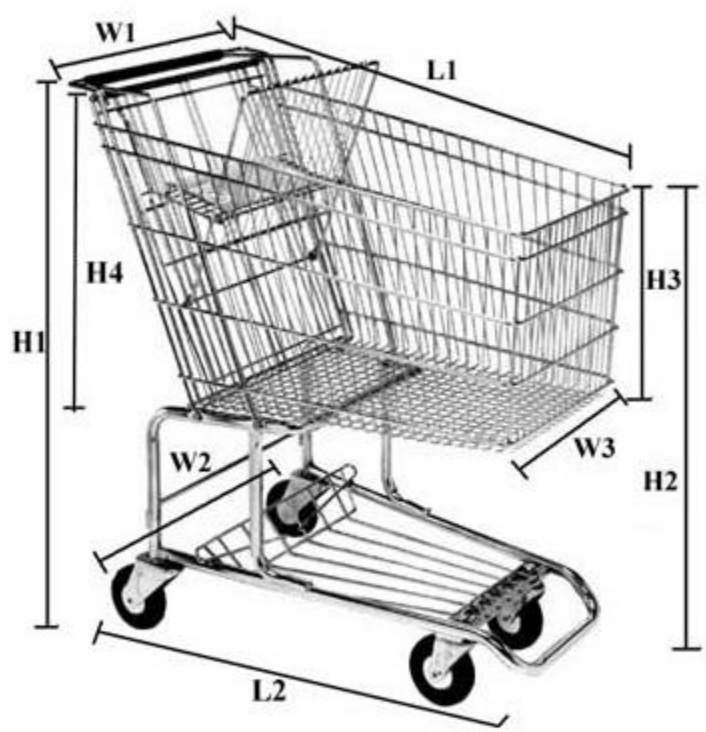

Figure 2-1: General Shopping Cart

Model	Application	Basket Capacity Cubic Inches	Bottom Capacity	Total Capacity Cubic Inches	Nesting Distance	W1	W2	W3	L1	L2	H1	H2	H3	H4	Weight in lbs.
T1336	Pharmacy	3,960		7,600	8 3/4	18	20	15	20 3/4	28 1/4	36	32	12Â 7/16	15 5/8	38
T1540	Hobby Store	9,720		12,630	10 1/4	20 1/4	20 1/4	14 7/8	34 3/4	32 1/8	40 3/8	34 1/2	16 5/8	21	50
T1737	Pharmacy/Drug	5,100		7,530	7 1/2	17 5/8	18 7/8	12 1/4	30 3/4	28 3/4	37 1/4	31 3/8	14	18 1/2	35
T2141	Pet Store	12,690		16,490	10 1/4	22 1/2	22 1/2	16	37	31 7/8	42	35 1/2	19 3/8	23 5/8	54
T2440	Hobby Store	9,740		12,050	10	21	20 5/8	14 7/8	37 1/4	34 5/8	40 1/4	33 3/8	16 1/2	21	51
T2638	Hobby Store	9,460		12,300	10	21	20 1/2	14 3/4	35 3/4	34	38	33 1/4	15 1/2	19 3/4	52
T3340	Hardware/Hobby Store	8,940		15,060	12	25 1/8	22 7/8	19 3/8	37 1/2	33 1/2	40 3/8	35 1/4	11 11/16	16 1/4	55
T3342	Grocery Store	8,940	6,370	15,310	13 1/4	25 1/4	22 7/8	19Â 7/16	32	33 3/8	42 1/2	37 1/2	16Â 1/16	11Â 9/16	56
T3440	Pet Store	10,830		17,450	12	24 1/4	23	18 5/8	42 1/2	38 1/8	40 3/8	35 1/8	11	16	57
T3541	Grocery Store	10,830	7,750	18,580	12 1/8	24	22 1/8	18 3/4	34	37 1/2	41	36	18 1/2	15 1/8	57
T3638	Electronics Store (Anti theft cart)	13,300		13,300	12	22 1/2	22 3/8	16	32 1/4	36 1/2	39	33 1/4	24 1/2	19 3/8	55
T5141	Small Grocery Liquor Store Library Cart	2,500	2,700	5,200	7.5	20	20Â 9/16	16 1/4	17 1/2	22 5/8	39 1/2	33 1/4	10	8	30
T5141D	Small Grocery Liquor Store Library Cart	2,500	2,500	5,000	7.5	20 1/2	24 3/8	16	17 1/2	27 1/4	39 1/2	36	10	8	37

Figure 2-2: Shopping Cart Sizing Chart

From the sizing chart it can be seen that the value of w_2 varies from 20 inches to 20 3/8 inches. It means that the size of power kit must be fit into this configuration in order for proper functioning.

2.2 Tire Configuration

The configuration and size of tires is very necessary for designing the Power Kit so that it can attach to carts of different sizes. This study focuses on analyzing different tire configurations and investigating the optimal tire size typically ranging from 4 to 5 inches [11]. The findings from this study will contribute to optimizing power kit design, ensuring smooth and stable movement and ultimately improving the overall shopping experience for customers. The figure below shows the different sizes of tires:

Figure 2-3: Tire Size and Configuration

Mostly tires which are used in manual shopping carts are of diameter in range 4-5 inches [12]. It means that clearance of shopping cart must be larger than 4 inches. The desired power kit must be able to fit in cart having base clearance greater than 4 inches.

2.3 Micro Controller

The selection of a suitable microcontroller for controlling the power kit in this project was a critical aspect to consider. Given the project's space constraints, a compact and versatile microcontroller was sought after. Arduino Uno was chosen as the preferred microcontroller platform due to its compact size, making it suitable for projects with limited space availability. The literature indicated that Arduino Uno offers a wide range of features and capabilities, facilitating seamless integration with various sensors and actuators. The extensive community support surrounding Arduino Uno was also highlighted as a valuable resource for troubleshooting and knowledge sharing. Considering these factors, Arduino Uno was deemed an optimal choice for the microcontroller in this project, providing the necessary control and functionality for the power kit.

CHAPTER 3 - DESIGN METHODOLOGY

To model the power kit for a manual wheeled cart, we utilized SOLIDWORKS. This model will then be imported into ANYSIS to do a deformation and stress analysis before being similarly fabricated. The design of the power kit was developed using SOLIDWORKS. A systematic approach is followed to the design process, starting with the identification of the problem and the development of design criteria.

To begin the design process in SOLIDWORKS, first created a new part file and established the appropriate units and dimensions. The sketching tools were used to create 2D profiles and shapes, which were used to generate 3D models using extrusion, revolution, threads, cavity, mirror and pattern features.

The Hole wizard tool was used to create holes and the cut-extrude tool to create cuts and openings in the model. The mirror and pattern features were utilized to create symmetry and repetition in the design.

To add the various components, such as the motor, sensors and controller, to the model, the relevant files were imported such as external references and positioned them using the move and rotate tools. The mates feature were used to constrain the components in the appropriate positions and orientations. Throughout the design process, use of the dimension and annotation tools was made to add dimensions and the configurations feature to create different variations of the design.

Finally, the simulation and analysis tools were used to test the functionality and reliability of the power kit, including tools such as the motion study stress analysis and fatigue analysis.

3.1 Initial Designs

The initial phase of the design process involved a comprehensive exploration of various design options and concepts. The team employed brainstorming sessions, sketching and prototyping to generate and visualize multiple design alternatives. This phase allowed for creative thinking and generated a diverse range of possibilities.

3.1.1 Iteration 1

In first iteration, power kit that was made consisting the springs and lead screw mechanism. The height is adjusted by lead screw mechanism and width is adjustable by springs. These springs are compressed and strips are then attached to the base of shopping carts. The figure below shows the 1st Iteration design:

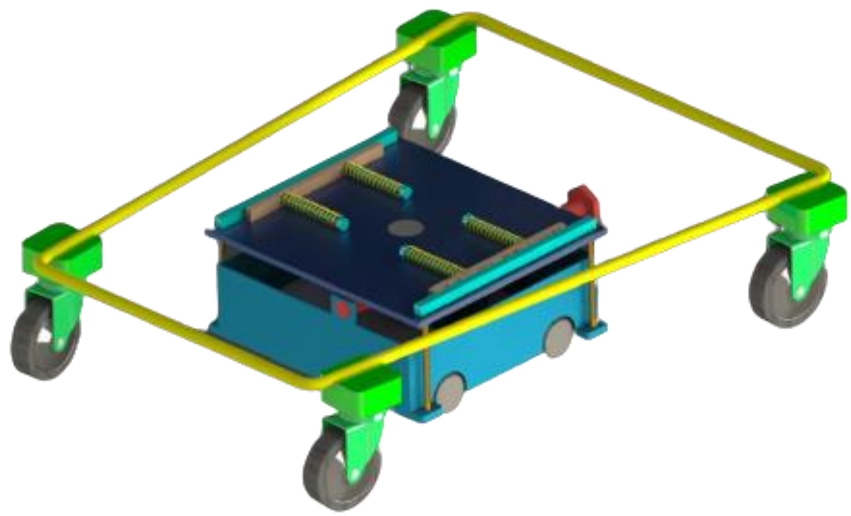

Figure 3-1: Design Iteration 1

3.1.2 Challenges in Iteration 1

Although this design is simple but it is no user friendly because the users have to sit down and then stretch the strips to attach it with base of shopping cart.

3.1.3 Iteration 2

As our main task was to make a user friendly power kit, so we can do this by introducing some controlled system in power kit. In this design, the height is adjusted by same lead screw mechanism but this time a motor is used to do this. When the motor rotates the bolt on it also rotates and the height adjustable plate is connected with that bolt also move up and down. Similarly the width adjustment mechanism is also controlled by lead screw mechanism.

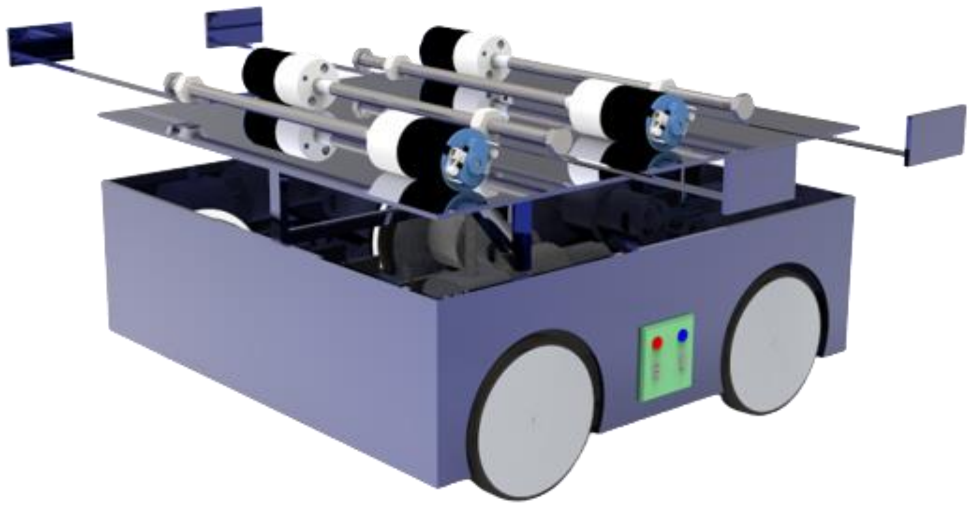

Figure 3-2: Design Iteration 2

3.1.4 Challenges in Iteration 2

The main issue was that it consists of 7 motors and the motors were present on the top of height adjustable plate, so this design is not feasible for proper functioning of power kit.

3.1.5 Iteration 3

The 7 motors in the previous design is reduced to 4 motors. Moreover in this design, motors for width adjustment mechanism is under the plate so it can now adjust more space to go under the cart as height of power kit is reduced.

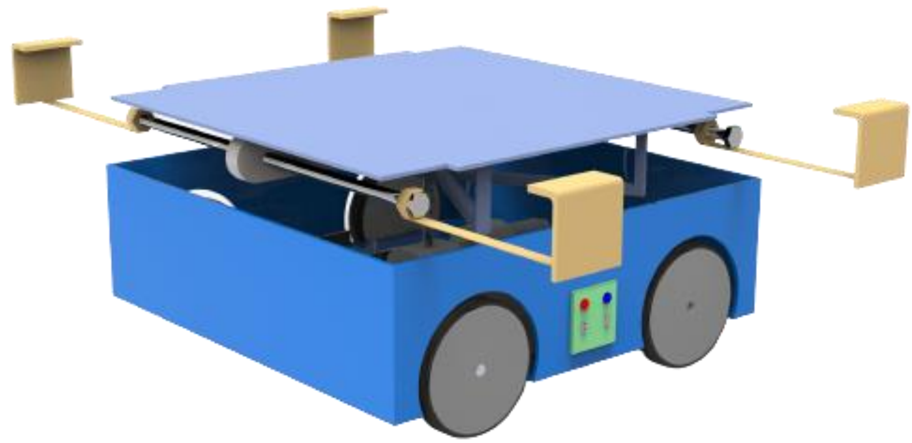

Figure 3-3: Design Iteration 3

3.1.6 Challenges in Iteration 2:

Although this design is very user friendly and easy to operate but the main issue here was that many problems were faced during fabrication of this type of design. As the height adjustable mechanism consists of supports under the plate. When the height adjustment mechanism is adjusted these supports makes the mechanism to remain open and makes jerk with motors.

3.2 Final Design

3.2.1 Wheeled Cart

The wheeled cart was designed using SOLIDWORKS. The design process began with the creation of a new part file and the establishment of the appropriate units and dimensions. Sketching tools were then used to create 2D profiles and shapes for the base, which were extruded and revolved to generate a 3D model. The extrude cut command was used to create openings for the wheels.

Once the base model was complete, it was imported into an assembly file and the wheels were added and positioned using the move and rotate tools. The mates feature was used to constrain the components in the appropriate positions and orientations.

The final design of the cart was exported as a 3D model file and the assembly file was used to visualize and animate the movement of the cart. Overall the use of SOLIDWORKS and the specific commands mentioned allowed us to efficiently and accurately design and develop the base of the wheeled cart. The figure below shows the wheeled shopping cart which is taken as a reference for making power kit:

Figure 3-4: Wheeled Cart

3.2.2 Power Kit Base

The base was created using a combination of sketching, extrusion and revolution features to generate the 3D model. The extrude cut command was used to create openings for the motors and other electrical components. The base was also designed to accommodate the battery and the tires, which were imported as external references and positioned using the move and rotate tools.

Once the base model was complete, it was imported into an assembly file and the various components, such as the motors and sensors, were added and positioned using the move and rotate tools. The mates feature was used to constrain the components in the appropriate positions and orientations. Finally this part is rendered in KeyShot.

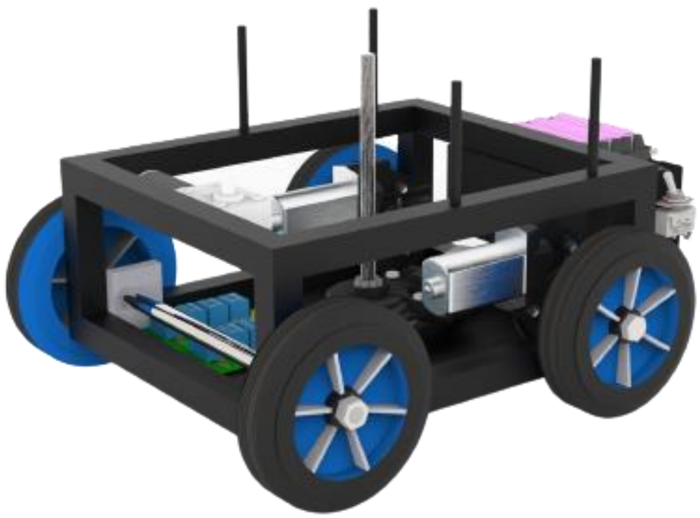

Figure 3-5: Power Kit Base

3.2.3 Height and Width Adjustment Mechanism

The mechanism was created using a combination of sketching, extrusion, and revolution features to generate the 3D model. The worm gears were designed to move the mechanism up and down for height adjustment, and the spring and strips mechanism was used for adjusting the width. The height mechanism works using the lead screw mechanism. A shaft of diameter is 12mm is attached to the gear of widow lift mechanism. When the motor rotate the pinion gear on the motor also rotates, in result of which the shaft also rotates then the nut on the shaft moves up and down and in this way the height can be adjusted.

Once the mechanism model was complete, it was imported into an assembly file and added to the base of the power kit. The mates feature was used to constrain the mechanism in the appropriate position and orientation, and to ensure that it functioned smoothly and reliably.

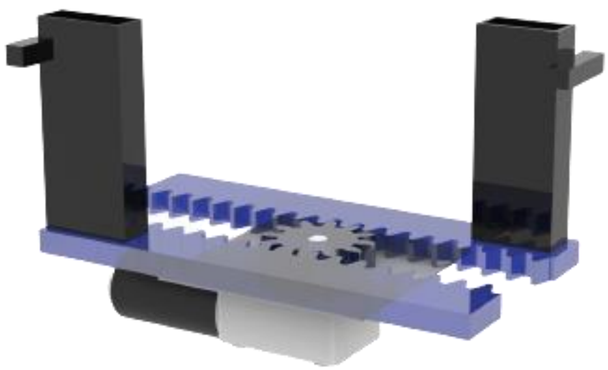

Figure 3-6: Width Adjustment mechanism

Figure 3-7: Height Adjustment mechanism

3.2.4 Complete Assembly

The final assembly of the power kit was created using SOLIDWORKS. The base, mechanism for adjusting the height and width, and all other components were imported into an assembly file and positioned using the move and rotate tools. The mates feature was used to constrain the components in the appropriate positions and orientations, and to ensure that the power kit functioned smoothly and reliably.

Once the assembly was complete, the rendering tool in KEYSHOT was used to create realistic and visually appealing images of the power kit. The lighting, materials, and other visual properties of the model were adjusted to achieve the desired appearance. The figure below shows complete assembly of Power Kit:

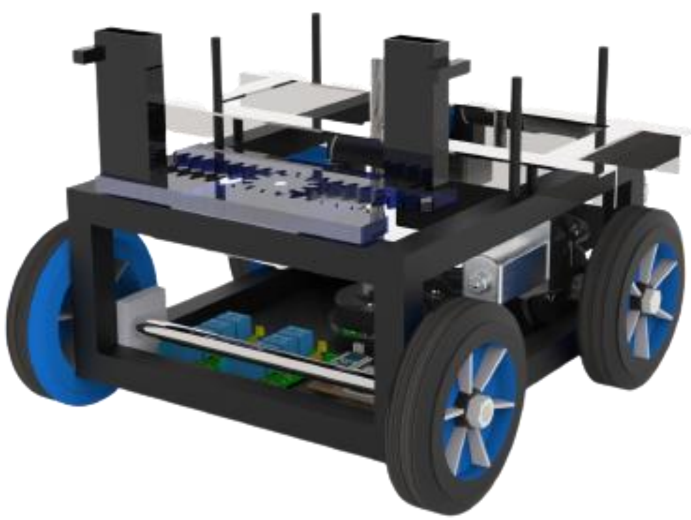

Figure 3-8: Complete Assembly of Power Kit

The final renderings of the power kit provided a clear and detailed representation of the design and allowed us to showcase the various features and components of the product. Overall, the use of SOLIDWORKS and KEYSHOT enabled us to create a functional and visually appealing assembly of the power kit. The figure below shows the complete assembly of power kit attached to shopping cart:

Figure 3-9: Assembly of Power Kit attached to Wheeled Cart

CHAPTER 4 – THE PROPOSED DESIGN AND ANALYSIS

The objective of the analysis was to evaluate the performance of the power kit and ensure that it meets the necessary design requirements. ANSYS software was used to simulate the behavior of the power kit under various loading conditions, and to assess the stress, strain and deformation of the components. The methodology involved was selecting appropriate material properties and applying boundary conditions to simulate the actual operating conditions of the power kit. It was analyzed that the results of simulation and identified areas of concern that needed to be addressed. Based on analysis, modifications were made to the design and re-ran the simulation until the power kit met the necessary performance criteria. The results of analysis provide insight into the behavior of the power kit and will guide us in making further design improvements. Overall, the design analysis in ANSYS has been a valuable tool in our design process, allowing to evaluate and optimize the performance of our power kit in a virtual environment before fabrication.

4.1 Methodology

After creation of 3D Model then the model is imported in the ANSYS Workbench. This model is then divided into smaller finite elements using ANSYS's meshing tools. Material properties are assigned to each element based on the physical properties of the materials involved. Next, the loads and boundary conditions are applied to the model. The solver settings are configured to ensure that the simulation is accurate and efficient. The simulation is then run and the results are obtained. The results are analyzed and interpreted to draw conclusions about the problem.

4.1.1 Material Selection

First Step in analysis is selection of material. As the material that is used in fabrication is cast iron, so in ANSYS, the material that is choose is Gray Cast iron:

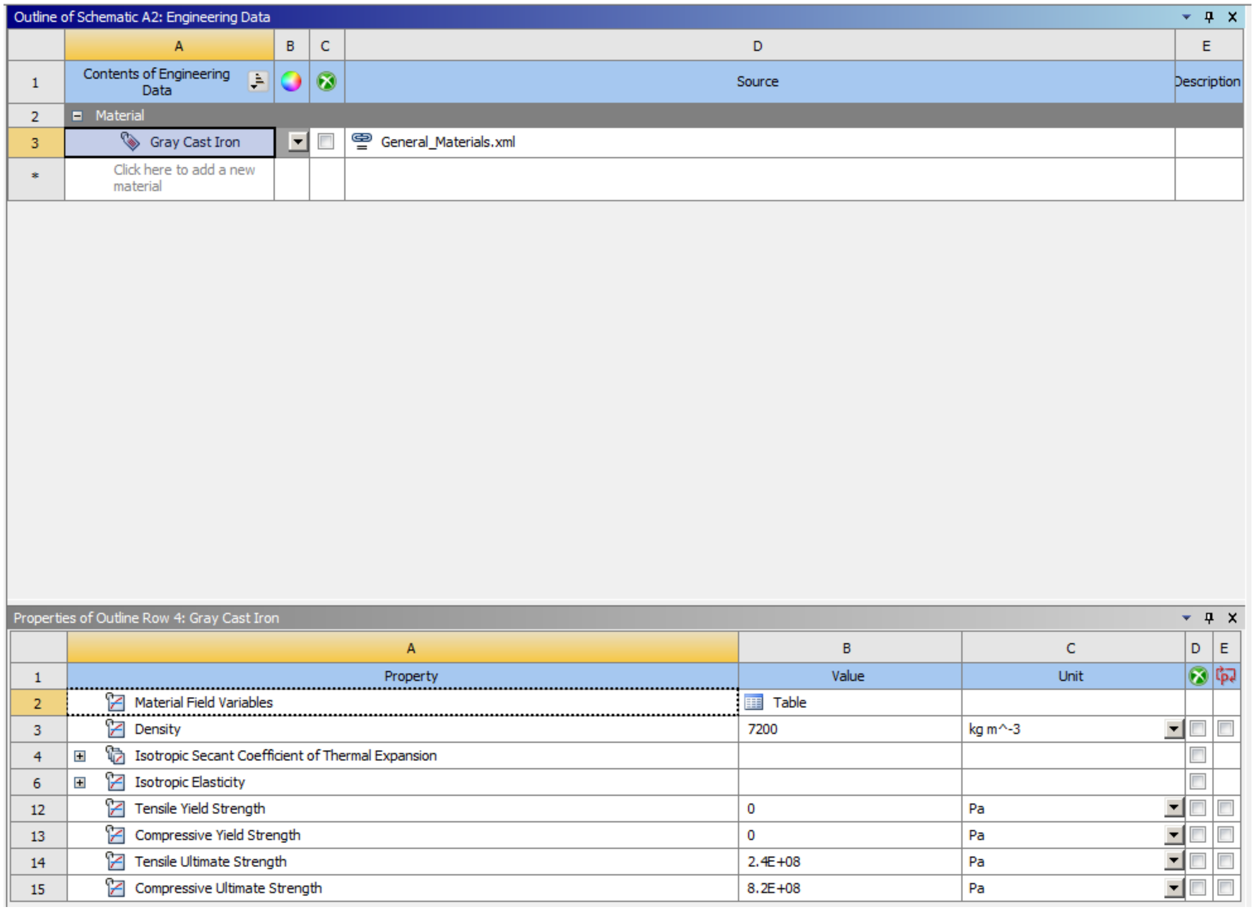

Figure 4-1- Material Selection

4.1.2 Importing the Model for Analysis

The model is imported into design Modular and material is assigned to part:

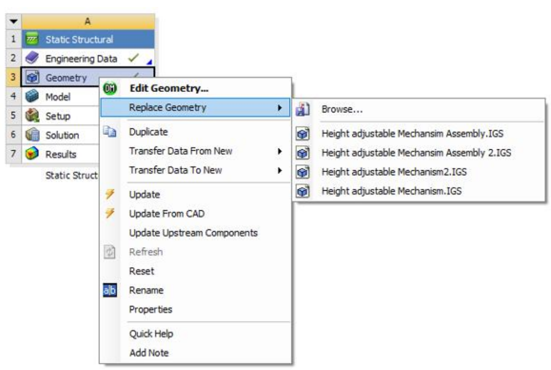

Figure 4-2: Importing Model

4.1.3 Meshing

The meshing is done on the material by selecting the whole geometry and applying the Sizing Mesh from the Outline menu. Total number of faces which are selected for the analysis are 23 faces. The element size selected for the project is 0.05 mm. The sizing mesh is selected instead of automatic mesh to make the perfect mesh to achieve good result. The meshing property is shown as in figure below:

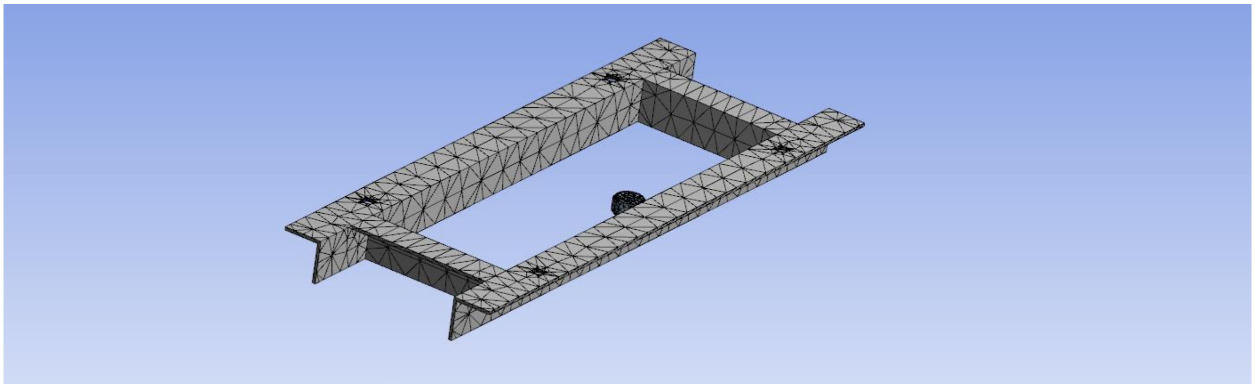

Figure 4-3: Meshing

4.1.4 Applying the constraints and loads

Now apply the constraints on the modal. The constraints for this geometry are the fixed Support on nut that is attached with mechanism:

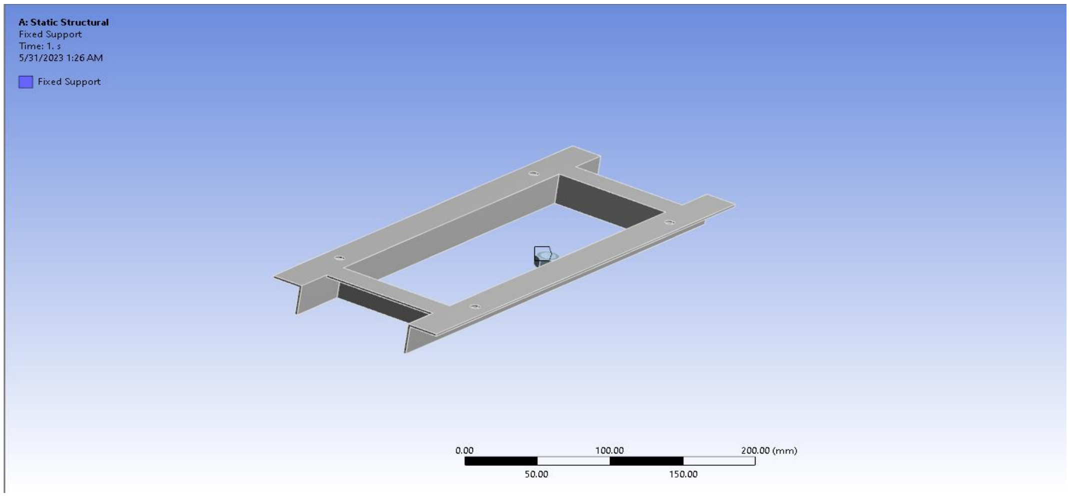

Figure 4-4: Applying the fixed Support

Now apply the load on the height adjustment mechanism. As the cart is designed to carry load of 40kg, so the applied load is about 400N in downward direction:

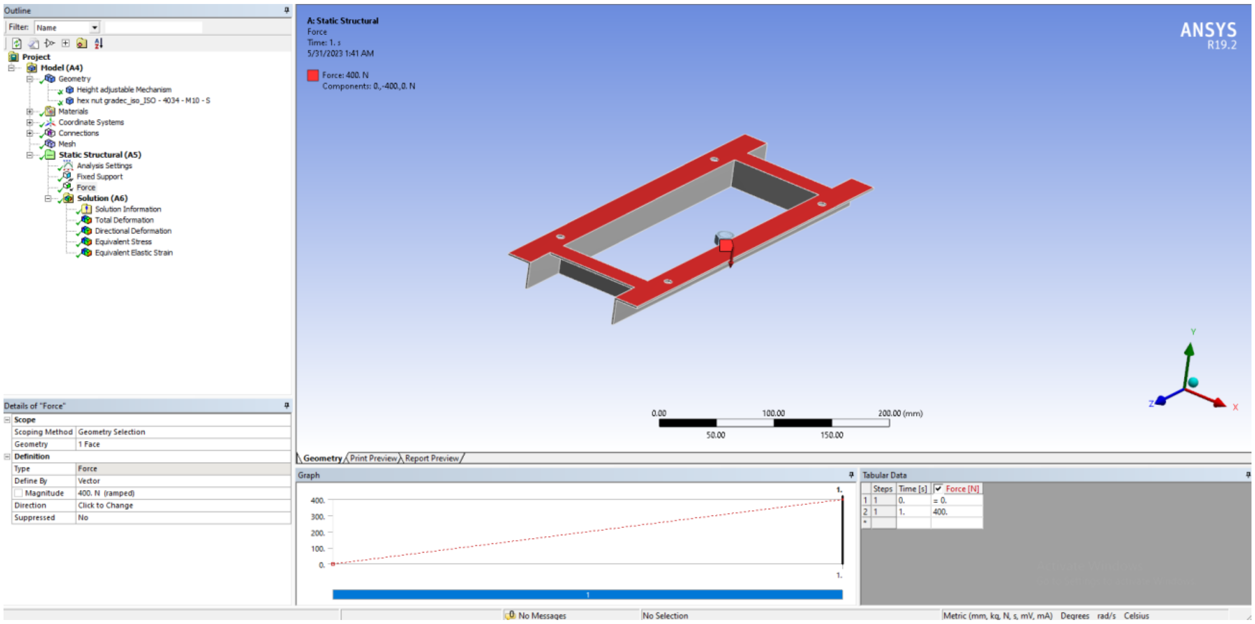

Figure 4-5: Applying load

4.2 Results

In this step the analysis is run to achieve different results. These results include total Deformation, Directional Deformation, Equivalent Stress and Equivalent Elastic Strain.

4.2.1 Deformation

According to the results, the maximum deformation occurs at one side of plate where the force is applied. The reason for this deformation is that the plate is where the force of 400N is acting normal to the plate. The maximum deformation is 2.2631mm and the minimum deformation is 0 mm which occurs at fixed support. The reason for the 0 mm deformation is that this part of mechanism has fixed support at the nut so no deformation will produce at these ends. The results are shown in figure:

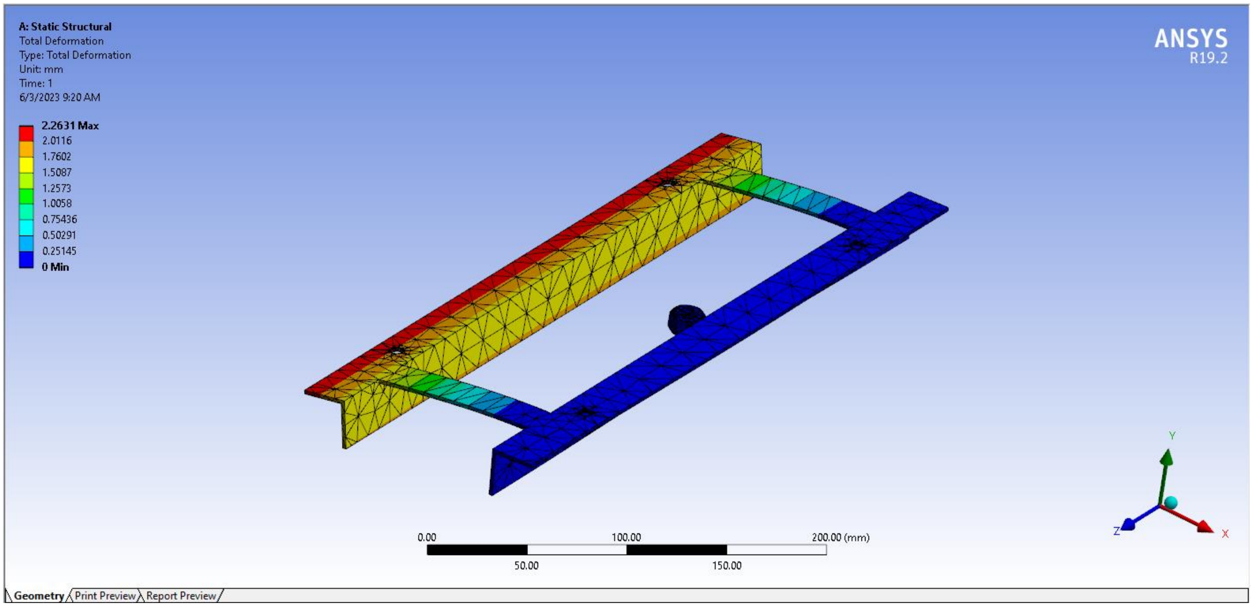

Figure 4-6: Deformation of Height Adjustment Mechanism

As the deformation is too large so design must be change in order to have small deformation. This can be achieved by adding the support in the middle part of previous design. When the plate is added and analysis is done the deformation results 0.83561mm which is in acceptable range. So this design is opted for the final fabrication of this part of project.

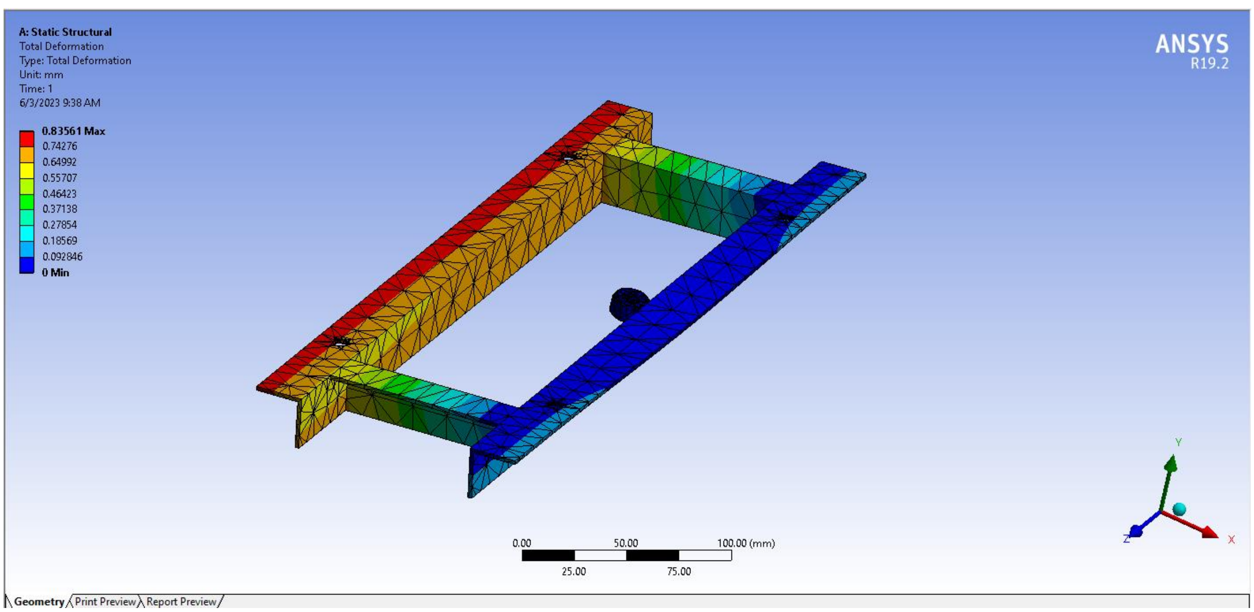

Figure 4-7: Deformation of Height Adjustable Mechanism

4.2.2 Directional Deformation

According to the results, the maximum directional deformation occurs at one side of plate where the force is applied. The maximum deformation is 0.61506 mm and the minimum deformation is 0 mm which occurs at fixed support. The reason for the 0 mm deformation is that this part of mechanism has fixed support at the nut so no deformation will produce at these ends. When the design is changed then the maximum deformation decreased to 0.18593 mm.

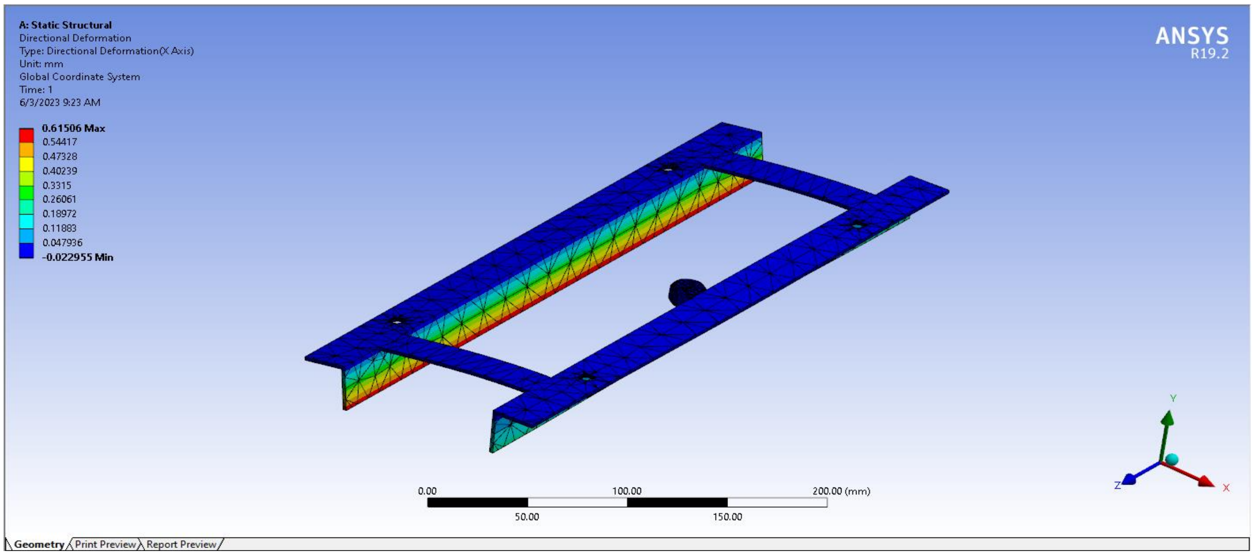

Figure 4-8: Directional Deformation of Height Adjustment Mechanism

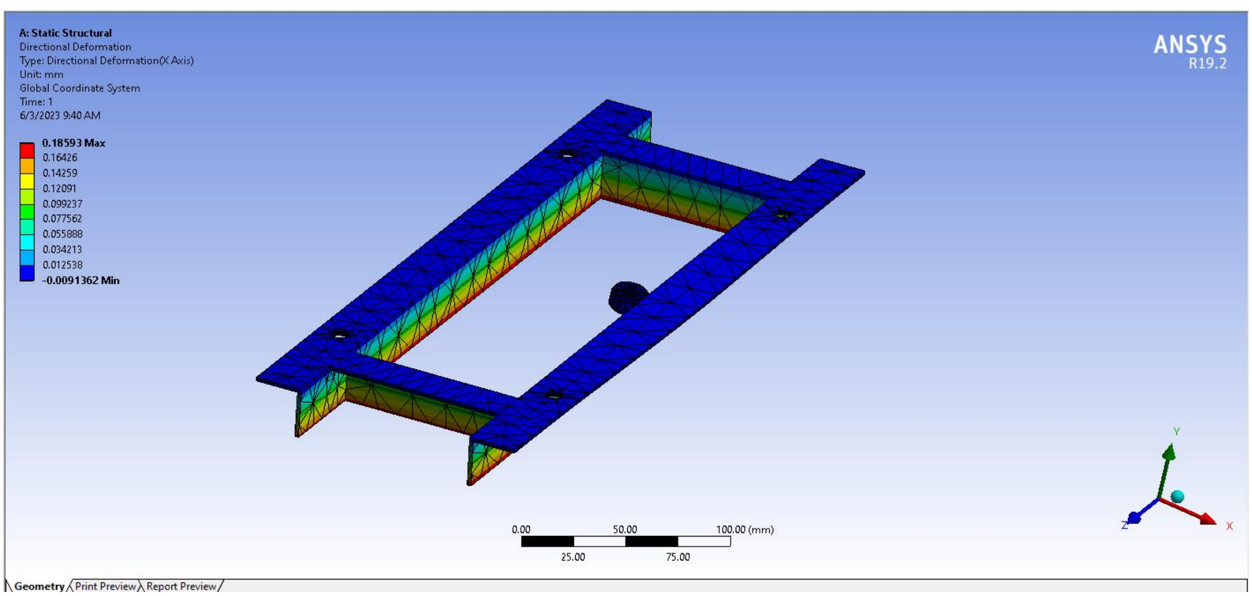

Figure 4-9: Directional Deformation of Height Adjustment Mechanism

4.2.3 Equivalent Stress

According to the result the maximum stress occurred at the mid plates. The value of Maximum Equivalent Stress is 35.857 MPa. When the designed is changed, the value of maximum stress becomes 46.039 MPa. The minimum stress is occurred at the hex screw which is used for clamping the height.

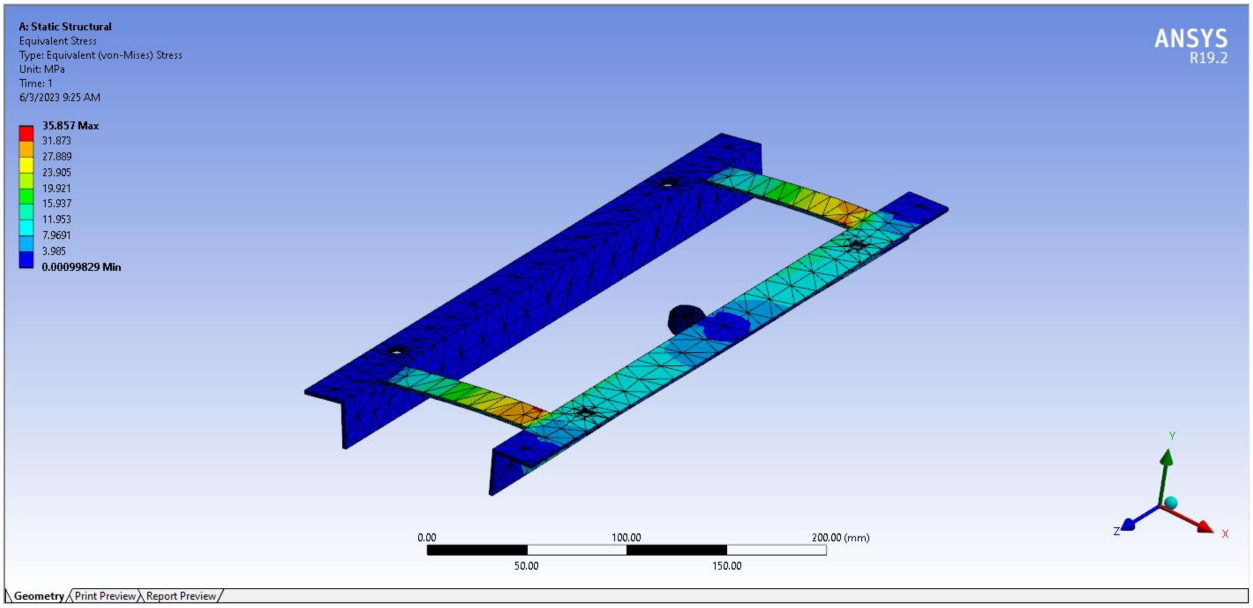

Figure 4-10: Equivalent Stress of Height Adjustment Mechanism

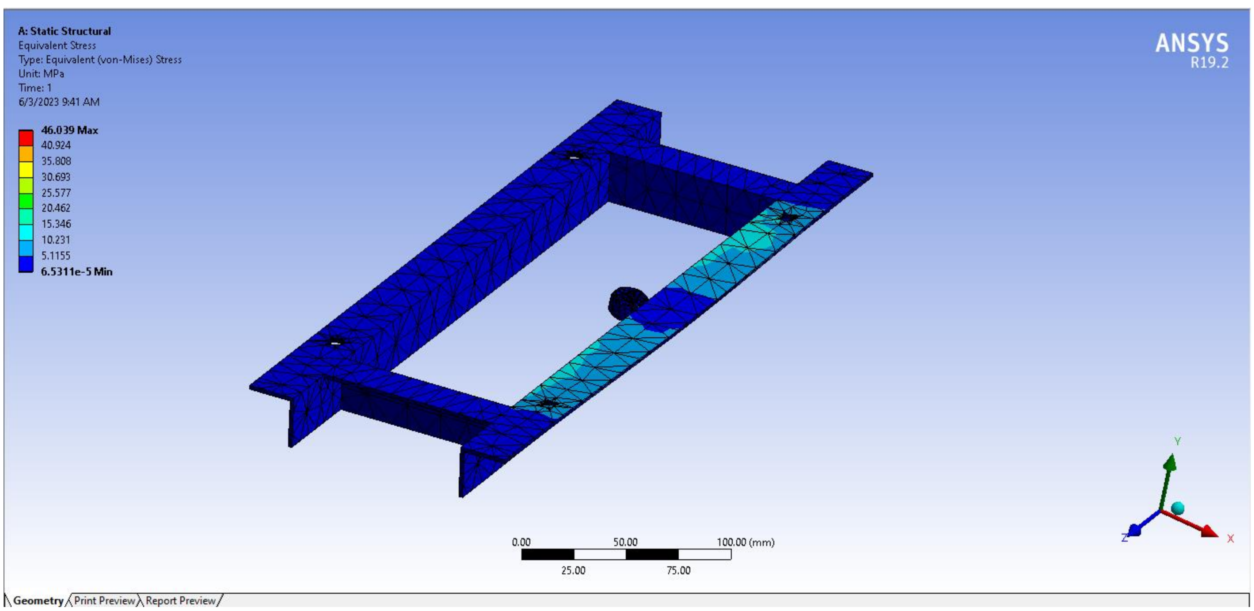

Figure 4-11: Strain in Height Adjustable Mechanism

4.2.4 Equivalent Elastic Strain

According to the results the maximum Elastic Strain occurs at middle plate and having the value 0.00032621. When the design is changed the maximum elastic strain is 0.00044512. The minimum Elastic Strain occurs at the hex screw and having a value of 6.78E-10s.

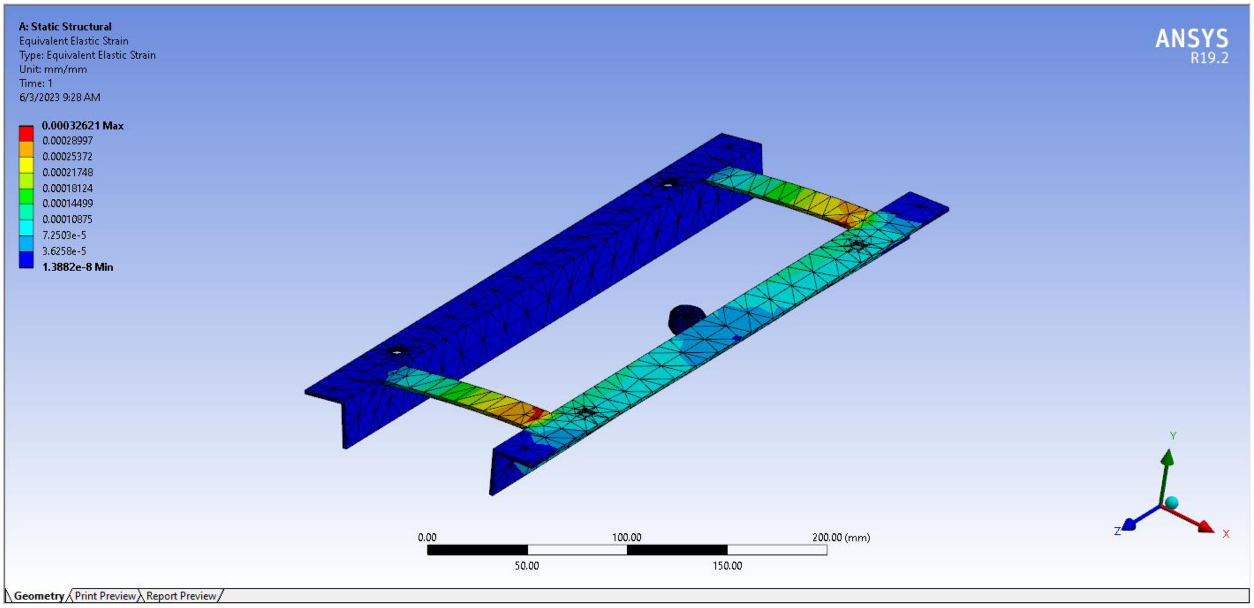

Figure 4-12: Equivalent Elastic Strain in Height Adjustable Mechanism

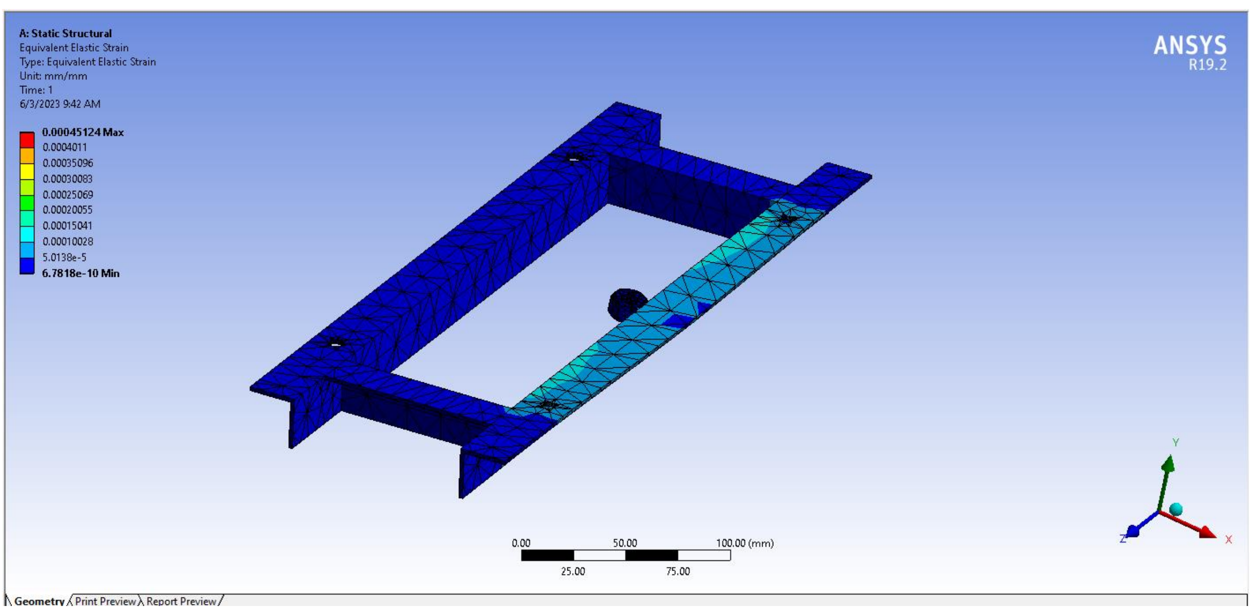

Figure 4-13: Equivalent Elastic Strain in Height Adjustable Mechanism

CHAPTER 5 – MANUFACTURING MODALITIES

5.1 DC Motors

The power kit utilizes three worm gear motors for various functionalities. Two of these motors control the rear wheels, operating at a maximum speed of 100rpm with high torque. These motors are typically found in vehicle door mirrors and are employed to achieve a speed of 5km/h, slightly faster than the average walking speed of humans (4.82km/h). Using a DC gear motor for wheel power is not feasible due to the high torque requirement, which could potentially damage the motor gears [13]. The motor which is used for project is shown in figure below:

Figure 5-1: Power Window Motor

1 worm motor is employed for the uplifting mechanism using a lead screw mechanism. All these motors are of 12V and 5A. 1 gear motor with a voltage rating of 12V, 3A and a slow rotational speed of approximately 150rpm is utilized to control and manage the gripping mechanism, which operates using a rack and pinion system. The slower speed is necessary as the gear motor needs to complete a maximum of two revolutions to grip the cart effectively.

The worm gear motor which is used is given below:

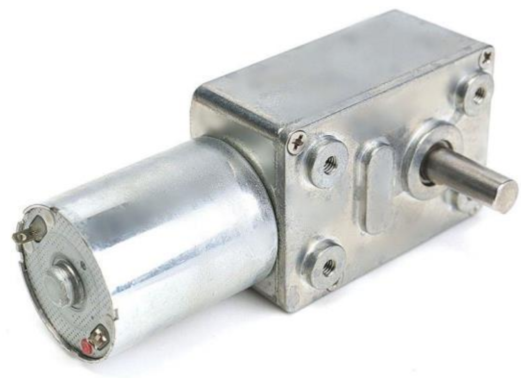

Figure 5-2: Warm Gear Motor

5.1.2 Motor Calculations

The total mass taken is 50 kg, the required speed is 5 km/h. First of all convert the 5 km/h to m/s:

$$5\ \frac{km}{h} = 1.39\ \frac{m}{s}$$

By using the formula of power:

$$Power = Force\ \times\ Velocity$$

In order to calculate the force, use the Newton 2nd Law of Motion:

$$F = m\ \times\ a \qquad (5\text{-}1)$$

As acceleration is given as a = $(\frac{Vf - Vi}{t})$, so substitute the values in above formula:

$$F\ = 50\ \times (\frac{1.39 - 0}{1})$$

$$F\ = 69.5\ N$$

Now Substitute the values of force and velocity in formula of power:

$$P = F \times V \quad (5\text{-}2)$$

$$P = 69.5 \times 1.39$$

$$P = 96.605\, W$$

Depending upon the calculations, the total power required is 96.605 W. Keeping this in mind, two motors were used, each of power 60W to move the Cart. Similarly one 60 W motor to carry weight of 50 kg has been used.

5.2 Battery

Rechargeable dry batteries, such as nickel-metal hydride (NiMH) or nickel-cadmium (NiCd) batteries, are a type of rechargeable battery that resemble rechargeable dry batteries in appearance. They consist of an anode (usually made of cadmium or a hydrogen-absorbing alloy), a cathode (composed of metal oxide or hydroxide), and an alkaline electrolyte. Rechargeable dry batteries can be charged and discharged multiple times, offering cost savings and environmental benefits. However, they typically have lower energy density and self-discharge rates compared to lithium-ion batteries, requiring proper handling and maintenance for optimal performance [14].

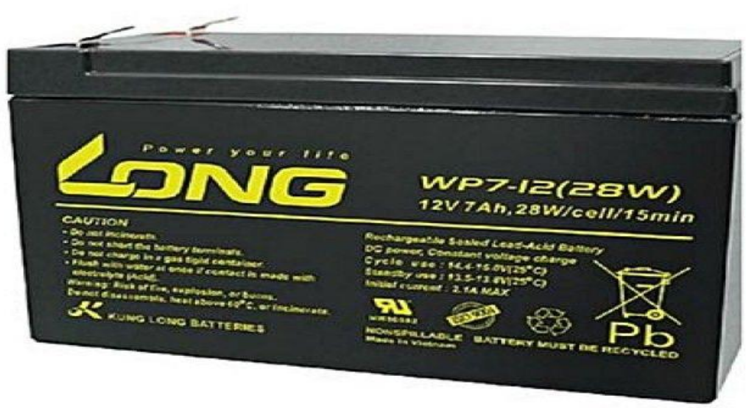

Figure 5-3: Dry Battery

Dry Batteries have a number of advantages over other types of batteries, including a high energy density, low self-discharge rate, and a relatively low rate of capacity loss when compared to other rechargeable batteries [15]. They are also relatively lightweight and have a relatively long lifespan, making them an attractive choice for a wide range of applications.

5.2.1 Battery Calculation

The requirement for the project is to run for at least 0.5 hour. To determine the battery used to run a motor with power of 180 watts, calculate the energy required by the motor.

By using the equation:

$$Energy = Power \times Time\ Energy \tag{5-3}$$

Substitute the Power= 180 W and Time Energy =0.5 in above equation:

$$Energy = 180\ watts \times 0.5\ hours$$

$$Energy = 90\ watts\ hours$$

For the 12V battery, the energy it can provide is:

$$Energy = Voltage \times Capacity \tag{5-4}$$

$$90\ watt\ hours = 12 \times Capacity$$

$$Capacity = 7.5\ ampere\ hours$$

So, the 12 volt battery needs to have a capacity of at least 7.5 ampere hours to provide the required energy.

For the 24V battery, the energy it can provide is:

$$Energy = Voltage \times Capacity$$

$$90\ watt\ hours = 24 \times Capacity$$

$$Capacity = 3.75\ ampere\ hours$$

So, the 12 volt battery needs to have a capacity of at least 7.5 Ampere hours to provide the required energy.

Therefore, to run the motor for 0.5 hour, the best battery is 12 volt battery with a capacity of at least 7.5 ampere hours.

5.3 Sensors

5.3.1 JDY-31 Bluetooth Module

The JDY-31 Bluetooth module is a compact and versatile wireless communication module designed for Bluetooth-enabled devices. It is commonly used in various applications such as wireless data transmission, remote control systems, and Internet of Things projects. The JDY-31 module is based on the Bluetooth 3.0 standard and operates in the 2.4GHz frequency range [16].

With its compact form factor and low power consumption, the JDY-31 Bluetooth module is suitable for battery-powered applications where energy efficiency is crucial. It also supports various Bluetooth profiles, such as the Serial Port Profile (SPP), which allows for transparent data transmission between connected devices.

To use the JDY-31 module, it is typically connect it to a microcontroller, such as an Arduino and program the microcontroller to send and receive data over the virtual serial port. The module can be powered using a 3.3V to 5V power supply and communicates with the microcontroller using UART (Universal Asynchronous Receiver/Transmitter) serial communication.

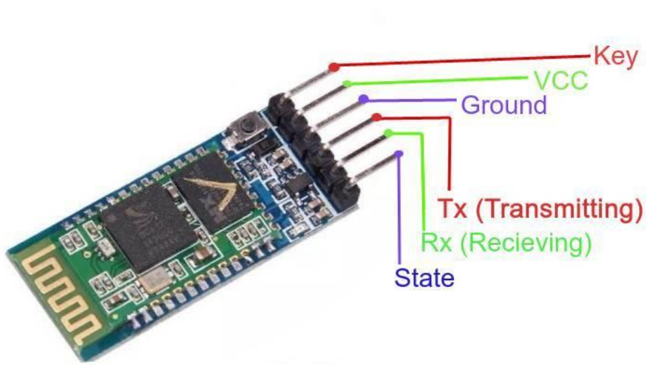

Figure 5-4: JDY-31 Bluetooth module

This module has a range of up to 10 meters and supports a data transfer rate of up to 2.1Mbps. It also supports multiple modes of operation, including AT command mode and transparent mode [17].

The Bluetooth module in the power kit enables seamless connectivity between the kit's control system and a mobile application. By establishing a Bluetooth connection, users can remotely control and manage the power kit's functionality through the dedicated mobile app.

5.3.2 Arduino Nano

A microcontroller is a small computer on a single integrated circuit that is designed to control and perform specific tasks in electronic devices. The Arduino Nano is a popular microcontroller board that is based on the ATmega328P microcontroller chip [18].

The Arduino Nano microcontroller board provides a convenient and easy-to-use platform for building and programming electronic projects. It includes a number of input and output pins that can be used to connect to sensors, actuators, and other electronic components.

The Arduino Nano microcontroller board works by executing code that is uploaded to it from a computer. The code is typically written in the Arduino Integrated Development Environment (IDE) using a simplified version of the C++ programming language [19].

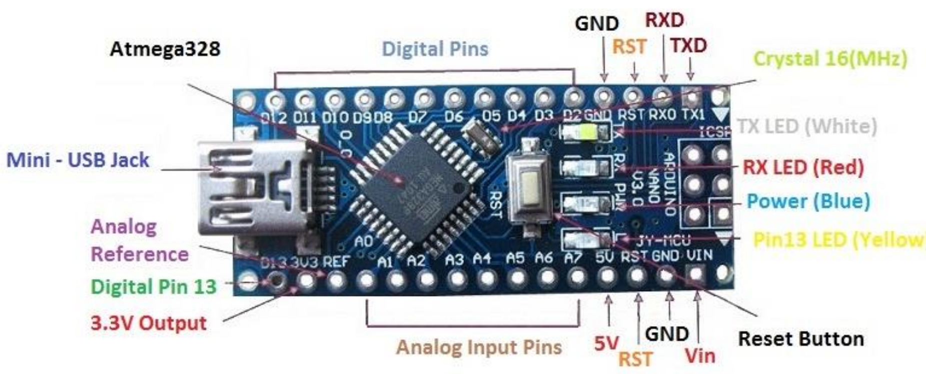

Figure 5-5: Arduino Nano

The Arduino Nano microcontroller board includes a bootloader that allows it to be programmed via a USB connection to a computer. This makes it easy to upload and test code on the board without the need for external programming hardware.

Overall, the Arduino Nano microcontroller board is a versatile and affordable platform that provides an easy way to build and program electronic projects. It is commonly used in hobbyist and educational settings to teach programming and electronics, as well as in more advanced projects that require custom microcontroller control [20].

The Arduino Nano serves as the primary controller for the power kit, chosen over the Arduino Uno due to its smaller size. Operating on 9 volts, the Arduino Nano effectively reduces the voltage to 5 volts internally to meet the power requirements.

5.3.3 Voltage Regulator (7809) for Arduino

The voltage regulator plays a crucial role in the power supply of the Arduino. In this particular case, the regulator is responsible for converting the voltage provided by the battery, which is 11.1 volts into a constant 9 volts. This step is essential to ensure that the Arduino receives a stable and appropriate power supply. By reducing the voltage to a consistent 9 volts, the regulator safeguards the Arduino from potential voltage fluctuations or surges that could otherwise disrupt its operation. The regulator acts as a reliable intermediary between the battery and the Arduino, allowing for consistent and efficient power delivery to support the board's functionality and ensure its proper operation.

Figure 5-6: Voltage Regulator (7809)

5.3.4 Buck Convertor

The LM2596 is a popular Buck Convertor integrated circuit that can be used to step down voltage from a higher voltage source to a lower voltage level. It is commonly used in electronic circuits to provide a stable and adjustable output voltage [21].

The LM2596 variable voltage regulator operates by using a switching regulator topology, which allows it to provide high efficiency while minimizing heat dissipation. The input voltage is switched on and off rapidly by the internal control circuitry, and then filtered to produce a stable output voltage.

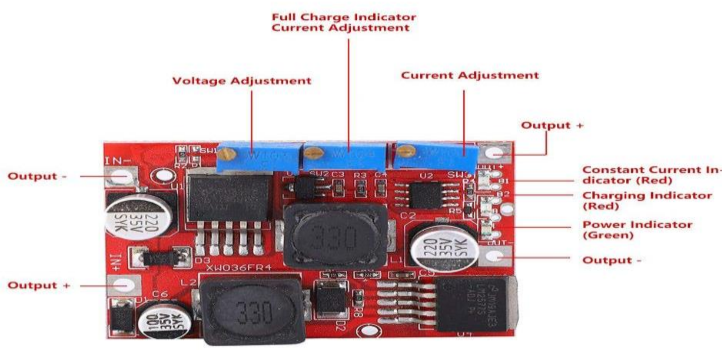

Figure 5-7:LM2596 Buck Convertor

The LM2596 module typically includes additional components, such as capacitors and inductors, to filter the output voltage and minimize noise and ripple. It also includes built-in protection circuits, such as overcurrent protection and thermal shutdown, which help to prevent damage to the module and the load. Overall, the LM2596 variable voltage regulator is a versatile and affordable integrated circuit that provides an easy way to step down voltage from a higher voltage source to a lower voltage level while maintaining stability and efficiency [22]. It is commonly used in electronic projects to provide a stable and adjustable power supply for microcontrollers, sensors, and other electronic components.

In the power kit, a buck converter is employed to convert the 12-volt input from the battery to a lower 5-volt output. This step-down conversion is necessary to ensure compatibility with the relays used in the kit.

5.3.5 Relay Module

A 4-channel relay module is a device that allows you to control multiple electrical circuits using low-voltage signals. It typically consists of four individual relays on a single module, each capable of independently switching on or off a separate circuit. Relays are electromechanical switches that use an electromagnet to control the flow of electricity through their contacts. They are commonly used in various applications where you need to control high-power devices or isolate sensitive electronic components from the main power source [23].

The relay module plays a crucial role in the power kit by providing control and power distribution to the motors. The kit utilizes two four-channel relay modules, each capable of handling a maximum current of 10 amperes. These relay modules are operated on a 5-volt power supply. By utilizing the relay modules, the power kit effectively powers and controls the motors, allowing for smooth and precise movement. The relay modules act as switches, enabling the kit to activate and deactivate the motors as needed, providing reliable power distribution and control for the motorized components of the kit.

Figure 5-8: Relay Module

5.3.6 Optocoupler

The optocoupler plays a significant role in the Arduino's connection with the relays within the power kit. It acts as a signal isolator between the Arduino and the relays, ensuring electrical separation and protection. The optocoupler consists of an LED and a phototransistor, with the LED connected to the Arduino's output pin and the phototransistor linked to the relay's control pin. When the Arduino sends a signal to the optocoupler's LED, it activates the phototransistor, allowing current to flow through and triggering the relay's operation [24]. This isolation prevents any electrical interference or damage from affecting the Arduino, ensuring reliable and safe control of the relays by the Arduino within the power kit.

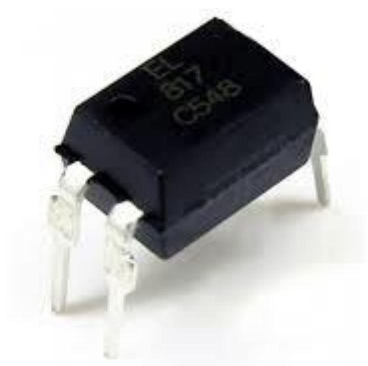

Figure 5-9: Optocoupler

5.4 Circuit Diagram

The circuit diagram of the power kit, created using Proteus Software, showcases the interconnections between various components. The diagram illustrates the connection of the relays module, motors, Bluetooth module, voltage regulator and a battery to the Arduino. Each component is linked to the Arduino through appropriate electrical connections, enabling communication and control between them. The relays module facilitates motor control, while the Bluetooth module allows for wireless communication with a mobile application. The battery serves as the power source for the entire system. Overall, the circuit diagram provides a visual representation of the connections and interactions among the components in the power kit, aiding in design, analysis and troubleshooting during the development process.

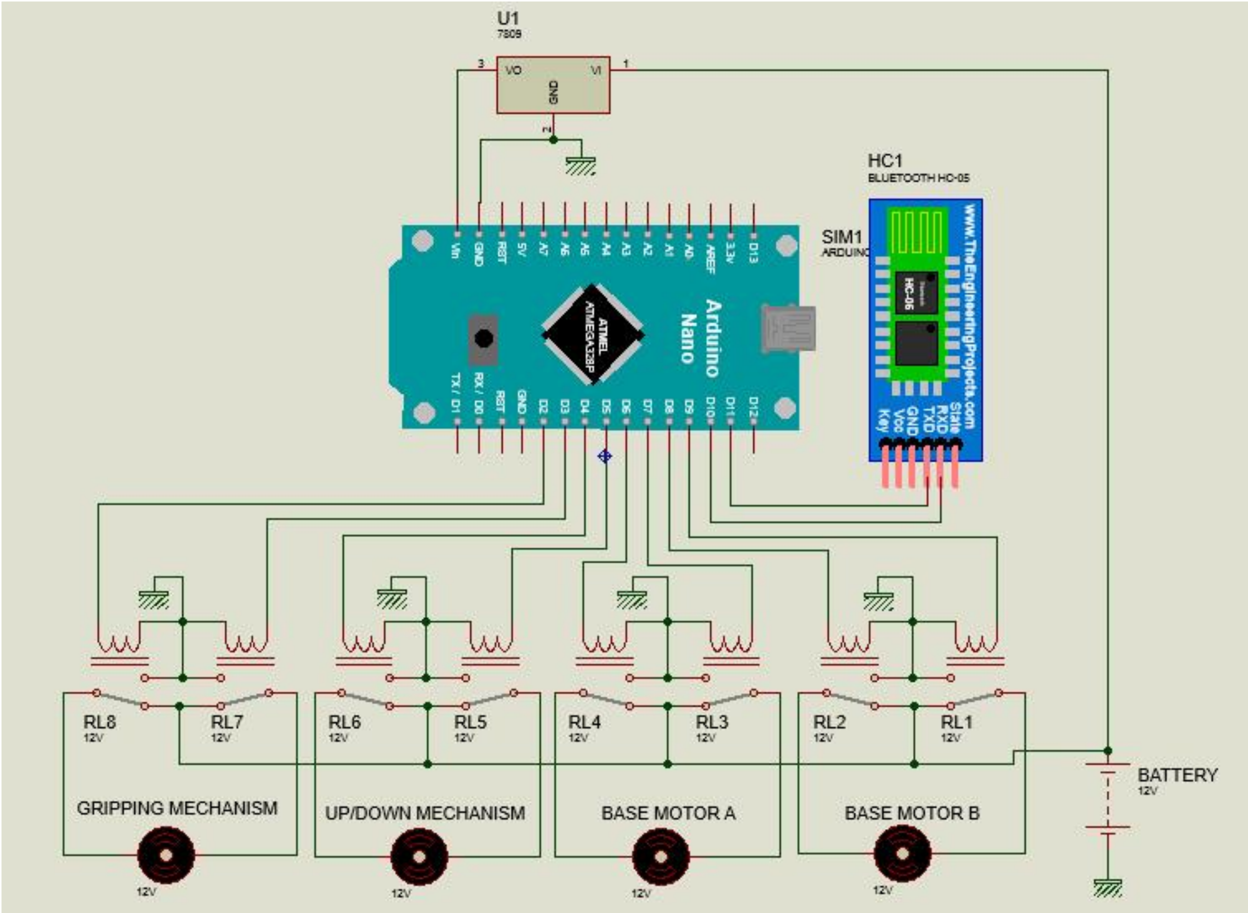

Figure 5-10: Circuit Diagram

CHAPTER 6 – TESTING, ANALYSIS AND FUTURE RECOMMENDATIONS

6.1 Testing

After the manufacturing and fabrication stage, the next crucial phase in the development of the power kit for wheeled carts is testing. Testing is essential to ensure that the kit performs as intended and meets the desired specifications. In this project, several tests were conducted to evaluate different aspects of the power kit's performance and functionality.

6.1.1 Width Adjustment Test

The width adjustment test was conducted to assess the power kit's compatibility and adjustability with shopping carts of varying widths. The objective of this test was to determine the range of widths within which the power kit could be effectively attached and adjusted. To conduct the test, the power kit was fitted onto different shopping carts with varying widths. Measurements were taken to ensure accurate recording of the cart widths. The kit's attachment mechanism, specifically designed to accommodate different cart sizes, was then adjusted to secure the power kit in place. During the test, it was observed that the power kit demonstrated excellent adaptability and ease of adjustment. It could be easily fitted onto shopping carts with rear widths ranging from 15 to 24 inches. The attachment mechanism provided a secure and stable connection, ensuring that the power kit remained firmly fixed to the cart throughout the test.

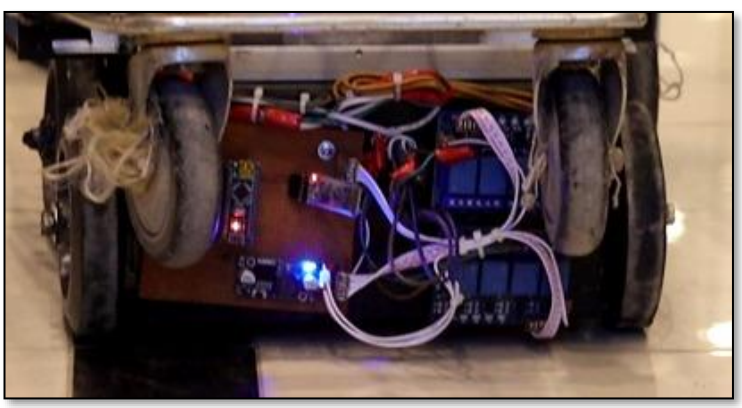

Figure 6-1 Width Adjustment Test with low width Cart

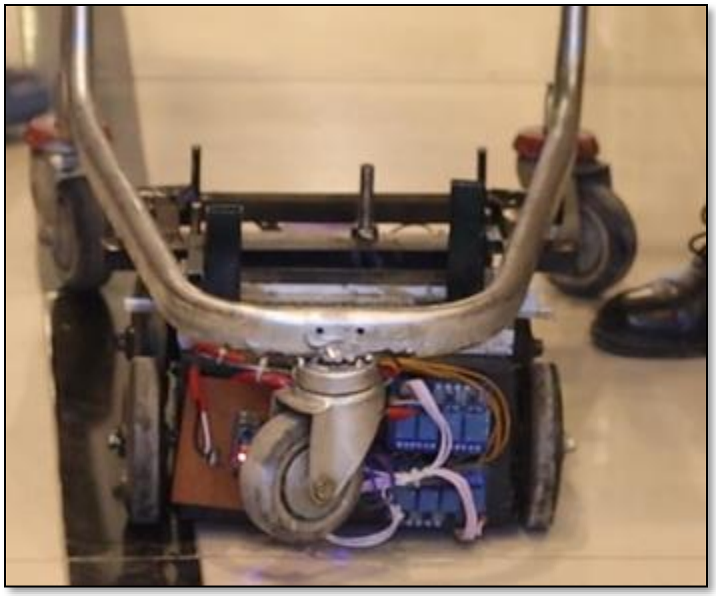

Figure 6-2: Testing width adjustment with high width cart

6.1.2 Weight Testing

The weight testing phase aimed to evaluate the power kit's performance under different load capacities. Shopping carts were loaded with various weight increments ranging from 20kg to 40kg, simulating different shopping scenarios where the cart could be carrying a range of items. The objective was to assess how the power kit would perform in terms of propulsion, control, and stability when subjected to varying weight loads.

During the test, the power kit was engaged to drive the loaded cart in different directions, including forward, reverse, left, and right turns. The purpose was to observe the kit's response and assess its ability to handle the additional weight while maintaining control and stability.

Interestingly, during the initial phase of the weight testing, when the cart was loaded with a lower weight capacity, it was observed that the cart tended to slip or lose traction, especially during sudden movements or turns. This slipping phenomenon occurred due to the reduced weight pressing down on the wheels, resulting in less friction between the wheels and the surface. As a result, the power kit's ability to propel and control the cart was compromised under these lighter load conditions.

However, as the weight capacity of the cart increased, reaching the higher end of the weight range, the power kit's performance significantly improved. With a greater weight load, the wheels had increased traction and maintained better contact with the ground, enhancing the power kit's ability to drive the cart smoothly and maneuver it effectively.

Figure 6-3: Testing of kit at low weight

Figure 6-4: Testing of kit at high weight

6.1.3 Speed Test

The speed test was conducted to determine the velocity at which the power kit propelled the shopping cart. The objective was to measure the speed of the cart and assess its compatibility with the desired range of movement in a retail environment.

To conduct the speed test, a specific distance was marked out, and the time taken by the power kit to cover that distance was measured using a stopwatch. The distance was carefully chosen to provide an accurate representation of the typical distances covered by shoppers while moving around a store.

Using the measured time and distance, the velocity of the power kit was calculated using the formula V = S/t, where V represents the velocity, S represents the distance covered, and t represents the time taken.

Here's a table depicting the testing of the cart at different distances:

Table 1 Speed Testing of Power Kit

Distance (m)	**Time Interval (s)**	**Speed (km/h)**
10	5.2	6.92
20	9.8	7.35
30	14.6	7.40
40	20.1	7.16
50	26.5	6.79
60	33.2	6.50
70	40.1	6.28
80	47.5	6.06
90	55.2	5.86
100	63.3	5.69

6.1.3 Battery Time Test

Battery time testing is a crucial aspect of evaluating the performance and efficiency of the power kit. It is essential to assess the battery's capacity and how long it can sustain the power kit's operation before requiring a recharge.

During the battery time test, the power kit was operated under realistic conditions, taking into account that shoppers using the cart would intermittently stop to select items before resuming movement. This testing approach aimed to simulate real-world usage patterns and ensure that the battery could provide sufficient power for a typical shopping trip.

The test involved monitoring the battery voltage over a specific time period. Starting with a fully charged battery at 12V, the voltage was measured at regular intervals. It was observed that the battery voltage dropped from 12V to 11.6V after half an hour of operation.

To make a column of the predicted time (in minutes) for the battery to drop to various voltage levels, including 9V, we can use the observed data as a reference. Let's consider specific voltage levels and calculate the corresponding estimated time based on the observed rate of voltage drop:

Table 2 Battery Estimate Time

Voltage Level (V)	**Estimated Time (min)**
12	0
11.6	30
10	60
9	(9 - 11.6) / (12 - 11.6) * 30

Using linear interpolation, we can calculate the estimated time for the battery to drop to 9V:

Estimated Time (min) = (9 - 11.6) / (12 - 11.6) * 30

Estimated Time (min) ≈ 80

Therefore, based on the observed rate of voltage drop, it is estimated that it would take approximately 80 minutes for the battery to drop from 12V to 9V.

It's important to note that this estimation assumes a linear relationship between voltage drop and time, and it may not perfectly reflect the actual battery behavior. The actual time may be influenced by factors such as load, battery capacity, and environmental conditions. Hence, regular monitoring of the battery voltage during operation is crucial to ensure optimal usage and prevent any unexpected interruptions.

6.1.4 Bluetooth Range Testing

The JDY-31 Bluetooth module used in the power kit has a specified range of 10 meters. To evaluate its performance and range in a real-world setting, the kit was operated at EME Cash & Carry, specifically at the entrance and checkout counter areas. The purpose was to assess the functionality and reliability of the kit throughout the different sections of the cash and carry store.

During the operation, the power kit was controlled remotely using a mobile device through the Bluetooth module. It was observed that the power kit operated smoothly and effectively in all sections of the Cash & Carry, including the entrance and checkout counter. The signal transmission remained stable, enabling seamless control and operation of the kit throughout the store. This successful operation in various sections of the Cash & Carry indicates that the Bluetooth module's range was sufficient to cover the desired areas effectively.

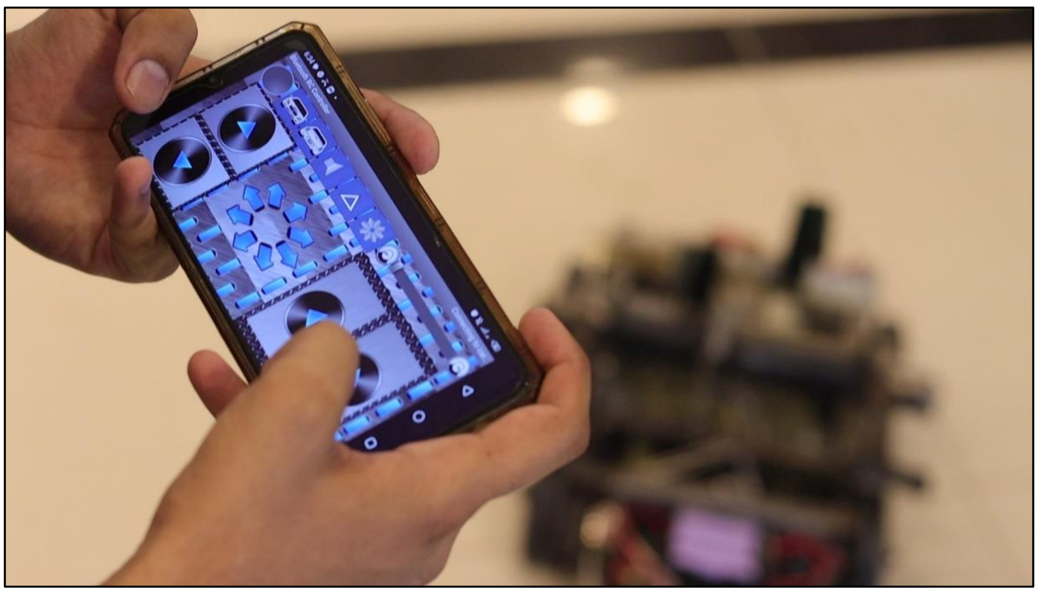

Figure 6-5: Bluetooth Testing

6.2 Future Recommendations

The power kit, as an innovative solution for enhancing the ease and efficiency of transporting goods in various environments, has been the subject of extensive research and development. This thesis project represents a significant step towards harnessing the potential of the power kit, but it is important to recognize that research is an ongoing process that continually demands further exploration and refinement. The future of work in power kit design and implementation holds immense possibilities for improving its functionality, user experience, and impact across different industries.

With a foundation built upon extensive research and practical implementation, the power kit has demonstrated its ability to revolutionize the way we approach cart-based transportation. However, this thesis project is merely a stepping stone towards the broader objective of creating an optimized and comprehensive power kit solution. The future of work lies in further enhancing its design, features, and performance to meet the evolving needs and challenges of the retail, logistics, and related sectors.

To unlock the full potential of the power kit, several avenues of improvement and exploration must be pursued. These include integrating additional sensors to enhance safety and maneuverability, incorporating advanced motor control techniques like PID control for smoother and more precise movement, and designing a user-friendly graphical interface for intuitive control and real-time feedback. Moreover, ongoing research will enable the identification and implementation of innovative features such as wireless charging capabilities, smart navigation systems, and scalable designs to accommodate various cart sizes.

It is essential to acknowledge that the research conducted in this thesis project is not an endpoint, but rather a foundation for future work. The power kit's potential is boundless, and with continued research and development, its impact can be extended to various industries and work environments. The future of work in power kit design and implementation entails a commitment to constant improvement, innovation, and adaptation to meet the ever-changing needs of the modern workplace.

Here are few suggestions that can be implemented on this FYP in future:

6.2.1 Addition of more Sensors

Explore the possibility of integrating additional sensors into the power kit design, such as proximity sensors or load sensors, to enhance its functionality and provide more advanced control options.

By incorporating proximity sensors into the power kit, it can detect obstacles or objects in its path. This feature can be particularly useful in crowded or narrow spaces, preventing collisions and ensuring the safety of both the user and the surrounding environment. Load sensors can provide valuable information about the weight distribution and overall load capacity of the cart. This data can be utilized to optimize the power kit's performance, preventing overloading and enabling better control and maneuverability. Additionally, load sensors can be integrated with the power kit's power management system to provide real-time feedback on the weight of the cart, allowing for efficient load distribution and preventing strain on the motors.

6.2.2 Advance Techniques

Investigate the use of advanced motor control techniques, such as PID (Proportional-Integral-Derivative) control, to achieve smoother and more precise movement of the cart.

Implementing PID control in the power kit's motor control system can significantly enhance its performance. PID control utilizes feedback from sensors to dynamically adjust the motor's speed and torque, ensuring accurate positioning and smoother movement. By continuously monitoring the cart's position and making real-time adjustments, PID control can compensate for external factors like uneven terrain or changes in load distribution, resulting in improved stability and precision during cart movement. This advanced motor control technique can greatly enhance the user experience, enabling seamless navigation and reducing the effort required to maneuver the cart.

6.2.3 Implementation of GUI

Consider implementing a user-friendly graphical user interface (GUI) in the mobile application, providing users with intuitive control options and real-time feedback on the status of the power kit.

A well-designed graphical user interface (GUI) in the mobile application can greatly enhance the usability of the power kit. It should provide users with intuitive control options, such as virtual joystick controls or gesture-based commands, allowing for easy and precise control of the cart's movement. The GUI should also display real-time feedback on the power kit's status, including battery level, cart position, and any detected obstacles. Visual indicators and alerts can help users quickly understand the current state of the power kit, ensuring safe and efficient operation. Furthermore, the GUI can provide additional features like customizable settings, route planning, or integration with other smart devices, further expanding the functionality and versatility of the power kit.

Overall, by incorporating additional sensors, implementing advanced motor control techniques, and providing a user-friendly GUI, the power kit design can be greatly improved. These enhancements will not only enhance the user experience but also optimize the performance, safety, and functionality of the power kit, making it a valuable tool for various applications in retail, logistics, and other sectors.

CONCLUSION

In conclusion, the fabrication of model has been completed and testing has done. The power kit consists of a motor, sensors and an electronic controller, and it is activated by pressing a button. The power kit has an adjustable width and height to fit different sizes of carts. The resulting power kit was able to successfully move carts of different sizes in our testing. Various tests are conducted to ensure that the kit was functional and met the project objectives. However, it is also acknowledged that there is still room for improvement and will continue to analyze and test the design to optimize its performance.

Overall, the design and fabrication of a power kit for carts represents a practical and innovative solution to the problem of manually pulling heavy carts. It has the potential to improve the transportation of goods and materials and to facilitate greater independence and mobility for users.

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