Prototype Design and Research Collection

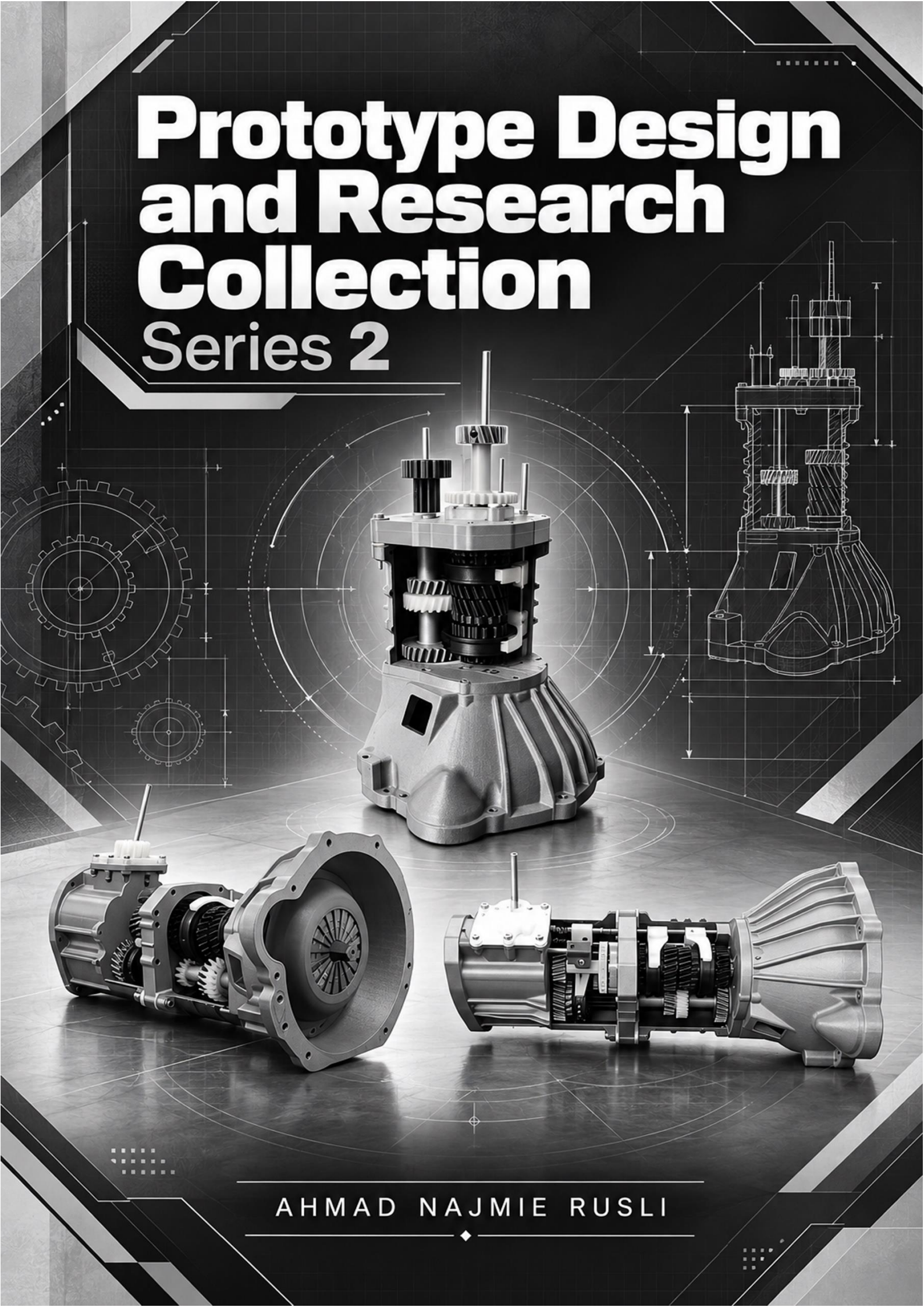
Series 2



Universiti Teknologi MARA Johor Branch

Prototype Design and Research Collection

Series 2



AHMAD NAJMIE RUSLI

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FOREWORD

The *Prototype Design and Research Collection Series 2 (PDRC Series 2)* is a digital publication developed to serve as a comprehensive reference and valuable learning resource for mechanical engineering students. This collection showcases a diverse range of innovative design projects that integrate engineering principles, systematic design analysis, prototype development and research. This collection aims to foster innovation by offering students valuable insights into both the technical and research aspects of product design. It is hoped that this book will inspire future engineers and designers to approach product development with a deeper understanding of the design and research processes.

Each project presented in this collection undergoes a rigorous design and analysis process prior to prototype fabrication. Emphasis is placed on evaluating design concepts, technical specifications and engineering parameters to ensure a comprehensive understanding of the principles underlying product development. Detailed project descriptions, design considerations, and research findings are presented to provide readers with meaningful insights into the engineering design process.

Beyond serving as a technical reference, this collection aims to cultivate a culture of innovation, critical thinking and research-driven design among aspiring engineers. It is hoped that this publication will inspire students as future engineers to explore new ideas and approach product development with a deeper appreciation of the integration of design and research.

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CHAPTER 1

IoT-based Self Control Lawn Mower

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ABSTRACT

This project presents the design and development of a self-controlled grass cutter using an Arduino-based system as a proof of concept to improve safety, control, and portability compared to a traditional grass cutter. The system integrates a microcontroller to control the movement motor and the cutting motor, powered by a rechargeable battery supply. A compact frame is fabricated using suitable materials to reduce overall weight while maintaining sufficient strength for outdoor operation. Key components such as the motor driver, battery, wheels, and cutting mechanism are arranged to optimize balance and ease of maintenance. Performance evaluation focuses on motor movement, cutting operation, and battery usage over time to verify that the system operates as intended. The results demonstrate that the proposed design is capable of controlled grass cutting with stable operation, meeting the project objectives of functionality, compact, and basic automation. This project shows the potential of applying simple embedded systems to enhance conventional grass-cutting equipment for safer and more efficient use.

Keywords: IoT-based system, Self-control lawn mower,

1 INTRODUCTION

In Malaysia, lawn mower is an essential tool used to keep outdoor areas such as residential lawns, public parks, and commercial landscapes neat and well-maintained [1]. Other than that, a well-cut lawn makes the yard look clean, neat, and well-kept [2]. However, due to Malaysia country tropical climate, grass grows rapidly throughout the year, requiring frequent trimming to keep surroundings neat and manageable. Traditionally, most people rely on petrol powered brush cutters, which are labour intensive and safety risks due to exposed blades and flying debris [3].

Manual law maintenance cause extensive physical strain and reduced productivity especially for people who manage large areas [3]. The use of lawn mower also poses significant safety risks, especially when it is operated without any proper personal protective equipment (PPE) [4]. Other than that, traditional mowers also create noise and air pollution, making them less suitable for quiet residential areas [5]. The cost of fuel and frequent maintenance of manual grass cutter also one of factor people need to think first.

As an alternative to reduce the limitation, the use of electric lawn mower in introduced due to its ecofriendly feature and ease to use. The main advantage is that they produce zero emissions during operation, making them more environmentally friendly [5]. Other than that,

electric lawn mower is significantly quieter, reducing noise pollution in residential area. Maintenance cost of electric lawn mower is smaller compared to gas mower as electric models do not require oil changes, spark plugs or air filter.

However, electric lawn mower come with the same limitation as traditional fuel-powered machine, is the need of manual labour. To overcome these limitations, the development of IoT-based Self Control Lawn Mower in proposed.

The aim of this project is designing a robotic lawn mower to function autonomously or semi autonomously without constant human supervision. This lawn mower is controlled wirelessly using Wi-Fi connection. It uses Arduino R4 Wi-Fi microcontroller connected to an ESP32-S3 module. This project also inspired by remote-controlled car combining with cutting mechanism. The result for this project is to save time and reduce physical effort compared to traditional electric mower.

2 LITERATURE REVIEW

Comparisons between available consumer products are made to identify the possible strength and weakness in each design, including the level of automation, control features, and overall user experience. Table 2.1 shows some examples of comparisons on commercial products:

Table 2.1: Comparison of Commercial Autonomous Transport Robots

Feature / Aspect	**Remote Controlled Lawn Mower** [6]	**Automated Robotic Lawn Mower (ECOVACS Goat O1000 RTK)** [7]	**Basic Electric / Manual Lawn Mower (Husqvarna LC219P)** [8]
Control Type	Remote control (manual guidance)	Fully autonomous with RTK mapping and app control	Manual push / walk-behind operation
Automation Level	Low – user must steer	High – navigates and mows with minimal supervision	None – fully manual operation
Navigation	User-directed; limited sensors	GPS/RTK positioning, 3D obstacle detection	Operator-controlled; no sensors
Ease of Use	Easier than manual mowers; requires remote skill	Very easy once setup; app interface simplifies operation	Physically demanding; requires operator attention
Cutting Efficiency	Depends on user skill and guidance	Optimized route planning; edge-to-edge mowing	Consistent cut, but limited by human operation
IoT / Connectivity	Remote via dedicated controller	App-based control, cloud-connected	None
Power Source	Electric	Electric with rechargeable battery	Petrol
Limitations	Requires constant user input; high cost	Occasional sensor or software errors; setup required	Labor-intensive; no remote or autonomous features

Through the patent literature, the lawn mower technologies evolution can be observed

as shown in Table 2.2

Table 2.3: Comparison of Relevant Patents

Patent	**US1622611A** [9]	**US20030037525A1 / US6826895B2** [10]	**US7318493B2** [11]
Publication / Filing	Manual lawn mower (filed 1924, published 1927)	Electric lawn mower (filed 2002, published 2003 / granted 2004)	Hybrid remote control lawn mower (filed 2003, granted 2008)
Control / Operation	Manual operation	Electric‑motor driven	Remote control with hybrid drive
Core Innovation / Features	Classic rotary lawn mower with blades supported on vertical shaft; adjustable cutting height; driven by hand, electric motor or gas engine via mechanical transmission. Introduced safety razor blades and adjustable deck	Battery‑powered mower with electric drive motor and housing design that collectively covers motor + battery; improved air flow/heat dissipation for extended operation	Remote‑controlled mower using DC drive motors for motion and a gyro for straight‑line control; includes microprocessor “brain”, gas engine with alternator to generate electricity for propulsion; aims for reduced physical labour.
Automation / Sensing	None — fully operator ‑driven	Basic ― no remote or autonomous guidance	Manual remote guidance; no autonomous path planning

3 METHODOLOGY

The prototype was developed following the engineering design process, consisting of problem identification, conceptual design, material selection, fabrication, and testing. This project is creating another version of lawn mower with compact size and can be control by using handphone from far away using microcontroller Arduino Wi-Fi R4. The project starts with problem identification, focusing on power consumption, cutting efficiency, and mobility on uneven terrain. Rough concept was designed in the beginning of project to determine the size and shape of the mower, mechanism and position of the cutting system, motor movement for manoeuvre system and what selection of the suitable power sources.

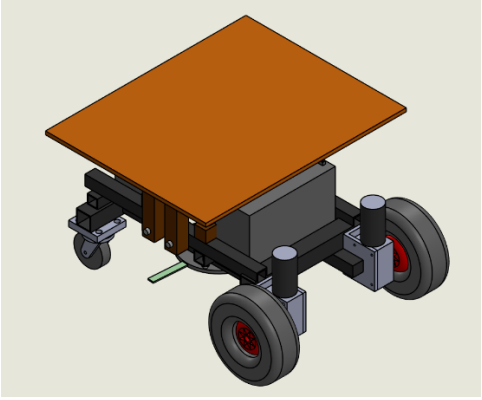


Fig. 3.1: Detailed assembly of final prototype design

From there, the materials were chosen based on the most suitable material that can handle outdoor environment while still being lightweight and affordable. Then, the mower was assembled using a 12V battery setup in parallel circuit, a pair of DC geared motors for movement, and a nylon-string trimmer motor for cutting. An Arduino with bult in Wi-Fi esp-32 was added to control the mower by using Blynk mobile application.

```
#define BLYNK_PRINT Serial

#define BLYNK_TEMPLATE_ID "TMPL6vL1qZdHa"
#define BLYNK_TEMPLATE_NAME "rc car 2"
#define BLYNK_AUTH_TOKEN "KiOLYXOlf5pwUymRwrEp4gDaznTOwPxF"

#include <WiFiS3.h>
#include <BlynkSimpleWifi.h>


#define RPWM_A 3
#define LPWM_A 5
#define REN_A  7
#define LEN_A  8

#define RPWM_B 6
#define LPWM_B 9
#define REN_B  10
#define LEN_B  11

```

Fig. 3.2: Arduino R4 code for the lawn mower

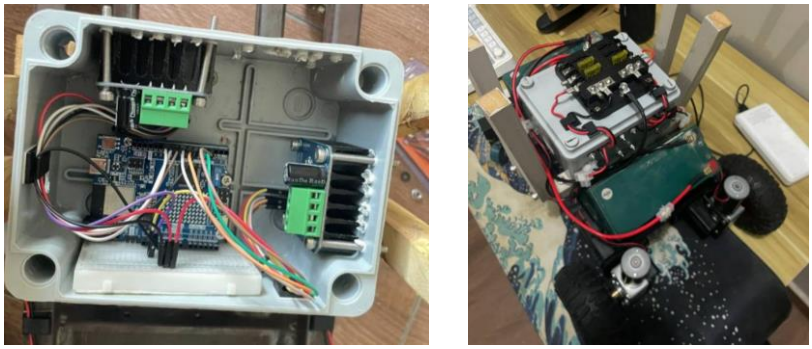


Fig. 3.3: Installation of Arduino module and electronic components

The whole unit was put together through normal workshop methods such as welding the frame, mounting the components, drilling, cutting and wiring the electronics. Lastly, the mower was tested to evaluate the cutting performance, battery life duration, and stability of its motion. The tests include the sturdiness test for the frame. Any issues found during testing were corrected to optimize the mower reliability and improve its overall performance.

4 RESULTS AND DISCUSSION

The project demonstrates a practical integration of Arduino control, motor drivers, and battery power to control grass cutter. The system allows controlled movement and blade operation, improving efficiency and reducing human manual effort. In addition, the project successfully proves the concept through fabrication and testing, showing that the system operates as intended under real conditions.

Due to still in the prototype phase, several weaknesses have been identified, including low battery capacity which requires optimization, affecting operating time during continuous use. The prototype is also dependent on electronic components that may be sensitive to water, dust, and vibration in outdoor environments, which requires certain level of waterproofing. Cutting performance may reduce when operating on thick or wet grass due to limited motor

torque. Furthermore, the system requires regular monitoring to ensure electrical connections and mechanical parts remain reliable.

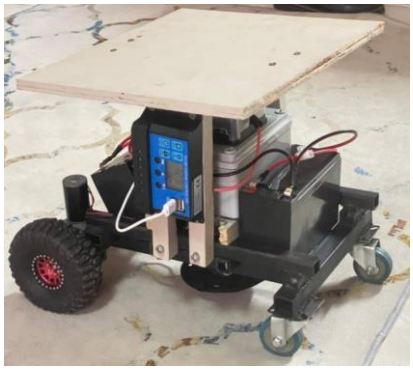


Fig. 4.1 Final prototype design

Table 4.1: Testing Parameter

Test parameters	**Measurement type**	**Value**	**Remarks**
Battery life (min)	Discharge duration	45	Full charge
Motor voltage (V)	Displayed value	12.6	Stable voltage
Safety response time (sec)	Duration until blade and motor totally stop	0.5	Immediate response

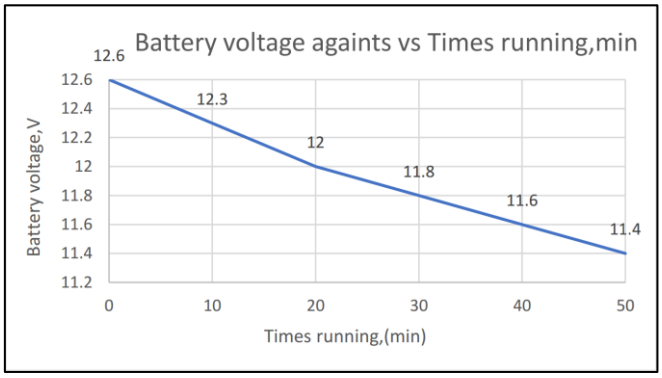


Fig. 4.2: Graph Battery Voltage Against Time

Figure 4.2 shown almost linear battery voltage drop, indicating stable usage rate over time. Maximum battery life can be obtained over 50 minutes of continuous usage.

5 CONCLUSIONS

The development of IoT-based Self-Control Lawn Mower achieved intended results where the design and fabrication of a self-controlled grass cutter using an Arduino-based control system produce stable output with acceptable performance margin, meeting the intended operational requirements. The objective to control the movement motor and cutting blade motor was achieved through the integration of motor drivers and a rechargeable battery supply, enabling stable power supply to motor and smoothly operation. The prototype demonstrated effective grass cutting and controlled movement, validating the system as a functional proof of concept. However, there are some limitations observed such as battery life duration and performance during cutting on thick grass. Overall, the project was achieved the objectives and provides future improvements in efficiency, safety, and sustainability.

REFERENCES

[1] 360iResearch, "Lawn Mower Market Projected to Reach $14.59 billion by 2030," PR Newswire, 10 April 2024. [Online]. Available: https://www.prnewswire.com/news-releases/lawn-mower-market-projected-to-reach-14-59-billion-by-2030---exclusive-report-by-360iresearch-302113096.html. [Accessed 3 January 2026].

[2] "9 Benefits of Mowing Your Lawn," NewSouthTractor.com, 4 March 2020. [Online]. Available: https://www.newsouthtractor.com/blog/9-benefits-of-mowing-your-lawn--21955. [Accessed 1 January 2026].

[3] M. C. Lim, K. Awang Lukman, N. Giloi, J. F. Lim, H. Salleh, A. S. Radzran, M. S. Jeffree and S. S. Syed Abdul Rahim, "Landscaping Work: Work-related Musculoskeletal Problems and Ergonomic Risk Factors," *Risk Management and Healthcare Policy,* vol. 14, pp. 3411-3421, 2021.

[4] S. Ch, "Lawn Mower Safety: Types, Hazards, and Control Measures," HSEBlog, 10 September 2025. [Online]. Available: https://www.hseblog.com/lawn-mower-safety/. [Accessed 16 January 2026].

[5] J. D. Bourdeau, "How Gas-Powered Lawn Mowers Are Bad For The Environment And What To Do About It," The Momentum, 2025. [Online]. Available: https://www.themomentum.com/articles/how-gas-powered-lawn-mowers-are-bad-for-the-environment-and-what-to-do-about-ithttps://www.themomentum.com/articles/how-gas-powered-lawn-mowers-are-bad-for-the-environment-and-what-to-do-about-it. [Accessed 13 January 2026].

[6] "Remote Lawn Mower," UAV Supplies, [Online]. Available: https://uavsupplies.com/remote-lawn-mower/?gad_source=1&gad_campaignid=23319134607&gclid=CjwKCAiAnoXNBhAZEiwAnItcGwzX0oqDD-SxRk2-Nl0afGCxucvPOEGDJGN2dKlTfYkkJrZThDCimhoCj5UQAvD_BwE. [Accessed 26 January 2026].

[7] "GOAT O1000 RTK Robot Lawn Mower (1/4 Acre, Edge Mowing, Obstacle Avoidance)," ECOVACS US, [Online]. Available: https://www.ecovacs.com/us/goat-robotic-lawn-mower/goat-o1000-rtk. [Accessed 26 January 2026].

[8] "Husqvarna LC 219P Lawn Mower," Husqvarna Malaysia, [Online]. Available: https://www.husqvarna.com/my/lawn-mowers/lc219p/. [Accessed 26 January 2026].

[9] S. Ryumatsu, "Lawn mower". United States Patent US1622611A, 29 March 1927.

[10] T. Iida, T. Kobayashi, T. Takizawa and N. Shimizu, "Electric lawn mower". United States Patent US6826895B2, 7 December 2004.

[11] L. M. Medina, "Hybrid remote control lawn mower". United States Patent US7318493B2, 15 January 2008.

CHAPTER 2

Automated Clothes Drying System

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ABSTRACT

Drying clothes is one of the fundamental household tasks that still commonly relies on manual labour up to this day despite current technological advancements. Traditional clothes drying methods such as stationary outdoor racks and clotheslines are often impractical in urban settings due to limited space and unpredictable weather. These issues highlight the need for a more intelligent and convenient solution. Thus, the aim of this project is to develop enhanced automated clothes drying system which utilizes the function of rain detector and motor to develop a mechanism that deploy a canvas as a shade that cover the drying clothes from getting wet in the rain. The system will be designed to be mobile, compact, and user-friendly, even for individuals with physical limitations. The project methodology would include comprehensive product development such as computer aided design (CAD) for precise and intricate modelling. After the designing phase, materials will be meticulously selected for each component to ensure compatibility, cost-effectiveness and even durability. The entire project will be completed within two academic semesters with a maximum budget of RM450. The expected result for this project is a functional prototype efficiently and effectively automates the drying process, reduce dependency on costly electric dryers and most importantly enhances overall user convenience. This solution could potentially be beneficial in shared housing environments, especially during rainy season, and is a great example of how assistive technology can be implemented into our daily life to improve everyday living.

Keywords: Automated clothes drying system, Motorized mechanism

1 INTRODUCTION

In current times, the weather seems to be less predictable. For example, unexpected rains and thunderstorms. This could most definitely compromise the drying process which ultimately wastes our time and effort. These challenges show the need for a more automated and intelligent approach to clothes drying [1].

The integration of automation into home appliances has assisted in the development of "smart" systems that seem to enhance convenience and efficiency of our daily tasks. An automatic clothes hanger system represents a more practical application of this case, combining sensors, microcontrollers, and mechanical components to automate the drying process [2]. However, most current designs for this system have the potential to be improved to help with the user's experience and make the process of manufacturing easier and less time consuming.

The aim of this project is to develop an enhanced version of these automated clothes

drying system that instead uses rain detectors and a motorised roller which holds a canvas to cover the top and sides of the system to avoid the clothes from getting wet in the rain. The target is to ensure the system is mobile and able to not take up too much space in the house compound. During this project, ample redesigning and improvements will be made using SolidWorks software to find the most suitable possible design.

This project offers personal convenience by simply automating the drying process, reducing the effort need to manually check or bring in the clothes during rainy days [3]. it also shows the effectiveness of a smart home solutions that can be developed using easily accessible materials and technology. This system could possibly be placed and used in shared housing and apartment complexes in the future to reduce laundry handling issues during the yearly rainy season.

The use of this system reduces dependency on electric dryers just by relying on natural drying along with protection from rain. This could potentially help with conserving energy and lowering carbon emissions globally if used effectively

2 LITERATURE REVIEW

The findings from the literature review have assisted in influencing the final decisions made in the proposed automated clothes drying system. Previous studies and existing products brought up key issues such as high energy consumption, lack of mobility, poor adaptability to unpredictable weather, and limited user accessibility. Some literature on energy conservation has put great emphasise on the importance of reducing household electricity usage to support sustainability, further supporting the decision to rely on natural drying instead of energy-intensive electric heaters.

As far as the commercial product goes, there are still no available design that incorporate the integration of rain detector and motor to create a system that assist in retracting hanger or cover that protect the clothes during rainy days. However, several patents are found to serve as guidelines during the development of the Automated Clothes Drying System:

Table 2.1: Comparison of Relevant Patents

Aspect	**CN202208846U** [4]	**CN103882659A** [5]	**US8015726B2** [6]
Drying mechanism	Passive rack; no active drying air/heat	Passive hanger movement	Active tumbling and airflow drying
Innovation focus	Motorized rack extension/retraction	Weather-triggered clothes protection	Airflow sensing and control in dryer
Control system	Wired/wireless motor control	Rain-weight trigger switch	Sensor feedback & logic control
User interaction	Controls movement of support rod	Automatic response to rain	Automatic drying cycle management
Scope of application	Home balcony / wall rack	Outdoor clothes hanger	Electrical clothes dryer appliance

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3 METHODOLOGY

The development process begins with defining the primary requirements, which is to detect rainfall and automatically deploy a motor-driven shade to protect drying clothes, then retract the shade when rain stops. Environmental constraints such as outdoor humidity, wind load, and solar exposure are considered. Performance specifications are established, including sensor response time, motor torque requirements, deployment speed, power consumption, and structural durability.

In designing the system of the main function, the integration between rain sensor module, microcontroller unit, motors, shade, and power supply in being constructed. The rain sensor is selected based on sensitivity, corrosion resistance, and outdoor reliability. The motor is sized according to calculated load torque, considering the weight of the shade, friction in the rails, and potential wind resistance. Mechanical design includes a sliding or rolling canopy supported by rails or hinged arms, designed using appropriate material strength calculations to ensure structural stability. Three-dimensional (3D) modelling is generated after all components are determined, taking consideration of the system layout and the optimum distribution of the components throughout of the design.



Fig. 3.1: Detailed assembly of final prototype design

Hardware development follows with circuit design and assembly. The rain sensor is interfaced with the microcontroller to provide digital or analogue input. A motor driver (such as an H-bridge module) is integrated to control motor direction for shade extension and retraction. Limit switches or position sensors are incorporated to prevent over-travel and mechanical damage. A regulated power supply, possibly supplemented by a rechargeable battery or small photovoltaic panel, ensures continuous outdoor operation.

Coding process involved developing algorithm for rain detection, followed by rigorous calibration and optimisation based on the specification of the motors, shade materials and the prototype design. Safety features such as obstruction detection (via current sensing or limit

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feedback) and manual override functionality are implemented.

Performance evaluations are conducted against the initial design, identifying any errors, weaknesses, efficiency, and reliability is within the acceptable margin.

4 RESULTS AND DISCUSSION



Fig. 4.1: Final prototype

As shown in Figure 4.1, the rectangular design of the upper frame and the arrangement of the clothes hanger bars can be seen under the roof structure. The roller mechanism is positioned along one side of the frame, which shows where the roll of shade is being held before deployment onto the angle bars. The parallel hanger bars assist in distributing clothing weight and maximizing usable drying space.

The motor housing is mounted on one of the vertical beams and directly connected to the roller mechanism, which main purpose is to store and deploy the shade when needed. The inclined angle beams guide the extended shade when deployed ensure that the clothes remain fully covered during rainfall.



Fig. 4.2: Laundry Being Left on the Hanger Bars

The vertical support beams hold together the upper roof frame and roller mechanism, motor housing, as well as the clothes hanger bars, which are placed at a slightly lower level to

allow easy access for placing and removing clothes hangers. The triangular support brackets at the lower part of the frame improves structural stability and minimizes any potential deflection or deformation during the operation or movement of the system. The wheels at the base are visible, indicating the mobile capabilities of the system.

5 CONCLUSIONS

The objective of fabricating automated clothes drying system has been achieved. This project also successfully highlights the limitations of the typical clothes drying system simply by introducing an automated, weather-responsive, and user-friendly system. The proposed system effectively responds to unpredictable weather conditions using rain detectors and a motorised canvas roller mechanism. This system ensures that clothes remain protected from getting wet in the rain without requiring manual intervention. By prioritising accessibility and user comfortability, the design provides for those with physical limitations while also remaining practical for everyday household use.

In addition, the design of the prototype is tailored to be able to be used by those with limited space for such systems. The compact shape and foldable capabilities of certain components help with the issue of fitting it into smaller spaces. Plus, the wheels on the base of the system improves the overall mobility of the system by allowing ease of movement across most types of surfaces. This can be demonstrated in the figure below

Finally, the system promotes energy efficiency by lessening the electric dryers which uses high amounts of energy and by encouraging natural drying methods, which then improves the system's sustainability and lowers household energy consumption. As a closure, the developed prototype demonstrates that smart and modern household technology can be effectively implemented into day-to-day living using accessible materials and simple automated mechanisms, offering a practical solution for modern living environments.

REFERENCES

[1] G. &. S. A. Kaur, "Smart Home Automation for Elderly and Disabled," *Journal of Emerging Technologies and Innovative Research,* vol. 8, no. 6, pp. 512-517, 2021.

[2] J. &. K. H. Lee, "Design and Implementation of a Weather-Sensitive Automatic Clothes Drying System," *Journal of Mechanical Systems and Signal Processing,* 2019.

[3] J. A. &. B. T. L. Smith, "Smart Home Technologies for Aging-in-Place: A Review," *Journal of Ambient Intelligence and Smart Environments,* vol. 13, no. 1, 2021.

[4] T. Hu and S. Chen, "Automatic clothes hanger". China Patent CN202208846U, 2 May 2012.

[5] J. Song, "Clothes hanger". China Patent CN103882659A, 25 June 2014.

[6] J. P. Carow and M. E. Glotzbach, "Automatic clothes dryer". United States Patent US8015726B2, 13 September 2011.

CHAPTER 3

Autonomous Transport Bot

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ABSTRACT

Development of automation systems in small scale industries has gained importance, to increase productivity and workplace safety. Nevertheless, most local workshops in Malaysia still have material handling on-site which results in worker fatigue, decreased efficiency and possibility of risk. Industrial Automated Guided Vehicles (AGVs) have become common in the large manufacturing sectors, but because such vehicles are expensive, accessibility seems to be limited for small businesses. Furthermore, most educational robotic platforms do not feature real-time obstacle detection as required for industrial use. This project hence emphasizes on producing a low-cost autonomous transport bot that has certain fundamental functions of AGV, suitable for small industrial purpose. Basically, the task is the design and development of an AGV that can traverse a given black line path while being automatically halted when an obstacle is detected within a certain distance. Using an Arduino Uno as primary controller, line-following and ultrasonic based obstacle detection forms an integrated system. The hardware set is a mild steel chassis, plywood platform, four-wheel-drive (4WD) mobile base, TCRT5000 infrared sensors for line detection, an HC-SR04 ultrasonic sensor for obstacle detection, and 18650 lithium-ion batteries as power source. The design process includes creating a framework, analysis using Pugh method and morphological charts, forming three-dimensional (3D) model in SolidWorks, integration of sensors, and organized manufacturing. line-tracking accuracy will be evaluated by functional testing, obstacle response and operational repeatability to deliver the functionable and cost-effective prototype that demonstrates the basic tenets of AGVs. Under the framework of Industry 4.0, this project is a proof-of-concept for low-cost automation that provide a great step towards the expansion of practical robotics education and innovation in the small-sized industrial environment.

Keywords: Automation systems, Obstacle detection

1 INTRODUCTION

Automation under the framework of Industry 4.0 has been evolving quickly, and it has resulted in major changes in the manufacturing and warehousing for material handling. AGVs emerged as a valuable technology contributing to productivity, operational consistency, and safety. The initial AGV was introduced in 1953 by A. M. Barrett, Jr, implemented by Barrett-Cravens of Northbrook, Illinois [1]. This is the start of automated transport systems in industrial environments. AGVs have developed since then as an intelligent system that could move materials from production workstations or between working areas in a workstation, or even to an entire manufacturing process.

Nevertheless, although these systems are widely implemented in big businesses, small and medium size enterprises (SMEs) in Malaysia still carry out much material handling manually. The manual work process at the local warehouses and workshops are causing inefficiency, fatigue of workers and susceptibility to musculoskeletal problems, which affects the lower back and shoulders. The injuries carry an enormous economic liability; workplace accidents from manual handling cost Malaysia about RM2 billion per annum [2]. The low adoption of AGVs in SMEs is attributed mainly to large implementation costs and system complexity. As a result, there exists an obvious need for an economical and practical automation solution adapted for a small-scale industrial setting.

This project aims to develop and implement a cost-effectively low-cost autonomous transport robot as a proof-of-concept AGV. The robot is designed to follow to a designated line path and able to detect any obstacles along the way using an Arduino Uno as the main control system. The robot uses a two-wheel-drive (2WD) motorized mobile base, supported by caster wheels, programmed using Arduino IDE for the functions of line tracking using infrared sensors and obstacle detection using ultrasonic sensors. The line-following, obstacle response, and load carrying accuracy will be assessed by functional testing. The project is key to proving that automation for cost-effective use by Malaysian SMEs and academia can be achieved, helping to promote safer material handling, and can be a supportive factor in national progress on digitization and industrial modernization.

2 LITERATURE REVIEW

Autonomous transport robots such as AGVs (Autonomous Guided Vehicles) and AMRs (Autonomous Mobile Robots) are essential in the automation of material handling and service delivery. They enable the transportation of cargo with the tools of all-in-one navigation, sensing, control and mechanical design with no continuous human intervention. Research and commercial applications are based on a trade-off between autonomy, trustworthiness, price, and ease of integration. The systems transformed from simple guided vehicles into truly autonomous sensor-rich platforms with dynamic decision-making capabilities in complex environments.

From a commercial standpoint, autonomous robots exhibit a multitude of designs that can be used across multiple domains. Several commercial products have been chosen for benchmarking purposes, as shown in Table 2.1.

Table 2.1: Comparison of Commercial Autonomous Transport Robots

Feature / Robot	**Amazon Robotics Hercules** [3]	**Pudu Robotics BellaBot** [4]	**MiR100 by MiR Mobile Industrial Robots** [5]
Application Domain	Heavy-duty warehouse logistics	Service/delivery in restaurants, hotels, retail	Flexible industrial material transport
Navigation Method	Encoded floor markers + vision; centralized fleet management	LiDAR + Vision-based SLAM; RGBD sensors; dynamic obstacle avoidance	360° LiDAR + 3D sensors; onboard path planning; dynamic obstacle avoidance
Payload Capacity	Up to 570 kg	40 kg	100 kg (towing modules up to 300 kg)
Human Interaction	Minimal; optimized for structured warehouse environment	High; interaction feedback via lights, display; human-safe navigation	Moderate; safety lasers for humans; fleet integration software

Strengths	High throughput for repetitive tasks; robust in structured environments	Safe and stable operation around people; adaptable for service contexts	Flexible, safe, and modular; suitable for mixed industrial environments
Limitations	Less flexible in unstructured spaces; high infrastructure cost	Not suitable for heavy payloads	Moderate cost; requires sensor investment

The evolution of autonomous transport technologies is also highlighted through the patent literature, as presented in Table 2.2.

Table 2.3: Comparison of Relevant Patents

Patent No.	**US8527153B2** [6]	**US10414586B2** [7]	**US11200532B2** [8]
Focus / Title	AGV Stabilization System	Autonomous Transport Vehicle	Delivery Robot and Operation Method
Key Innovation	Mechanical stabilization system for precise payload positioning	Intelligent path planning with autonomous traversal and sensor fusion	Context-aware delivery with user authentication and interactive outputs (lights, displays)
Application / Relevance	Enhances accuracy for industrial AGVs performing tasks that require exact placement	Enables safe navigation in varied and dynamic environments; foundational for modern AMRs	Focus on service robots interacting with humans; extends autonomy beyond transport to user-centric operation

3 METHODOLOGY

The building of the Autonomous Transport Bot (AGV) relies on a systematic engineering design engineering process, which takes a structured approach to design to move from the concept level to the validation stage. The first step in this work is problem solving and needs identification. Small-scale industrial applications with specific attention to material handling issues are analysed to identify the lack of automation being necessitated. Analysis includes environmental conditions (workspace layout, floor surface, hazards, etc.) for appropriate system design.

The second phase deals with design of the systems, consists of mechanical, electrical and control subsystems. Mechanical design consists of designing the chassis, wheel configuration, drive mechanism and platform and load using CAD for modelling and structural evaluation. The electrical component comprises of a battery selection, motor drivers, sensors, microcontroller and electrical wiring layout. The control system architecture specifies the navigation technique, the obstacle detection method, and the communication logic necessary to drive the vehicles autonomously.

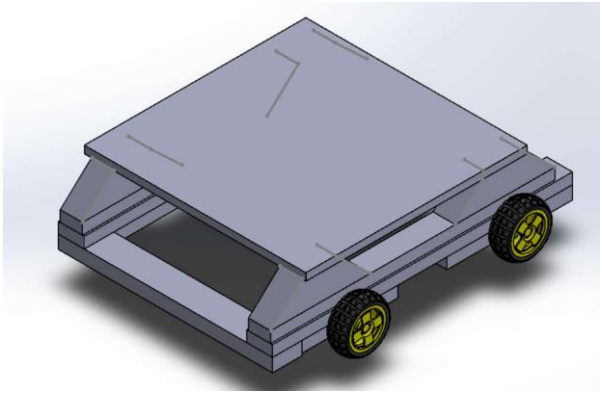


Fig. 3.1: Detailed assembly of final prototype design

After the design stage, the component selection is done based on performance, cost, and availability. The chassis is crafted with steel suitable for the durability required of it, such as aluminium or mild steel. On these assembly lines, motors, sensors, control units, and the power supply system are all built according to this design specification. All the hardware elements are properly assembled and integrated in this phase.

In the next phase, coding process is implemented and integrated to the system, providing navigation algorithms such as path tracking based on predetermined lines, and obstacle detection.

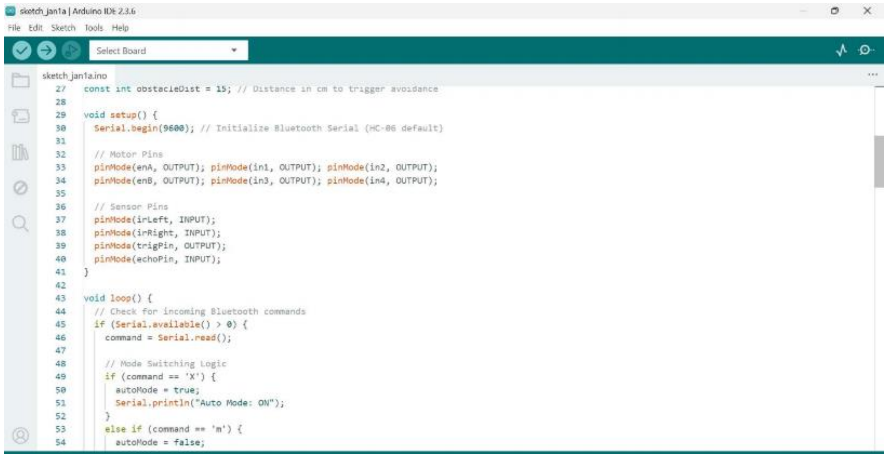


Fig. 3.2: Arduino IDE code for the robot

Tests and evaluation will be done for measuring the prototype's performance, to compare with the initial design requirement, which include several crucial parameters such as maximum payload capacity, obstacle detection responding time, navigation accuracy, travel speed, and battery life. This is also crucial for optimisation and validation of the prototype.

4 RESULTS AND DISCUSSION

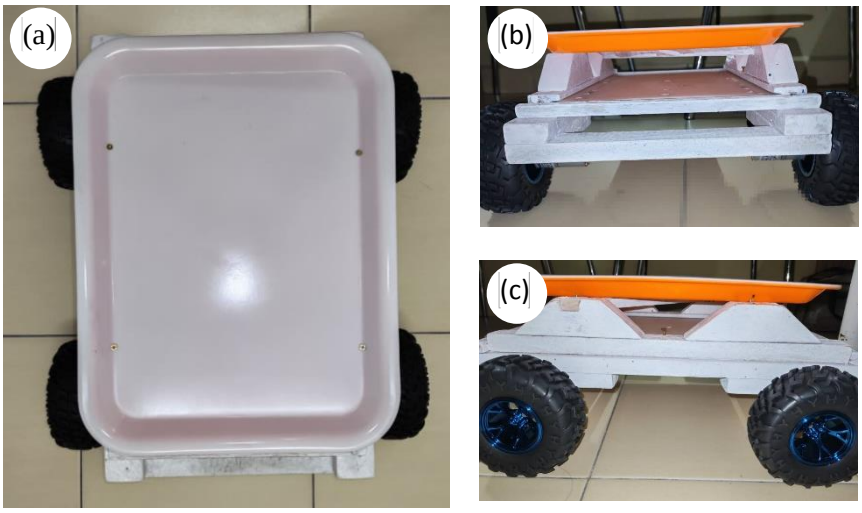


Fig. 4.1: (a) top view, (b) front view, and (c) side view of the Autonomous Transport Bot.

As shown in Fig. 4.1, the prototype is designed as a small transport robot that can move along a set path while carrying items such as small boxes and documents. It can work in two modes, which are automatic mode that follows a line on the floor, and manual mode that allows a user to control it using Bluetooth. In automatic mode, data from the signal of the black line detected by the infrared sensor at the front side of the robot will be sent to the Arduino program, allowing it to adjust the speed of the left and right motors, resulting in the robot turning left or right following the pattern of the black line on the floor. Ultrasonic sensor placed at the front of the robot can detect obstacles at the distance range of 10-15 cm allowing the robot to stop before collision happens. Wooden chassis is used for the robot, relying on its strength as a strong base to place one DC motor for each wheel, producing a four-wheel drive system. The setup aims for smooth robot movement and high stability while transferring loads. Load is placed inside a tray that is placed on top of the robot during transportation.

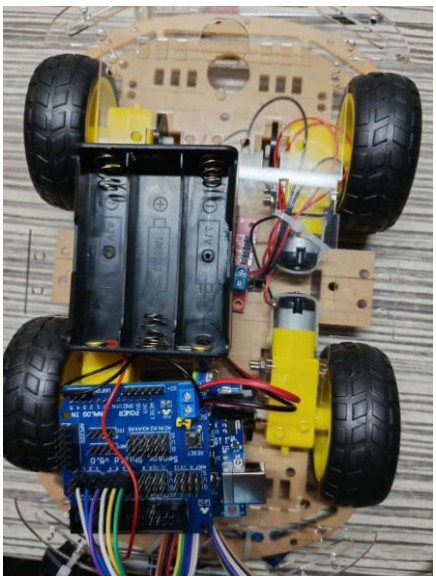


Fig. 4.2: Top view of electrical system

Manual mode requires human intervention using Bluetooth connection from smartphone app. Simple user interface (UI) from the app enable the operator to control and

give simple commands such as forward, backward, left, right, and stop, in an event that required for robot repositioning during loading or unloading before switching it back to automatic mode. Together, these features allow the robot to operate as a simple but practical autonomous transport system.

5 CONCLUSIONS

The key results in the development and performance evaluation of a low-cost Autonomous Transport Bot reflect the robust path-following with a motion model, collision avoidance ability in structured indoor environment. With embedded control, motor drive mechanisms, and proximity sensors, navigation accuracy and safe load transportation were consistently maintained over the intended range of payload. Performance testing also showed that the prototype could reduce manual handling requirements while maintaining operational stability and energy efficiency appropriate for workshop-scale applications. Future investigations ought to prioritize the enhancement of adaptive navigation by employing real-time mapping and localization technologies, advancing sensor fusion methods to achieve greater positioning precision, and refining structural designs to boost payload capacity while ensuring cost-effectiveness. Additionally, a deeper exploration into fleet coordination, wireless monitoring systems, and energy management tactics is essential for augmenting practical implementation capabilities.

REFERENCES

[1] G. Ullrich and T. Albrech, *Automated Guided Vehicle Systems: A Guide - With Practical Applications - About The Technology - For Planning*, 2 ed., Voerde: Springer Vieweg, 2023.

[2] M. F. Md Nordin, "The Criticality of Manual Handling Safety in Malaysia: A Guide to Reducing Workplace Injuries," 7 March 2024. [Online]. Available: https://www.linkedin.com/pulse/criticality-manual-handling-safety-malaysia-guide-mohd-faiz-md-nordin-zxpof. [Accessed 27 February 2026].

[3] A. Staff, "The story behind Amazon's next generation robot," *Amazon News*, 11 March 2019. [Online]. Available: https://www.aboutamazon.com/news/innovation-at-amazon/the-story-behind-amazons-next-generation-robot. [Accessed 19 January 2026].

[4] P. Robotics, "BellaBot," *Pudu Robotics*, [Online]. Available: https://www.pudurobotics.com/uk/product/detail/bellabot. [Accessed 19 January 2026].

[5] "MiR100 Mobile Robot," *MiR Mobile Industrial Robots*, [Online]. Available: https://howtorobot.com/products-catalog/mir100-mobile-robot. [Accessed 19 January 2026].

[6] P. G. Doan, "Automated guided vehicle (AGV) system". United States Patent US8527153B2, 18 July 2011.

[7] J. Holwell and S. C. Toebes, "Autonomous transport vehicle". United States Patent US10414586B2, 17 September 2019.

[8] K. Peterson, M. DELANEY, Z. Witte, J. Calaiaro, J. Anderson and Z. Shivers, "Delivery robot and method of operation". United States Patent US11200532B2, 14 December 2021.

CHAPTER 4

Development of Moving Shoe Display Kit for Advertising

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ABSTRACT

The contemporary retail environment is characterized by a hyper-competitive attention economy where static product presentations frequently fail to engage consumers effectively. This research addresses the critical gap between traditional static shelving systems and prohibitively expensive high-power digital signage by developing a mechatronic solution: the Responsive Mechanical Advertising Shoe Display. The study details the design and fabrication of a moving shoe display kit that utilizes a rack and pinion mechanism driven by a high-torque power window motor to provide smooth linear motion for product presentation. The methodology involves a multi-stage engineering approach, beginning with computer-aided design (CAD) and finite element analysis (FEA) in SolidWorks to evaluate structural integrity and stress distribution under load. The fabrication process utilizes lightweight aluminium composite panels (ACP) and 3D-printed components to ensure portability and cost-efficiency. Testing was conducted to evaluate system latency, positioning accuracy, and user engagement metrics, including dwell time and interaction rates. Preliminary findings indicate that the mechatronic prototype achieves a significant increase in consumer attention compared to static benchmarks. This report concludes that mechanical motion provides a sustainable, low-energy, and highly effective alternative for small-scale retail advertising.

Keywords: Shoes display kit, Moving advertisement

1 INTRODUCTION

The current state of shoe display advertising in brick-and-mortar retail is undergoing a period of significant stagnation. As digital commerce continues to reshape consumer expectations, physical stores are challenged to create immersive and interactive environments that justify the continued relevance of in-person shopping. Traditional shoe shops primarily rely on static product displays, such as wall-mounted racks, glass-enclosed cabinets, or tiered shelving. While these methods are cost-effective and durable, they often suffer from a lack of visual salience in crowded retail environments. Consumers have become habituated to stationary environments, leading to a phenomenon where even high-quality merchandise is overlooked due to a lack of dynamic stimulus[1].

The specific problem identified in this research is the inability of static displays to capture and sustain the continued attention of bystanders in highly cluttered retail spaces. In competitive shopping environments, the first second of visual contact is critical for establishing consumer interest[2]. Static displays do not provide the sensory interruption necessary to break the "scanning" behavior of modern shoppers. While digital screen displays have been

introduced as a more interesting alternative, they present their own set of challenges, including high installation and maintenance costs, significant electricity consumption, and a tendency to distract from the physical product itself by focusing attention on 2D graphics rather than 3D merchandise[3].

2 LITERATURE REVIEW

Visual merchandising has traditionally been viewed as a silent technique for boosting sales, relying on the strategic layout of products to guide customer behaviour[5]. However, the digital transformation of the retail sector has shifted this paradigm toward "interactive marketing." Modern retailers are increasingly utilizing emerging technologies such as augmented reality (AR), artificial intelligence (AI), and sensor-based mechatronics to connect consumers with brands through multisensory experiences.

Interactive displays are no longer just about aesthetic appeal; they are designed to offer a personalized shopping experience. Research indicates that 5-15% of consumers are more likely to purchase from brands that deliver personalized content[6]. In the context of a shoe shop, an interactive display that responds to a customer's proximity by moving a shoe forward for closer inspection creates a "dialogue" between the product and the consumer. This shift from passive observation to active interaction is a fundamental element in modern retail theory. The psychological impact of motion in retail cannot be overstated. From an evolutionary perspective, the human visual system is highly attuned to detecting movement as a priority stimulus. In a retail environment, kinetic content whether it is an animated digital screen or a mechatronic physical display sustain engagement by preventing the rapid habituation that occurs with static objects[7].

Studies in Digital Out-of-Home (DOOH) advertising have demonstrated that dynamic content achieves 21% longer dwell times and twice the conversion rates of static ads[8]. When this motion is applied to a 3D physical object, such as a shoe on a moving platform, the effect is amplified. Three-dimensional physical movement in space has been found to be more persuasive and compelling than a projected image of the same movement on a screen.[9] This is partly because physical movement provides a more "tangible" and "credible" experience, reducing the psychological distance between the consumer and the product.

3 METHODOLOGY

3.1 Hardware and Mechanical Components

The prototype architecture is built around a centralized mechatronic drive system. The selection of components was dictated by the requirement for high starting torque to move a shoe-bearing platform from a static position without jarring or slipping.

Table 1: Components Selection

Components	**Details**
Actuator (Motor)	A 12V DC Mabuchi JC-578VA Power Window Motor was selected as the primary drive unit. This choice was deliberate; power window motors are engineered with an integrated worm gear reduction system. This provides a self-locking mechanism that prevents the shoe platform from moving due to gravity or external vibrations when the motor is de-energized.1
Transmission	To convert the motor's rotational energy into linear motion, a rack and

(Rack and Pinion)	pinion system was utilized. The pinion gear, with a pitch diameter of 20 mm, meshes with a linear rack spur. These components were fabricated using Fused Deposition Modeling (FDM) 3D printing with Polylactic Acid (PLA) filament. PLA was selected for its ease of prototyping and adequate compressive strength.
Power and Control	The system is powered by a 12V 1.2Ah rechargeable lead-acid battery, ensuring that the display can be operated in environments without immediate access to mains power, such as mall corridors or outdoor exhibitions. The control circuit utilizes a 5-pin power window switch and a separate master ON/OFF switch for safety and energy management.1

3.2 Product Architecture and Fabrication

The fabrication process was divided into structural frame assembly and mechatronic integration. The design was first visualized in SolidWorks to ensure that the rack and pinion mechanism and the acrylic platform would fit within the envelope of the ACP enclosure. The choice of materials was crucial for balancing structural rigidity with the lightweight requirements of a portable advertising kit.

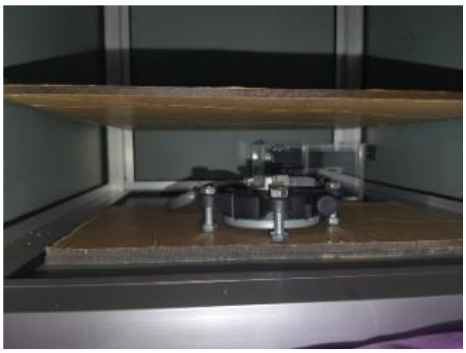
Table 2: Materials Selection

Materials	**Details**
Aluminium Composite Panel (ACP)	The primary chassis and display box were constructed from 4mm thick ACP. ACP consists of two 0.5mm aluminium sheets (alloy 3105-H14) bonded to a polyethylene core. This material provides excellent flatness and high rigidity-to-weight ratios
Acrylic Platform	The shoe-carrying platform was made from PMMA (Acrylic) sheet. PMMA provides a premium, transparent aesthetic that allows the mechatronic components to be visible or concealed depending on the brand requirements. Its tensile strength of 66 MPa is more than sufficient to support the dynamic load of a standard shoe
Aluminium Hollow Square Tubes	Used for the internal structural frame to provide a stable mounting point for the rack and the motor assembly.

3.3 Fabrication Steps

Table 3 Fabrication Processes

Steps	**Details**	**Figure**
Marking and Cutting	Precise measurements were taken using a digital Vernier calliper and long ruler. ACP sheets were cut using a benchtop band saw. A radial saw was used for more complex notches in the aluminium hollow tubes	
Drilling and Joining	Holes were drilled at marked intervals for rivet installation. A manual rivet gun was used to join the aluminium frame components, creating permanent,	

	vibration-resistant joints. This is superior to screw-based joining for mobile displays that may experience transport-related shocks.	
3D Printing Integration	The 3D-printed rack was mounted to the underside of the acrylic platform using epoxy and mechanical fasteners. The pinion was press-fitted onto the motor coupling, ensuring concentricity to prevent eccentric loading and gear noise.	
Actuator Assembly	The power window motor was secured to the base of the ACP enclosure. Wiring was organized using 20AWG cables and secured with ties to prevent interference with the moving rack.	

4 RESULTS AND DISCUSSION

The mechatronic prototype was tested in a simulated retail environment to measure its "dwell time" compared to a standard static shoe shelf and a 2D digital signage screen.



Fig. 1: Moving Shoe Display

Table 4 Comparison of 3 Types of Display

Features	**Static Display**	**Digital Signage**	**Moving Display Kit**
Motion	None	2D/3D Graphics	3D Physical Motion
Attention Capture	Low – High (Based on contents)	2D – Moderate 3D - High	High
Energy Use	Low	High	Moderate
Initial Cost	Low	High	Moderate
Average Dwell Time	2.3s	8.7s	12.5s
Maintenance	Minimal	High (Hardware/Software)	Moderate (Mechanical)

The moving shoe advertising kit, as shown in Figure 2, is effective due to its longer "dwell time." Consumers are curious about the movement of the shoe, urging them to wait and observe what happens next. Feedback included questions about the automatic nature of the door and whether the movement was merely back and forth. Additionally, the finished product's box-like appearance evokes the feeling of unboxing a new pair of shoes.

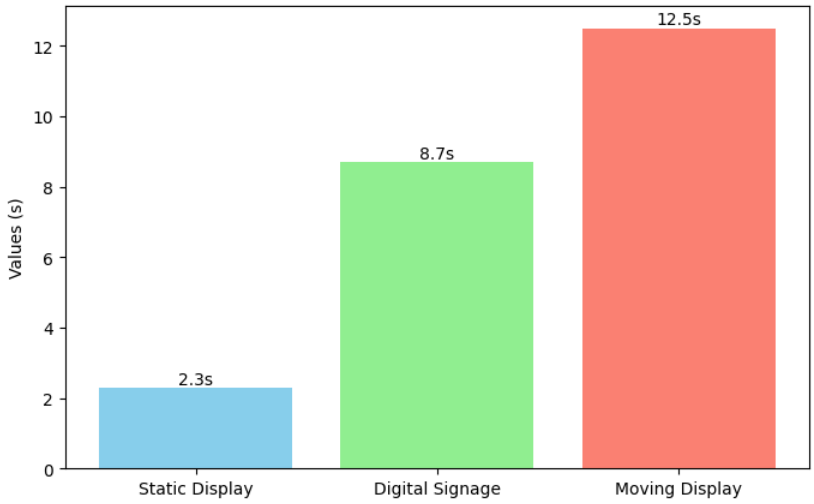


Fig. 2: Dwell Time

5 CONCLUSIONS

The development Moving Shoe Display Kit for Advertisement represents a paradigm shift in visual merchandising for the shoe retail sector. This research has demonstrated that mechatronic displays provide a viable, energy-efficient, and highly engaging alternative to both static shelving and high-cost digital signage. Through a rigorous fabrication process utilizing aluminium composite panels and power window motors, a prototype was successfully constructed that meets professional engineering standards for torque, stability, and latency.

REFERENCES

[1] A. Colley, P. W. Wozniak, F. Kiss, and J. Häkkilä, “Shoe integrated displays: A prototype sports shoe display and design space,” in *ACM International Conference Proceeding Series*, 2018. doi: 10.1145/3240167.3240216.

[2] R. Ravnik and F. Solina, “Audience measurement of digital signage: Quantitative study in real-world environment using computer vision,” *Interact. Comput.*, vol. 25, no. 3, 2013, doi: 10.1093/iwc/iws023.

[3] A. Jimeno-Morenilla, J. L. Sánchez-Romero, and F. Salas-Pérez, "Augmented and Virtual Reality techniques for footwear," *Comput. Ind.*, vol. 64, no. 9, 2013, doi: 10.1016/j.compind.2013.06.008.
[4] Ni Made Dwiyana Rasuma Putri, Reni Sulistiyowati, and Pamela, "Does Dummy Food Display Effect on Food Purchase Decisions? (A Case Study of Coco Ichibanya Neo Soho Jakarta)," *International Journal of Travel, Hospitality and Events*, vol. 1, no. 1, 2022, doi: 10.56743/ijothe.v1i1.8.
[5] N. V. Florea, G. Croitoru, D. M. Coman, and M. D. Coman, "The Influence of Fashion Retailers on Customer Psychology Using Visual Merchandising and Store Layout to Improve Shopping Decision," *Journal of Theoretical and Applied Electronic Commerce Research* , vol. 20, no. 1, 2025, doi: 10.3390/jtaer20010040.
[6] S. Chandra, S. Verma, W. M. Lim, S. Kumar, and N. Donthu, "Personalization in personalized marketing: Trends and ways forward," 2022. doi: 10.1002/mar.21670.
[7] Pragati Bhati, "The Impact of Animated Advertisements on Consumer Engagement in the Digital Age," *Journal of Information Systems Engineering and Management*, vol. 10, no. 23s, 2025, doi: 10.52783/jisem.v10i23s.3811.
[8] "The Science of Dwell Time: Why Indoor DOOH Outperforms Mobile in Retail Environments," https://dolphin-digital.com/blogs/the-science-of-dwell-time-why-indoor-d00h-outperforms-mobile-in-retail-environments.
[9] L. E. Jin, K. B. How, and M. Shanmugavel, "Mechatronic design of a high-resolution, portable, compact 3D dynamic shape display device," in *2014 IEEE International Conference on Computational Intelligence and Computing Research, IEEE ICCIC 2014*, 2015. doi: 10.1109/ICCIC.2014.7238535.

CHAPTER 5

Design and Fabrication of Silent Air Purifier Using Water Filter

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ABSTRACT

This project presents the development of a Silent Air Purifier Using a Water Filter, an innovative solution designed to overcome common limitations of conventional air purifiers. Existing systems often suffer from excessive noise caused by high-speed fans, high maintenance costs due to frequent HEPA filter replacement, and poor portability resulting from large and heavy designs. This project addresses these issues by integrating a water-based filtration mechanism into a compact, quiet, and cost-effective system. The main objectives of the project were to design a silent air purifier using water-based filtration with SolidWorks 2021 and to fabricate a functional prototype capable of effective air purification with minimal noise and maintenance cost. The design process involved concept sketching, evaluation using morphological and Pugh charts, and detailed 3D modelling. The final design was selected based on performance, eco-friendliness, cost efficiency, and compactness. Engineering analyses, including stress, strain, and factor of safety simulations, were performed to ensure structural reliability. Fabrication included precise measurement, cutting, welding of stainless-steel components, and safe installation of electronic parts.

Keywords: Water filter

1 INTRODUCTION

Air pollution means the presence of harmful or excessive substances in the air that puts people, the environment, and the climate at risk. These pollutants can be either gases like PM2.5 and PM10, particulate matter like PM2.5, or volatile organic compounds. They can come from both natural sources like wildfires and dust storms and human activities like industrial emissions, exhaust from vehicles, and burning of fossil fuels. Long term exposure to air pollution is associated with neurological abnormalities, cardiovascular ailments, respiratory illnesses, and early mortality.[1] Furthermore, it fuels environmental problems including smoke production, acid rain, and climate change. Air pollution is one of the worst environmental health hazards in the world, causing millions of deaths annually because of its effects on the heart, brain, and lungs, according to the World Health Organization (2021).[1] In a similar vein, the US Environmental Protection Agency (EPA, 2023) highlights that tackling air pollution is essential to enhancing public health, cutting medical expenses, and lessening the harm caused by climate change.[2] This project titled "Silent Air Purifier Using Water Filter" aims to develop a low-cost, energy efficient, and noise-free system that purifies indoor air while simultaneously maintaining healthy humidity levels. Traditional air purifiers are often expensive, noisy, and require frequent filter replacements, making them less suitable for everyday use in homes or small offices. This project addresses these issues by utilizing a

water-based filtration system that cleans the air. The purifier functions by drawing in ambient air using a silent blower or brushless DC fan, which then forces the air through water. As the air passes through the water, dust particles, smoke, and other airborne pollutants are trapped. After that, a fan will transfer the fresh air to the surroundings.

2 LITERATURE REVIEW

A comparison of available commercial products reveals significant differences in design, functionality, and market suitability. The Sirena Twister Air Purifier (Fig. 1(a)), for example, uses a water-based filtration system with added aromatherapy capabilities and is designed for compact and quiet operation; however, its small water capacity and low airflow make it unsuitable for larger rooms [3], [4]. Similarly, the Bluonics Fresh Aire Water-Based Revitalizer (Fig. 1(b)) is capable of removing dust, pollen, spores, smoke, and odors while offering LED lighting features, yet it suffers from limitations such as low airflow and a small tank capacity, restricting its effectiveness despite being user-friendly and portable [5], [6]. In contrast, the Dyson TP07 Cool Air Purifier (Fig. 1(c)) employs a HEPA H13 filtration system capable of capturing 99.95% of ultrafine particles and includes a powerful air circulation system; however, its high cost, larger size, and expensive filter replacements reduce its feasibility for users seeking a low-cost and compact alternative [7], [8]. These comparisons highlight a clear market gap for a quiet, affordable, and portable water-based air purifier with improved airflow performance.



(a)



(b)



(b)

Fig. 1: Available commercial products (a) Sirena Twister Air Purifier, (b) Bluonics Fresh Aire Water-Based Revitalizer and (c) Dyson TP07 Cool Air Purifier.

In summary, the literature indicates that while existing water-based purifiers offer quiet operation and user-friendly maintenance, they often lack sufficient airflow capacity and filtration strength for larger spaces. Meanwhile, high-end HEPA purifiers provide superior filtration but at significantly higher cost and reduced portability. Manufacturing insights confirm that an affordable and structurally reliable prototype can be produced using accessible materials and straightforward fabrication techniques. The patent review reinforces the scientific basis and effectiveness of water-based air purification. Collectively, the literature supports the development of a silent, affordable, and portable water-based air purifier**,** aligning with the objectives of this project.

3 METHODOLOGY

3.1 Design Process

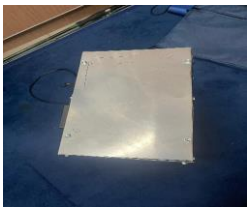
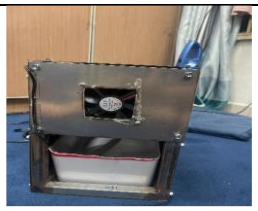
The 3D model parts of the Silent Air Purifier Using Water Filter were designed using SolidWorks. An assembly file was created by connecting all parts with both standard and

mechanical mates. Finally, a detailed technical drawing was produced from the assembly, showing all dimensions and a complete list of materials required to fabricate the prototype.

3.2 Fabrication Process

The fabrication process was conducted using the design completed in SolidWorks. The fabrication process done were as shown in Table 1.

Table 1: Fabrication process of silent air purifier using water filter.

Process	Picture
Measuring Process The materials were measured accurately to ensure they fit properly during assembly. Each stainless-steel sheet was marked using a ruler and marker pen to indicate the correct dimensions, including the positions of the screw holes. The ruler provided precise measurements while the marker ensured the markings were clearly visible.	
Cutting Process The mild steel square bar was cut to the required dimensions using an abrasive saw, which is suitable for cutting hard materials that conventional saws cannot handle. Proper safety gear, such as eye and hearing protection, was used during this process.	
Drilling Process After cutting, the stainless-steel sheet and plastic bowl were drilled using a bench drill to create the screw holes. The bench drill provides precise drilling but must be used carefully to avoid damaging the drill bit.	
Welding Process The Gas Metal Arc Welding (GMAW) process is employed to join the components, using a shielding gas to protect the weld pool from atmospheric contamination. This protection is essential to maintain the corrosion resistance and mechanical properties of stainless steel.	
Assembly Process Assembly processes were conducted using a screw to connects the electrical part to the machine. Power window was placed and connected to the shaft of mold that will be pressing on the machine	

4 RESULTS AND DISCUSSION

The complete details of the entire product are shown in Fig. 3 and Fig. 4. The assembly Figure provides an integrated view of all the individual components that were modelled on their own using SolidWorks. A detailed 3D model is used to visualize the product, check for assembly problems and make any necessary adjustments before the actual manufacture of the product.

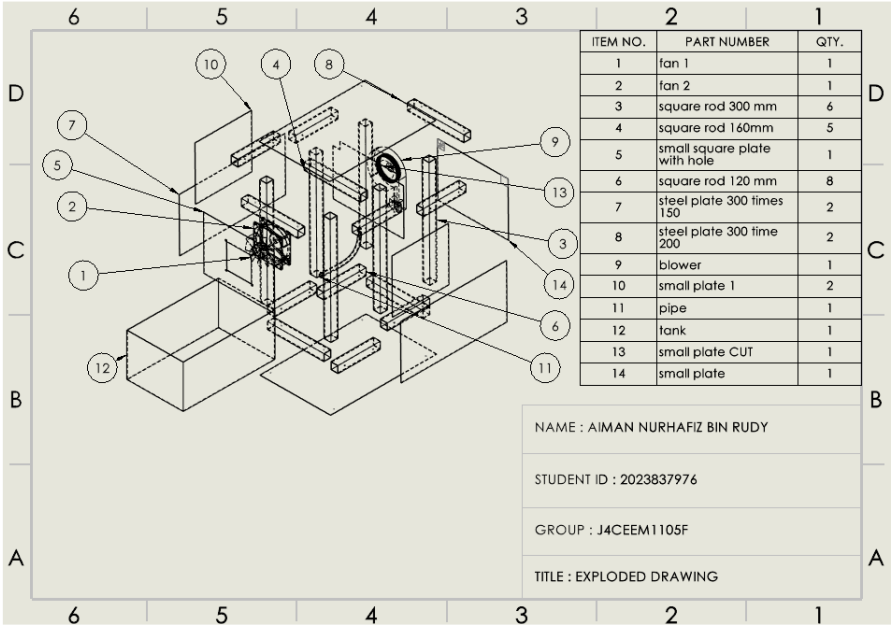


Fig. 3: Exploded Drawing

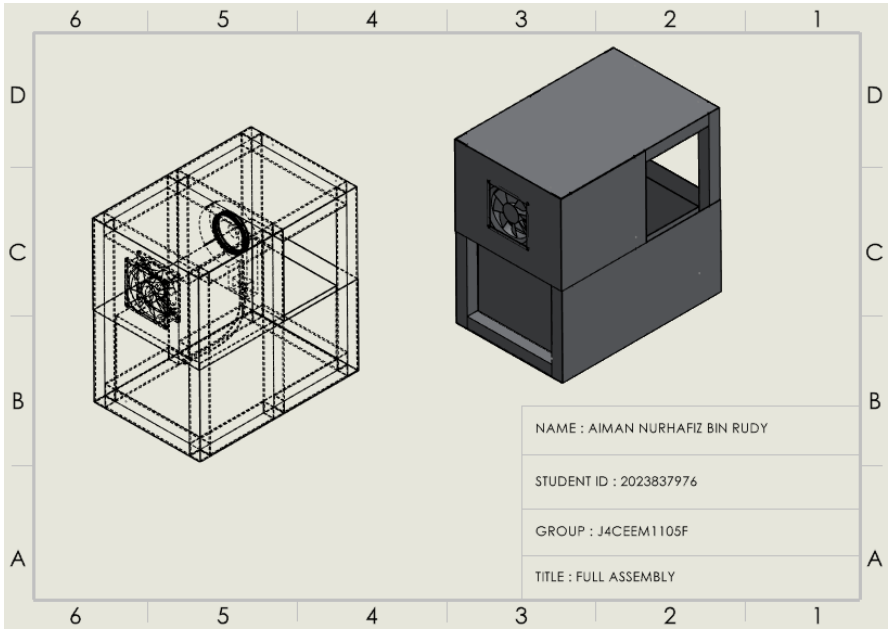
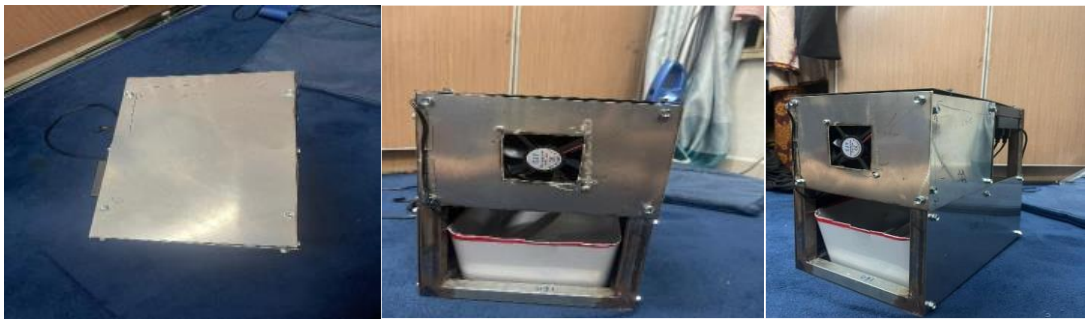


Fig. 4: Assembly Drawing

The complete details of the entire product are shown in Fig. 3 and Fig. 4. The assembly Figure provides an integrated view of all the individual components that were modelled on their own using SolidWorks. A detailed 3D model is used to visualize the product, check for assembly problems and make any necessary adjustments before the actual manufacture of the

product. The final fabricated prototype was successfully completed, as shown in Fig. 5. The prototype was manufactured based on the SolidWorks design, with all dimensions conforming to the planned specifications within a tolerance of 1.0 - 1.5 mm.



(a) (b) (c)

Fig. 5: (a) Top view, (b) front view and (c) side view of the completed prototype.

5 CONCLUSIONS

Overall, the proposed concept, Silent Air Purifier Using Water Filter, successfully achieved its primary objectives. Using SolidWorks 2021 for careful design and planning, a sturdy and practical structure was developed. The total local fabrication cost for the high-performance air purification system was RM206.78, which meets the project cost target of RM250.00. The system operates by passing air through water using a low-noise mechanism that effectively traps pollutants. As a result, the device provides quiet operation while supporting sustainable purification principles. By combining mechanical durability with user-friendly maintenance, this project offers a suitable solution for reducing indoor air pollution in sensitive environments such as clinics, bedrooms, and libraries. Overall, the project demonstrates a low-cost, eco-friendly domestic technology that helps reduce both economic and environmental impacts.

REFERENCES

[1] World Health Organization, "Ambient (outdoor) air pollution," WHO, 2021. [Online]. Available: https://www.who.int/news-room/factsheets/detail/ambient-(outdoor)-airqualityand-health [Accessed: 07-May-2025].

[2] U.S. Environmental Protection Agency, "Air Pollution: Current and Future Challenges," EPA, 2023. [Online]. Available: https://www.epa.gov/clean-airact-overview/airpollutioncurrent-and-future-challenges [Accessed: 07-May-2025].

[3] Sirenasystem.com.[Online].Available:https://sirenasystem.com/product/sirenatwister-air-purifier-blue/. [Accessed: 27-Oct-2025].

[4] Nitrocdn.com.[Online].Available:https://cdndgcng.nitrocdn.com/xKvHTNdCfmoFirZlMccydUgnXdUtOwRF/assets/images/optimized/rev6a0f1b2/sirenasystem.com/wp-content/uploads/2021/08/Sirena-Twister-Blue-Aromatize-and Deodorize.jpg. [Accessed: 27-Oct-2025].

[5] "Bluonics fresh Aire water based air revitalizer with 7 LED color changing light. Air freshener for small and large rooms," Bluonics. [Online]. Available: https://www.bluonics.com/collections/all-fresh-aire/products/fresh-aire-airpurifier-black-color-with-6-led-color-changing-lights-rainmate-rainbow. [Accessed: 27-Oct-2025].

[6] Bluonics.com. [Online]. Available: https://www.bluonics.com/cdn/shop/products/1BLKFreshAireNoLogoResized_compact.jpg?v=1658698759. [Accessed: 27-Oct-2025].

[7] "Dyson Purifier Cool purifying fan TP07 (Black/Nickel)," Dyson.com. [Online]. Available:

https://www.dyson.com/air-treatment/air-purifiers/purifiercool-tp07/ black-nickel?utm_source. [Accessed: 27-Oct-2025].
[8] Assetsadobe2.com. [Online]. Available: https://dysonh.assetsadobe2.com/is/image/content/dam/dyson/leappetiteglobal/markets/thai/products/ec/tp07-wshepa13-pdp.png?scl=1. [Accessed: 08-May2025].
[9] N. D. Tittle, "Water-based air filter system," 6955715, 18-Oct-2005. [Accessed: 27-Oct-2025].

CHAPTER 6

Design and Fabrication of Automatic Food Composter

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ABSTRACT

This project focuses on the development of an Automatic Food Composter, a device designed to convert household food waste into compost through an efficient and user-friendly process. Food composters are essential for promoting sustainable waste management, yet many existing models on the market are often complex, costly, and difficult to maintain, making them less practical for everyday users. To address these limitations, the main objectives of this project are to design a simplistic and easy-to-maintain Automatic Food Composter, and to fabricate the designed composter at a low cost without compromising functionality. The final design was developed through multiple conceptual stages and analysed using SolidWorks to ensure structural integrity and performance. The result of this project includes a finalized engineering drawing and a 3D model of the food composter. The expected outcome is a functional prototype that is affordable, durable, and easy to operate and maintain, making it suitable for household or small-scale use while supporting environmental sustainability.

Keywords: Automatic food composter

1 INTRODUCTION

Food waste remains a critical global challenge, contributing to environmental pollution and resource inefficiency. Defined as food intended for human consumption that is wasted or lost, food waste encompasses uneaten meals from homes and restaurants as well as raw materials lost during farming, harvesting, transportation, and storage [1]. In Malaysia, approximately 8.3 million metric tons of food waste are generated annually, and without effective management, landfill space will become insufficient by 2050 [2]. Despite numerous initiatives, significant reduction of food waste has proven difficult, highlighting the need for practical and sustainable solutions. Composting is recognized as an environmentally friendly method for managing organic waste, as it recycles food scraps and other organic matter into nutrient-rich fertilizer while reducing methane emissions from landfills [3]. However, traditional composting methods are time-consuming, taking two to three months and require regular maintenance, such as turning and monitoring moisture levels [4][5]. Although technological innovations, such as automated kitchen countertop composters, have improved convenience and efficiency [6], their high cost and limited availability have hindered widespread adoption. The objective of this project is to design and fabricate an Automatic Food Composter that provides an affordable, user-friendly, and low-maintenance solution for household food waste management. The scope of work includes conceptual design, structural analysis using SolidWorks, fabrication of the prototype, and evaluation of functionality. This project is significant as it aims to reduce reliance on plastic waste bags, encourage public

participation in composting, and promote sustainable waste management practices. By offering a practical and accessible alternative, the project seeks to address the growing problem of food waste while contributing to environmental conservation and resource sustainability.

2 LITERATURE REVIEW

Food waste is widely recognised as a critical global environmental issue, with significant social, economic, and environmental consequences. Food waste refers to edible food that is lost or discarded throughout the supply chain, including during production, processing, transportation, retail, and consumption stages [1]. In Malaysia alone, approximately 8.3 million metric tons of food waste are generated annually, and projections indicate that existing landfill capacity will be insufficient by 2050 if no effective intervention is implemented [2]. This highlights the urgent need for sustainable household-level waste management solutions. Composting is identified in the literature as one of the most environmentally friendly methods for managing organic waste. It is defined as a natural biological process that converts organic matter into nutrient-rich compost, which improves soil quality and reduces methane emissions from landfills [3].

To overcome these limitations, several automatic food composters have been introduced to the consumer market. Benchmarking studies on commercial products such as FoodCycler, Mill Food Recycler, and Lomi 2 Food Recycler as in Fig. 1 show that these systems successfully reduce food waste volume and improve user convenience through automated grinding, heating, and odour control mechanisms. However, important drawbacks are consistently reported. These include high retail prices ranging from approximately RM 2,400 to RM 4,200, bulky designs, high energy consumption, noise during operation, and complex components that increase maintenance difficulty [7].



(a) (b) (c)

Fig. 1: Available commercial products (a) FoodCycler, (b) Mill Food Recycler and (c) Lomi 2 Food Recycler.

3 METHODOLOGY

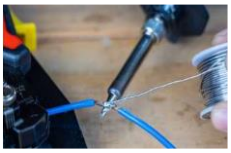
3.1 Design Process

The 3D model parts of the Automatic Food Composter were designed using SolidWorks. An assembly file was created by connecting all parts with both standard and mechanical mates. Finally, a detailed technical drawing was produced from the assembly, showing all dimensions and a complete list of materials required to fabricate the prototype.

3.2 Fabrication Process

The fabrication process was conducted using the design completed in SolidWorks. The fabrication process done were as shown in Table 1.

Table 1: Fabrication process of an Automatic Food Composter

Process	**Picture**
Measuring Process All materials were first measured according to the finalized dimensions from the SolidWorks design. Measuring tools such as a measuring tape, ruler, and marker were used to ensure accuracy. Hole locations were marked using a centre punch to prevent drill slippage during machining.	
Cutting Process After marking, the materials were cut to the required sizes. Sheet materials were cut using a shearing machine, while metal pipes and bars were cut using a hand grinder. This step ensured that all parts matched the design dimensions and fit properly during assembly.	
Drilling Process Drilling was performed on parts that required holes for bolts, screws, or mounting components. A bench drill was used to produce accurate and clean holes. Proper alignment and safety precautions were followed to avoid material damage and accidents.	
Assembly Process The main structure of the Automatic Food Composter was assembled by joining the cut components. Mechanical fasteners such as bolts, nuts, and screws were used to allow easy disassembly for maintenance. Welding and adhesive bonding were applied where permanent joints were required to ensure structural strength and stability.	
Wiring and Electrical Installation Electrical components such as the motor, heater, thermostat, timer, relay, and power supply were connected according to the schematic diagram. Proper insulation and secure wiring were applied to prevent short circuits and electrical hazards. All electrical connections were checked before testing.	
Testing and Inspection The completed prototype was tested to ensure proper operation of the motor, heating system, and control components. Functional checks were conducted to confirm safe operation, correct temperature control, and smooth mechanical movement.	

4 RESULTS AND DISCUSSION

The complete details of the entire product are shown in Fig. 3 and Fig. 4. The assembly Figure provides an integrated view of all the individual components that were modelled on their own using SolidWorks. A detailed 3D model is used to visualize the product, check for assembly problems and make any necessary adjustments before the actual manufacture of the product.

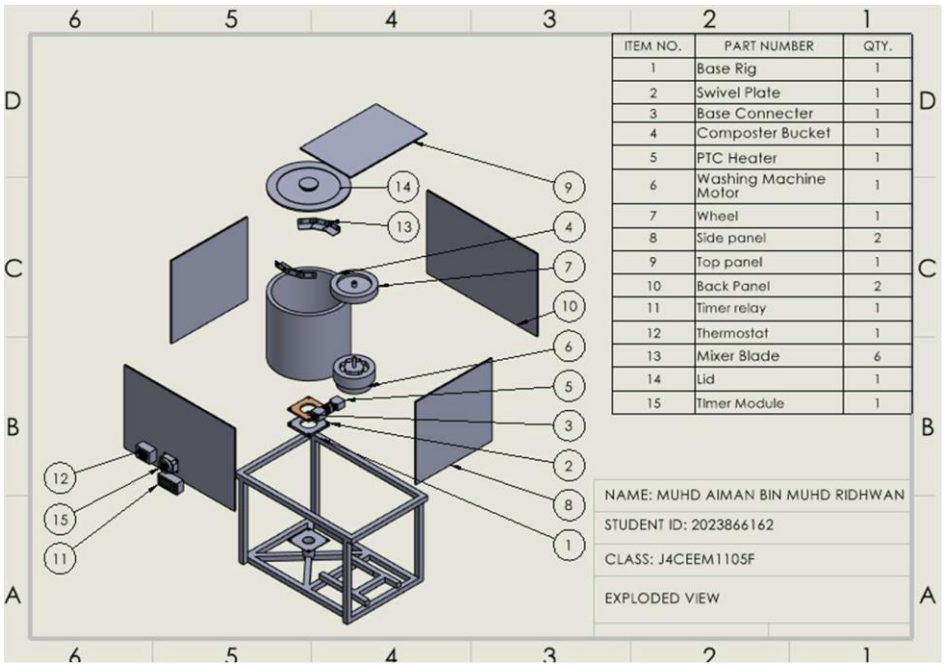


Fig. 3: Exploded Drawing

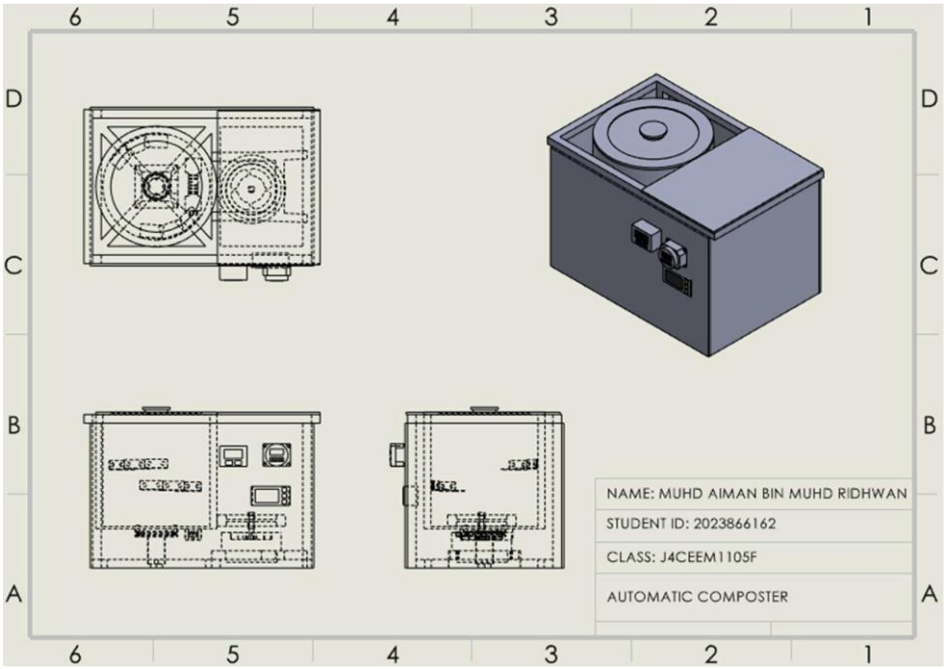


Fig. 4: Assembly Drawing

The final fabricated prototype was successfully completed, as shown in Fig. 5. The prototype was manufactured based on the SolidWorks design, with all dimensions conforming

to the planned specifications within a tolerance of 1.0 - 1.5 mm.



(a) (b) (c)

Fig. 5: (a) Top view, (b) front view and (c) side view of the completed prototype.

5 CONCLUSIONS

This project successfully achieved its objectives of designing and fabricating a simple, easy-to-maintain, and low-cost Automatic Food Composter. The total fabrication cost of the prototype was RM 393.45, which is significantly lower than the market price of comparable commercial products and remains within the proposed budget range. The prototype was designed with simplicity and ease of maintenance in mind, utilising only essential components to ensure reliable functionality while remaining suitable for household use. Furthermore, the project promotes environmentally friendly practices by encouraging home composting, which can help reduce the amount of food waste generated by households. In addition, this project supports sustainability goals by providing an effective solution to reduce the volume of food waste sent to landfills. Overall, the project demonstrates an affordable, practical, and environmentally sustainable solution for household food composting.

REFERENCES

[1] O. Lai, “Explainer: What is food waste?” Earth.org, 22-Nov-2021. [Online]. Available: https://earth.org/what-is-food-waste/. [Accessed: 05-May-2025].
[2] “Malaysia waste management,” International Trade Administration | Trade.gov. [Online]. Available: https://www.trade.gov/market-intelligence/malaysia-wastemanagement. [Accessed: 05-May- 2025].
[3] S. Hu, “Composting 101,” Nrdc.org, 20-Jul-2020. [Online]. Available: https://www.nrdc.org/stories/composting-101. [Accessed: 05-May-2025].
[4] V. Patel, “Why isn’t composting done more often,” beyondGREEN biotechTM, 09-Dec-2023. [Online]. Available: https://byndgrn.com/blogs/news-1/why-isntcomposting-done-more- often?utm_source=chatgpt.com. [Accessed: 05-May-2025].
[5] GrowVeg, “How to make compost - fast and easy.” [Online]. Available: https://www.youtube.com/watch?v=_K25WjjCBuw. [Accessed: 05-May-2025].
[6] “Kitchen countertop food recycler,” Lomi. [Online]. Available: https://lomi.com/?srsltid=AfmBOorZrsNcPtfN_h4QwQMlT201hYe0OzD9vt69AsOG01hKuNfrSlk. [Accessed: 05-May-2025].
[7] J. Panaro, “6 reasons NOT to buy an electric kitchen composter,” Honestly Modern, 27-Sep-2022. [Accessed: 06-May-2025].

CHAPTER 7

Design and Development of an Umbrella Dryer Machine for Indoor Safety and Hygiene

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ABSTRACT

Wet umbrellas frequently create safety and hygiene problems in indoor environments such as offices, shopping malls, and educational institutions. When individuals enter buildings during rainy weather, umbrellas often carry excessive moisture that may cause slippery floors and increase the risk of accidents. This study presents the design and development of an umbrella dryer machine prototype intended to reduce water dripping and improve indoor safety. The proposed system combines centrifugal force, airflow, and heat transfer to remove moisture from wet umbrellas within a short period. The development process began with conceptual design and three-dimensional modelling using SolidWorks software. The fabrication stage involved several manufacturing processes including cutting, drilling, grinding, and mechanical assembly using PVC pipes, a blower system, and heating elements. Experimental observations indicate that the developed prototype is capable of drying umbrellas effectively while collecting excess water through a drainage system. The proposed machine offers a practical solution for public facilities by improving safety, reducing maintenance work, and enhancing user convenience.

Keywords: Umbrella dryer machine

1 INTRODUCTION

Umbrellas are commonly used as protective accessories against rainfall, particularly in tropical regions where frequent precipitation occurs throughout the year. When individuals enter indoor spaces after exposure to rain, their umbrellas remain wet and continue dripping water onto floors and surrounding surfaces. This issue is commonly observed in public buildings such as shopping malls, offices, and educational institutions. Water dripping from umbrellas may accumulate on the floor and create slippery surfaces, which can potentially lead to accidents and safety hazards [1]. Conventional approaches for handling wet umbrellas typically involve placing them in umbrella stands or allowing them to dry naturally. However, these methods are often inefficient because water may continue to drip onto floors and surrounding areas. In addition, leaving umbrellas unattended outside buildings may increase the risk of loss or theft. The spread of moisture and dirt may also reduce the cleanliness of indoor environments and increase maintenance efforts for facility management [2].

To address these issues, automated umbrella drying systems have been introduced in several public facilities. These machines are designed to remove water from umbrellas quickly and prevent moisture from spreading onto indoor surfaces. Various designs have been

developed, including umbrella bagging machines and airflow-based drying systems. However, many existing products require high installation costs or generate additional waste such as disposable plastic covers [3]. Therefore, the development of a compact and cost-effective umbrella dryer machine is necessary to provide a more sustainable solution. The objective of this study is to design and fabricate a prototype umbrella dryer machine capable of removing moisture efficiently while maintaining safe operation in indoor environments.

2 LITERATURE REVIEW

Several technologies have been developed to manage wet umbrellas in public spaces. One widely used solution is the umbrella bagging machine, which wraps a plastic sleeve around the umbrella to prevent water from dripping onto the floor. Although this method is effective in preventing water spread, it generates plastic waste and requires continuous replacement of disposable covers [3]. Another approach involves the use of umbrella drying machines that remove water through mechanical spinning and forced airflow. These machines often employ centrifugal force to separate water from the umbrella surface, followed by airflow or heating to accelerate evaporation. Such systems are commonly installed in public buildings where large numbers of people enter during rainy weather [4].

Research has shown that drying performance can be significantly improved when airflow systems are combined with heat transfer mechanisms. The use of heated airflow increases evaporation rates and reduces drying time, making the system more efficient. Additionally, modern umbrella dryers incorporate features such as humidity sensors, automatic shutdown mechanisms, and water collection trays to improve safety and usability [4]. Despite these advancements, existing machines may have limitations in terms of cost, energy consumption, and drying capacity. Many commercial machines are relatively expensive and may not be suitable for small facilities or educational institutions. Therefore, developing a low-cost prototype with simple fabrication processes remains an important research area.

The present study aims to develop a prototype umbrella dryer machine using commonly available materials and basic fabrication techniques while maintaining effective drying performance.



Fig. 1: Many umbrella drying machines are cost-prohibitive for smaller facilities.

3 METHODOLOGY

3.1 Design Process

The design process of the umbrella dryer machine began with the development of a conceptual model that focuses on compact structure and efficient drying performance. The machine was designed as a vertical cylindrical structure that allows umbrellas to be inserted easily while directing airflow along the umbrella surface. Three-dimensional modelling was performed using SolidWorks software to create detailed designs of each component. Individual parts such as the outer casing, inner pipe, airflow vents, and support structures were designed separately before being assembled into a complete system. The assembly design ensured that all components fit properly and function together as an integrated drying mechanism [5]. The primary components of the machine include PVC pipes forming the cylindrical body, a blower system that generates airflow, heating elements that increase air temperature, and air vents that facilitate airflow circulation. A water drainage system was also incorporated at the bottom of the machine to collect excess water removed from the umbrella.

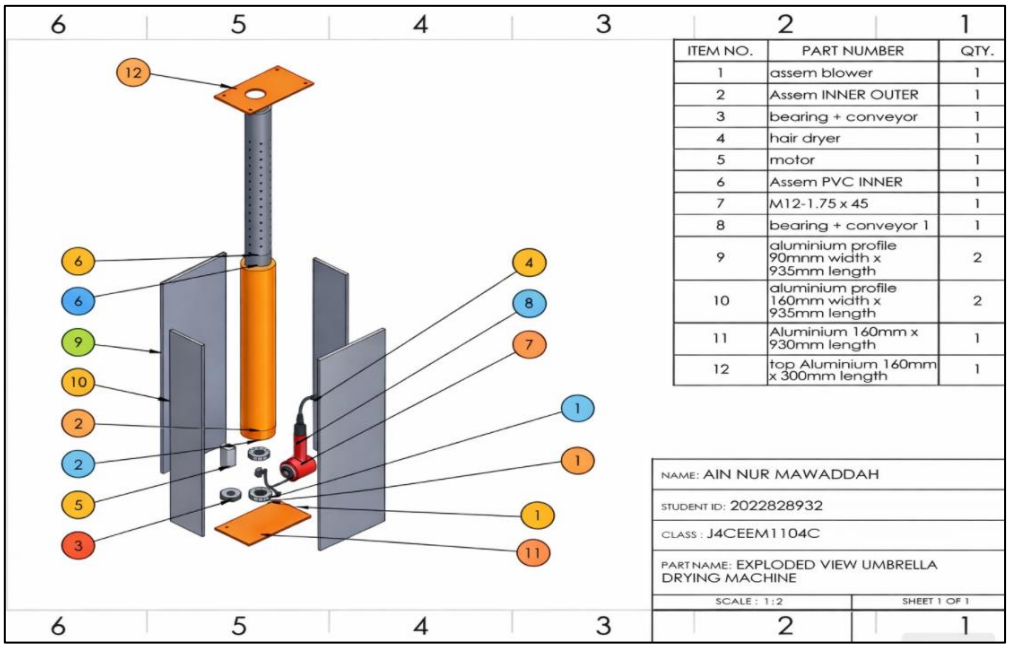


Fig. 2: Exploded assembly view of the proposed umbrella design (SolidWorks).

3.2 Fabrication Process

After the design phase was completed, the fabrication process was carried out according to the technical drawings produced from the SolidWorks model. The fabrication process involved several manufacturing steps including cutting, drilling, grinding, and assembly. First, PVC pipes were measured and cut according to the required dimensions to form the outer and inner cylindrical structures. Drilling operations were performed to create airflow openings and mounting holes for mechanical components. Grinding and finishing processes were then conducted to smooth the edges of the cut materials and ensure safe assembly. Next, the blower system and heating element were installed within the internal structure of the machine. Electrical connections were made to supply power to the blower and control switch. Finally, all components were assembled using bolts and fastening elements to produce the complete umbrella dryer prototype.

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Fig. 3: Fabrication of the umbrella drying machine

4 RESULTS AND DISCUSSION

The final fabricated prototype demonstrates a compact vertical design suitable for installation near building entrances. The structure consists of two cylindrical PVC pipes that guide airflow through the umbrella during operation. When the machine is activated, the blower generates airflow that travels through the internal chamber. The airflow passes along the umbrella surface and removes moisture through forced convection. At the same time, the heating element increases the temperature of the air, which accelerates the evaporation process and improves drying efficiency.

The system also incorporates a drainage mechanism that collects water removed from the umbrella. Excess water flows downward through the inner pipe and is collected in a container at the base of the machine. This feature prevents water from spilling onto the floor and maintains cleanliness in indoor spaces. The developed prototype offers several advantages, including improved indoor safety by reducing slippery floors, increased convenience for users, and reduced maintenance work for building management. In addition, the use of lightweight materials such as PVC pipes helps reduce manufacturing cost while maintaining structural functionality.

However, some limitations were observed during testing. Umbrellas with thicker fabric may require longer drying times due to higher moisture retention. Furthermore, continuous use of the heating element may increase energy consumption if the system is operated for extended periods.



Fig. 4: Prototype of the umbrella drying machine

5 CONCLUSIONS

This study presented the design and development of a prototype umbrella dryer machine intended to improve safety and cleanliness in indoor environments. The machine integrates airflow and heat transfer mechanisms to remove moisture efficiently while collecting excess water through a drainage system. The prototype was successfully designed using SolidWorks and fabricated through several manufacturing processes including cutting, drilling, and assembly. Experimental observations indicate that the machine is capable of drying umbrellas effectively and preventing water from spreading onto indoor surfaces. The developed system demonstrates potential for application in public buildings such as offices, shopping malls, and educational institutions. Future improvements may include the integration of automatic sensors, improved heating efficiency, and energy-saving control systems to enhance overall performance and usability.

REFERENCES

[1] K. L. Hotels, “Umbrella stolen at NSK Grocer,” Safety Report, 2018.
[2] F. Products et al., “What is the best way to care for wet umbrellas?” Facility Safety Guide, pp. 1–5, 2016.
[3] W. Umbrella, “Umbrella bagger technology for public facilities,” Building Safety Journal, vol. 12, no. 2, pp. 45–49, 2014.
[4] X. Zeng and J. Huang, “Design and research of umbrella drying machines in public places,” Proc. Int. Conf. Engineering Technology, 2024
[5] M. Aguair and K. Behdinan, “Design, prototyping, and programming of a bricklaying robot,” Journal of Student Science and Technology, vol. 8, no. 3, pp. 27–34, 2015

CHAPTER 8

Comparative Analysis of Fluid Flow Around Different Go-Kart Body Cover Designs

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ABSTRACT

Aerodynamic and rigid cars are four-wheeled vehicles commonly used in recreational and competitive motorsports. A critical challenge in car design is ensuring the chassis possesses adequate strength and rigidity to safely support the driver and withstand the dynamic forces encountered during operation. The aim of this project is to design and analyse a car body cover. These shortcomings often arise from inadequate structural analysis, insufficient use of simulation tools such as CAD, and a lack of proper consideration for fluid flow, which affects aerodynamic performance

Keywords: Body cover, Go-Kart, Fluid flow

1 INTRODUCTION

In high-performance cars, aerodynamics plays a vital role in reducing drag and increasing downforce, which are critical for stability and speed. The shape of a car and its chassis significantly influence its overall performance. Analysis of the designed model using CFD shows that the final product not only enhances performance but also introduces a new level of adaptability in automotive aerodynamics. The aim of this study is to ensure that the car's chassis can safely withstand operating speeds of up to 60 km/h without structural failure or excessive deformation, is structurally capable of supporting the driver's weight, and operates well under dynamic motion.

2 LITERATURE REVIEW

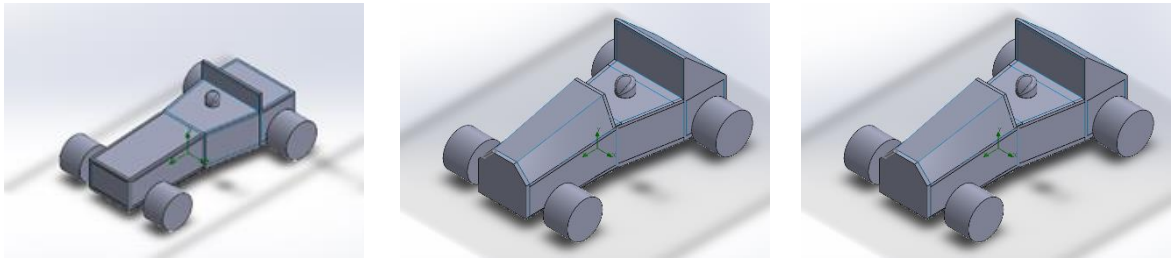
The primary structural component of a car is its chassis. As the car's structural core, it provides the framework for all other parts, including the engine, suspension, wheels, seats, and body panels [1]. A space frame chassis, a type of chassis composed of interconnecting steel tubes arranged in a triangular pattern for optimal strength and stiffness. When designing the chassis, the structural integrity and safety must be secured [2]. The chassis design should withstand all operational loads, including the weight of the driver and engine, as well as dynamic forces during acceleration, braking, and cornering [2]. However, most importantly, the chassis must protect the driver in the event of a rollover.

In the analysis of the aerodynamic go-kart, it can be identified as a "blunt body" with exposed wheels and a drive. As the go-kart moves, it creates significant pressure drag that resists the forward movement [3]. The previous study emphasizes that as the go-kart moves at

a certain speed, air hits the drive, the go-kart, and the front tire, resulting in high pressure on the front surface and low pressure behind. The evaluation of the car design was catalyzed by the method to analyze its performance [4]. The testing has shifted from a trial-and-error test to the use of Computational Fluid Dynamics and CAD software tools. The key data were exported to CAD software, and the relevant scenarios were tested based on the study cases. In most studies on Go-karts or other vehicles, virtual simulations can be used to predict lift, drag, and downward force with high accuracy [5].

3 METHODOLOGY

To obtain the drag coefficient, three cars were modeled in SolidWorks Flow Simulation. SolidWorks was used to design and analyze the first car. From there, modifications were made, and a second design was presented. continue using the same method, making modifications, and the third and final car is created as in Figure 1.



(a) Design 1 (b) Design 2 (c) Design 3

Fig. 1: Design 1, Design 2 and Design 3

The go-kart design then transfers into SolidWorks for the further study. The input data assigned to the CFD study as in Figure 1.

Table 1. Summarization of the settings used

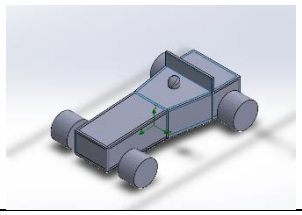
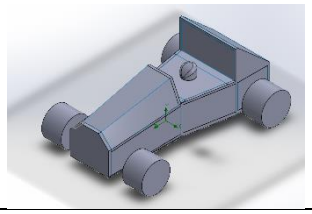
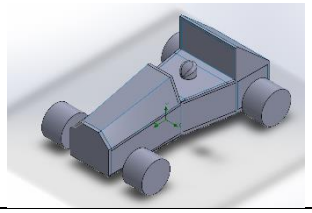
Analysis Type	**External**
Gravity (Y-plane)	$-9.81\ \frac{m^2}{s}$
Gases	Air
Velocity	$-19.44\ \frac{m}{s}$
Goals	1. GG Force (X) 2. GG Force (Y) 3. GG Force (Z) 4. Drag Coefficient
Results	1. Surface Plot (1) 2. Flow Trajectories 3. Goal Plots (All)

4 RESULTS AND DISCUSSION

Table 2 show the drag value from the test design one become standard for the comparison with drag coefficient of 0.9 which design 2 was reduce to 0.86 while design three reduce more to 0.83.

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Table 2 Summarization of the drag Improvement for each of the Go-Kart

Car Model	Drag Coefficient	% Reduction
Car One 	0.90	0
Car Two 	0.86	4.44
Car Three 	0.83	8.43

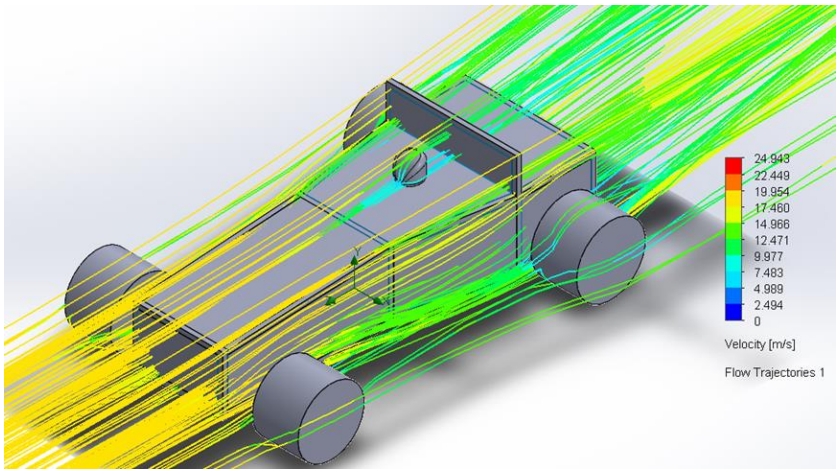


Fig. 2: Airflow for Car One

Regarding the first car in Figure 1, we can observe that the airflow at the back of the car is mostly light green in color. When observe the Solidworks indicator, the arrow of green indicates 12.471 m/s, which indicates that the air movement has drastically decreased from its starting speed of 19.44 m/s by almost 35.85%.

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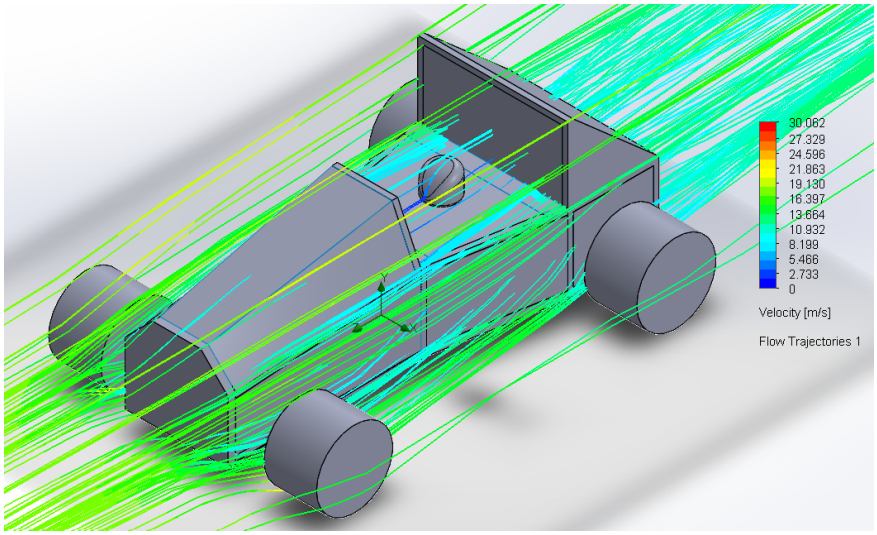


Fig. 3. Airflow for Car Two

Figure 3 shows that the airflow at the back of the car is currently generally at a speed of 16.397 m/s, which is better than the previous speed of 12.471 m/s. The car has smooth aerodynamics when its rearward velocity is almost equal to its starting velocity. In this instance, it is 23.94% better than design one.

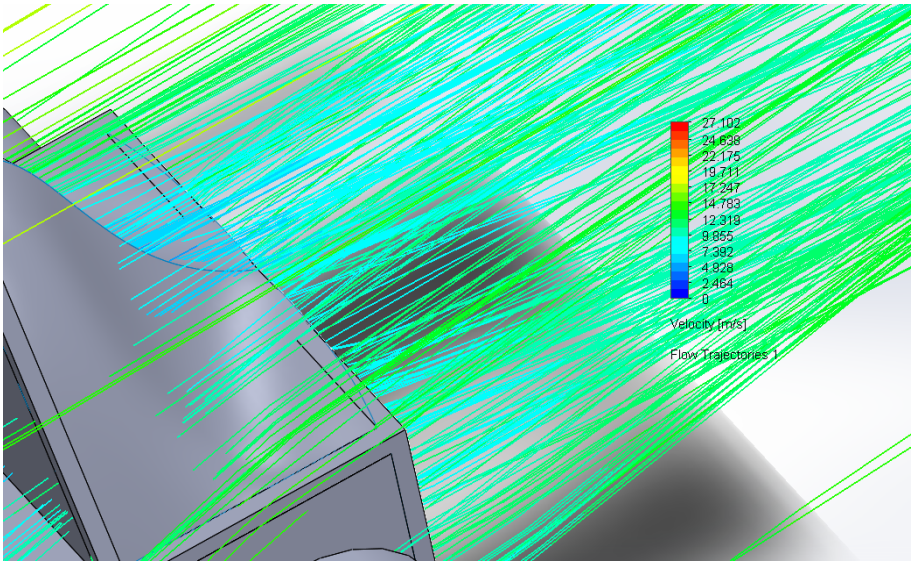


Fig. 4: Zoom-in Rear Airflow for Car Three

Speaking of the last car in Figure 4, the lighter green color indicates airspeed of 17.247 m/s at the back of the car. This indicates that the shape has improved by 4.92% when compared to the previous vehicle.

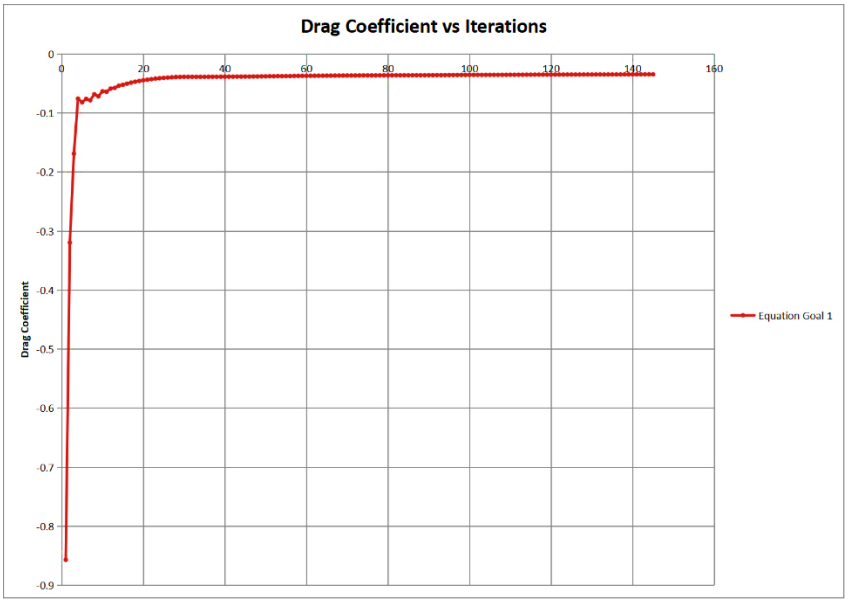


Fig. 5: Drag Analysis Graph

The results in the Figure 5 makes it quite evident that there are swings at the beginning, which is typical. Iterations in this graph indicate how frequently the data has been produced. After 40 iterations, the data is normal, and the graph may be used to determine the drag coefficient value.

5 CONCLUSIONS

In conclusion, the mini sander belt machine, designed and manufactured for sanding tasks, demonstrates reliability and effectiveness. Recommendations to enhance its utility include adding a dust barrier, utilizing a higher-voltage motor and grit belt, and employing more durable materials. These measures aim to maximize its potential applications, catering to diverse sanding needs across different materials while ensuring longevity and efficiency.

REFERENCES

[1] Patil, N., et al., *Static analysis of go-kart chassis frame by analytical and SolidWorks simulation.* International Journal of Scientific Engineering and Technology, 2014. **3**(5): p. 661-663.

[2] Mekalke, G., *Static Analysis of a Go-Kart Chassis.* International Journal of Mechanical and Industrial Technology, 2016. **3**(2): p. 73-79.

[3] Sammangi, D.K., et al. *A study on structural behaviour and vibrational characteristics of a go-kart chassis*. in *E3S Web of Conferences*. 2023. EDP Sciences.

[4] Pattanshetti, V., *Design and analysis of go kart chassis.* International Journal of Mechanical and Industrial Technology, 2016. **4**(1): p. 150-164.

[5] Kalita, U., Y.S. Teja, and D.S.V.V. Manikanta, *Design and analysis of Go-kart chassis.* International Journal of Engineering Development and Research, 2018. **6**(2): p. 290-295-290-295.

CHAPTER 9

Analysis of the Gear Ratio for Manual Transmission of the Fabricated Gearbox

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ABSTRACT

A gearbox functions as a transmission system for a vehicle as it transfers the power generated from the engine to the wheels. It is a mechanical device that utilizes different gear ratios to change its speed and movement direction such as to accelerate, decelerate or move in reverse. The gears serve a crucial role in adjusting the direction, torque and speed of the vehicle. The aim of the project is to design and fabricate a prototype of a gearbox system for a go-kart to have the ability move in forward and in reverse. To accomplish this project's objective, sufficient research and benchmarking must be done. Following this, the design of the gearbox will be done in SolidWorks. The analysis carried out based on the gear ratio to find the best configuration of the gear to make sure the prototype working properly. The analysis of gear ratios is essential to determine the most suitable gear arrangement to ensure efficient power transmission and reliable operation of the prototype. Overall, the successful development of this gearbox system will contribute to a functional and practical transmission mechanism for the go-kart.

Keywords: Gearbox, Gear ratio, Transmission

1 INTRODUCTION

A gearbox is a mechanical device containing a set of gears that transfers power from one source of rotation to another. In the case of a moving vehicle, this refers to the power generated by the engine being transferred to the wheel system. By changing gear ratios, a gearbox can effectively adjust a vehicle's speed, torque, and direction of motion [1]. Modern-day applications of gearboxes are typically found in automobiles and industrial machinery [2]. Something as crucial as moving in reverse should not be left out in modern-day go-karts. The ability to go in reverse is important for getting out of troubling situations or undesired circumstances, especially in the event of a crash or bad road condition [3]. To address this dilemma, a proper gearbox that allows reverse is vital. There are many criteria to consider when deciding the best type of gearbox to fabricate for this purpose [4]. Therefore, proper research into the pros and cons of each gearbox type on the market must be conducted.

The main purpose of this study is to choose the most appropriate type of gearbox system to fabricate for the purpose of enabling a go-kart to move in reverse. Since the main purpose is for the go-kart to move in reverse, the design choice will heavily impact its functionality. The added practicality of being able to move in reverse will add to the overall user experience of the go-kart. Additionally, the materials used to construct the gearbox's gear system and shaft

will heavily affect the overall performance and longevity of the go-kart. Moreover, the research will provide valuable insights into the best way to make the gearbox system more compact and efficient.

2 LITERATURE REVIEW

The innovation regarding gearboxes have increased following its creation in the year 1904. Several types of gearboxes have seen heavy usage in modern times, such as the Manual Transmission (MT). The MT is most common in older vehicles and uses a typical clutch and stick system. It is very efficient both performance and fuel consumption wise as it has direct engagement with the gears. Following this, is the Automatic Transmission (AT) which is typically seen in more modern vehicles due to its ability to shift gears automatically using a torque convertor [3]. The AT is less efficient when it comes to performance and fuel consumption due to the addition of the torque convertor. Next is the Continuously Variable Transmission (CVT) which is a type of automatic transmission that can adjust its gear ratio continuously. It provides a smooth transition between gear shifts and ensure that the vehicle is always in the most optimal gear ratio [4].

Lastly, is the Dual-Clutch Transmission (DCT) which uses two clutches to automatically change gears [5]. The DCT doesn't use the torque convertor found in most automatic transmission gearboxes. Instead, it uses two clutches, one for even and one for odd gears, enabling for a more efficient and higher performance ceiling for vehicles while maintaining high ride comfortability [5]. The DCT is more commonly seen in sports cars due its performance and high maintenance cost.

3 METHODOLOGY

Figure 1 below illustrate design of the gearbox. This design was developed using SolidWorks. The gearbox was function manually which required driver to control the gear configuration to move forward and reverse. By controlling the gear to produce different gear ratio, torque and direction of go-kart move. Schematic diagram of the gear show in the Figure 1, which contain 2 sections and working using five gears with difference gear teeth.

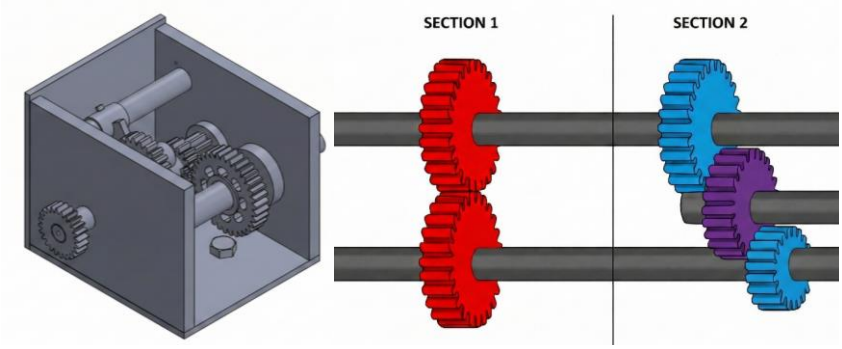


Fig. 1: Design of the gearbox

This analysis was carried using gear ratio equation which focuses on the theoretical calculations used for the gear ratio, torque output, output speed and bending stress of the gears in the gearbox.

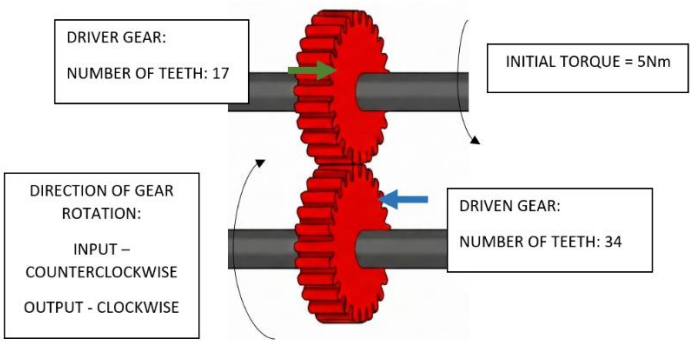


Fig. 2: Design of the section 1

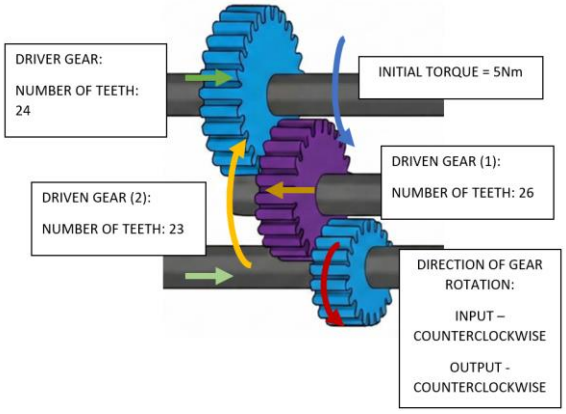


Fig. 3: Design of the section 2

4 RESULTS AND DISCUSSION

Based on the results, the analysis indicated that the gearbox is capable of operating in two modes through its configuration. In section 1, the forward gear, driver gear with 17 gear teeth, and driven gear with 34 teeth produce a gear ratio of 2. With this setup, it effectively produces double the initial torque, from 14.24 Nm to 28.48 Nm, reducing the input speed of 500 rpm to an output speed of 250 rpm. The rotation of the output speed is reversed relative to the input speed to provide a mechanical drive for forward movement. In section 2, the gearbox used 3 gears to facilitate reverse movement. These features are always missing in the go-kart. It includes a driver gear of 24 teeth and two driven gears of 26 and 23 teeth. The gear configuration resulting in a final gear ratio of 1.13. Under this configuration, the expected output torque is 16.09 Nm, with a maximum output speed of 442.47 rpm. Difference from the first section, the output shaft remains counterclockwise, following the input direction, to allow go go-kart to move in the reverse direction

The forward configuration in section 1 focused on the power and speed for go-kart utilization. It is important to move forward by overcoming the static friction and achieving the expected acceleration. Meanwhile, the reverse configuration in section 2 provides less torque to provide a compact and smooth function of the gearbox while improving go-kart controllability.

5 CONCLUSIONS

The analysis was conducted using calculations to demonstrate the gearbox's functionality. The system operates using these two gearbox sections for forward and reverse.

This integration of the 2 sections fulfils the project objective of moving the go-kart forward and backward. By utilizing a three-gear arrangement with a gear ratio of 1.13, the system maintains a counter-clockwise output rotation that matches the input direction

REFERENCES

[1] Motions, G. *Gearboxes*. 2024 Oct. 10; Available from: https://gearmotions.com/capabilities/gearboxes/.
[2] Kusumgar, A. *Future Trends in Gearbox Technology*. 2024 July 15; Available from: https://www.millgears.com/blog/future-trends-in-gearbox-technology.
[3] Tamada, S., D. Bhattacharjee, and P.K. Dan, *Review on automatic transmission control in electric and non-electric automotive powertrain.* International Journal of Vehicle Performance, 2020. **6**(1): p. 98-128.
[4] Carbone, G., et al., *CVT dynamics: Theory and experiments.* Mechanism and Machine Theory, 2007. **42**(4): p. 409-428.
[5] Milindar, S., S. Prasanna, and P. Baskar, *Comprehensive review on dual clutch transmission.* International Journal of Vehicle Performance, 2022. **8**(1): p. 74-108

CHAPTER 10

Design and Development of Automatic Rice Portion Dispenser

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ABSTRACT

Rice is a staple food widely consumed in many Asian countries, particularly in Malaysia, where it is served daily in households and food service establishments. Conventional rice portioning methods rely on manual scooping or measuring cups, which are time-consuming, inconsistent, and prone to human error. These limitations often result in overcooking or undercooking, contributing to food wastage and operational inefficiency. This project presents the design and fabrication of an Automatic Rice Portion Dispenser aimed at improving portion accuracy, reducing manual effort, and enhancing kitchen efficiency. The system integrates mechanical and embedded system principles using an Arduino UNO microcontroller as the central controller. The dispensing mechanism employs a rotary compartment system driven by a NEMA17 stepper motor through an A4988 driver. Two push buttons allow users to select predefined portion sizes (½ cup and 1 cup), controlled by precise motor rotation angles (90° and 180° respectively). The fabricated prototype consists of a stainless-steel frame, acrylic rice container, and a 3D-printed PETG rotary mechanism. Experimental evaluation demonstrated consistent dispensing performance with acceptable tolerance influenced by rice flow characteristics. The prototype successfully demonstrates a cost-effective and practical automation solution for domestic and small-scale commercial applications. The system reduces food waste, improves portion consistency, and promotes efficient resource utilization through simple embedded system integration.

Keywords: Rice dispenser

1 INTRODUCTION

The scope of this study focuses on the design, fabrication, and testing of a prototype Automatic Rice Portion Dispenser intended for household and small-scale food service applications. The system is developed using an Arduino UNO microcontroller to control a NEMA17 stepper motor–driven rotary dispensing mechanism with fixed portion sizes of ½ cup (90° rotation) and 1 cup (180° rotation). The maximum dispensing capacity per operation is limited to 180 ml of dry rice, and the system does not incorporate mobile connectivity, wireless communication, or weight-based sensor feedback. Performance evaluation is limited to functional testing under normal operating conditions using dry rice, acknowledging that slight variation in portion accuracy may occur due to differences in rice grain type and flow characteristics.

The significance of this study lies in its ability to improve kitchen efficiency, hygiene, and portion consistency through simple automation. The Automatic Rice Portion Dispenser

reduces direct hand contact and repetitive manual scooping, promoting cleaner food handling and faster meal preparation, especially for students, busy individuals, and small food businesses. By standardizing rice portioning, the system helps increase operational consistency while encouraging better portion awareness, which contributes to minimizing unnecessary rice waste.

2 LITERATURE REVIEW

Automation in food portioning and dispensing systems has gained significant research attention due to increasing demands for efficiency, consistency, hygiene, and waste reduction in both domestic and commercial settings [1]. Traditional manual portioning methods, such as scooping rice with measuring cups, present limitations in repeatability, accuracy, and user convenience; thus, researchers and engineers have proposed various automated mechanisms to address these challenges.



(a) (b) (c)

Fig. 1: Variety of Rice Dispenser [2][3][4]

Commercially available rice dispensers such as the Measuring Rice Stocker SS-12 WH [2], as shown in Figure 1(a), provide a gravity-based mechanical dispensing mechanism. The system typically uses a lever-actuated rotary chamber that releases a fixed volume of rice (commonly 150 g per pull). These devices are simple, durable, and require no electrical components. However, they lack programmable control, portion flexibility, and automation. The dispensing accuracy depends entirely on mechanical tolerance and user actuation consistency. The key finding from reviewing such commercial products is that while mechanical simplicity ensures reliability and low cost, these systems do not address automation, portion customization, or integration with smart systems.

Embedded systems have become central to modern automation solutions. Platforms such as the Arduino UNO enable cost-effective control of electromechanical components. Stepper motors such as the NEMA17, driven by controllers like the A4988, provide precise angular positioning without requiring additional feedback sensors. Existing automated food dispensers as in Figure 1(b) and 1(c), often incorporate load cells or optical sensors for real-time measurement [3][4]. While this approach enhances accuracy, it increases cost, calibration requirements, and system complexity.

3 METHODOLOGY

The primary design stage of this rice dispenser started with outlining several design concepts based on literature review. A morphological chart was constructed to compare alternative components including frame materials, container materials, motor types, control platforms, and dispensing mechanisms. Initial sketches of the concept were brainstormed to

generate ideas and finally being finalized using Pugh decision matrix selection method to evaluate durability, cost, complexity, and manufacturability.

The prototype was fabricated in-house at the Machine Shop, Faculty of Mechanical Engineering, Universiti Teknologi MARA Pasir Gudang. The fabrication followed a structured mechanical and electrical assembly process. The process began with frame construction, where mild steel sections were measured, cut, and welded using arc welding techniques to form the main structural support. The welded frame was then ground and finished to ensure smooth edges and structural stability. Next, the rice hopper was fabricated using acrylic sheets. The sheets were cut according to the designed dimensions and assembled using adhesive bonding to form a transparent storage container. Openings were precisely cut to accommodate the rotary dispensing mechanism. The rotary blade mechanism was produced using 3D printing to achieve accurate dimensions for controlled volumetric dispensing. The blade was mounted onto the shaft of a NEMA17 to ensure precise angular rotation.



Fig. 2: Fabrication process

For the electrical integration, it consists of an Arduino UNO, an A4988 stepper motor driver, a NEMA 17 stepper motor, an external 12 V power supply. Two push buttons were installed to allow users to select portion sizes (½ cup or 1 cup). Proper wiring, soldering, and insulation were carried out to ensure safe operation. The system was programmed using Arduino IDE to control the stepper motor and user inputs. Finally, system testing and calibration were conducted. The motor rotation angles (90° and 180°) were programmed and adjusted to achieve consistent rice portions. Functional tests were performed to verify smooth operation, structural stability, and dispensing accuracy.

4 RESULTS AND DISCUSSION

The Automatic Rice Portion Dispenser prototype was successfully developed, as shown in Figure 3 and tested to validate its mechanical stability, dispensing consistency, and control accuracy. Functional testing confirmed that the stepper motor rotation at 90° and 180° reliably produced approximately ½ cup and 1 cup rice portions, respectively. The programmed angular

displacement method demonstrated consistent operation without the need for additional weight sensors.



Fig. 3: Prototype of Automatic Rice Portion Dispenser

Repeated dispensing trials showed minimal variation in portion size, with minor deviations attributed to rice grain flow characteristics and hopper geometry. No significant motor stalling or jamming was observed during normal operation. Structural simulation results indicated that the frame and hopper could safely withstand the applied load (1 - 2 kg of rice), maintaining stress levels below material yield strength and ensuring a satisfactory factor of safety.

5 CONCLUSIONS

The Automatic Rice Portion Dispenser project successfully achieved its primary objective of designing and developing a low-cost, automated rice dispensing system for household and small-scale applications. The integration of a rotary volumetric mechanism with microcontroller-based stepper motor control demonstrated that accurate and consistent portioning can be achieved without complex sensor systems. By utilizing the Arduino UNO in combination with a NEMA17 and A4988, the system provided precise angular displacement corresponding to ½ cup (90°) and 1 cup (180°) rice portions. The study highlights that automation in domestic food handling does not necessarily require advanced sensor integration. Instead, a well-designed mechanical system combined with controlled motor positioning can provide an effective balance between precision, affordability, and simplicity.

REFERENCES

[1] F. Sanfilippo, "The Role of Robotics in Food Manufacturing and Processing," *African Journal of Food Science and Technology*, vol. 15, no. 6, 2024.
[2] "Measuring Rice Stocker SS-12 WH," *Nitori Malaysia*. [Online]. Available: https://www.nitori.my/collections/rice-stocker/products/measuring-rice-stocker-ss-12-wh. [Accessed: 07-May-2025].
[3] L. T. Yuan, V. A. Sagadevan, and P. A. Selvakumaran, "Cooked Rice Dispenser," Politeknik Malaysia, 2022.
[4] A. 4u, "104 rice scalling," *YouTube*, 2018. [Online]. Available: https://youtu.be/tmkYF5cfxbk?si=v_NsTpRVfGVHzobP. [Accessed: 16-Nov-2025].

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CHAPTER 11

Design and Fabrication of Automated Lemang Burner

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ABSTRACT

This project focuses on an automated lemang burner system designed to simplify and improve the traditional method of cooking lemang, a popular Malaysian food typically prepared during festive seasons. Traditionally, the process of cooking lemang is time-consuming and labor-intensive, requiring constant attention and manual rotation of the bamboo sticks over an open flame. This leads to uneven cooking and a high risk of overcooking or burning. Thus, an automated lemang burner system tin needed to improve cooking efficiency, reduce manual labor and ensure consistent quality in lemang production. The system is powered by a motor connected to a gear that ensures uniform rotation of the bamboo sticks. The methodology includes research and design, material selection, mechanical fabrication, and testing. Basic electronics are incorporated for motor control. The finding indicated that the product could burn lemang evenly, reduce manual labor, and improve safety during operation.

Keywords: Automated machine, Lemang

1 INTRODUCTION

Lemang is a traditional Malaysian food prepared from glutinous rice, coconut milk, and salt, cooked inside bamboo tubes over an open fire. This cooking method is deeply rooted in Malay cultural heritage, particularly during festive celebrations such as Hari Raya Aidilfitri and Hari Raya Aidiladha. The traditional preparation process is labor-intensive, time-consuming, and requires continuous monitoring to maintain stable heat conditions. The lack of heat control often results in inconsistent cooking quality, affecting texture, moisture content, and overall product uniformity [1]. Conventional lemang preparation requires manual rotation of bamboo tubes for several hours to ensure even exposure to heat. This repetitive process becomes physically demanding, especially during large-scale production, leading to operator fatigue and reduced productivity. Furthermore, the absence of a controlled rotation mechanism and regulated heat source frequently causes uneven heat distribution. As a result, certain portions of the lemang may remain undercooked while other sections become over-roasted or burnt, compromising both quality and yield [2].

2 LITERATURE REVIEW

Efficient thermal control systems are essential in improving traditional food processing operations. Studies in food thermal processing emphasize the importance of uniform heat distribution, temperature stability, and controlled combustion in ensuring consistent product texture and safety. Proper heat management reduces energy waste and enhances cooking

performance. In small-scale food production, simplified combustion systems with controlled airflow and stable burner structures have been shown to improve operational reliability while maintaining traditional characteristics [3].

Several improved roasting and biomass burner systems have been developed to enhance cooking efficiency. Modern burner designs commonly incorporate controlled gas flow, adjustable air inlets, and insulated combustion chambers to stabilize temperature and reduce heat loss. These systems improve fuel efficiency, minimize smoke emission, and provide safer working conditions compared to traditional open-fire methods. In addition, rotating or fixed-support rack mechanisms are often integrated to ensure uniform heat exposure during roasting processes [4].



Fig. 1: Improvised version of lemang burner

3 METHODOLOGY

3.1 Design Process

The 3D model parts of an automated lemang burner were designed using SolidWorks. An assembly file was created by connecting all parts with both standard and mechanical mates. Finally, a detailed technical drawing was produced from the assembly, showing all dimensions and a complete list of materials required to fabricate the prototype.

3.2 Fabrication Process

The fabrication process was conducted using the design completed in SolidWorks. The fabrication process done were as shown in Table 1.

Table 1: Fabrication processes

Process	Picture
Measuring and Cutting Process The lemang burner first underwent a measuring process to determine the required dimensions. Then cutting process was carried out using a hand saw cutting machine to obtain the correct dimensions of each component. Accurate measurements were followed to ensure precise cuts and achieve the required results for proper assembly.	
Drilling Process Drilling was used to create holes on the side of the machine where shafts are installed to ensure proper alignment and smooth operation. Safety precautions were taken by wearing gloves during the drilling process to reduce the risk of injury.	
Welding Process The welding process was carried out to join and assemble the frame of the lemang burner machine, ensuring a strong and stable structure. Proper welding techniques were applied to maintain alignment and durability of the frame.	
Motor Installation Process The AC motor and motor speed controller were installed as part of the automation system for this project. To provide stability and correct connection with the rotating mechanism, the motor was securely attached to the frame using bolts and brackets. The electrical connection between the motor and the speed controller was made. The speed controller is used to adjust and control the rotational speed of the motor based on the operational requirements.	

Assembly Process To securely fasten the can and gear and ensure the stability of the complete structure, bolts and nuts are installed. All fasteners are tightened to avoid loosening during operation, and the appropriate bolt size is chosen based on the design specifications. After that, the chain is put in place to transfer power from the motor to the rotating mechanism. To ensure smooth operation, the chain tension and gear. A final inspection is carried out to verify that all bolts, nuts, gears and chains are properly installed and functioning properly	

4 RESULTS AND DISCUSSION

The final fabricated prototype was successfully completed, as shown in Figure 2. The prototype was made based on the SolidWorks design. All dimensions follow the planned size with a tolerance of 1-1.5 mm. The machine frame uses mild steel because it is strong and high durability when expose to high heat. This helps make the machine more durable and safer for long-term use.



(a) (b)

Fig. 2: (a) Front view and (b) side view of the completed prototype

5 CONCLUSIONS

In conclusion, the development of the automated lemang burner successfully addresses the limitations associated with traditional lemang preparation methods. Conventional open-fire methods often result in inconsistent heat distribution, leading to uneven cooking where some portions may be undercooked while others are burnt. The proposed system integrates a controlled heat source and automated rotation mechanism to ensure uniform heat exposure and improved cooking consistency. This design enhances productivity, reduces operator fatigue, and maintains the authentic bamboo-based cooking method that gives lemang its distinctive flavor and cultural value.

REFERENCES

[1] L. Sandhana, "What is lemang?" DelightedCooking, May 16, 2024. [Online]. Available: https://www.delightedcooking.com/what-is-lemang.htm. [Accessed: April 26, 2025].
[2] Mesin pembakar lemang," Astro Awani, Mar. 2019. [Online]. Available: https://img.astroawani.com/2019- 03/41552377900_MESINPEMBAKARLEMANG.jpg
[3] M. Azizi, "Traditional Lemang Making Process: Cultural Significance and Techniques," Malaysian Journal of Heritage Studies, vol. 4, no. 1, pp. 15–22, 2017
[4] M. A. Nor and W. H. Ismail, "Design and Fabrication of a Lemang Roaster with Thermal Insulation System," Proceedings of the Malaysian Technical Universities Conference on Engineering and Technology (MUCET), pp. 112–118, 2022.

CHAPTER 12

Design and Fabrication of Portable Water Turbine to Generate Electricity

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ABSTRACT

Clean and renewable energy has become increasingly important in modern society as the world faces serious challenges related to pollution and climate change. Many countries are transitioning toward sustainable energy sources to reduce environmental impact and dependence on fossil fuels. Among these sources, hydropower is one of the most reliable and efficient methods of generating electricity. Energy can be harnessed from flowing water through systems such as turbines and wave-based devices. However, many miniature water turbines available in the market are expensive and do not fully satisfy requirements in terms of power output, portability, and practicality. This project proposes the development of a portable water turbine that can generate electricity from nearby flowing water. The design prioritizes ease of installation, user safety, wildlife protection, and resistance to debris, while producing sufficient electricity to power riverbank lighting.

Keywords: Water turbine, Renewable energy

1 INTRODUCTION

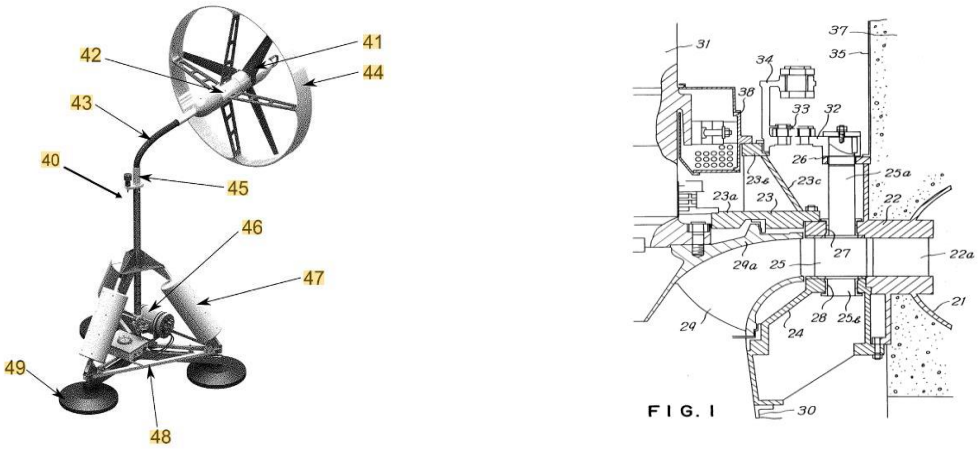
Renewable energy sources including solar, wind, hydro, and geothermal energy expanded rapidly due to global efforts to lower carbon emissions and promote sustainable development [1]. Among these sources, hydropower remains one of the most reliable and widely used renewable energy technologies. From the first hydroelectric plant in 1882 to large-scale dams in the 20th century, hydropower has played a major role in electricity generation. In recent years, small-scale and environmentally friendly hydro systems have gained attention to reduce environmental impact [2]. Miniature water turbines are now available for households located near flowing streams, making hydropower more accessible. However, many commercial models produce limited electricity and lack proper protection against debris and potential harm to wildlife. Therefore, this study aims to design and fabricate a portable water turbine that improves power output, maintains portability, and enhances safety features for both the device and the surrounding environment [3].

2 LITERATURE REVIEW

Recent developments focus on micro-hydro and portable turbine systems for rural and off-grid applications. Studies highlight the importance of optimized blade design, lightweight materials, debris filtration systems, and environmentally friendly operation to prevent harm to aquatic life. The performance of a water turbine is highly influenced by the blade design pattern

and water flow characteristics. Blade pattern refers to the geometric configuration, curvature, angle, number of blades, and arrangement around the hub. An optimized blade pattern ensures efficient conversion of kinetic energy from flowing water into rotational mechanical energy [4].

Existing commercial portable turbines often face limitations in cost, durability, and installation complexity. Several studies highlight that curved blade profiles improve water impact efficiency compared to flat blades, as they allow smoother redirection of water flow and reduce energy loss due to turbulence. The blade pitch angle also plays a critical role in maximizing torque generation. A smaller angle may reduce resistance but produce lower torque, while a larger angle increases torque but may cause excessive drag if not properly optimized [5].



(a) (b)

Fig. 1: (a) Flexible water turbine (b) Francis turbine assembly

3 METHODOLOGY

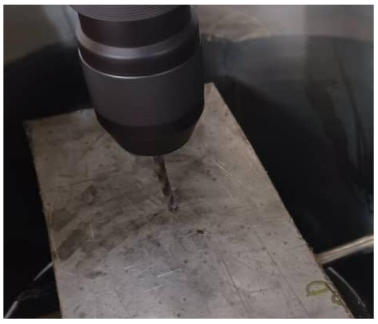
3.1 Design Process

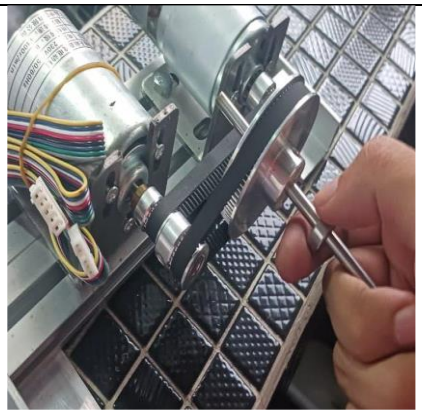
The 3D model parts of the water turbine were designed using SolidWorks. An assembly file was created by connecting all parts with both standard and mechanical mates. Finally, a detailed technical drawing was produced from the assembly, showing all dimensions and a complete list of materials required to fabricate the prototype.

3.2 Fabrication Process

The fabrication process was conducted using the design completed in SolidWorks. The fabrication process done were as shown in Table 1.

Table 1: Fabrication processes

Process	Picture
Measuring Process The water turbine first underwent a measuring process to determine the required dimensions.	
Cutting Process Then cutting process was carried out using a hand saw cutting machine to obtain the correct dimensions of each component. Accurate measurements were followed to ensure precise cuts and achieve the required results for proper assembly.	
Drilling Process Once all major parts are assembled, a point is determined at the very center and marked with a center punch. The mark is then drilled into to allow for the shaft that connects the propeller blades to the pulley and belt systems which will run the generators and ultimately produce electricity.	
Welding Process The welding process was carried out to join and assemble the frame, ensuring a strong and stable structure. Proper welding techniques were applied to maintain alignment and durability of the frame.	

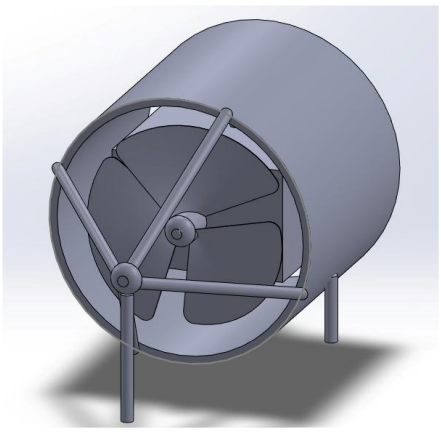
Motor, Belt and Pulley Installation Process Once the housing of the portable water turbine is completed, inner mechanisms and electrical system are assembled and placed into the electrical box. A ball bearing is connected to the housing itself and allows the shaft that connects the propeller to the pulley and belt system to rotate with ease	
Assembly Process All components were assembled, tightened, and inspected to ensure smooth operation and proper alignment.	

4 RESULTS AND DISCUSSION

The final fabricated prototype was successfully completed, as shown in Figure 2. The prototype was made based on the SolidWorks design. All dimensions follow the planned size with a tolerance of 1-1.5 mm. The prototype shows a strong, sturdy build with a lot of stability, preventing it from rolling and getting damaged easily



(a)



(b)

Fig.2: (a) Final fabricated prototype (b) Final design of portable water turbine

5 CONCLUSIONS

In conclusion, the development of the automated lemang burner successfully addresses the limitations associated with traditional lemang preparation methods. Conventional open-fire methods often result in inconsistent heat distribution, leading to uneven cooking where some portions may be undercooked while others are burnt. The proposed system integrates a controlled heat source and automated rotation mechanism to ensure uniform heat exposure and improved cooking consistency. This design enhances productivity, reduces operator fatigue, and maintains the authentic bamboo-based cooking method that gives lemang its distinctive flavor and cultural value.

REFERENCES

[1] D. Farber, "Renewable Energy, a Timeline," Legal Planet, 15 7 2024. [Online]. Available: https://legal-planet.org/2024/07/15/renewable-energy-a-timeline/. [Accessed 30 4 2025].

[2] National Hydropower, "History," National Hydropower Association, [Online].Available: https://www.hydro.org/about/history/. [Accessed 30 4 2025].

[3] Mutuli, "Waterlily Turbine Review," Archute, 16 4 2025. [Online]. Available: https://www.archute.com/waterlily-turbine-review/. [Accessed 6 5 2025].

[4] A. Ghimire, D. Dahal, A. Kayastha and S. Chitrakar, "Design of Francis turbine for microhydropower applications," ResearchGate, 8 2020. [Online]. Available:https://www.researchgate.net/publication/343789429_Design_of_Francis_turbine_for_micro_hydropower_applications. [Accessed 6 5 2025].

[5] EUROPEAN PATENT APPLICATION, "Francis turbine assembly - European Patent Office - EP0786594 A2," EUROPEAN PATENT APPLICATION, 30 7 1997. [Online]. Available:https://data.epo.org/publication-server/rest/v1.2/publication dates/19970730/patents/EP0786594NWA2/document.pdf. [Accessed 7 5 2025].

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CHAPTER 13

Design and Fabrication Semi-Automatic Traditional Malay Kuih Machine

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ABSTRACT

This project focuses on the challenge faced by many home bakers and small businesses who manually produce traditional Malay kuih during the Hari Raya festive season, when customer demand is especially high and time is limited. The methodology includes designing a semi-automatic kuih machine using SolidWorks, followed by fabrication using a stainless-steel frame, a motorized pressing mechanism, and traditional kuih molds to maintain authenticity. The findings indicate that the machine can produce kuih more quickly while ensuring consistent shape, size, and overall quality. In conclusion, the proposed machine helps reduce physical fatigue, saves time, increases productivity, and provides practical support to small-scale producers while preserving the traditional design of Malay kuih.

Keywords: Machine, Traditional kuih

1 INTRODUCTION

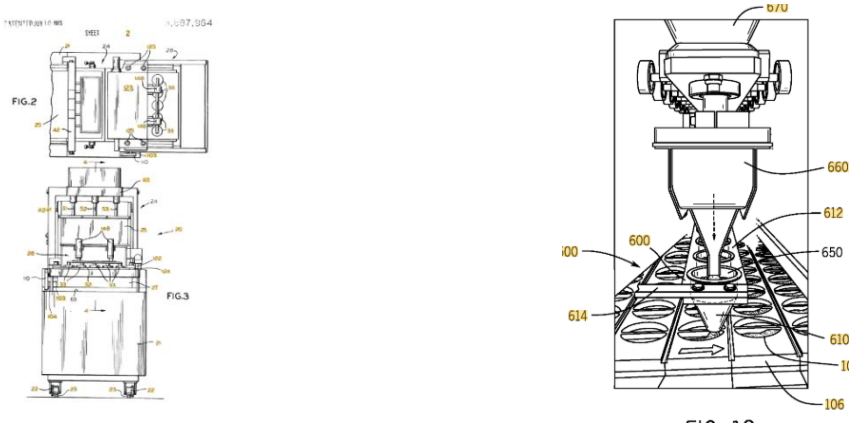
Many people are actively involved in making traditional Malay kuih, whether for their own household consumption or as part of small-scale business activities. However, the traditional kuih-making process requires a large amount of manual work, time, and physical effort, which makes it tiring and inefficient, especially when production needs to be increased. These difficulties often lead to problems in maintaining consistent shape, size, and overall quality of the kuih produced [1]. At present, most traditional Malay kuih are still prepared by hand using basic tools and traditional techniques. Although this method helps to preserve cultural heritage, it is very time-consuming and depends greatly on the individual's skill and experience. Long hours of manual work can cause physical fatigue, reduce productivity, and limit the amount of kuih that can be produced each day. This situation may affect income levels and slow down business growth for small entrepreneurs.

To solve these issues, a semi-automatic traditional Malay kuih machine is proposed to assist and improve the kuih-making process. The machine is designed to reduce manual effort while still maintaining the traditional characteristics of the kuih, leading to better efficiency, consistency, and faster production rates. It is developed to be user-friendly, compact, and suitable for small-scale use, allowing users to produce kuih with less physical strain. The main aim of this project is to design and enhance the machine using SolidWorks, with a focus on functionality, ergonomics, and practicality to support individuals, local communities, and the preservation of traditional food culture [2].

2 LITERATURE REVIEW

There are several semi-automatic food processing machines that have already been patented and are related to this project. One example is shown in (a), a semi-automatic food forming machine patented by Louis R Richards from United States (Patent number: US3887964A). In this patent, it is explained that the machine is designed to assist manual food production by incorporating a motorized pressing system powered by an electric motor. The machine allows food material to be placed into a mold chamber, where controlled pressure is applied to produce consistent shape and size. The structure includes a rigid frame, a pressing plate, and interchangeable molds, enabling users to maintain traditional food designs while reducing manual effort [3].

Another example of a patented food-forming machine is shown in (b), patented by Thomas M. McLenithan from United States (Patent number: US11878829B2). As illustrated in the figure, the machine uses a motor-driven dispensing and forming system where food material is guided through a funnel and shaped using a mold tray positioned below. The pressing and guiding mechanism ensures uniform flow and accurate shaping of the product across multiple mold cavities. This design allows continuous and consistent production while minimizing physical strain on the user. The machine is suitable for small-scale food production and supports efficient forming of traditional food products [4].



(a) (b)

Fig. 1: Semi-automatic mold kuih machine patented by (a) Louis R Richards [3] and (b) Thomas M. McLenithan [4]

3 METHODOLOGY

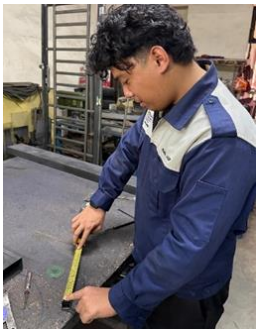
3.1 Design Process

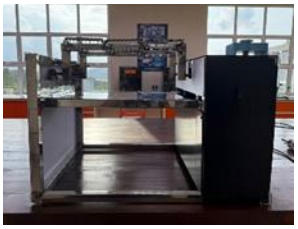
The 3D model parts of the semi-automatic traditional Malay kuih machine were designed using SolidWorks. An assembly file was created by connecting all parts with both standard and mechanical mates. Finally, a detailed technical drawing was produced from the assembly, showing all dimensions and a complete list of materials required to fabricate the prototype.

3.2 Fabrication Process

The fabrication process was conducted using the design completed in SolidWorks. The fabrication process done were as shown in Table 1.

Table 1: Fabrication process of a semi-automatic traditional Malay kuih machine

Process	Picture
Measuring Process The semi-automatic machine first underwent a measuring process to determine the required dimensions. The frame dimensions were set at 70 cm in length, 50 cm in height, and 40 cm in width to ensure proper structure and functionality.	
Cutting Process The cutting process was carried out using a hand saw cutting machine to obtain the correct dimensions of each component. Accurate measurements were followed to ensure precise cuts and achieve the required results for proper assembly.	
Drilling Process Drilling was used to create holes on the side of the machine where the kuih mold shafts are installed to ensure proper alignment and smooth operation. Safety precautions were taken by wearing gloves during the drilling process to reduce the risk of injury.	
Welding Process The welding process was carried out to join and assemble the frame of the semi-automatic machine, ensuring a strong and stable structure. Proper welding techniques were applied to maintain alignment and durability of the frame.	

Grinding Process The machine was grinded to obtain a smooth surface at every corner and joint after welding to ensure there were no sharp edges or rough surfaces that could cause injury and to improve the overall finish of the machine.	
Wiring Electrical Combination Process The electrical system was assembled by combining the power supply, motor, switch, and wiring into a simple control circuit to operate the machine. All components were connected properly to ensure safe and reliable motor operation.	
Assembly Process Assembly processes were conducted using a screw to connects the electrical part to the machine. Power window was placed and connected to the shaft of mold kuih that will be pressing on the machine	

4 RESULTS AND DISCUSSION

The final fabricated prototype was successfully completed, as shown in Figure 2. The prototype was made based on the SolidWorks design. All dimensions follow the planned size with a tolerance of 1-1.5 mm. The machine frame uses stainless steel because it is strong, does not rust easily, and is suitable for food use. This helps make the machine more durable and safer for long-term use.



(a) (b) (c)

Fig. 2: (a) Top view, (b) front view and (c) side view of the completed prototype

5 CONCLUSIONS

In conclusion, the goals of designing and constructing a semi-automatic traditional Malay kuih machine have been successfully fulfilled. Challenges such as slow production speed, uneven kuih shapes, and the high physical effort required in conventional kuih making have been effectively resolved with this machine. Its efficiency is shown through its capability to aid the molding process, enhance uniformity, and lessen operator fatigue, while still preserving the traditional qualities of Malay kuih production.

REFERENCES

[1] M. Y. Kamaruzaman, S. Ab.Karim, F. A. Che Ishak, and M. M. Arshad, "Production Protocols in the Current Practice of Instilling Traditional Values in Malay Kuih," The Malaysian Journal of Qualitative Research, vol. 9, no. Issue 1, May 2023.

[2] R. nor F. K. R. Othman, S. Z. M. Isa, N. A. Md. Zuki, S. R. C. Ahmad, F. A. A. Shukor, and Md. N. Othman, "Modelling and analysis of linear DC motor with constant thrust characteristics," International Journal of Power Electronics and Drive Systems/International Journal of Electrical and Computer Engineering, vol. 16, no. 4, p. 2212, Dec. 2025.

[3] L. R. Richards and F. Inc, "US3887964A - Food patty molding machine - Google Patents," Jan. 24, 1972.

[4] T. M. McLenithan et al., "US11878829B2 - Packaging machine with independently controllable movers - Google Patents," Sep. 25, 2015. [5] M. R. Ibrahim, A. Razlee, A. Kadir, A. Abdullah, N. Zahelem, and M. Al, "The Study of Furniture Slider Mover," vol. 1, no. 1, pp. 1–4, 2017.

CHAPTER 14

Design and Fabrication Multipurpose Orbital Shaker

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ABSTRACT

This project focuses on the challenge faced by educational institutions and small laboratories in accessing affordable and versatile laboratory equipment due to high costs and limited availability. The methodology involves the design of a multipurpose orbital shaker using SolidWorks, followed by fabrication using an aluminium profile frame, stainless steel plates, and a motor-driven orbital motion mechanism integrated with basic electronic control. The shaker is designed to perform multiple laboratory functions such as mixing, sieving, and agitation while maintaining stable and consistent orbital motion. The results show that the fabricated prototype can operate at adjustable speeds with reliable performance under varying load conditions. In conclusion, the multipurpose orbital shaker reduces equipment cost, saves laboratory space, improves experimental efficiency, and provides a practical solution for educational and small-scale laboratory applications.

Keywords: Multipurpose orbital shaker, Laboratory equipment

1 INTRODUCTION

An orbital shaker is commonly used for these purposes; however, most commercially available orbital shakers are expensive, bulky, and mainly designed for industrial or professional laboratory use. This limits accessibility for educational institutions and small laboratories operating under budget and space constraints [1]. Currently, many institutions rely on limited numbers of laboratory machines or improvised manual methods to perform mixing and agitation tasks. Manual shaking or basic stirring methods are time-consuming, inconsistent, and physically tiring, especially when experiments require long operating durations or repetitive processes.

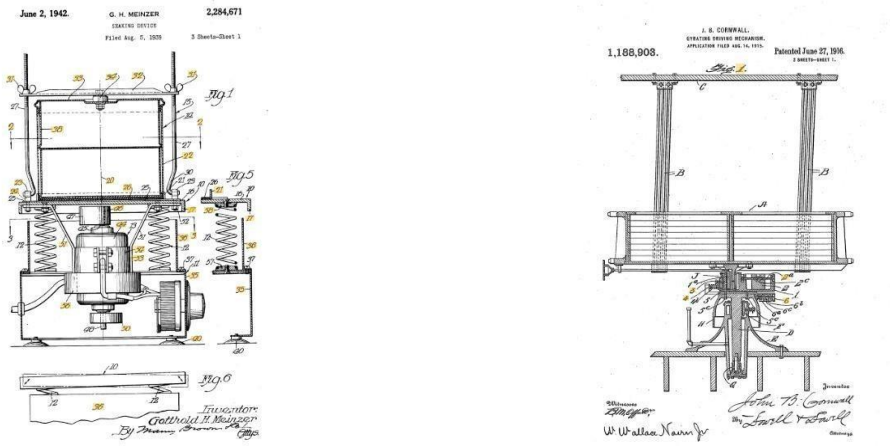
In addition, inconsistent motion can lead to uneven sample distribution, unreliable experimental results, and reduced efficiency. These challenges highlight the need for a cost-effective and versatile laboratory device that can perform multiple functions reliably [2]. To address these issues, a multipurpose orbital shaker is proposed in this project. The shaker is designed to perform various laboratory operations such as mixing, sieving, and agitation using controlled orbital motion. The machine aims to reduce manual effort, improve consistency, and increase experimental efficiency while remaining compact and affordable. The design and fabrication process is carried out using SolidWorks, with emphasis on structural stability, functionality, and practicality. By developing a low-cost multipurpose orbital shaker, this project supports educational and small-scale laboratory applications while improving accessibility to essential laboratory equipment [3].

2 LITERATURE REVIEW

Previous patented designs emphasize the use of automated or semi-automated shaking mechanisms to enhance reliability, repeatability, and long-term operational stability in laboratory equipment [3]. Several patents also highlight the importance of mechanical simplicity, balanced motion, and controlled drive systems to reduce wear, noise, and energy consumption, thereby extending machine lifespan. These design principles are directly relevant to the development of a multipurpose orbital shaker, as they support efficient agitation while remaining suitable for compact and low-cost applications.

There are several patented shaking and orbital motion devices related to this project. One example is shown in (a), a shaking device patented by Gotthold H. Meinzer from the United States (Patent No.: US2284671A). In this patent, the device is designed to generate effective shaking motion using an eccentric-driven mechanism powered by an electric motor. The system incorporates a rigid frame, a rotating shaft with eccentric weights, and a supported platform to produce controlled orbital and oscillatory motion. This design improves material distribution and mixing efficiency while reducing screen clogging and uneven vibration, making it suitable for laboratory and industrial shaking applications [4].

Another example of a patented shaking mechanism is shown in (b), patented by J. B. Cornwall from the United States (Patent No.: US1188903A). As illustrated in the patent, the system uses a gyrating driving mechanism combined with adjustable counterweights to generate stable and balanced orbital motion. The design minimizes jarring forces and isolates vibration from the main drive components, resulting in smoother operation and reduced mechanical stress. This mechanism is particularly relevant to orbital shaker development, as it demonstrates how controlled motion and dynamic balancing can improve performance, durability, and user safety in continuous shaking operations [5].



(a) (b)

Fig. 1: Semi-automatic shaking mechanisms patented by (a) Gotthold H. Meinzer [4] and (b) J. B. Cornwall [5]

3 METHODOLOGY

3.1 Design Process

The 3D model components of the multipurpose orbital shaker were designed using SolidWorks. An assembly file was created by combining all individual parts using appropriate standard and mechanical mates to ensure correct alignment and motion. Based on the completed assembly, detailed technical drawings were generated to present accurate dimensions, part relationships, and a complete list of materials required for the fabrication of the prototype.

3.2 Fabrication Process

The fabrication process was conducted using the design completed in SolidWorks. The fabrication process done were as shown in Table 1.

Table 1: Fabrication process of a multipurpose orbital shaker

Process	Picture
Measuring Process The fabrication process began with a measuring stage to determine the required dimensions of the multipurpose orbital shaker based on the SolidWorks design. Measurements were taken for the aluminium profile frame, stainless steel plates, motor mounting position, and bearing locations to ensure proper alignment and stable orbital motion during operation.	
Cutting Process The cutting process was carried out to obtain the required dimensions of the aluminium profiles and stainless-steel plates. Aluminium profiles were cut according to the specified lengths for the main frame, while stainless steel plates were cut to form the top and bottom mounting platforms. Accurate cutting was necessary to ensure correct assembly and minimize structural misalignment.	
Drilling Process Drilling operations were performed on the stainless-steel plates and aluminium profiles to create holes for bearings, fasteners, and mounting components. Bearing holes were drilled precisely at the centre of the plates to ensure smooth orbital motion, while additional holes were drilled for bolts and nuts to secure the frame structure. Safety precautions were followed throughout the drilling process.	

Grinding and Surface Finishing Process After cutting and drilling, grinding was performed to smoothen sharp edges and rough surfaces on the metal components. This process improved user safety reduced the risk of injury and enhanced the overall appearance of the orbital shaker. Surface finishing also helped ensure proper fitting during assembly.	
Mechanical Assembly Process The mechanical assembly process involved joining the aluminium profile frame using profile connectors, bolts, and nuts. The stainless-steel plates were mounted securely to the frame, and bearings were installed to support the orbital motion mechanism. The DC motor was mounted at the designated position, and a linkage system was connected between the motor shaft and the moving platform to generate orbital motion.	
Electrical Wiring and Control System Process The electrical system was assembled by connecting the power supply, DC motor, PWM speed controller, Smart WiFi switch, and wiring into a controlled circuit. Proper wiring connections were ensured to allow safe power distribution and stable motor operation. The PWM controller was used to regulate motor speed, while the Smart WiFi switch enabled remote on/off control.	
Final Assembly and Testing Process In the final stage, all mechanical and electrical components were inspected to ensure secure installation and proper alignment. The orbital shaker was tested at different speeds to observe orbital motion stability and vibration behaviour. Adjustments were made where necessary to achieve smooth operation before the prototype was declared ready for use.	

4 RESULTS AND DISCUSSION

The final fabricated prototype was successfully completed, as shown in Figure 2. The prototype was made based on the SolidWorks design. All dimensions follow the planned size with a tolerance of 1-1.5 mm.



(a) (b) (c)

Fig. 2: (a) Top view, (b) front view and (c) side view of the completed prototype

5 CONCLUSIONS

In conclusion, the objectives of designing and fabricating a multipurpose orbital shaker have been successfully achieved. Challenges such as limited access to laboratory equipment, inconsistent manual mixing methods, and the physical effort required for prolonged agitation processes have been effectively addressed through the development of this machine. The effectiveness of the orbital shaker is demonstrated by its ability to provide stable and consistent orbital motion, improve mixing and sieving uniformity, and reduce manual workload during laboratory operations. Overall, the proposed multipurpose orbital shaker enhances experimental efficiency, supports small-scale and educational laboratory applications, and offers a cost-effective solution while maintaining reliable performance and practical usability.

REFERENCES

[1] S. Freeman, E. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth, “Active learning increases student performance in science, engineering, and mathematics,” Proceedings of the National Academy of Sciences (PNAS), vol. 111, no. 23, pp. 8410–8415, Jun. 2014.
[2] R. Nor, F. K. R. Othman, S. Z. M. Isa, N. A. Md. Zuki, S. R. C. Ahmad, F. A. A. Shukor, and Md. N. Othman, “Modelling and analysis of DC motor characteristics for controlled motion applications,” International Journal of Electrical and Computer Engineering, vol. 16, no. 4, pp. 2205–2212, Dec. 2025.
[3] R. A. Patel and L. Wang, “Design principles of automated shaking and agitation systems for laboratory applications,” Journal of Mechanical Design and Automation, vol. 14, no. 2, pp. 55–63, 2018.
[4] G. H. Meinzer, “Shaking Device,” U.S. Patent US2284671A, Jun. 2, 1942.
[5] J. B. Cornwall, “Gyrating Driving Mechanism,” U.S. Patent US1188903A, Jun. 27, 1916.

CHAPTER 15

The Effectiveness of Waste Material from Kitchen as Corrosion Inhibitor for Mild Steel in Acidic Environment

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ABSTRACT

This project focuses on investigating the effectiveness of eggshell derived calcium carbonate as a natural corrosion inhibitor for mild steel in acidic environments. Eggshell waste was extracted using ethanol in a Soxhlet extraction and concentrated by rotary evaporation. Inhibitor solutions of 1–15 g was prepared. FTIR and XRD were used to characterize the inhibitor. Corrosion behavior was evaluated by weight loss tests in 1.0 M HCl for 3, 5, and 7 days. Results showed increased $CaCO_3$ adsorption on steel surfaces, reducing corrosion rate and improving inhibition efficiency under acidic conditions.

Keywords: Eggshell, Acidic, Corrosion, Weight loss, FTIR

1 INTRODUCTION

Corrosion is the gradual degradation of materials caused by chemical or electrochemical reactions with the surrounding environment, resulting in significant economic losses worldwide. Mild steel is one of the most used materials in industries such as construction, transportation, pipelines and manufacturing due to its low cost and good mechanical properties. However, it is highly susceptible to corrosion, especially in acidic environments like industrial effluents, where aggressive conditions accelerate material deterioration [1].

Chloride ions play a major role in accelerating corrosion by breaking down protective oxide layers on metal surfaces, which increases the corrosion rate and leads to higher maintenance and replacement costs. Although chemical corrosion inhibitors are commonly used to control this problem, many of them contain toxic compounds that pose risks to human health and the environment. This has created a growing demand for safer and more environmentally friendly corrosion protection methods [2].

Eggshells are an abundant waste material rich in calcium carbonate ($CaCO_3$), making them a promising sustainable alternative as natural corrosion inhibitors Utilizing eggshell waste not only helps reduce environmental pollution but also provides a low-cost solution for corrosion protection. Therefore, this study investigates the effectiveness of eggshell-derived inhibitors for mild steel using FTIR and weight loss analysis to evaluate their corrosion inhibition performance, with the aim of achieving both economic and environmental benefits [3].

2 LITERATURE REVIEW

Previous studies have extensively investigated the use of organic and waste derived materials as corrosion inhibitors for steel in aggressive environments. These materials have gained attention due to their low cost, biodegradability, and reduced environmental impact compared to traditional chemical inhibitors [4]. Many researchers focus on using natural waste sources to replace toxic synthetic compounds while maintaining effective corrosion protection.

Several studies have reported that eggshell waste extract performs effectively as an organic corrosion inhibitor for AISI 1020 mild steel in acidic media. Significant corrosion reduction was observed in hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) solutions using both weight loss and electrochemical analysis methods [1]. The high calcium carbonate content in eggshells contributes to the formation of a protective adsorption layer on the steel surface, which limits metal dissolution.

In addition to eggshell based inhibitors, other research has explored commercial organic coatings and plant-based materials such as apple pomace extract in chloride-rich environments like sodium chloride (NaCl) solutions. These studies showed that organic inhibitors effectively reduce corrosion by forming protective films on steel surfaces, even under highly aggressive conditions [2]. Overall, the findings support the potential of organic inhibitors as sustainable, environmentally friendly, and low-cost alternatives to conventional chemical corrosion inhibitors.

3 METHODOLOGY

3.1 Samples and Solution Preparation

The mild steel specimens were prepared with uniform dimensions and polished to obtain smooth, clean surfaces for accurate corrosion analysis. Waste eggshells were collected, washed, boiled to remove impurities, dried and ground into fine powder. The powder was sieved to ensure uniform particle size. Further purification was carried out using ethanol Soxhlet extraction to remove remaining organic matter. After extraction, the material was vacuum filtered, and oven dried to eliminate moisture and residual solvent. The final eggshell powder was stored in sealed containers and used as an eco- friendly corrosion inhibitor in the corrosion inhibition study.

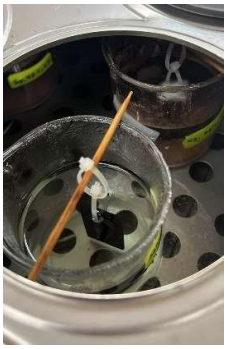
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3.2 Characteristics Testing

FTIR is an analytical technique used to identify the chemical composition, and functional groups present in a material by measuring how it absorbs infrared radiation at different wavelengths. Each chemical bond absorbs IR energy at specific frequencies, producing a unique spectrum known as a molecular fingerprint. In this study, FTIR analysis was carried out using a VERTEX 70 FTIR spectrometer manufactured by Bruker. This high-performance instrument offers high sensitivity, accuracy, and a wide spectral range, making it suitable for analyzing solid and powdered samples such as eggshell powder and corrosion-inhibited mild steel surfaces.

3.3 Weight Loss Testing

Table 1: Weight loss testing

Process	Picture
Preparation of inhibitor concentrations Different amounts of eggshell powder are accurately weighed using a digital analytical balance. This ensures precise and repeatable concentrations of the inhibitor. Preparing multiple concentrations allows the effect of inhibitor dosage on corrosion rate to be studied and helps identify the optimal amount for maximum protection.	
Preparation of corrosive solution Each weighed eggshell sample is added to 250 mL of 1 M hydrochloric acid. This acidic solution acts as a highly aggressive environment that accelerates corrosion, making it suitable for evaluating the effectiveness of the eggshell inhibitor under severe conditions.	
Mixing and labelling The mixtures are stirred thoroughly to ensure uniform dispersion of the eggshell powder throughout the solution. Proper labelling of each beaker prevents confusion between different concentrations and test conditions during the experiment.	
Immersion of mild steel samples Mild steel specimens are suspended in the solutions using cable ties. This method ensures complete immersion while preventing contact with the container walls or base, which could affect corrosion behavior and lead to inaccurate results.	

Temperature control The beakers are placed in a water bath set at 30 °C, 40 °C, and 50 °C. Temperature control is important because corrosion reactions are temperature dependent. Studying different temperatures helps evaluate the stability and effectiveness of the inhibitor under varying thermal conditions.	
Exposure time and sample cleaning The steel samples are immersed for 3, 5, and 7 days to analyze both short term and long-term corrosion effects. After immersion, samples are removed, washed with distilled water to eliminate acid residues, gently cleaned to remove corrosion products, and dried completely before weighing.	
Data analysis and evaluation Initial and final weights of each sample are recorded to calculate weight loss. Corrosion rates are determined using standard formulas, and inhibition efficiency is calculated by comparing results with and without inhibitor. The data are then tabulated to identify the most effective eggshell concentration and testing conditions.	

4 RESULTS AND DISCUSSION

FTIR analysis of eggshell powder confirmed that calcium carbonate is the main component, as shown by absorption bands similar to industrial $CaCO_3$. The O–H stretching band (3230–3500 cm^{-1}) indicates the presence of hydroxyl groups, while the C–H stretching band (2960–2970 cm^{-1}) suggests organic residues. The strong asymmetric stretching of carbonate ions at 1410–1420 cm^{-1} and the out-of-plane bending band at 875 cm^{-1} are characteristic of $CaCO_3$. These functional groups enhance the adsorption of eggshell powder onto mild steel surfaces, forming a protective film that effectively reduces corrosion in acidic environments.

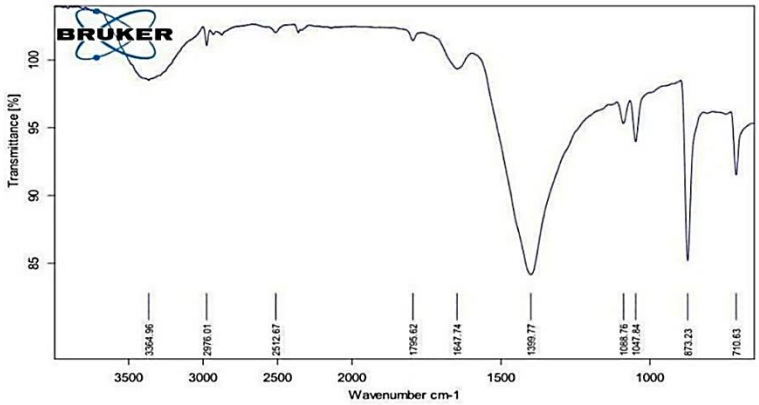


Fig. 1: FTIR result for eggshell

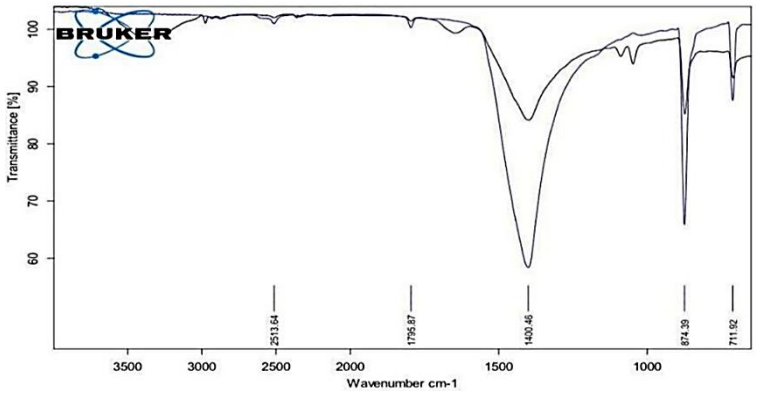


Fig. 2: FTIR result for eggshell against $CaCO_3$

The corrosion behavior of mild steel was assessed using the weight loss method in 1.0 M HCl with eggshell powder concentrations ranging from 0 to 15 g. Immersion periods of 3, 5, and 7 days were used to study both short-term and longer-term effects. Corrosion rates and inhibition efficiencies were calculated for each condition, and the relationship between corrosion rate and eggshell concentration was analyzed to determine the effectiveness of the natural inhibitor.

Table 2: Weight loss data result

Concentration (g)	Corrosion Rate (mm/y)	Inhibitor Efficiency (%)	Corrosion Rate (mm/y)	Inhibitor Efficiency (%)	Corrosion Rate (mm/y)	Inhibitor Efficiency (%)
	3 Days	3 Days	5 Days	5 Days	7 Days	7 Days
RAW	3.6965	0.0000	6.812	0.0000	9.2227	0.0000
1	0.5748	84.4511	1.2944	64.9838	1.9849	90.8036
3	0.3970	89.2606	1.206	67.3737	1.05	95.1353
5	0.3997	89.1860	0.5197	85.9398	0.9285	95.6981
7	0.3075	91.6804	0.4905	86.7314	0.8598	96.0162
9	0.2617	92.9201	0.3597	84.8593	0.6118	97.1656
11	0.1960	94.6975	0.2886	92.1932	0.443	97.9475
13	0.1353	96.3406	0.1139	96.9181	0.4222	98.0439
15	0.1347	96.3555	0.0939	97.4608	0.0559	99.7408

The uninhibited sample showed the highest corrosion rate of 3.6965 mm/y after 3 days of immersion. Adding just 1 g of eggshell powder drastically reduced the corrosion rate to 0.5748 mm/y, corresponding to an inhibition efficiency of over 84%. Further increases in eggshell concentration up to 15 g continued to improve corrosion protection, indicating that higher amounts of the natural inhibitor enhance the formation of a protective layer on the steel surface, effectively reducing metal dissolution in acidic environments.

5 CONCLUSIONS

The corrosion behavior of mild steel was studied using the weight loss method in 1.0 M HCl [5] with eggshell powder concentrations from 0 to 15 g and immersion periods of 3, 5, and 7 days. The uninhibited sample exhibited the highest corrosion rate of 3.6965 mm/y after 3 days. Adding 1 g of eggshell significantly reduced the corrosion rate to 0.5748 mm/y, achieving over 84% inhibition. Increasing the eggshell concentration up to 15 g further enhanced corrosion protection [6] , as the powder adsorbs onto the steel surface, forming a protective layer. This demonstrates the effectiveness of eggshell powder as a natural corrosion inhibitor in acidic conditions [7].

REFERENCES

[1] Alias, S. K., Pahroraji, H. F., Hairi, H. M., Ali, M. M., M. Shah, M. A., & Abdullah, B. (2024). Eggshell waste extract as potential natural corrosion inhibitor for AISI 1020 steel in acidic environment. Journal of Mechanical Engineering and Sciences, 10192–10201. https://doi.org/10.15282/jmes.18.3.2024.8.0805

[2] Honarvar Nazari, M., Havens, E. A., Shi, X., & Shihab, M. S. (2020). Mechanism of corrosion protection in chloride solution by an apple-based green inhibitor: experimental and theoretical studies. Journal of Infrastructure Preservation and Resilience, 1(1). https://doi.org/10.1186/s43065-020-00007-w

[3] Sanni, O., Iwarere, S. A., & Daramola, M. O. (2023). Investigation of Eggshell Agro-Industrial Waste as a Potential Corrosion Inhibitor for Mild Steel in Oil and Gas Industry. Sustainability, 15(7), 6155. https://doi.org/10.3390/su15076155

[4] KM, S., Praveen, B. M., & Devendra, B. K. (2024). A review on corrosion inhibitors: Types, mechanisms, electrochemical analysis, corrosion rate and efficiency of corrosion inhibitors on mild steel in an acidic environment. In Results in Surfaces and Interfaces (Vol. 16). Elsevier B.V. https://doi.org/10.1016/j.rsurfi.2024.100258

[5] Darmawan, A., & Leman, S. (2020). Embossment effect analysis on compression of mild steel using finite element methods. Iop Conference Series Materials Science and Engineering, 1007(1). https://doi.org/10.1088/1757- 899X/1007/1/012058

[6] Khadija, H., Boubaker, J., & Rim, C. (2024). Characterization of Chicken White Eggshells for Possible Textile Applications (pp. 230–234). https://doi.org/10.1007/978-3-031-63612- 7_29

[7] Ahlstrøm, Ø., & Skrede, A. (2020). Eggshell as a calcium source replacing limestone meal in mink (Neovison vison) diets. Journal of Animal and Feed Sciences, 29(4), 338–344. https://doi.org/10.22358/jafs/129973/2020

CHAPTER 16

The Possibility Organic Material as Corrosion Inhibitor for Mild Steel in Alkaline Solution

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ABSTRACT

The use of natural corrosion inhibitors based on calcium carbonate has gained attention as an environmentally friendly alternative to conventional inhibitors. In this study, eggshell waste, which contains a high amount of calcium carbonate, was used as a natural corrosion inhibitor to investigate its effect on the corrosion behavior of mild steel. The eggshells were extracted using ethanol through a Soxhlet extraction process and concentrated using a rotary evaporator. The composition and characteristics of the extracted inhibitor were confirmed using FTIR and XRD analyses. Corrosion performance was evaluated using the weight loss method in a 30% sodium hydroxide solution. The corrosion rate and inhibition efficiency were calculated to study the effect of different eggshell concentrations. The results showed that increasing the eggshell concentration reduced the corrosion rate and improved the inhibition efficiency, which is attributed to the formation of a protective $CaCO_3$ layer on the steel surface. These findings demonstrate that eggshell waste can be effectively utilized as a sustainable natural corrosion inhibitor for mild steel in an alkaline environment.

Keywords: Eggshell, Alkaline, Corrosion, Weight loss, FTIR

1 INTRODUCTION

Corrosion is a natural process that occurs when metals interact with their surrounding environment, causing a gradual loss of material properties and structural strength [1][2]. Mild steel is widely used in industries such as construction, marine, manufacturing, and chemical processing because of its low cost good mechanical strength and ease of fabrication [3][4]. However, mild steel is highly prone to corrosion, particularly in aggressive environments like alkaline solutions containing chloride ions. If left uncontrolled, corrosion can lead to serious structural damage, equipment failure, safety concerns, and high economic losses due to frequent maintenance and replacement.

To reduce corrosion, industries commonly apply chemical corrosion inhibitors such as chromates, phosphates, and amines. Although these inhibitors are effective, many of them are toxic, harmful to human health, and damaging to the environment. Growing concerns about environmental safety and sustainability have encouraged researchers to explore environmentally friendly and biodegradable corrosion inhibitors made from organic or waste-based materials.

Eggshell waste, which is rich in calcium carbonate ($CaCO_3$), has gained attention as a potential natural corrosion inhibitor [5]. Calcium carbonate can form a protective layer on the

metal surface, reducing direct contact between the steel and the corrosive environment. Using eggshell waste not only provides a safer alternative to conventional inhibitors but also helps reduce waste and promotes sustainable material reuse. Therefore, this study examines the effectiveness of eggshell-based organic material as a corrosion inhibitor for mild steel in an alkaline sodium hydroxide solution.

2 LITERATURE REVIEW

Corrosion is a complex electrochemical process that plays a major role in reducing the durability, safety, and economic value of mild steel, particularly when it is exposed to aggressive environments [6]. Different forms of corrosion and their harmful effects have been widely reported in previous studies, highlighting the seriousness of this issue in industrial applications. As a result, various corrosion control methods have been developed, including protective coatings, cathodic protection, and the use of corrosion inhibitors, to slow down or prevent material degradation.

Among these methods, corrosion inhibitors are commonly used due to their effectiveness and ease of application [7]. However, many conventional chemical inhibitors, although efficient, are associated with high costs, toxicity, and adverse environmental impacts. These drawbacks have raised concerns regarding human safety and environmental sustainability, encouraging researchers to seek alternative solutions that are safer and more environmentally friendly. In recent years, organic corrosion inhibitors derived from natural sources or waste materials have attracted significant attention because of their biodegradable nature and lower environmental risk.

Organic inhibitors are particularly effective because it can absorb onto metal surfaces and form a protective layer that reduces the interaction between the metal and the corrosive environment [8]. Calcium carbonate that can obtained from eggshell waste, which has been identified as an eco-friendly corrosion inhibitor due to its wide availability, low cost, and corrosion-resistant properties. Based on findings from previous studies, eggshell-based organic inhibitors offer a sustainable and effective approach for reducing corrosion in mild steel, which supports the objectives and motivation of the present study.

3 METHODOLOGY

3.1 Samples and Solution Preparation

The eggshell waste was cleaned, boiled to remove bacteria, sun-dried, and oven-dried at 110–120 °C for two hours. The dried shells were ground into fine powder, sieved, and stored in an airtight container. Ethanol extraction was carried out using a Soxhlet extractor, followed by filtration and drying to obtain the eggshell-based corrosion inhibitor. Mild steel samples (50 mm × 25 mm × 2 mm) were polished, cleaned, and dried before testing. A 30% sodium hydroxide solution was prepared as the corrosive medium, and different inhibitor concentrations (1g, 3g, 5g, 7g, and 9g) were added. The steel samples were immersed in the solutions at room temperature for 7 and 14 days for corrosion testing.

3.2 Characteristics Testing

The characteristics of the eggshell-based corrosion inhibitor were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) to identify the functional groups and chemical

compounds present in the material. FTIR analysis was carried out using a Bruker VERTEX 70 spectrometer [9], which measures the absorption of infrared radiation by the sample over a specific wavelength range. This technique allows the identification of key functional groups associated with calcium carbonate and organic compounds in the eggshell extract. The FTIR results were used to confirm the presence of active components responsible for forming a protective layer on the mild steel surface and contributing to corrosion inhibition.

3.3 Weight Loss Testing

Table 1: Weight loss testing

Process	Picture
Measure Weight The first step in the weight loss measurement involved recording the initial weight of each mild steel sample using a digital balance to ensure accuracy. Before weighing, the samples were cleaned and dried to remove any dust, oil, or contaminants. The eggshell powder was also weighed accurately using the digital balance, with amounts of 1 g, 3 g, 5 g, 7 g, and 9 g measured and placed into separate beakers	
Preparation of Inhibitor Solution Sodium hydroxide (NaOH) solution was added to each beaker as shown in Figure 26 to help dissolve and activate the eggshell powder. The mixture needs to stir using a glass rod to ensure homogeneity until there are no reactions. Label each beaker according to the weight and immersion time like 7 days and 14 days.	
Placement of Mild Steel The mild steel hangs freely by using a wooden stick such as satay stick and cable tie and needs to make sure the mild steel is fully immersed without touching the bottom or side of the beaker. This prevent uneven corrosion due to contact points.	

Fume Hood Immersion Place the beakers into fume hood to maintain a constant temperature. The beakers were placed in the fume hood, and the sash was partially opened to allow adequate airflow and safe handling, then leaves the samples for a few days for 7 days and 14 days to simulate long-term exposure in a controlled environment based on the test group.	
Post Immersion Cleaning Each of these samples needs to rinse thoroughly by clean water to remove loose corrosion products. The sample of mild steel is removed from the solution carefully. Then, gently scrub off any remaining residue or rust from the surface by use a soft toothbrush and wipe the sample with a tissue to make sure it dry perfectly.	
Final Weighing Once fully dry, take the weight of the mild steel samples again using the same digital balance. Record the final weight. The difference between the initial and final weights represents the mass lost due to corrosion. Next, wipe with the tissue and weight the sample back to record the final of weight loss by using the same digital balance.	

4 RESULTS AND DISCUSSION

FTIR spectroscopy was employed to analyze the eggshell powder and identify its functional groups and heteroatoms, which play a key role in adsorption onto the mild steel surface. Spectra were recorded for eggshell powder at concentrations of 1g, 3g, 5g, 7g, and 9g. The analysis confirmed that calcium carbonate ($CaCO_3$) is the main component of the eggshell powder, as indicated by characteristic carbonate absorption bands similar to those of industrial $CaCO_3$. A broad band observed between 3230 and 3500 cm^{-1} corresponds to O–H stretching, suggesting the presence of moisture or surface hydroxyl groups, while a weak band around 2960–2970 cm^{-1} is attributed to C–H stretching from residual organic matter. Strong peaks at approximately 1410–1420 cm^{-1} and 875 cm^{-1} further confirm the presence of carbonate ions. These functional groups facilitate the adsorption of eggshell powder onto the mild steel surface, forming a protective layer that enhances corrosion inhibition.

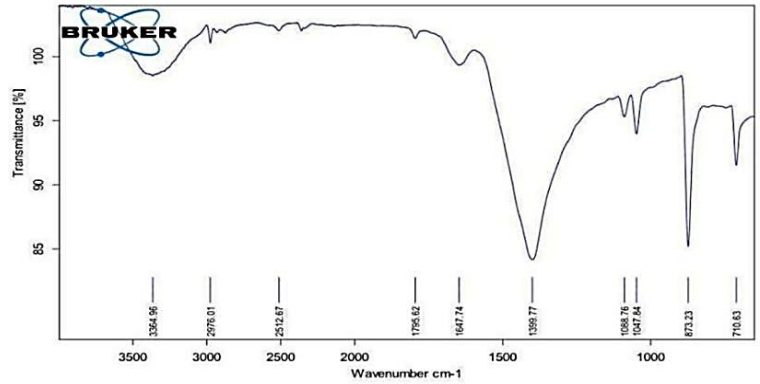


Fig. 1: FTIR result for eggshell

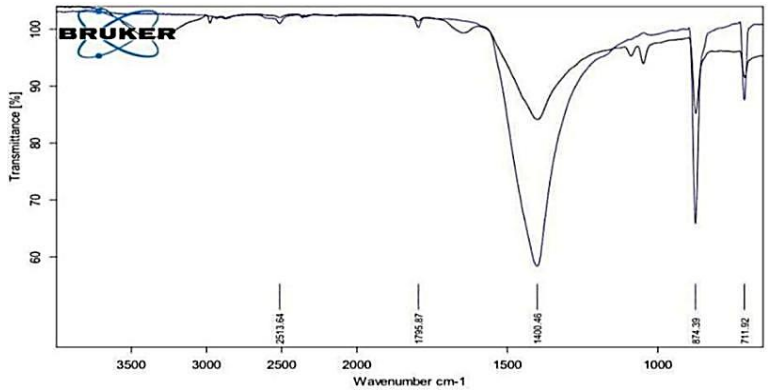


Fig. 2: FTIR result for eggshell against $CaCO_3$

The results show that corrosion decreases as inhibitor concentration increases, while efficiency rises with longer exposure. Without inhibitor, the corrosion rate was highest at 0.4445 mm/year for 7 days and 0.6659 mm/year for 14 days with 0% efficiency. Adding 1g reduced corrosion and improved efficiency to 32.5% for 7 days and 55.4% for 14 days. At 3g, efficiency reached about 71–72%, and at 5g it rose to 83–86%. Higher concentrations gave excellent protection: 7g achieved 90.8% for 7 days and 97.3% for 14 days, while 9g peaked at 93.7% for 7 days and 97.4% for 14 days. Overall, the data confirms that both concentration and time are key factors in maximizing corrosion protection.

Overall, the findings confirm that increasing inhibitor concentration consistently reduces the corrosion rate and enhances efficiency. The protective effect is also more pronounced after 14 days compared to 7 days, suggesting that longer exposure allows the inhibitor to stabilize and perform more effectively. These results emphasize that both concentration and time are critical factors in achieving maximum corrosion control, and they demonstrate the inhibitor's potential as a reliable method for extending the durability of materials in corrosive environments.

Table 2: Weight loss data result

Concentration (g)	Corrosion Rate (mm/year)	Inhibitor Efficiency (%)	Corrosion Rate (mm/year)	Inhibitor Efficiency (%)
	7 days	7 days	14 days	14 days
Raw	0.4445	0	0.6659	0
1	0.2998	32.5466	0.1982	55.4037
3	0.1286	71.0559	0.1237	72.1739
5	0.0723	83.7267	0.0629	85.8385
7	0.0409	90.8075	0.0121	97.2671
9	0.0282	93.6646	0.0116	97.3913

The uninhibited sample showed the highest corrosion rate of 3.6965 mm/y after 3 days of immersion. Adding just 1 g of eggshell powder drastically reduced the corrosion rate to 0.5748 mm/y, corresponding to an inhibition efficiency of over 84%. Further increases in eggshell concentration up to 15 g continued to improve corrosion protection, indicating that higher amounts of the natural inhibitor enhance the formation of a protective layer on the steel surface, effectively reducing metal dissolution in acidic environments.

5 CONCLUSIONS

This study demonstrates that eggshell extract, mainly composed of calcium carbonate ($CaCO_3$), has strong potential as an environmentally friendly corrosion inhibitor for AISI 1020 steel in alkaline conditions. FTIR and XRD analyses confirmed the dominance of $CaCO_3$, which contributes to the formation of a protective layer on the steel surface. Corrosion tests showed that inhibition efficiency increased with inhibitor concentration, with the highest efficiency achieved at 9 g due to a more stable protective film. Although longer immersion times increased the overall corrosion rate, the eggshell extract effectively reduced surface damage, especially at higher concentrations. Overall, eggshell waste is confirmed as a sustainable, non-toxic, and cost-effective corrosion inhibitor, supporting its potential as a green alternative to conventional synthetic inhibitors.

REFERENCES

[1] G. A. Cragnolino, "Corrosion fundamentals and characterization techniques," in *Techniques for Corrosion Monitoring*, Elsevier, 2021, pp. 7–42. doi: 10.1016/B978-0-08-103003-5.00002-3.

[2] F. Choudhary, A. Nair, J. Tripathi, K. Chandan, and P. More, "Starch as Corrosion Inhibitors," in *Biopolymers in Sustainable Corrosion Inhibition*, Boca Raton: CRC Press, 2024, pp. 59–75. doi: 10.1201/9781003400059-5.

[3] S. Dhar *et al.*, "Graphene-Based Coating on Mild Steel for Improving Anticorrosion and Microhardness Behavior," in *Novel Anti-Corrosion and Anti-Fouling Coatings and Thin Films*, Wiley, 2024, pp. 211–250. doi: 10.1002/9781394234318.ch8.

[4] J. Xie, R. Xi, C. Tong, and J.-B. Yan, "Mechanical properties of Q235～Q460 mild steels at low temperatures," *Constr. Build. Mater.*, vol. 363, p. 129850, Jan. 2023, doi: 10.1016/j.conbuildmat.2022.129850.

[5] O. Sanni, S. A. Iwarere, and M. O. Daramola, "Investigation of Eggshell Agro-Industrial Waste as a Potential Corrosion Inhibitor for Mild Steel in Oil and Gas

Industry," *Sustainability*, vol. 15, no. 7, p. 6155, Apr. 2023, doi: 10.3390/su15076155.
[6] M. K. Tyagi, "Theory of corrosion and corrosion inhibition," in *Computational Modelling and Simulations for Designing of Corrosion Inhibitors*, Elsevier, 2023, pp. 23–32. doi: 10.1016/B978-0-323-95161-6.00002-3.
[7] Y. P. Asmara, F. Herlina, and A. G. E. Sutjipto, "Selection of Inhibitor and Recent Advances in Enhancing Corrosion Prevention," *Defect and Diffusion Forum*, vol. 431, pp. 69–76, Feb. 2024, doi: 10.4028/p-iVXj7u.
[8] P. D. Desai, C. B. Pawar, M. S. Avhad, and A. P. More, "Corrosion inhibitors for carbon steel: A review," *Vietnam Journal of Chemistry*, vol. 61, no. 1, pp. 15–42, Feb. 2023, doi: 10.1002/vjch.202200111.
[9] K. Al-Amin, Md. Kawsar, Md. T. R. B. Mamun, and Md. Sahadat Hossain, "Fourier transform infrared spectroscopic technique for analysis of inorganic materials: a review," *Nanoscale Adv.*, vol. 7, no. 21, pp. 6677–6702, 2025, doi: 10.1039/D5NA00522A.

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CHAPTER 17

Design and Development of an Arduino-Controlled Robotic Arm for Learning and Demonstration

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ABSTRACT

This project develops a simple Arduino controlled robotic arm for learning and demonstration purposes. The robotic arm is designed to perform basic pick and place tasks using motor driven joints and a gripper. Arduino is used as the main microcontroller to control the movement of the robotic arm. The mechanical structure was designed for small load handling. The initial plan was to use acrylic material, but the final prototype was fabricated using sheet metal due to material availability and fabrication considerations. The prototype is able to perform basic object gripping and movement for educational activities. Testing shows that the robotic arm can perform basic movements with acceptable performance for learning purposes. However, the system has limitations in load capacity and smoothness of motion. Overall, this project provides a simple learning platform to introduce basic concepts of robotics and mechatronics.

Keywords: Robotic arm, Arduino, Learning prototype

1 INTRODUCTION

Robotic arms are machines that can move and pick up objects. They are commonly used in factories, laboratories, and education. However, many robotic systems are complex and difficult for beginners to understand. For learning purposes, simple robotic arm prototypes are often developed to help students understand basic robotic motion and control. Arduino is a popular microcontroller platform used in student projects because it is low cost and easy to program. It allows users to control motors and simple sensors in a straightforward way. By using Arduino, students can learn basic concepts such as motor control, wiring, and programming. This project focuses on developing a simple Arduino controlled robotic arm for learning and demonstration purposes. The robotic arm is designed to perform basic pick and place tasks with small objects. The main goal of this project is to provide a simple learning tool to introduce basic concepts of robotics, electronics, and mechanical design.

2 LITERATURE REVIEW

Robotic arms are widely used in industry and research because they help perform tasks that require movement and precision. Many educators and researchers develop simple robotic arm prototypes to help students learn basic robotics concepts such as motion control, kinematics, and programming [1][2]. These simple prototypes are useful tools for teaching and learning because they show how motors and controllers work together. Microcontroller

platforms such as Arduino are commonly used in educational robotic projects because they are low cost, easy to program, and have large community support [3]. Studies show that Arduino-based robotic arms can be used to demonstrate motor control and embedded system design in classroom and laboratory environments [4]. Using Arduino in robotic arms also helps students understand how software and hardware interact to produce controlled movement.

Research also highlights the importance of low-cost and accessible robotic arm designs for undergraduate and diploma engineering students. Simple robotic arms allow students to apply theory into practice and gain hands-on experience. However, challenges remain in improving load capacity and motion precision in low-cost prototypes [5]. This project builds on these studies by developing a simple Arduino-controlled robotic arm intended for learning and demonstration purposes.

3 METHODOLOGY

The overall development process of the robotic arm prototype is summarized in Figure 1, which illustrates the systematic workflow from requirement identification and concept development to fabrication, system integration, testing, and final prototype refinement. The project started with planning and concept selection for the robotic arm. Several design ideas were sketched and compared, and one final concept was chosen based on strength, stability, and ease of fabrication. The selected design was modelled using SolidWorks to create the base, arm links, joints, and gripper. An assembly model was prepared to check the fitting of all parts. Basic engineering analysis was carried out to evaluate stress, displacement, strain, and factor of safety for important components to ensure the structure could support small loads during operation.

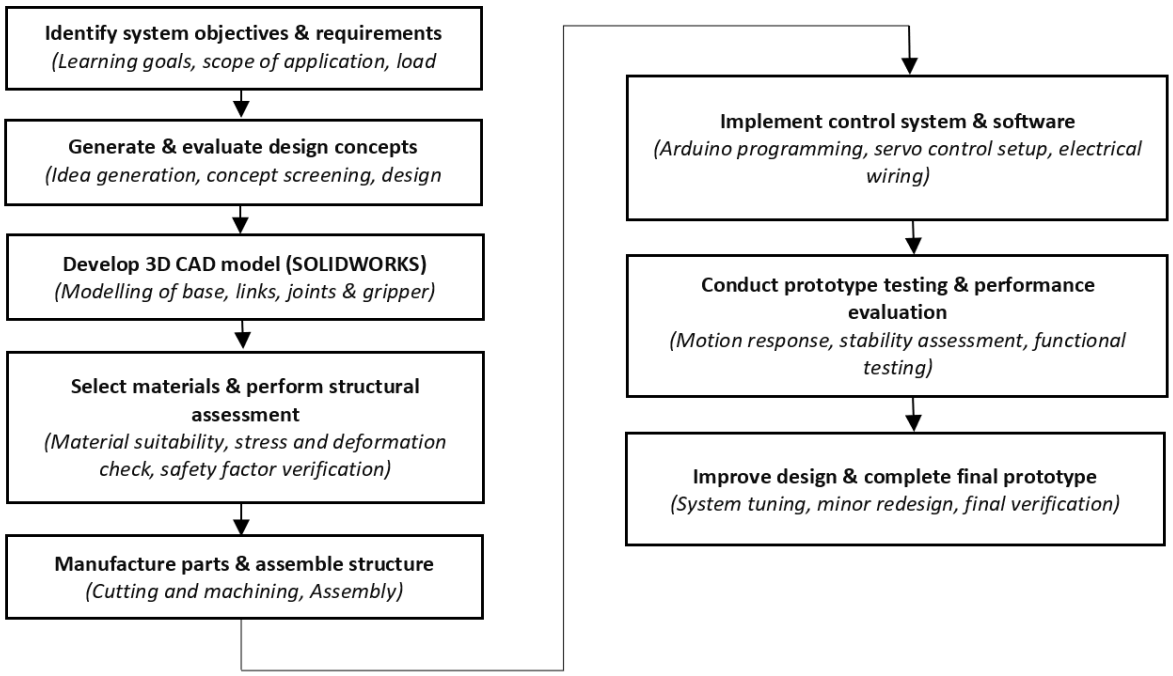


Fig. 1: Methodology flowchart of the robotic arm prototype development

After the design stage, the robotic arm parts were fabricated using acrylic material. Laser cutting was used to produce the parts according to the CAD drawings, followed by threading and assembly. Arduino was used as the main microcontroller to control the motors

at each joint. A wearable glove with sensors was used to detect hand movement, and the control signals were sent wirelessly to the robotic arm. The system was programmed using Arduino IDE. The prototype was tested for basic pick and place tasks, and adjustments were made to improve movement response and stability.

4 RESULTS AND DISCUSSION

The final fabricated prototype of the robotic arm is shown in Figure 2. The prototype was successfully assembled using sheet metal and electronic components. The material was changed from acrylic to sheet metal at the final stage due to availability and fabrication considerations. The structure is able to support the movement of the base, arm joints, and gripper for basic pick and place tasks. The overall size and layout are suitable for small object handling and demonstration purposes. The robotic arm responded to hand gesture input with acceptable performance for learning applications. The base rotation, arm movement, and gripper action were able to follow user hand movements in real time. However, some limitations were observed, such as limited load capacity and less smooth movement when lifting heavier objects. The exposed wiring also affects the neatness and safety of the prototype. Overall, the results show that the system functions as intended and demonstrates the feasibility of using hand gestures and Arduino to control a simple robotic arm.

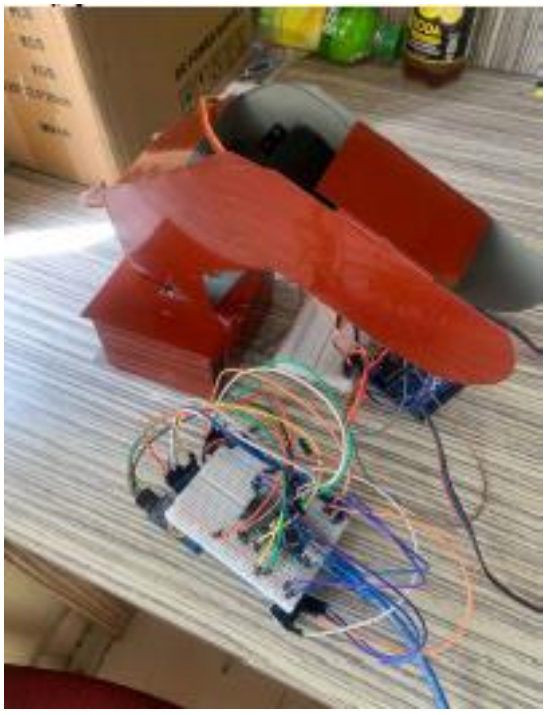


Fig. 2: Final prototype of the robotic arm system

5 CONCLUSIONS

This project successfully developed an Arduino-controlled robotic arm for learning and demonstration purposes. The prototype was able to perform basic movements and respond to hand gesture inputs with acceptable performance for educational applications, demonstrating the integration of mechanical design, electronic components, and embedded programming. Although the system achieved its intended learning objectives, limitations were observed in load capacity, motion smoothness when handling heavier objects, and wiring neatness. Overall, the project demonstrates the feasibility of using a low-cost Arduino-based robotic arm as an effective platform for introducing fundamental concepts of robotics and mechatronics, with potential for further improvement in future work.

REFERENCES

[1] K. Chenchireddy, R. Dora, B. Gouse, Mulla, V. Jegathesan, and S. A. Sydu, "Development of robotic arm control using Arduino controller," *IAES International Journal of Robotics and Automation (IJRA)*, vol. 13, pp. 264–271, Sep. 2024, doi: 10.11591/ijra.v13i3.

[2] H. Ali, Y. Hashim, and G. Alsakkal, "Design and implementation of Arduino based robotic arm," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, p. 1411, Apr. 2022, doi: 10.11591/ijece.v12i2.pp1411-1418.

[3] S. Yilmaz, C. Akay, and F. Kaysi, "Design and Implementation of a Low-Cost IoT-Based Robotic Arm for Product Feeding and Sorting in Manufacturing Lines," *Electronics*, vol. 14, p. 4801, Dec. 2025, doi: 10.3390/electronics14244801.

[4] S. Tikam, V. Jadhav, Y. Lokhande, A. Birje, and L. Upadhye, "Arduino Robot Arm – Controlled by Human," no. March, 2024.

[5] C. Zeng, H. Zhou, W. Ye, and X. Gu, "iArm: Design an Educational Robotic Arm Kit for Inspiring Students' Computational Thinking," *Sensors*, vol. 22, Apr. 2022, doi: 10.3390/s22082957.

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CHAPTER 18

Development of a Portable Solar-Powered Mixing Device for Outdoor Applications

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ABSTRACT

This project presents the design and fabrication of a portable solar-powered food processing device with a self-integrated cleaning system for outdoor and off-grid applications. The system is driven by a 12V DC motor powered by a lithium-ion battery pack and recharged using integrated solar panels. A DC–DC converter is used to regulate the output voltage, while a simple control switch activates the self-cleaning mechanism. The design emphasizes portability, ease of use, and sustainability. Experimental results show that the prototype is able to process soft ingredients and operate for short durations under battery power, with solar panels providing supplementary charging. Although the prototype demonstrates feasibility for outdoor use, limitations were observed in charging time and continuous operation. Overall, the developed system provides a practical and sustainable solution for portable food processing and educational demonstration.

Keywords: Portable food processing device, Solar-powered system, Self-cleaning mechanism

1 INTRODUCTION

Compact food-processing devices have gained attention for their practicality in outdoor activities and mobile lifestyles. Despite this growing demand, most commercially available portable units depend on USB charging or grid electricity, which restricts their use in remote locations. Moreover, maintaining cleanliness after use can be challenging when water supply is limited, potentially affecting hygiene and user convenience. This study proposes the development of a portable, solar-powered food-processing device equipped with an integrated cleaning mechanism to overcome these limitations. The system incorporates renewable energy harvesting through solar panels and on-board energy storage to minimize reliance on conventional power sources. In addition, the built-in cleaning feature simplifies post-use maintenance and improves usability in outdoor settings. The developed prototype also serves as an educational platform to demonstrate the integration of renewable energy systems, basic electrical components, and mechanical design principles in a compact consumer device.

2 LITERATURE REVIEW

Portable, battery-driven food processing devices have gained attention for outdoor, emergency, and off-grid use because they reduce dependence on grid electricity while supporting basic meal preparation. A common approach is to combine a DC motor load with a photovoltaic (PV) charging source so the device can operate from stored energy and be

replenished when sunlight is available. Prior studies on PV-fed small appliances and motor-drive applications show that solar-powered DC motor systems are feasible when the electrical subsystem is properly sized and controlled, especially to match the PV operating point and maintain stable motor performance under varying irradiance conditions [1]. In addition, portable solar-powered energy products are increasingly paired with monitoring or user-friendly interfaces to improve usability and energy awareness, indicating that compact PV battery systems can be practically implemented for field applications [2].

From a power-electronics perspective, efficient DC-DC conversion and robust charging control are key to improving charging time, protecting batteries, and supporting stable operation. Review work on solar energy harvesting highlights that converter topology selection like buck or boost families and related high-gain structures influences efficiency, ripple, and suitability for low-voltage PV sources [3]. Practical implementations also demonstrate that integrating a charge controller with DC-DC conversion can reduce component count and improve portability for off-grid systems [4]. For lithium-ion battery-powered devices, appropriate power conversion and regulation are required to ensure safe operation while achieving the torque and rotational speed needed for processing soft ingredients. Beyond power and motion performance, hygiene and cleaning convenience are important for food-contact devices; research on food soil adhesion and cleaning behaviour shows that surface soil.

3 METHODOLOGY

The concept generation process was carried out by decomposing the proposed portable food processing device into its main functional subsystems, as illustrated in Figure 1. The overall system was divided into the mechanical processing unit, container structure, power source and drive unit, control system, and cleaning subsystem. Each subsystem was then analysed to identify suitable components and configurations that meet the design requirements in terms of portability, performance, energy efficiency, and user convenience.

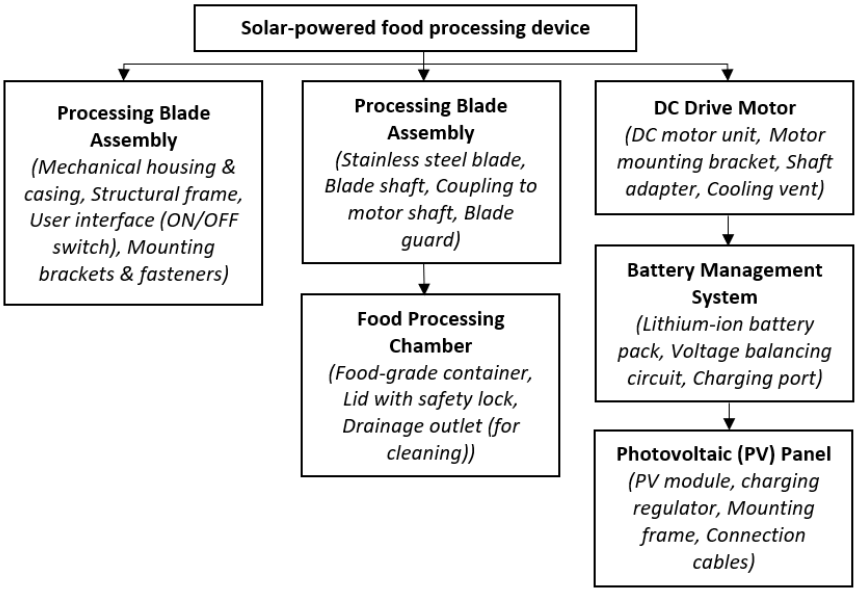


Fig. 1: Functional architecture of the solar-powered food processing device

Several design options were explored for the main subsystems, including the processing blade, chamber layout, motor selection, energy storage and management, photovoltaic integration, speed control, and the integrated cleaning unit. These options were assessed against criteria such as functional performance, energy demand, fabrication feasibility, cost, and suitability for portable outdoor use. The evaluation led to the selection of a configuration that offers a practical balance between performance, manufacturability, and sustainability, which was then adopted as the final system architecture for further development.

Following concept finalization, the enclosure and mounting components were fabricated using fused deposition modelling (FDM) 3D printing with Hyper PLA filament. The electrical subsystems, including the DC drive motor, battery management system, DC-DC converter (step-up converter), motor speed controller (PWM controller), and photovoltaic charging unit (PV panel), were integrated within the printed housing using soldered connections and basic insulation. The assembled prototype underwent preliminary functional checks to verify motor operation, voltage regulation, charging capability, and the operation of the self-cleaning system. Figure 2 shows the design evolution of the system from the 3D CAD model to the fabricated prototype. Minor refinements to component placement and wiring were implemented to improve accessibility, heat dissipation, and overall reliability prior to performance evaluation.

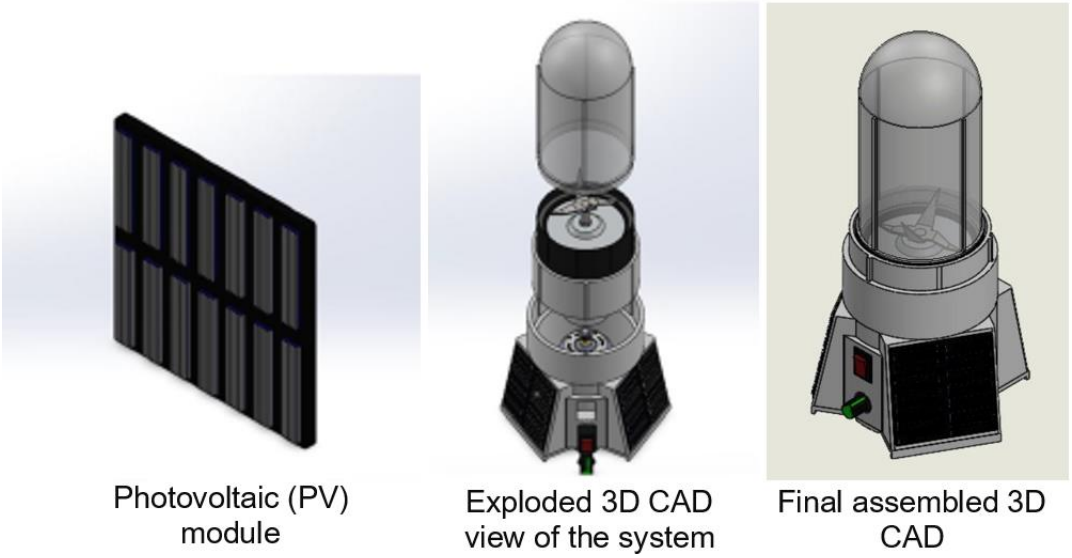


Fig. 2: CAD design views of the portable solar-powered food processing device

4 RESULTS AND DISCUSSION

The final fabricated prototype demonstrates successful integration of a photovoltaic (PV) charging module with a lithium-ion energy storage system, enabling portable operation without dependence on grid electricity as depicted in Figure 3. The compact mechanical structure supports basic processing of soft ingredients using the processing blade assembly and food processing chamber. The overall size and layout are suitable for small-scale, portable use and demonstration, confirming the feasibility of incorporating renewable energy into a compact electromechanical device.

During operation, the DC drive motor is supplied through the battery management system and regulated by the motor speed controller (PWM controller), allowing basic speed adjustment for light-duty tasks. Stable performance was observed for short operating durations, with PV charging providing supplementary energy under direct sunlight. Nevertheless, performance decreased during extended operation due to limited battery capacity and low PV output, and prolonged use led to noticeable motor heating. From a sustainability perspective, the prototype illustrates practical application of renewable energy in portable appliances and serves as an educational platform for photovoltaic integration and power electronics, while highlighting opportunities for improvement in charging efficiency, thermal management, and motor selection.



Fig. 3: Final prototype of the portable solar-powered food processing device

5 CONCLUSIONS

This work demonstrates the successful development of a compact, solar-powered food processing device intended for portable and off-grid use. The prototype integrates photovoltaic energy harvesting with battery-based power storage to support light-duty processing tasks, while also incorporating a basic self-cleaning feature to improve usability and hygiene. Experimental evaluation indicates that the system performs reliably for short operating periods and soft ingredients, confirming the practicality of combining renewable energy with small electromechanical appliances for educational and demonstration purposes. Although performance is constrained by charging duration, limited continuous operation, and motor thermal build-up, the prototype establishes a foundation for further refinement through improvements in energy conversion efficiency, thermal management, and component selection.

REFERENCES

[1] D. S. Nayak and R. Shivarudraswamy, "Solar fed BLDC motor drive for mixer grinder using a buck-boost converter," Bulletin of Electrical Engineering and Informatics, vol. 9, Feb. 2020, doi: 10.11591/eei.v9i1.1667.

[2] A. ur Rehman et al., "A solar-powered multi-functional portable charging device (SPMFPCD) with internet-of-things (IoT)-based real-time monitoring—An innovative scheme towards energy access and management," Green Technologies and Sustainability, vol. 3, no. 1, p. 100134, 2025, doi: https://doi.org/10.1016/j.grets.2024.100134.

[3] T. Sutikno, A. Samosir, R. A. Aprilianto, H. Purnama, W. Arsadiando, and S. Padmanaban, "Advanced DC-DC converter topologies for solar energy harvesting applications: a review," Clean Energy, vol. 7, pp. 555–570, May 2023, doi: 10.1093/ce/zkad003.

[4] M. S. Islam, H. Mohamad, and S. Z. M. Noor, "Development of a New Controller for Solar Home System: PWM Charge Controller & DC," 2022.

[5] D. Sözeri Atik, I. Palabiyik, G. Tirpanci Sivri, S. Uzun, Y. Koç, and K. Çalışır, "Improving Cleaning Efficiency through the Measurement of Food Fouling Adhesive Strength," ACS Omega, vol. 9, no. 20, pp. 22156–22165, May 2024, doi: 10.1021/acsomega.4c00576.

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CHAPTER 19

Development of Body Frame of Formula Student Race Car

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ABSTRACT

The Formula Student racing car project aimed to develop and construct an optimal body frame that complies with safety regulations while improving structural integrity, reducing overall weight, and enhancing aerodynamic performance. Achieving a balance between efficiency and effectiveness presented a challenge due to various design and manufacturing constraints. One of the primary objectives was to design and fabricate the body frame of the Formula Student racing car through a series of processes including cutting, welding, cleaning, and finishing. The completed body frame, constructed from hollow steel bars, successfully met the required durability and safety standards and withstood the evaluation without damage. The successful completion of the project within the allocated eight-week period demonstrates that the required specifications, standards, and client expectations were achieved. The final product offers several advantages, emphasizing the importance of meeting user requirements while ensuring strong performance, durability, and safety. Overall, the Formula Student racing car body frame developed in this project demonstrates potential value for motorsport development and innovation, particularly among student engineers and racing enthusiasts.

Keywords: Body frame, Formula student racing car, Structural integrity

1 INTRODUCTION

The main reason for inventing these body frames is to make the Formula Car safer, more durable, and also the car's performance. The chassis must accommodate various systems, such as the frame, wheels, brakes, steering, and suspension. To maintain the rigidity of the whole structure, solutions created from expertise and modern engineering capabilities are needed in the manufacturing of a chassis [1]. In addition, when the car is used regularly to join the competition, there is a probability that the car will break and cause an accident during the race. Overall, the available body frames are good enough, but there are some factors to improve the body frames itself.

Therefore, a new project should be invented to solve the current problem to make the drivers of the Formula car race safer. The main criteria of an invention must follow the latest era and technology. In addition, for the driver to give the best performance during the race competition, they must have a good machine and their car's power. So, they can't win the race with bad body frames and also the car that may cause accidents and other things that we do not want to happen. However, we need solid body frames for the formula car race to make sure that the driver is safe and can win the race with a good chassis.

This project aims to develop a solid body frame to ensure the car is durable, safe, and solid during the race competition. It will also be cost-effective and affordable for the user to produce or buy this chassis. The maintenance cost is also low, so it is suitable for students and affordable to maintain.

2 LITERATURE REVIEW

Benchmarking studies has been conducted by comparing the projects with related available products as shown in Table 1. There are three products that has been found which are ladder frame chassis, backbone chassis and tubular chassis.

Table 1: Benchmarking with Available Products [1-3]

Figure			
Product	Ladder Frame Chassis	Backbone Chassis	Tubular Chassis
Design	Racing Car	Racing Car	Racing Car
Material	Aluminium Alloy	Carbon Steel	Steel
Features	Used in vehicles that need to tow heavy objects around because it is quite heavy	The cylindrical tube protects the driveshaft from damage, which can also be a drawback	The chassis serves as the foundation for the entire vehicle
Advantages	1. Easier to put together because parts can be easily inserted. 2. The construction method makes it more durable. 3. Parts are not permanently attached, making repairs simpler.	1. The half axle has better ground contact when off-roading because of its design. 2. Because the driveshaft is protected by the chassis, off-roading is more likely to be successful. 3. The structure has better torsional rigidity, allowing it to withstand more twists.	1. Its cage-like construction makes it safer than either of the other chassis. 2. The balanced rigidity-and-weight ratio of this chassis allows the cars to be stronger and lighter.
Disadvantages	1. This body frame has weak torsional rigidity. 2. It is heavyweight.	1. If the driveshaft breaks, it must be opened because the main chassis surrounds the entire shaft, making repairs difficult. 2. The cost of chassis is quite high.	1. Tubular frames are complicated. 2. Mass production of this chassis is not possible because takes a long time to fabricate.

3 METHODOLOGY

The engineering calculations as it one of the important things in determining a product's safety and durability to come out with a good product in the end. The average weight of the driver is 90kg. From the analysis that had performed, it shows that the body frame is safe enough for the driver as shown in the Figure 1.

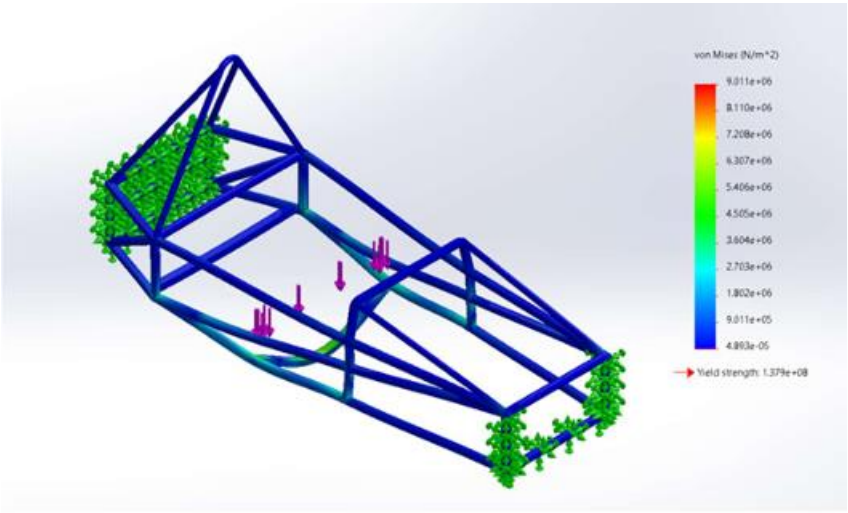


Fig. 1: Stress analysis results

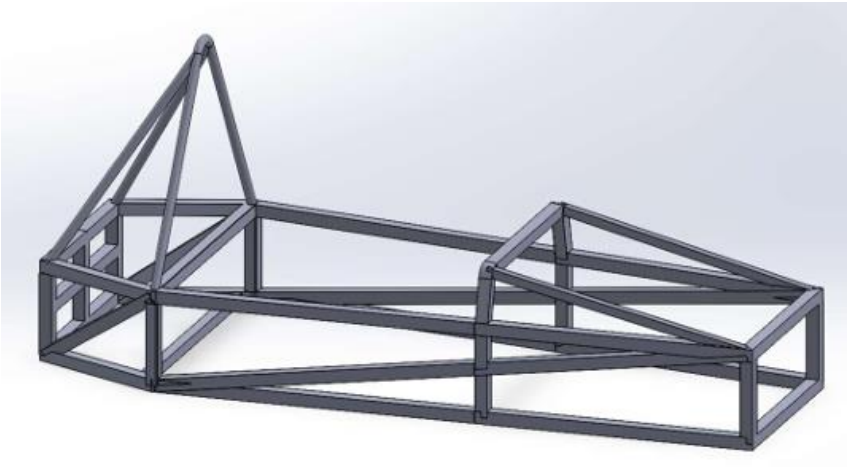


Fig. 2: Final design for body frame

Figure 2 shows the final design selected as the concept and design selection of a product body frame for the formula race car. The shape of the metal is a square hollow bar. This is because the shapes are more solid than other shapes. It is also safer and more durable for the driver and for the car itself. For the front part, it is designed for aerodynamic shape and safety for the driver if there are any accidents. The back part is used to place the drive shaft and the engine of the car. In the middle, the driver will sit there. The final design is expected to be fabricated with affordable cost, high safety, and can function well.

After done performing the design and analysis phase, it will go to the fabrication part of the body frame. The process will start with the measuring process for all the hollow steel bar according to the design. Next fabrication process then will commence with the cutting process where all the steel bar will be cut according to the measured value. Then by using the Metal Inert Gas (MIG) welding to weld the steel bar following the planning shape of the body frame. The joint section of the welded body frame surfaces will be smoothened out by using the hand grinding machine. For the finishing process, the body frame will be painted with oil paint to avoid any corrosion on the body frame.

4 RESULTS AND DISCUSSION

A final working prototype is created during every phase of the product design process, including durability, compatibility, and functionality testing at the outset and follow-up evaluations to ensure the design aligns with technical goals. The finished product is shown in Figure 3, which features all of its assembled parts. The final product nearly achieves the designed product in SolidWorks at the beginning of the project.



Fig. 3: Final Product

5 CONCLUSIONS

The fact that the final product was finished as a final year project, which involved designing and fabricating the body frame for a Formula Student Race Car, attests to the accomplishment of its main objectives. The project was completed in the given eight weeks with great precision and meeting every requirement. Additionally, it complied with standards and customer demands. The product has many benefits, highlighting how crucial it is to satisfy users. It also performs very well and is very durable and safe. It is anticipated to generate big sales, particularly from customers who want to join the racing competitions, and the product could become well-known and successful.

REFERENCES

[1] González-ViñasW. and ManciniH. L.,An Introduction to Materials Science. Princeton, NJ: Princeton University Press, 2015.
[2] “Chassis Manufacturing Process,”*Pressmark*, Oct. 19, 2016. https://www.pressmark.co.uk/chassis-manufacturing-process/
[3] “What is a Car Chassis? Types of Chassis Frames Explained!” *AckoDrive*, Mar. 09, 2022. https://ackodrive.com/car-guide/car-chassis/

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CHAPTER 20

Development of a Prototype Ignition System with Electrical Setup in a Formula Student Racing Car

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ABSTRACT

The ignition and electrical system are critical components in a Formula Student racing car, as they directly influence engine performance, combustion efficiency, and overall vehicle reliability. A well-designed system ensures stable engine starting, efficient power distribution, and compliance with safety regulations. However, high current demand during engine start-up, limited chassis space, safety requirements, and budget constraints present significant challenges in system design. Therefore, this project focuses on the design and fabrication of an ignition system integrated with an electrical system setup specifically for a Formula Student racing car. The project was carried out systematically in several stages. First, the electrical system layout was designed based on chassis configuration and component placement. The fabrication process involved measuring, cutting, welding, grinding, assembling, and wiring. The results show that the ignition and electrical system were successfully designed, fabricated, and installed. The use of two batteries ensured enough current supply for engine starting while maintaining stable operation of auxiliary components such as the radiator fan. The system functioned effectively, providing reliable ignition performance and proper electrical distribution throughout the vehicle.

Keywords: Ignition system, Electrical system, Formula student car

1 INTRODUCTION

The ignition system plays an important role in Formula Student racing cars for providing dependable engine performance and power delivery. The main reason this project chose to invent an ignition, and electrical system is to improve the performance and try to maximize the engine power output of the racing car. In this racing car, it will be equipped with an electronic ignition system such as an Electronic Control Unit (ECU) to provide precise control over ignition timing and performance. The key to an ignition system is reliability. The ignition system should be constructed with appropriate insulation and protection against heat and vibration in order to handle the high-stress environment of racing.

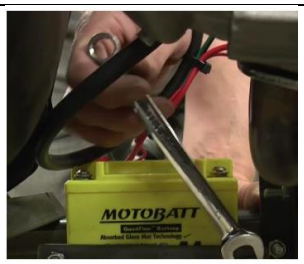
To make sure the formula student racing engine runs consistently and generates higher power, the ignition system is essential to fabricate perfectly. The design of an efficient and effective ignition system needs to follow the specifications and race regulation set by the race committee. The goal of this problem is to create the best performance ignition system for a formula student racing car. To protect the driver, the ignition system design must also

correspond to safety laws and requirements. It is essential to reduce the possibility of electrical malfunctions, fires, or other safety risks. To avoid that from happening, the project needs to prepare proper grounding, insulation, and shielding of electrical components.

2 LITERATURE REVIEW

In this section, it is important to review the current existing product with the intended project design. The most suitable design is the go-kart or one-seater vehicle is a compact and small design for racing and competitive reasons. Go-karts are generally low to the ground, with a lightweight chassis and a basic design that allows them to be controlled and responsive. They are propelled by tiny engines that range in size from 50cc to 250cc and can be two-stroke or four-stroke. Table 1 show the summary of the comparison with the available products.

Table 1: Comparison with Available Products

Diagram			
Product	Electric Go-Kart	One Seater Go Kart	FSAE Race Car
Specifications	• Use car alternator to convert to 3 phase motor to make sure get 3kW • Lithium polymer battery • Arduino Pro Mini to calibrate the system	• 125cc engine • Ignition switch and ignition key • Absorbed Glass Mat Battery • Standard Capacitor Discharge Ignition • Copper spark plug	• Use many sensor • YFZ450R ATV engine • Lithium ion battery • Electronic Control Unit
Advantages	• Low cost go kart • Light weight • Easy to fabricate	• High power output • Lightweight • Easy to fabricate	• High power output • Improve fuel efficiency -Improve acceleration
Disadvantages	• Max top speed 53km/h •Not safety enough	• Higher price	• Expensive Price • Complicated to fabricate

3 METHODOLOGY

The first step for the project is to prepare the detail drawing and design which includes the list of the parts that are used to finish the fabrication of the Ignition System with Electrical System Setup in A Formula Student Racing Car. Figure 1 shows the assembly drawing of the ignition system in A Formula Student Racing Car using SolidWorks Software 2021. This assembly drawings are used to represent more than one component or part that has been connected and their working position. Figure 2 show the schematic diagram for the electrical setup specifically for the ignition system.

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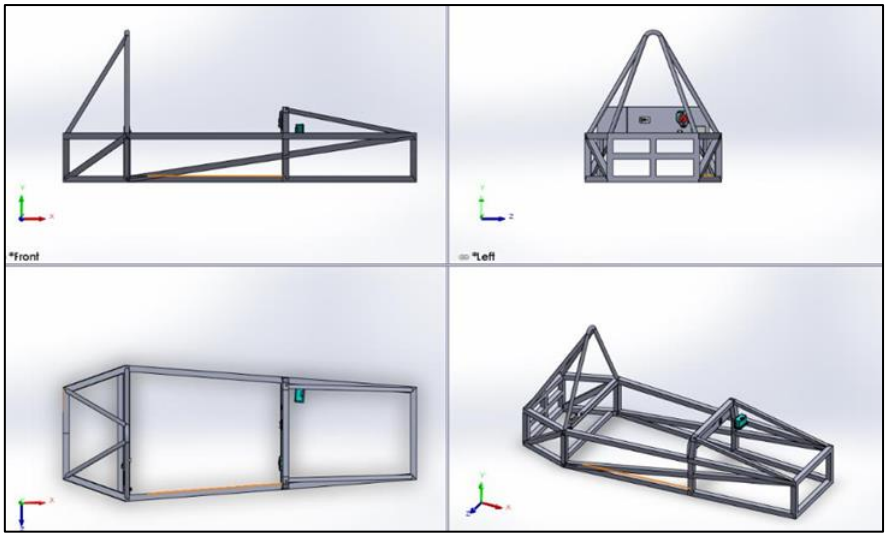
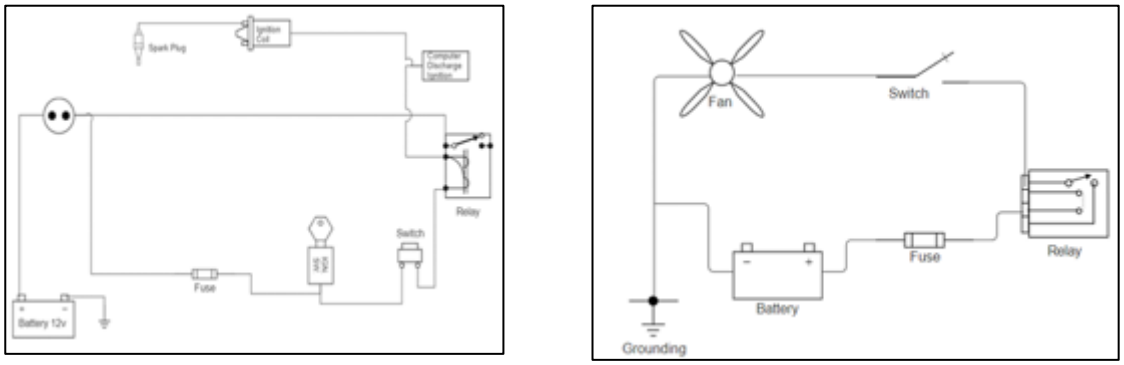


Fig. 1: Electrical panel drawing



(a) (b)

Fig. 2: Schematic diagram for ignition setup

4 RESULTS AND DISCUSSION

The product fabrication testing process has been verified and the product works follow the objective. The objective of this product is to design and fabricate an ignition system set up in a formula student racing car. This ignition system with electrical setup has been designed to maximize the engine power output and engine start-up. The parts that are applied in this in this ignition system with electrical setup are battery, rectifier, starter relay, starter motor, capacitor discharge ignition (CDI), and ignition switch. This product uses the racing capacitor discharge ignition (CDI) from Mb performance to give better engine performance to the engine.



Fig. 3: Functionality of prototype

5 CONCLUSIONS

In conclusion, the project successfully achieved its objectives by designing and fabricating an efficient ignition and electrical system setup for a Formula Student racing car. The dual-battery configuration improved engine start-up reliability and ensured stable electrical performance. The final system meets functional requirements and contributes to enhanced vehicle performance while complying with safety and budget constraints. Moreover, the ignition and electrical setup managed to get their job done but not perfect enough because of limited time and budget. This product also was successfully fabricated with follow the specifications with the time given. The product has been complete within 5 weeks.

REFERENCES

[1] “Hackaday.io,” Hackaday.io, 2019. https://hackaday.io/project/12978-e-kart-the-electric-go-kart/details

[2] D. Jung and N. Iida, “An investigation of multiple spark discharge using multi-coil ignition system for improving thermal efficiency of lean SI engine operation,” Applied Energy, vol. 212, pp. 322–332, Feb. 2018.

[3] “Understanding the working of battery ignition system - student lesson,” Student Lesson, Oct. 26, 2020. https://studentlesson.com/battery-ignition-system-definition function-working-components/

CHAPTER 21

Smart Vacuum Cleaner Robot

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ABSTRACT

This project aimed to design and build a low-cost smart vacuum cleaner robot that is easy to use, affordable, and effective for cleaning indoor spaces. The methodology included developing design concepts, choosing appropriate materials, producing suitable designs and simulations in SolidWorks. After that, the prototype was fabricated with sheet metal and PLA 3D printing. Electronic systems were also integrated and assembled. An L293D motor driver, DC geared motors for movement, motors for the cleaning brushes, an ultrasonic sensor with a servo for obstacle detection, and a rechargeable 18650 lithium-ion battery system were all used in the finished prototype, which was managed by an Arduino Uno microcontroller. According to the performance tests, the robot was able to move steadily, avoid obstacles, have adequate suction, and run long enough for tasks involving indoor cleaning. With stress and strain levels significantly below the material limits, engineering analysis verified that the structure was mechanically safe. Overall, the prototype succeeded in accomplishing the objectives of the project, developing a functional and affordable smart vacuum cleaner robot. Future improvement suggestions included improving the precision of navigation systems, improving cleaning efficiency, and adding other features of automation.

Keywords: Vacuum cleaner, Vacuum cleaner robot

1 INTRODUCTION

Floor cleaning is a well-known house chore that is often regarded as unpleasant, demanding and tedious [1]. Conventional vacuum cleaners are effective to clean the floors, but it requires human supervision and physical effort making them less practical for individuals with busy lifestyles [2]. Regardless the growing presence of commercial smart vacuum cleaners in the market, many models available in the market remain expensive and inaccessible especially for those with lower- income [3]. Furthermore, despite the expensive price of the vacuum cleaners, many models are ineffective when it comes to cleaning where most of them couldn't clean the edges effectively due to its limitations to reach the edges [4].

In response to this issue, some manufactures have begun offering low-cost models with the most basic features such as simple avoidance and scheduled cleaning [5]. Instead of selling round shape vacuum cleaners, some companies also have introduced new designed such as square shape and D- shape vacuum cleaners to clean the edges effectively [6]. However, these designs may require more complex manoeuvres to avoid getting stuck and require more open space to manoeuvre making it less manoeuvrable. They can also appear bulkier compared to the round shape design [7].

Hence, there is a need to design a cost-effective vacuum cleaner with good features and can clean the corners that are impossible to reach with round shape vacuum cleaners. The project aimed to design and prototype a cost-effective and functional automatic vacuum cleaner using readily available electronic components and materials. By focusing on affordability and functionality, this project demonstrated the practical application of technical knowledge and skills but also contributed to the advancement of smarter and more automated home cleaning solutions [8].

2 LITERATURE REVIEW

The vacuum compared were the iRobot Roomba i7+, Mi Robot Vacuum-Mop 2 and Ecovacs Deebot N8 Pro. The comparison in specification for the three vacuum robots is as shown in Table 1.

Table 1: Comparison Between 3 Robotic Vacuum Cleaner Models

Model	iRobot Roomba i7+ [9] 	Mi Robot Vacuum-Mop 2 [10] 	Ecovacs Deebot N8 Pro [11] 
Navigation System	vSLAM (visual navigation + smart mapping)	vSLAM (visual navigation)	TrueMapping Laser Navigation + TrueDetect 3D Obstacles Avoidance
Suction Power	1800 Pa (3-stage cleaning system)	Up to 2700 Pa	Up to 2600 Pa
Auto Dirt Disposal	Clean Base – Automatic Dirt Disposal	Manual emptying	Optional (sold separately)
Battery Life	75 minutes	110 minutes	110 minutes
Recharge and Resume	Yes	Yes	Yes
Shape	Round	Round	Round
Corner Cleaning Ability	Limited due to shape	Limited due to shape	Limited due to shape
Price Range	RM 5000+	RM 900 - RM 1200	RM 1500 – RM 2000

Table 1 shows that each design had its own strengths and weaknesses. The iRobot Roomba i7+ offered advanced features such as smart mapping and automatic dirt disposal, but it was very expensive [9]. Meanwhile, the Mi Robot Vacuum- Mop 2 was much more affordable and had good suction power with a 2-in-1 vacuuming and mopping function, but it lacked advanced obstacle detection and automatic dirt disposal [9]. The Ecovacs Deebot N8 Pro provided better navigation performance with laser mapping and 3D object avoidance, but the auto-disposal feature was sold separately, which increased the overall cost [9]. All three models used a round -shaped design, which limited their ability to clean corners and edges

effectively. Lastly, it was concluded that there was a need for a low-cost robotic vacuum cleaner that focused on basic cleaning functions, strong suction power, and improved corner cleaning.

3 METHODOLOGY

Material selection stage is carried out to choose suitable materials for the prototype. The selected materials need to be lightweight, durable, affordable, and easy to obtain. This helps to ensure that the final prototype is practical and cost - effective. Next, the design measurement and dimensioning process is performed. Accurate measurements are determined to ensure proper assembly and smooth operation of all components. This step is important to reduce errors during modelling and fabrication as shown in Figure 1.



Fig. 1: Measuring and marking of raw material

Once the measurements are finalized, SolidWorks modelling and simulation were conducted. The design is developed in a 3D model to clearly visualize the structure and arrangements of the components. The final design completed based on the research in literature review is as shown in Figure 2.

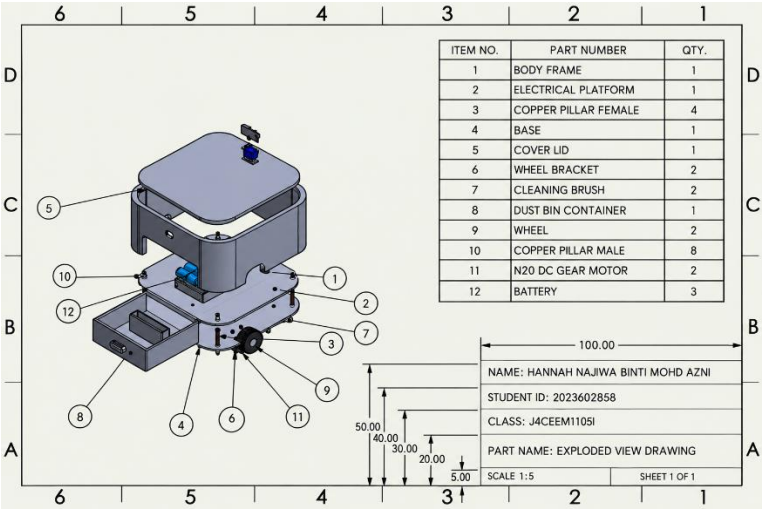


Fig. 2**:** Exploded view drawing

4 RESULTS AND DISCUSSION

Figure 3 shows the final fabricated Smart Vacuum Cleaner Robot



(a) (b) (c)

Fig.3: Fabricated Smart Vacuum Cleaner Robot

Table 2: Key features and functionality of prototype

Component	Key features and functionality
Arduino Uno R3	Main controller that processes sensor input and controls motors for navigation and cleaning.
Ultrasonic Sensor	Detects obstacles by measuring distance using reflected sound waves.
Motors (DC Geared & TT Hobby)	DC geared motors drive the robot; TT motors rotate the cleaning brushes.
L293D Motor Driver	Controls motor speed and direction while ensuring stable and coordinated operation.
DC Motor Fan	Generates suction to pull dust and small particles into the dustbin.
Power Supply (18650 Batteries)	Provides rechargeable power for all electronic and mechanical components.
Chassis (Sheet Metal + PLA)	Compact lightweight structure that offers strength and easy fabrication.

5 CONCLUSIONS

The development and testing of the smart vacuum cleaner robot showed that it can successfully perform autonomous indoor cleaning. The prototype, powered by three 18650 Li-ion rechargeable batteries and controlled by an Arduino Uno, moved reliably and turned smoothly, allowing it to navigate indoors spaces effectively. The ultrasonic sensor for obstacle detection worked well, achieving an 80% success rate in avoidance tests, showing that it is suitable for typical household cleaning tasks. Practical testing also showed a battery runtime of 3.5 to 4 hours, which is enough to complete normal cleaning sessions without frequent recharging. Improvements can be made to handle some minor issues observed such as slight ripping during sharp turns, motor overheating during prolonged use.

REFERENCES

[1] IAEME Publication, "DESIGN AND ANALYSIS OF AUTOMATIC ROBOTIC VACUUM CLEANER," IAEME PUBLICATION, 2020, doi: https://doi.org/10.34218/IJARET.11.11.2020.069.
[2] H. A. Shakhawat. H. Prayash, Md. R. Shaharear, Md. F. Islam, S. Islam, N. Hossain, and S. Datta, "Designing and Optimization of An Autonomous Vacuum Floor Cleaning Robot," IEEE Xplore, Nov. 01, 2019. https://ieeexplore.ieee.org/abstract/document/9087486
[3] A. EREN and H. DOĞAN, "Design and Implementation of a Cost-Effective Vacuum Cleaner Robot," Turkish Journal of Engineering, Apr. 2021, doi: https://doi.org/10.31127/tuje.830282.
[4] S. Sridhar, R. Himabindu, P. Kumar, and R. Vasu, "DESIGN OF IOT BASED VACUUM CLEANING AND MOPPING ROBOT," vol. 5, 2018, Available: https://www.jetir.org/papers/JETIR1804103.pdf
[5] J. Bergman and J. Lind, "Robot Vacuum cleaner," 2019. Available: https://www.diva-portal.org/smash/get/diva2:1373823/FULLTEXT01.pdf
[6] S. S. Makadi, A. Mahulkar, N. Malave, and S. S. Maind, "Enhancing Obstacle Detection in Vacuum Cleaners Using Ultrasonic Sensors: A Comparative Study," SSRN Electronic Journal, 2024, doi: https://doi.org/10.2139/ssrn.4746566.
[7] A. Chavan, S. Ghadigaonkar, J. Avhad, S. Gurav, and N. Phatak, "Autonomous Robotic Vacuum Cleaners," International Journal of Scientific Research and Engineering Development, vol. 7, 2024, Available: https://ijsred.com/volume7/issue2/IJSRED-V7I2P124.pdf
[8] "Roomba® i7+," Visionary Solutions Sdn Bhd, 2023. https://visionary.com.my/products/irobot%C2%AE-roomba%C2%AE-i7 (accessed May. 03, 2025).
[9] "Mi Robot Vacuum-Mop 2 - Xiaomi Global Official," Mi Global Home. https://www.mi.com/global/product/mi-robot-vacuum-mop-2/ (accessed May. 03, 2025).

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CHAPTER 22

Educational Prototype: 3D Printed Manual Gearbox for the MEV321 Course

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ABSTRACT

This paper presents the fabrication of an educational three-dimensional (3D) printed manual gearbox prototype intended to support teaching and learning in the MEV321 course. Conventional gearbox illustrations can make it difficult for students to visualize the spatial relationship between gear pairs, shafts and the gear-selection mechanism. The project therefore aims to provide a physical, inspectable model that demonstrates the basic arrangement and mechanical interaction of manual-transmission components. The prototype was printed by using a modular approach in which the gearbox casing, gears, selector parts and supporting elements were fabricated and assembled. The completed assembly exposes the internal transmission arrangement so that students can identify individual components and discuss the path of motion through meshing gears. Future evaluation should include controlled gear-selection trials, durability assessment and structured student feedback.

Keywords: 3D prototype, Manual gearbox

1 INTRODUCTION

Conventional teaching methods often rely on textbooks, diagrams and videos which may limit students' understanding of the internal arrangement and operation of a gearbox. Additionally, actual automotive gearboxes are usually enclosed within metal housings, making it difficult to observe their internal mechanisms without disassembly. To overcome these limitations, a 3D-printed manual gearbox prototype was printed as an educational teaching aid for the MEV321 course. The prototype incorporates a partially open gearbox casing, allowing students to observe the gear arrangement, selector forks and shifting mechanism directly.

The main objective of this project is to print a physical gearbox model using 3D-printing technology to improve the visual demonstration of manual-transmission principles. The scope of work includes the selection of 3D model (STL format file) from an internet (open, then proceed by fabricating and assembling.

2 LITERATURE REVIEW

Physical demonstration is an important teaching approach in engineering education

because it enables students to observe and interact with mechanical systems while relating theoretical knowledge to practical applications. Prince [1] reviewed active learning in engineering education and found broad evidence supporting teaching strategies that actively involve students in the learning process. Similarly, Hake [2] reported that interactive-engagement teaching approaches produced greater conceptual learning gains than traditional lecture-based instruction in introductory mechanics courses. These findings support the incorporation of guided physical demonstrations into engineering education.

Dart and Lim [3] investigated the application of 3D-printed models in structural engineering education and found that students perceived the models as beneficial for visualizing engineering principles and connecting theoretical concepts with real-world applications. Their study demonstrated the educational potential of physical models as instructional resources for engineering students. The 3D manual gearbox design used in this project was retrieved from the Thingiverse platform, based on the model entitled Working 5 Speed Transmission Model for Toyota 22RE Engine, developed by Ericthepoolboy [4].

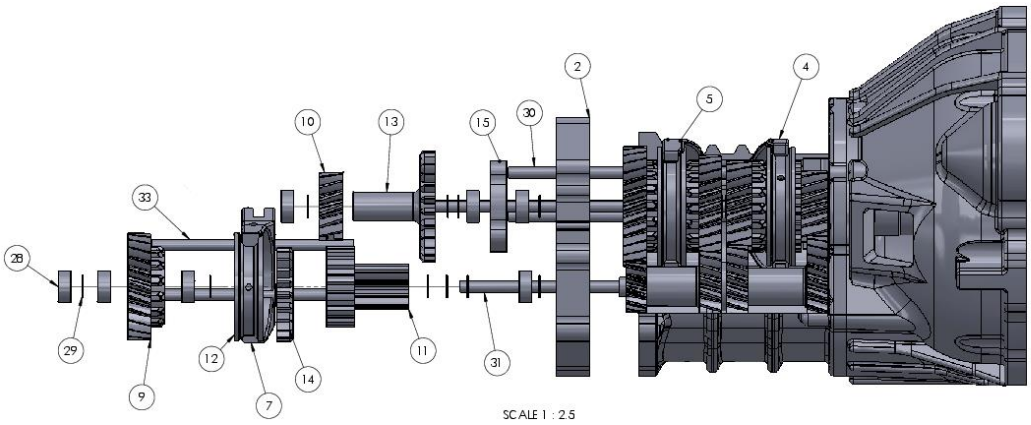


Fig. 1: Available design and 3D model from open source [4]

3 METHODOLOGY

The project methodology begins with identifying the problem and establishing the objectives. A literature review is conducted to select an available open-source 3D manual gearbox design. The selected components are fabricated using 3D printing and subsequently assembled into a functional prototype. Testing is performed to evaluate its operation. If the prototype fails, the process returns to fabrication for necessary improvements, followed by reassembly and retesting. Once the prototype passes testing, it proceeds to classroom demonstration. Material used for 3D printing is PLA. Figure. 2 shows the flowchart of the development methodology for the educational 3D printed manual gearbox prototype

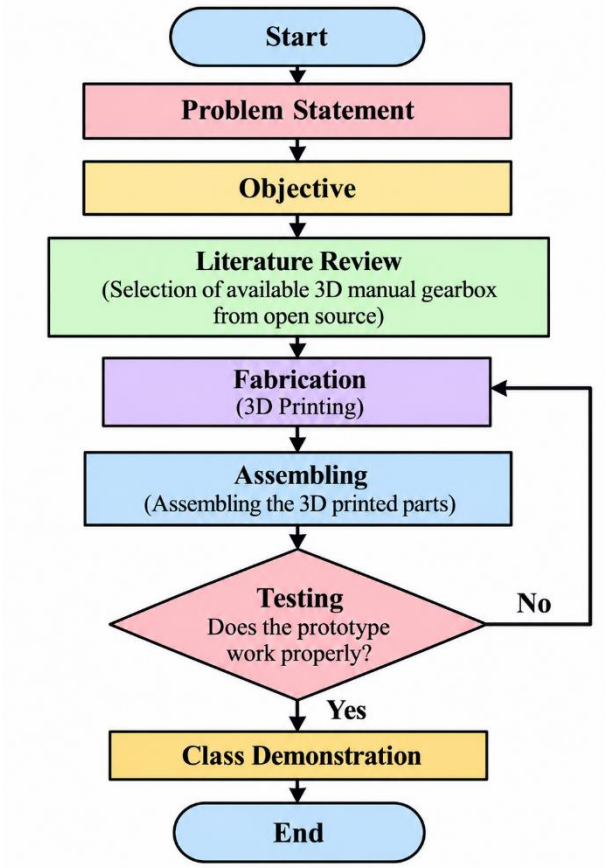


Fig. 2: Flowchart of the development methodology for the educational 3D-printed manual gearbox prototype.

4 RESULTS AND DISCUSSION

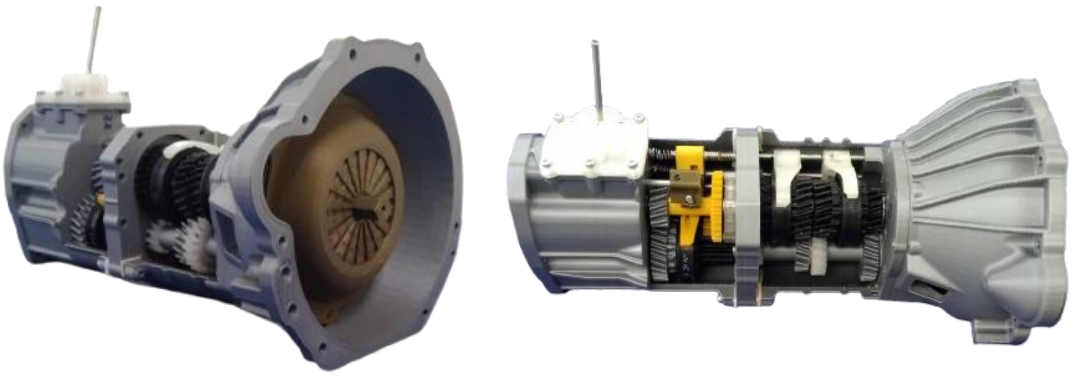
The main result of this project was the successful physical fabrication and assembly of an educational 3D-printed manual gearbox prototype. The completed model incorporates a recognizable gearbox housing with an exposed central section containing several gear assemblies and selector components. The assembled gearbox prototype demonstrates the internal arrangement of mechanical transmission components. The prototype also incorporates differently colored components, including yellow actuating elements and white selector forks, which help distinguish individual parts during classroom demonstrations. The grey outer housing represents the conventional gearbox casing, while the open central section allows direct observation of the gears and shifting components.

As illustrated in Figure 3, several gear sets are arranged along the gearbox assembly. The visible helical gear teeth represent the gear-meshing arrangement commonly used in automotive manual transmissions. Another important feature is the incorporation of a bell housing at one end of the gearbox assembly. The bell housing represents the connection between the transmission and engine-side clutch mechanism. As shown in Figure 4 (a), the front opening reveals a circular component resembling a clutch or pressure-plate assembly. This feature helps students visualise the location of the clutch-side transmission interface.

Figure. 4 (b) showing the exposed gear sets, selector forks and shifting mechanism. The exposed structure also enables the relative positions of gears, shafts and selector components to be examined without disassembling the gearbox.



Fig. 3: Gear sets are arranged along the gearbox



(a) (b)

Fig. 4: Clutch or pressure-plate assembly (a) and shifting mechanism (b)

5 CONCLUSIONS

This project successfully produced an educational 3D printed manual gearbox prototype intended to support teaching and learning in the MEV321 course. The prototype incorporates several important transmission components, including gear sets, shafts, selector forks and shifting mechanism. However, the current findings are limited to documented fabrication and physical assembly. Future works should be detailed performance testing, durability assessment. Besides, an educational assessment involving student feedback and practical learning exercises are recommended to evaluate the effectiveness of the prototype in the MEV321 course.

REFERENCES

[1] M. Prince, "Does active learning work? A review of the research," Journal of Engineering Education, vol. 93, no. 3, pp. 223–231, 2004.
[2] R. R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," American Journal of Physics, vol. 66, no. 1, pp. 64–74, 1998.
[3] S. Dart and J. B. P. Lim, "Three-dimensional printed models for teaching and learning structural engineering concepts: Building intuition by physically connecting theory to real life," Journal of Civil Engineering Education, vol. 149, no. 2, 2023.
[4] Ericthepoolboy, "Working 5 speed transmission model for Toyota 22RE engine," *Thingiverse*, Mar. 9, 2015. [Online]. Available: https://www.thingiverse.com/thing:713815. [Accessed: Oct. 22, 2024]

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CHAPTER 23

Educational Prototype: Conveyor System

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ABSTRACT

This paper presents the development of an educational prototype of a conveyor system intended to serve as a reference platform for engineering students conducting their Final Year Projects (FYP). Conveyor systems are widely used in industrial applications involving material handling, manufacturing and automation. However, students may face difficulties in understanding conveyor design, mechanical arrangement and speed-control principles when relying solely on theoretical learning resources. Therefore, a compact conveyor prototype was developed to provide a physical demonstration of a motor-driven conveyor system. The prototype consists of a supporting frame, rollers, conveyor belt, electric motor and power supply. Besides, bearing and 3D printed parts also display in this paper. The feature of controllable-speed concept allows students to explore how variations in motor rotational speed influence conveyor movement. The completed assembly provides a practical reference for students to understand conveyor construction and consider modifications for different types of project applications. The prototype also offers opportunities for future integration with sensors, microcontrollers and automated control systems.

Keywords: Educational prototype, Conveyor system

1 INTRODUCTION

Students conducting their Final Year Projects (FYP) may face difficulties in developing conveyor systems due to limited access to physical reference models and practical knowledge of mechanical design, fabrication and component assembly. Conventional learning resources, such as technical drawings, videos and theoretical explanations, may not adequately demonstrate the relationship between conveyor components and their operating principles.

The main objective of this project is to design and fabricate a conveyor prototype that can serve as a physical reference for students conducting FYP. The scope of work includes conveyor design, fabrication of structural components, 3D printing of selected parts, assembly, testing and finishing. The completed prototype is intended to support future student projects involving conveyor mechanisms, automation and control system development.

2 LITERATURE REVIEW

Conveyor design involves several important considerations, including the supporting structure, belt arrangement, roller dimensions, motor selection and operating speed. Bhoyar and Handa [1] investigated the design considerations for an adjustable belt conveyor system, highlighting the importance of belt width, belt speed and pulley diameter in determining conveyor configuration. Their study provides fundamental design considerations for developing a compact conveyor prototype. Gonçalves et al. [2] developed a conveyor-belt prototype as an educational experiment in mechatronics. Their system incorporated 3D printed components, an electric motor and a closed-loop control system to demonstrate concepts related to prototyping and motor control. The study illustrates how a conveyor platform can be used to introduce students to mechanical fabrication, electrical systems and control applications.

Furthermore, He et al. [3] investigated the speed control of belt conveyors during transient operation. Their findings emphasized the importance of considering acceleration and belt dynamics when adjusting conveyor speed. These considerations provide a basis for understanding the relationship between motor-speed control and conveyor operation. Several studies have investigated the design and development of miniature conveyor systems for educational and automation applications. Oyebode et al. [4] developed a laboratory-scale mini conveyor integrated with a robotic arm to demonstrate automated material handling for engineering students. Their study highlighted the potential of compact conveyor systems as practical educational platforms.

Aravindhan et al. [5] designed and fabricated a mini conveyor using a Geneva mechanism to achieve intermittent conveyor movement. Their work demonstrated the application of mechanical drive mechanisms in controlling conveyor motion. Furthermore, Pecen et al. [6] developed a modular conveyor system incorporating 3D-printed components and robotic sorting. The study demonstrated the suitability of additive manufacturing for developing compact conveyor prototypes used in engineering education. These studies provide relevant design considerations for the present project, which focuses on developing a controllable-speed mini conveyor as a physical reference for students conducting Final Year Projects.

3 METHODOLOGY

The project methodology begins with identifying the problem and establishing the objectives. A literature review is conducted to study existing conveyor designs and select a suitable configuration. The proposed conveyor is then developed through design and 3D modelling, followed by fabrication of structural components and 3D printing of selected parts. The fabricated components are assembled to form the conveyor mechanism before testing is carried out to evaluate its intended operation. Finally, finishing work is performed to complete the prototype for educational reference purposes. Figure 1 shows the flowchart for this project.

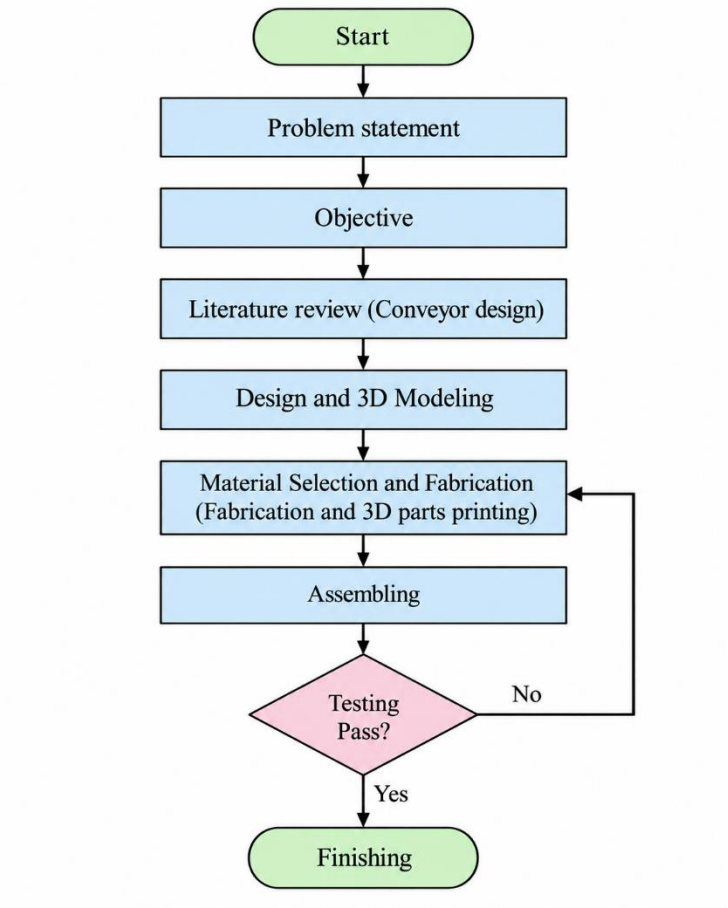


Fig 1: Flowchart for the project

4 RESULTS AND DISCUSSION

The main outcome of this project was the physical fabrication and assembly of a compact conveyor prototype intended for educational use. The completed model incorporates a supporting frame, two main rollers, a conveyor sheet, an electric motor and an electrical power supply. The arrangement provides a practical example of a motor-driven conveyor system that students can examine when developing their own FYP. The prototype successfully meets its intended objectives, demonstrating practical functionality in machining operations as in Figure 2. The specification of the prototype shows in Figure 3.

From an educational perspective, the prototype can serve as a reference for students developing FYP involving automated sorting systems, object detection, product counting and material transportation. Students may use the existing mechanical arrangement as a starting point for designing their own conveyor systems, thereby reducing the need to develop every structural component from the beginning.

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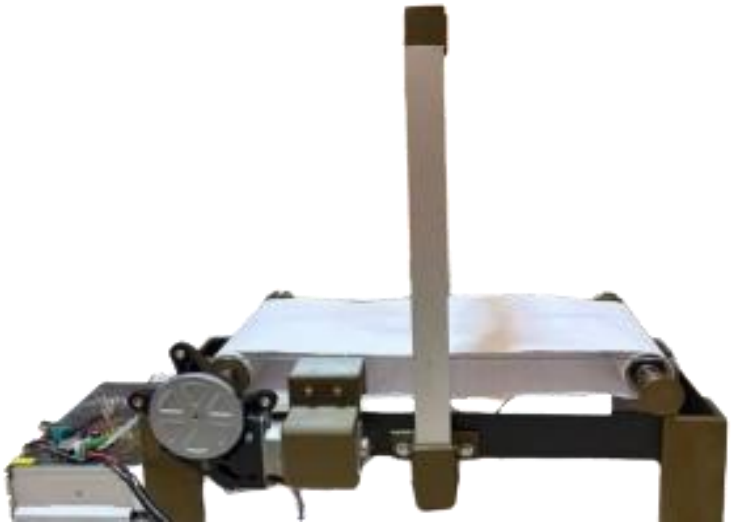
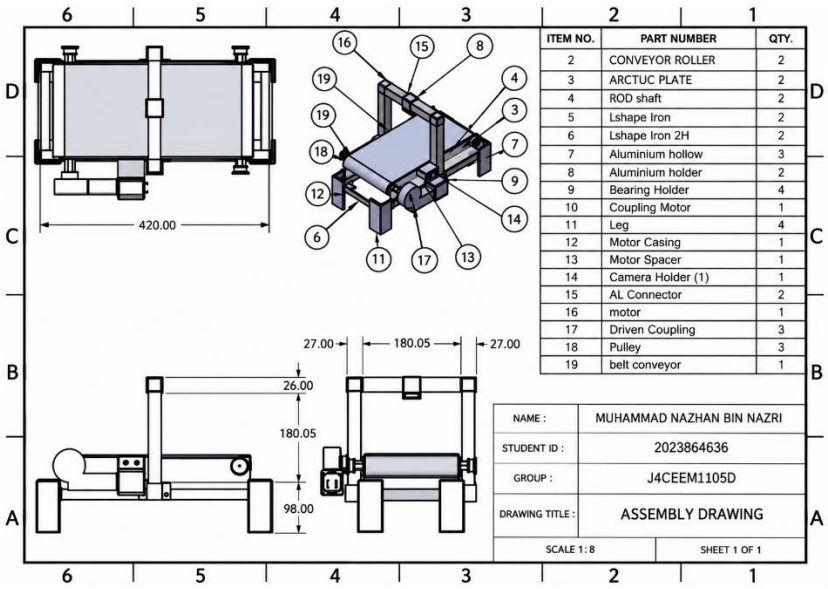


Fig 2.: Prototype of conveyor



ITEM NO.	PART NUMBER	QTY.
2	CONVEYOR ROLLER	2
3	ARCTUC PLATE	2
4	ROD shaft	2
5	Lshape Iron	2
6	Lshape Iron 2H	2
7	Aluminium hollow	3
8	Aluminium holder	2
9	Bearing Holder	4
10	Coupling Motor	1
11	Leg	4
12	Motor Casing	1
13	Motor Spacer	1
14	Camera Holder (1)	1
15	AL Connector	2
16	motor	1
17	Driven Coupling	3
18	Pulley	3
19	belt conveyor	1

Fig 3.: Bill of material drawing (specification of the prototype)

5 CONCLUSIONS

The project successfully met both primary objectives an educational prototype of a conveyor system intended to serve as a reference for engineering students conducting their Final Year Projects. The prototype incorporates several essential conveyor components, including a supporting frame, rollers, conveyor belt, electric motor and power supply. The physical arrangement provides students with an opportunity to understand the basic construction and working principles of a motor-driven conveyor system. The prototype can also serve as a platform for future FYP applications involving automation, sensing systems and motor-speed control. However, further experimental testing is required to evaluate speed-control performance, load capacity and operating reliability.

REFERENCES

[1] R. K. Bhoyar and C. C. Handa, "Design consideration for radial adjustable belt conveyor system," International Journal of Mechanical Engineering and Robotics Research, vol. 2, no. 4, pp. 342–347, Oct. 2013.

[2] J. Gonçalves, J. E. Ribeiro, and P. Costa, "Prototyping and control of a conveyor belt: An educational experiment in mechatronics," in CONTROLO 2020: Proceedings of the 14th APCA International Conference on Automatic Control and Soft Computing, Lecture Notes in Electrical Engineering, vol. 695, pp. 63–71, 2021. doi: 10.1007/978-3-030-58653-9_6.

[3] D. He, Y. Pang, and G. Lodewijks, "Speed control of belt conveyors during transient operation," Powder Technology, vol. 301, pp. 622–631, 2016. doi: 10.1016/j.powtec.2016.07.004.

[4] O. J. Oyebode, T.-C. Jen, R. E. Ochijenu, A. O. Adetunla, A. Adediran, and S.-S. Ajibade, "Design and fabrication of a mini conveyor and automatic hand-picking system for engineering education demonstration," NIPES Journal of Science and Technology Research, vol. 7, no. 2, pp. 3637–3642, 2025. doi: 10.37933/nipes/7.4.2025.SI446.

[5] T. K. Aravindhan, S. Dinesh Kumar, D. Gokul Raj, Ashish Kumar, and A. Gokul Karthik, "Design & fabrication of mini-conveyor using Geneva mechanism," International Journal of Creative Research Thoughts, vol. 6, no. 2, pp. 165–169, Apr. 2018.

[6] R. Pecen, U. Dakeev, and F. Yildiz, "Modular conveyor belt system with robotic sorting," in Proc. 2021 ASEE Virtual Annual Conference, Jul. 2021. doi: 10.18260/1-2--37516.



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