



جامعة الأمير سطام بن عبدالعزيز
PRINCE SATTAM BIN ABDULAZIZ UNIVERSITY
College of Engineering
Mechanical Engineering Department

Innovation and Technology

Pride of today and the future of tomorrow

The official magazine for graduation projects of
Mechanical Engineering Department

Volume 2, 24-25

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- 1. Thermodynamics and Heat Transfer:** Studies on energy conversion, heat exchangers, refrigeration, and thermal management.
- 2. Fluid Mechanics and Hydraulics:** Research on fluid behavior, fluid-structure interaction, and hydraulic systems.
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- 4. Solid Mechanics and Structural Analysis:** Analyses of stress, strain, elasticity, plasticity, fracture mechanics, and structural stability.
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- 11. Energy Systems and Renewable Energy:** Investigations into power generation, renewable energy technologies, energy storage, and energy efficiency.
- 12. Tribology and Surface Engineering:** Studies on friction, lubrication, wear, and surface treatments to enhance material performance.

Innovation & Technology magazine offers an online platform facilitating the effective exchange of innovative scientific and engineering ideas and the dissemination of recent, original, and significant research and developmental findings.

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Shell Eco-Marathon car: Combustion engine optimization and Test bench

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Abstract: This project focuses on designing and developing a fuel-efficient vehicle for the Shell Eco-Marathon competition. The primary objectives included optimizing a combustion engine, creating a high-efficiency fuel system, and engineering a robust power transmission system to maximize energy efficiency and minimize fuel consumption. The GY6 engine was chosen for its adaptability and reliability, enhanced by a fuel injection system. A comprehensive approach ensured compliance with the competition's technical and safety standards. The power transmission system facilitated efficient energy transfer, while the fuel system utilized a pressurized setup to meet regulations. The design process involved evaluating various components and implementing innovative solutions to optimize vehicle performance.

Keywords: GY6 engine, oil catch can, CVT, EFI Tune, Stoichiometry, Air-Fuel ratio.

1. INTRODUCTION

The project at Prince Sattam University aims to design and construct a fuel-efficient vehicle for the Shell Eco-Marathon in Qatar, focusing on maximizing distance traveled while minimizing fuel consumption. This initiative addresses the environmental impact of traditional vehicles by promoting innovative solutions for reduced emissions.

The team is responsible for selecting and optimizing the engine, ensuring it meets fuel efficiency and performance criteria. Key design areas include the powertrain, enhanced with an oil catch can to improve performance and reduce emissions, and a robust electrical system compliant with safety regulations.

2. ENGINE

1- We established specific requirements that are necessary for us to achieve the highest efficiency. These requirements include the following:

- Eco-Friendliness (Emissions), Fuel Efficiency, Availability, Aftermarket Modifications, Ease of Purchase, Reliability, Spare Parts Availability, Customization, Logistical Feasibility and Weighted Scores.
 - Choosing the Engine for the Shell Eco-Marathon Project
- We discussed the requirements and rules for the Shell Eco-Marathon competition.



Fig. 1. GY6 engine.

Then we built a PDS table and according to its results we chose GY6 engine.

2- Use of oil catch can in crankcase ventilation system.

A crankcase ventilation system (CVS) removes unwanted gases, known as "blow-by," from the crankcase of an internal combustion engine.

Blow-by gases result from combustion materials leaking past the piston rings into the crankcase. If not ventilated, these gases can condense with oil vapor, leading to sludge buildup.

An oil catch can is installed in the crankcase ventilation system to reduce oil vapor and contaminants entering the intake.[1]

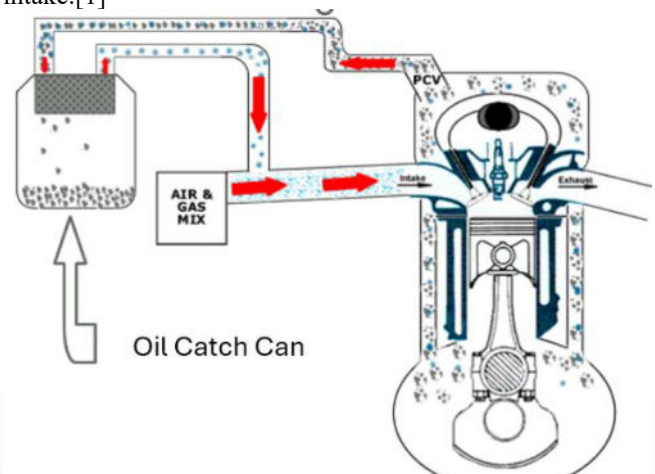


Fig. 2. Oil catch can.

3. POWER TRANSMISSION

For us, what matters in this part is the weight, ease of design, calculation, and load-bearing capacity. And because of these requirements, we had two options: one is the CVT (continuously variable transmission) and the other is chain and sprocket. After careful evaluation between these two systems, we chose chain and sprocket system.



Fig. 3. Transmission system

We have added to the traditional centrifugal (automatic) clutch a second electromagnetic clutch, which offers additional control over the transmission engagement while keeping the smoother performance of the automatic clutch.[1]

4. DESIGNING THE ELECTRICAL SYSTEM FOR AN INTERNAL COMBUSTION VEHICLE

In the development of an internal combustion vehicle for competitions like the Shell Eco-Marathon, the design of the electrical system plays a critical role in ensuring both safety and performance. The electrical system is responsible for powering essential components, including the ignition system and control units.

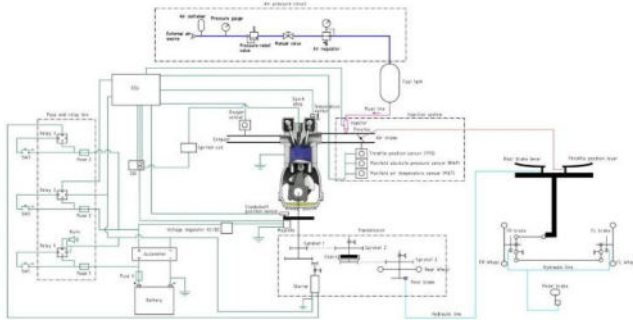


Fig. 4. Electrical system and energy flow diagram

5. TUNING

E-EFI is an Electronic Fuel Injection conversion kit for small engines. It is a bolt-on EFI kit to a lot of small engines used on variant applications. This kit replaces the OEM's carbureted fuel system completely, and it requires the minimum modifications of the engine. It could be a plug-

and-play EFI kit for some popular small engines like GY6 engines.



Fig. 5. EFI Tune kit

2- Stoichiometry, the term stoichiometric refers to the ideal chemical balance in a combustion process where all the fuel is completely burned using just the right amount of oxygen, leaving no excess fuel or oxygen. This balance is crucial in internal combustion engines, as it determines the air-fuel ratio needed for efficient and clean combustion.[2]

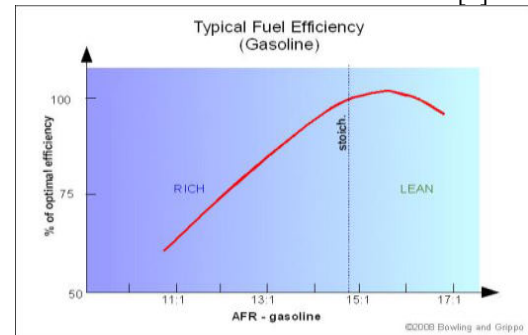


Fig. 6. Stoichiometry, optimal efficiency.

CONCLUSION

The journey of designing and building our vehicle for the Shell Eco-Marathon has been a transformative experience, culminating in our successful passage of the technical inspection. This achievement not only signifies compliance with the stringent regulations of the competition but also reflects our commitment to safety, innovation, and teamwork.

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Shell Eco-Marathon Car: Body Aerodynamics Analysis

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Abstract: The Shell Eco-Marathon is an international competition where student teams design vehicles to achieve the greatest energy efficiency. The project focuses on developing a prototype that maximizes fuel efficiency through the optimization of vehicle aerodynamics. We utilize ANSYS simulation software to analyse and compare three vehicle designs, each focusing on airflow patterns, drag coefficients, and overall vehicle performance. By examining various passive flow control techniques and aerodynamic principles, the study aims to reduce drag and improve energy efficiency. The selected model, based on simulation results, represents the most effective aerodynamic design to maximize fuel economy, aligning with the competition's emphasis on sustainable engineering practices. This work highlights the significant role of aerodynamics in energy conservation and the potential for future innovations in eco-friendly transportation.

Keywords: Aerodynamics, Computational Fluid Dynamics, Vehicle Design Optimization, Drag Coefficient.

1. INTRODUCTION

Engineers face the challenge of improving vehicle designs using aerodynamic principles to increase fuel efficiency. Aerodynamic drag accounts for more than half of a vehicle's energy consumption, making drag reduction one of the most effective solutions to improve efficiency. Aerodynamic drag consists of two main components: skin friction drag and pressure drag (See figure 1), with pressure drag contributing to over 80% of the total drag. It is highly influenced by vehicle geometry. The separation of airflow from the rear surface and the formation of a wake region behind the vehicle affect aerodynamic drag. According to Hucho [1], aerodynamic drag contributes up to 50% of fuel consumption at highway speeds, making drag reduction an effective way to improve fuel efficiency. This challenge of improving vehicle aerodynamics is clearly exemplified in the Shell Eco-Marathon competition, which encourages students to push the boundaries of fuel efficiency by designing and building ultra-energy-efficient vehicles. The competition serves as a key platform for innovations in sustainable engineering, where participants focus on optimizing shapes, reducing drag, and experimenting with new materials and techniques to achieve exceptional efficiency. Teams aim to reduce drag and enhance lift-to-drag ratios, allowing vehicles to travel longer

distances with less fuel consumption. A key tool for achieving efficiency is ANSYS Fluent simulation software. We used this software to analyze three vehicle designs, studying airflow patterns and identifying techniques to reduce drag and improve aerodynamic performance. Through ANSYS Fluent simulations, we were able to accurately identify separation points and airflow directions, which helped us refine the shape to reduce air resistance and increase fuel efficiency. These simulations provide teams with a solid foundation to test ideas and analyze designs before applying them in real-world conditions.

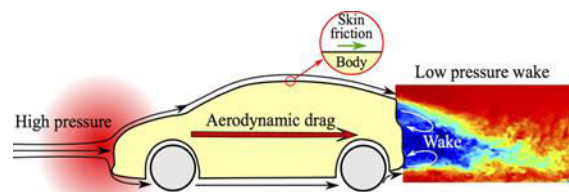


Figure 1: Common classification of aerodynamic drag [2].

2. DESIGN APPROACH AND RATIONALE

The design of the vehicle's shape shown in figure 2 was our first step. To be in accordance with the sought performance, the vehicle's shape is inspired by team's name SAQR (Arabian falcon) which symbolizes freedom, loyalty and devotion. The SAQR falcon is also known to have a very efficient shape with a high speed to power ratio. Its curves are inspired from the teardrop form, a proven concept in aerodynamics, have been used as a basis for the external design of the vehicle. Specifically, the design adopts a symmetrical NACA airfoil shape, which serves as the foundation for the prototype's streamlined structure. This choice not only enhances the vehicle's aesthetic appeal but also demonstrates the application of this aerodynamic principle. The dimensions of the vehicle were carefully selected based on the driver's measurements to ensure a comfortable and ergonomic fit. Additionally, we ensured that the dimensions comply with the competition's requirements, maintaining a balance between practicality and adherence to regulations. The impact of this shape on airflow control is significant. The smooth and continuous curves allow air to flow efficiently around the body, reducing drag and improving overall aerodynamic performance. By minimizing turbulence and resistance, the design ensures stable and

energy-efficient operation, making it a strong candidate for achieving the intended performance targets.

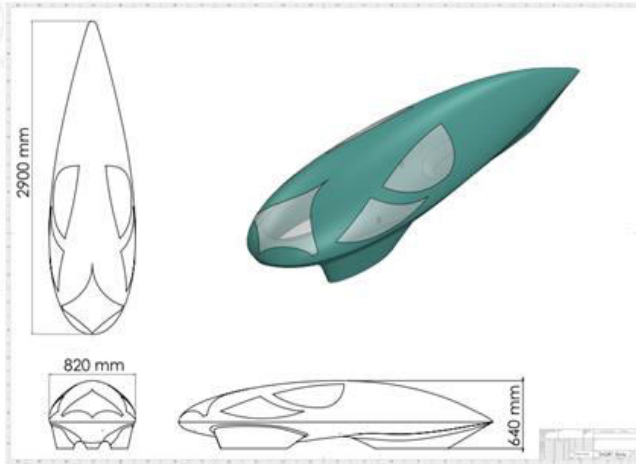


Figure 2: Body design.

3. PASSIVE FLOW CONTROL

Passive flow control, through body modifications, offers a simpler and more reliable alternative to active systems. These methods require no external energy, making them highly efficient and easy to implement. One key technique we used is rear tapering, a proven method for reducing drag by managing airflow around the vehicle. Numerical studies indicate that such modifications can reduce drag by up to 10%, significantly improving aerodynamic performance without the complexity and maintenance associated with active systems [3]. Specifically, rear-edge modifications streamline airflow and reduce wake turbulence, enhancing stability and minimizing energy loss. This simplicity and effectiveness made passive flow control the optimal choice for the vehicle design.

4. RESULTS AND DISCUSSION

Following several design modifications, the velocity contour plot (Figure 3) reveals smooth airflow along the vehicle's surface with minimal separation zones, particularly highlighting high-velocity regions at the upper surface and rear taper. These results confirm the effectiveness of the streamlined design in guiding airflow efficiently and reducing wake size at the rear, which contributes directly to minimizing turbulence and pressure drag. Complementing this, the pressure contour plot (Figure 4) illustrates pressure distribution around the vehicle, with high pressure at the front due to airflow stagnation and naturally lower pressure at the rear caused by turbulence. The design efforts focused on reducing this rear turbulence to maintain higher rear pressure compared to typical bluff body shapes. While rear pressure does not exceed the front, the noticeable improvement over an unoptimized shape validates the aerodynamic modifications and promotes a more balanced pressure distribution, further reducing overall drag. These improvements are reflected in the vehicle's aerodynamic performance metrics, with a drag coefficient of 0.1193 and a lift coefficient of -0.1363. With a weight of 1100 N, the vehicle experiences a downward lift force of -3.25 N, which

helps maintain consistent ground contact and enhances overall stability. This balanced aerodynamic behavior reduces the risk of instability, minimizes tire friction, and optimizes both performance and energy efficiency. These results demonstrated the success of the design in achieving a stable, efficient, and aerodynamically optimized vehicle.

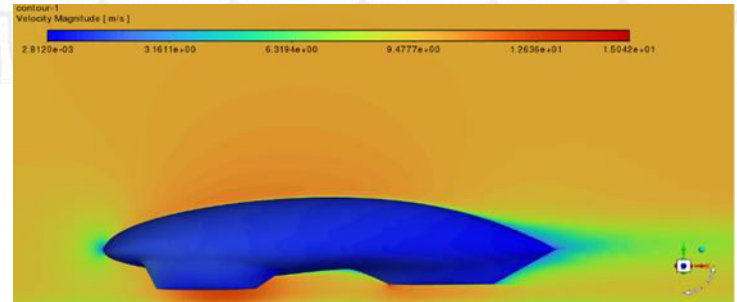


Figure 3: Velocity contour.

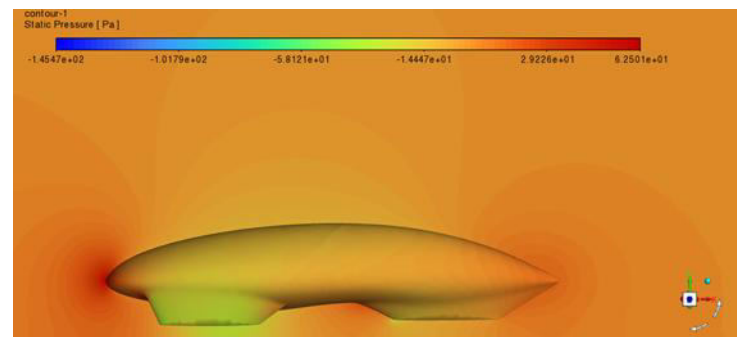


Figure 4: Pressure contour.

CONCLUSIONS

The vehicle design integrates advanced aerodynamic principles focused on optimizing fuel efficiency, as reflected by the drag coefficient of 0.1193 and the lift coefficient of -0.1363. These performance metrics validate the vehicle's exceptional aerodynamic efficiency, contributing to stable handling and reduced tire friction. Simulations, including velocity and pressure contour plots (Figures 3 and 4), reveal smooth and uninterrupted airflow, with minimal separation and reduced wake turbulence at the rear, further enhancing both stability and energy efficiency. The use of rear tapering, a passive flow control technique, effectively minimizes drag by streamlining airflow and reducing turbulence, ensuring a more energy-efficient design.

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Shell Eco-Marathon Prototype Car: Chassis, Steering, and Braking Design

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Abstract: This paper presents the design and validation of the chassis, steering, and braking systems of the SAQR1 prototype vehicle developed by Prince Sattam Bin Abdulaziz University for the Shell Eco-Marathon 2025. The chassis was designed as a lightweight aluminum spaceframe structure, the steering system was based on a trapezoidal linkage approximating Ackermann geometry, and the braking system implemented a hydraulic disc brake to meet safety standards. Finite Element Analysis (FEA) was conducted to evaluate mechanical strength and deformation. All components were designed in compliance with the competition's regulations and manufactured to meet lightweight and safety objectives.

Keywords: Shell Eco-Marathon, aluminum chassis, trapezoidal steering, disc brake, finite element analysis

1. INTRODUCTION

The Shell Eco-Marathon is a global competition that promotes energy-efficient vehicle innovation. The SAQR1 team participated in the 2025 edition with a three-wheeled prototype. The project focused on developing a lightweight, structurally safe, and regulation-compliant chassis, steering, and braking system. Emphasis was placed on reducing mass, improving manufacturability, and verifying performance through simulation and analysis.

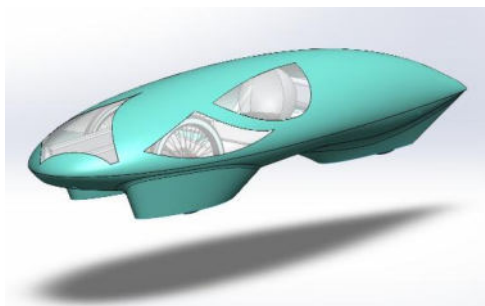


Fig. 1. SAQR1 Team's Car.

2. CHASSIS DESIGN

The chassis was constructed using 6063 T6 aluminium circular tubes with a 30 mm diameter and 2 mm wall thickness. A spaceframe design was selected for its structural efficiency and ease of fabrication. Finite Element Analysis (FEA) in ANSYS confirmed the structural adequacy under loading conditions.

- Maximum equivalent stress: 104 MPa
- Maximum deformation: 4.4 mm
- Factor of safety: Greater than 2
- Bending stiffness: Met the minimum target of 290,000 N/m
- Weight: 5.5 kg
- Modal analysis: Ensured the natural frequency did not coincide with engine operation to avoid resonance.

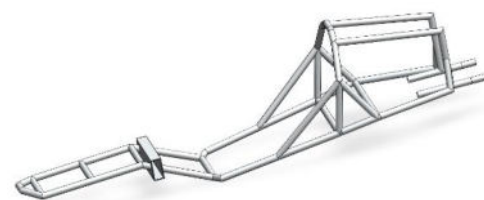


Fig. 2. Spaceframe Chassis Design.

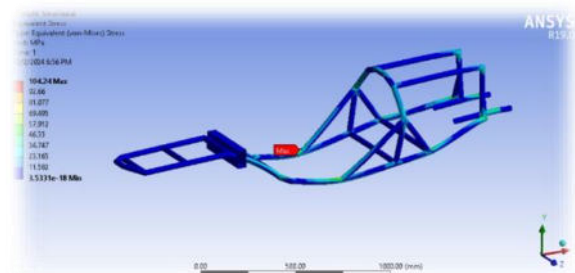


Fig. 3. Chassis Equivalent (Von-Mises) Stress (MPa).

3. STEERING SYSTEM

The steering system uses a trapezoidal four-bar linkage to approximate the Ackermann condition, which ensures the correct angle difference between the inner and outer front wheels during turns. This reduces tire slip and enhances stability.

- Camber angle: Adjustable between 3° and 5°
- Steering components: Manufactured from aluminium with stainless steel inserts
- Analysis: MATLAB was used to calculate angle errors compared to ideal Ackermann geometry
- Validation: Structural components including the steering shaft and brackets were analyzed using FEA to confirm stress limits were not exceeded.

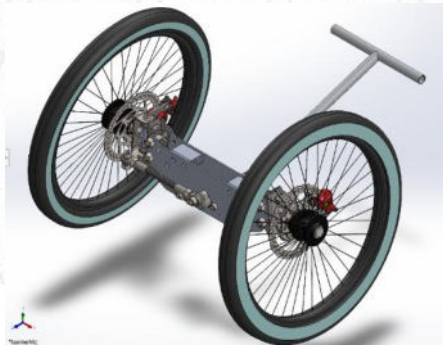


Fig. 4. Isometric View of Steering System.

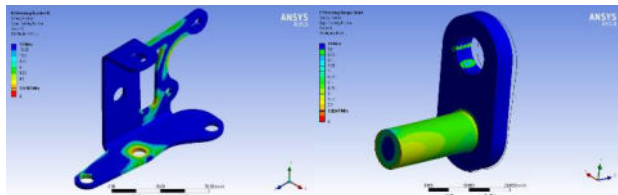


Fig. 5. Minimum Factor of Safety $\approx +1.6$



Fig. 6. Front View of Steering System.

4. BRAKING SYSTEM

A Shimano BR-M315 hydraulic disc brake was chosen for the front wheel. The system was designed to provide reliable stopping performance and comply with Shell Eco-Marathon rules.

Pedal-operated braking with a single hydraulic circuit for the front

The axle shaft was modeled and analyzed to ensure strength during braking loads.

The system includes adequate pedal area and redundancy according to regulations

ANSYS simulations verified the mechanical safety of the shaft and related components under maximum force conditions.

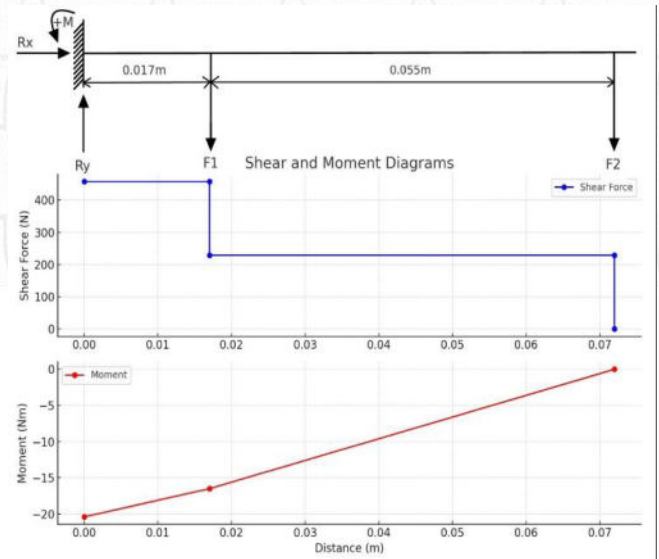


Fig. 7. Free Body Diagram and Shear, Moment Diagrams

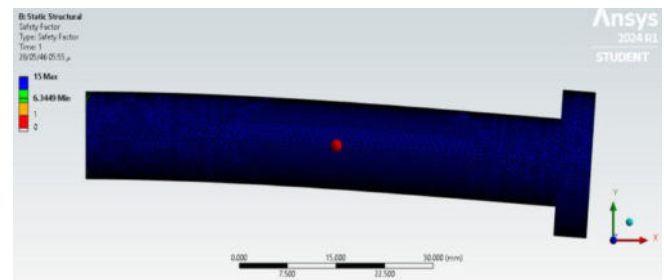


Fig. 8. Factor of Safety = 6.3

CONCLUSIONS

The chassis, steering, and braking systems of the SAQR1 vehicle were successfully designed, validated, and manufactured to meet the requirements of the Shell Eco-Marathon 2025. The systems achieved the intended balance between lightweight design and mechanical performance. The work serves as a foundation for future iterations and enhancements in student-developed energy-efficient vehicles.

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Shell Eco-Marathon Car: Manufacturing of the Car's Body

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Abstract: This paper presents the advanced composite body manufacturing process developed for the Shell Eco-Marathon 2025 prototype vehicle. The project emphasizes aerodynamic efficiency, lightweight design, and structural integrity. Carbon Fiber Reinforced Polymer (CFRP) was selected for its superior mechanical properties, combined with Resin Infusion Molding for precise and efficient fabrication. Additional innovations include vibration isolation systems, integration of 3D printed aerodynamic ducts, and the use of Lexan and carbon fiber panels for enhanced driver safety. The outcome is a high-performance, competition-ready car body that reflects modern engineering principles and hands-on design innovation.

Keywords: Shell-Eco-Marathon, CFRP, Composite manufacturing, VARIM, 3D printing, aerodynamic duct, Lexan, vehicle safety.

1. INTRODUCTION

The Shell Eco-Marathon challenges student teams to develop vehicles with maximum fuel efficiency [1]. In the Prototype category, achieving minimum weight and aerodynamic drag is critical. This paper presents the design and composite manufacturing of a car body using Carbon Fiber Reinforced Polymer (CFRP), selected for its high strength-to-weight ratio. The process focused on integrating lightweight construction techniques with safety, structural reliability, and environmental responsibility. Beyond material choices, the design strategy was centered around minimizing drag force by developing a streamlined body profile. Inspiration was drawn from aerospace and automotive principles, and iterative digital simulations were used to refine the external shape. Environmental sustainability was also considered, as the use of VARIM results in fewer volatile organic compound emissions compared to traditional hand lay-up methods. Furthermore, this project was executed in a university setting with limited financial and tooling resources, emphasizing creative problem-solving and practical application of theoretical knowledge. The end goal was not only to meet competition requirements but to engineer a repeatable and scalable approach that other teams can adopt and improve upon.

2. DESIGN SPECIFICATION & MANUFACTURING PLAN

The vehicle was designed within the dimensional and safety limits defined by Shell Eco-Marathon 2025 rules. The car body was constrained to a maximum height of 1000 mm, width of 1300 mm, and length of 3500 mm. A Product Design Specification (PDS) was developed to address requirements such as material strength, aerodynamics, safety, and manufacturability. Materials included CFRP, vinyl ester resin, and structural foam. Tooling was selected to match the composite layup process and include items like a vacuum pump, foam cutter, and safety.

3. BODY MANUFACTURING PROCESS

The process started with a 3D CAD model designed in SolidWorks. A skeleton CAD model was created and used to laser cut section bucks from MDF. These were assembled, filled with polystyrene foam, and shaped using electric saws and hot-wire foam cutters. After bonding the foam, sanding and coating were done using multiple putty layers to refine the surface.

Fiberglass molds were created using the hand lay-up method. Gel coat and resin were applied in successive layers with glass fiber to form the mold. Then, the final carbon fiber layup was done using VARIM. Issues such as structural breakage during foam filling and body misalignment were solved using metal reinforcements and CNC-cut MDF spacers. Magnetic closure and ergonomic design enhanced usability.

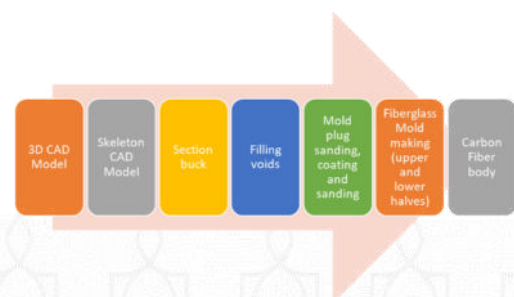


Fig. 1. Process flow diagram of the body car manufacturing step.

4. AERODUCT FABRICATION USING 3D PRINTING

To enhance engine cooling, a 3D printed aerodynamic duct mold was created using PLA material on the AnkerMake M5 printer [2]. SolidWorks was used for design and AnkerMake slicing software prepared the file. Vacuum infusion was applied on the mold after applying carbon fiber, peel ply, mesh, and vacuum film. Some surface damage occurred due to the lack of mold release agent, highlighting the need for better preparation.

Fig. 2. final part after attempting to demold it from the printed mold



5. DRIVER SAFETY DESIGN

To protect the driver from moving parts, Lexan was used to cover the front wheels and chain system. It offered visibility, impact resistance, and was easy to cut and bend. A carbon fiber partition separated the driver from the engine. Safety features also included vibration reduction using rubber-insulated metal U-brackets under the chassis.

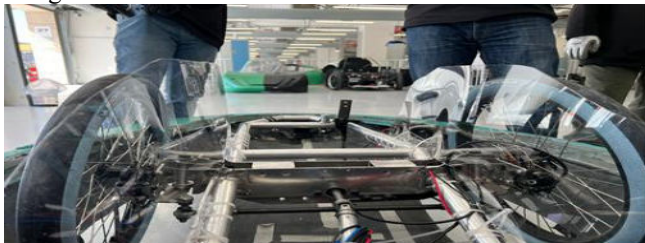


Fig. 3. Front view demonstrating how the Lexan shields surround the tires.

6. RESULTS AND DISCUSSION

The final car body achieved the required strength-to-weight ratio and passed functional tests. The use of CFRP and vacuum molding enabled a rigid yet lightweight shell. Innovative tooling, 3D printing, and safety design were integrated successfully. The project met its objectives and offered valuable engineering insights into composite manufacturing under competitive constraints.



Fig. 4 Final Appearance of the Car After Completion of Manufacturing.

CONCLUSIONS

The project successfully achieved its intended outcomes by effectively integrating advanced composite materials and engineering techniques. The car body constructed using CFRP and vacuum-assisted resin infusion demonstrated structural robustness, aerodynamic efficiency, and compliance with Shell Eco-Marathon standards. Lessons learned from mold handling, alignment challenges, and vacuum process optimization will enhance future iterations of student-designed energy-efficient vehicles.

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Shell Eco-Marathon car: Cockpit Design, Steering and Chassis Manufacturing

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Abstract: This project focuses on designing and manufacturing a high-efficiency vehicle for the Shell Eco-Marathon, with emphasis on the cockpit design, steering system, and chassis structure. Lightweight and high-strength materials such as aluminum and steel were selected to ensure performance and durability. Advanced manufacturing technologies such as laser cutting and precision welding were used to enhance quality and reduce waste. The project aims to stimulate sustainable engineering thinking among students and prepare them for modern industry challenges.

Keywords: Sustainable Vehicle Design, Lightweight Materials, Aluminum 6063, Chassis Manufacturing, Steering System.

1. Introduction

The Shell Eco-marathon – Prototype category is a highly respected international competition that challenges student teams to design and build ultra-energy-efficient vehicles. The goal is not speed, but to travel the farthest distance using the least amount of energy. Vehicles in this category are entirely custom-built, focusing on advanced aerodynamic design, minimal weight, and maximum efficiency.

A major part of the challenge lies in engineering key components such as the chassis, which must be both extremely lightweight and structurally strong. Materials like carbon fiber and aluminum are often used, and innovative construction techniques help reduce weight while maintaining safety.

Other critical systems include the steering, drivetrain, and cockpit. Each must be optimized for efficiency, simplicity, and performance. The driver's cockpit, for instance, must be compact and ergonomic, allowing for comfortable and safe control while contributing to the vehicle's aerodynamic profile.

Beyond the technical aspects, the competition also emphasizes teamwork, problem-solving, and sustainability. Students work together under real-world constraints to develop creative solutions that reflect a commitment to cleaner, more efficient transportation. The Prototype category, in particular, pushes the limits of what is possible in vehicle efficiency and helps prepare the next generation of engineers to innovate for a sustainable future.

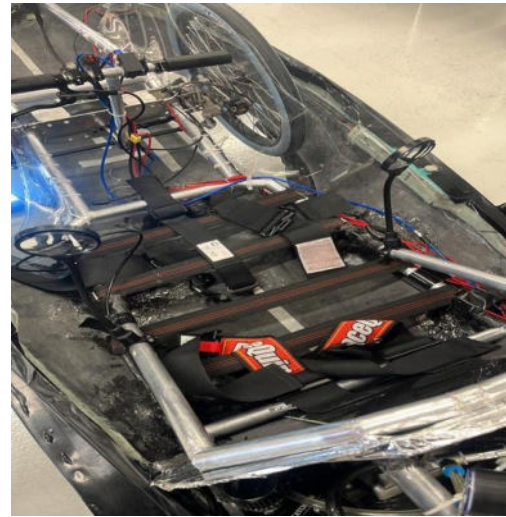


Fig. 1 the car from inside

2. Problem Statement

The main challenge is to develop a design that minimizes aerodynamic drag and vehicle weight without compromising safety or functionality. This required careful selection of materials, precise manufacturing techniques, and strict compliance with competition specifications including size, weight, and safety standards.

3. Objectives

The primary objective of this project was to design and manufacture key structural and control components of a Shell Eco-Marathon prototype vehicle, with a specific focus on the driver's cockpit, chassis, and steering system. The design of the cockpit emphasized ergonomics, visibility, and safety to ensure optimal driver comfort and performance. The chassis was engineered using lightweight aluminum alloys to achieve strength and structural efficiency while minimizing weight. In parallel, the steering system was developed for precise control and durability, using modern materials and fabrication methods. Tools such as SolidWorks were used for 3D modeling, and advanced manufacturing processes like laser cutting and laser welding were implemented to ensure precision and high build quality throughout the project.

4. Design and Manufacturing

The vehicle's chassis was constructed using 6063 aluminum alloy for its favorable mechanical properties and corrosion resistance. The process began with 3D modeling and was followed by laser cutting to achieve precision with minimal waste [1,2]. Laser welding was used to join the parts with high strength and minimal heat distortion. The steering system was designed using aluminum and carbon fiber components to reduce weight while maintaining reliability. The steering wheel was designed for comfort, ease of use, and included a screen display to provide essential data to the driver during operation.



Fig. 2. Chassis



Fig. 3. Steering system



Fig. 4. Cockpit design

5. Testing and Validation

Several performance tests were conducted to ensure structural integrity and operational readiness. Tensile tests on the seat belts showed they could withstand up to 200 N of force. Visibility tests were performed inside the cockpit to ensure optimal field of view. The steering system was

tested under different conditions to evaluate responsiveness and strength. These trials helped refine the design and confirm the vehicle's compliance with competition requirements.

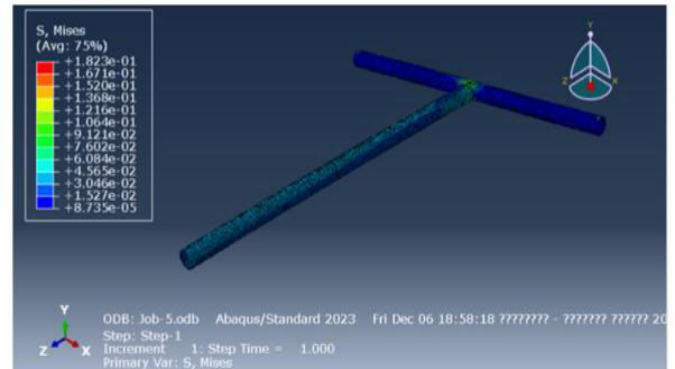


Fig. 5. Simulation

CONCLUSIONS

This project presents a practical example of how students can integrate innovation and sustainability in mechanical engineering. By selecting suitable materials and applying advanced manufacturing techniques, the team succeeded in developing an efficient vehicle that meets the performance and safety standards of the Shell Eco-Marathon. Beyond technical goals, the project strengthened the students' problem-solving, teamwork, and design skills, contributing to their readiness for future challenges in sustainable mobility.



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Mechanical properties evaluation of glass and date palm fronds fibers-polyester reinforced hybrid composite

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Abstract: Composite materials comprise two or more fibers and polymers. Composites provide numerous advantages, including resistance to corrosion, flexibility in design, long-lasting durability, lightweight properties, and enhanced strength. Composite products used in construction, medical applications, oil and gas, permeate our everyday lives in sports, aerospace, and other applications. The main objective of this project is to evaluate the mechanical properties of glass and date palm frond fibers-polyester reinforced hybrid composite. The first stage of this project is to design and fabricate a closed mold to carry out laminates from glass fibers and date palm fibers composite material using the hand layup process. The specimens will differ in the percentages of glass fiber and date palm Fibers. The highest Ultimate tensile strength is obtained for the hybrid composite containing 50% GF and 50% of DPF with a value of 23.00 MPa. The total absorbed energy of pure resin (0.36 J) is less than that of any hybrid composite sample. In the second stage, the design of the experiment approach is carried out to refine the specimen's mechanical properties by incorporating nanoparticles such as CNT, Al₂O₃, and SiO₂. The optimal combination is composed of 88% CNT and 12% Al₂O₃. The composite doped by the optimal combination obtained by design of experiment shows the highest strength up to 35 MPa, and the energy absorbed increases up to 4 joules.

Keywords: Date palm fiber, Glass fiber, Composites laminates, Tensile test, Impact test, Design of experiment.

1. INTRODUCTION

The Food and Agriculture Organization (FAO) Council approved Saudi Arabia's proposal to declare the year 2027 as the International Year of Date Palm. This day would contribute to raising awareness of the suitability for sustainable cultivation of date palm trees under adverse climatic conditions and empower businesses to develop agribusiness systems that include crop byproducts. The date palm tree offers fruit, fiber, sheltering material, and fuel, demonstrating its versatility and great importance.

To meet the lightweight, lower-volume, lower-cost material requirement, a composite made of more than one

reinforcement material, named a hybrid composite, is developed.



Fig. 1. Bateel's Date Farms in Al Ghat region of Saudi Arabia

The advantage of hybrid composites is that they carry better properties than those with only one type of reinforcement [1]. The reinforcing layers in hybrid composites may comprise two or more dissimilar reinforcing materials to get the properties of the combined materials. Many research studies have been conducted on glass and date palm fiber hybrid Composites [2].

The objective of our project was to fabricate glass and date palm fronds fiber-polyester reinforced hybrid composites and to evaluate their benefits on the cost, weight, and mechanical properties.

2. EXPERIMENTAL WORK

2.1 Glass and Date Palm Fibers Hybrid Composite Fabrication

The first stage of this project is to design and fabricate a closed mold to carry out laminates from glass fibers and date palm fibers composite material using the hand layup process. The specimens will differ in the percentages of glass fiber and date palm fibers. The steps of sample fabrication are as follows:

- The reinforcement is prepared.
- Applying the wax on all parts of the mold.
- The matrix is prepared from polyester resin. Hardener at 5 to 7% is added to activate the polymerization of the resin.
- After 8 to 10 hours(curation time) since the application of resin and reinforcement, the samples are extracted from the molds. Figure 2 displays composite laminates.
- The specimens were cut according to ASTM D 638 for the tensile test.

-Coupons were cut from specimens according to the standard ASTM D5942-96 for the impact test.

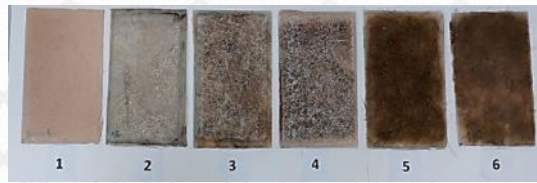


Fig.2. Extracted samples from the molds with the compositions.

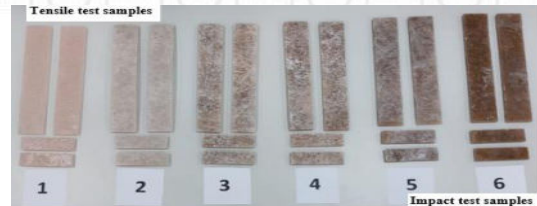


Fig.3. Composite Tensile samples & impact samples.

2.2 GLASS AND DATE PALM FIBERS /POLYESTER NANOPARTICLES HYBRID COMPOSITE

In the second stage, the design of the experiment approach was carried out to refine the specimen's mechanical properties by incorporating nanoparticles such as CNT, Al_2O_3 , and SiO_2 . A schematic representation of the fabrication of the polyester /nanoparticles mixture is presented in Figure 4.

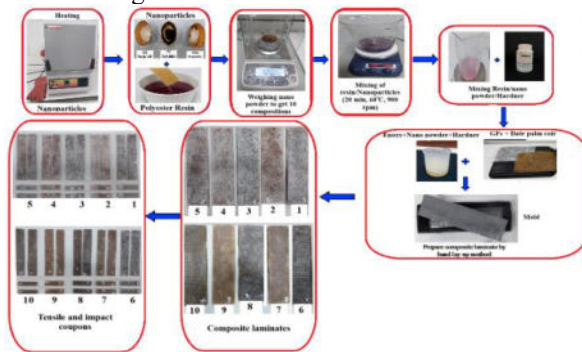


Fig.4.: Schematic representation of the fabrication of the polyester /nanoparticles mixture

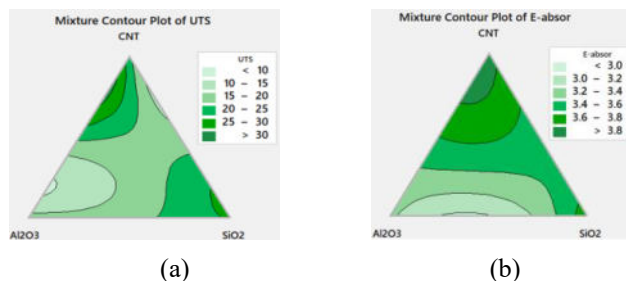


Fig.5. Mixture contour of plot for the strength (a) and the absorbed energy (b)

4. RESULTS AND DISCUSSION

The results show that the strength is obtained for the hybrid composite containing 50% GF and 50% DPF with a value of 23.00 MPa. The total absorbed energy of pure resin (0.36 J) is less than that of any hybrid composite sample.

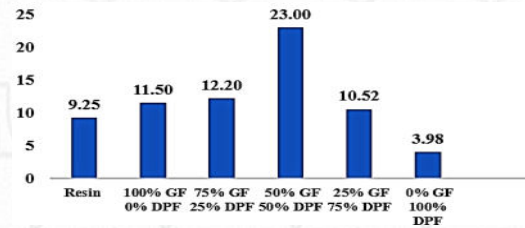


Fig.6. Ultimate tensile strength results [MPa].

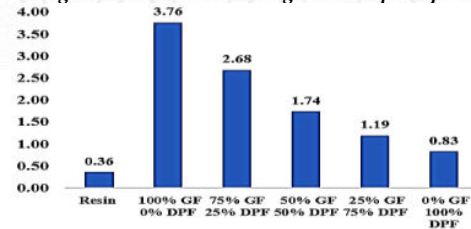


Fig.7. Impact test results [joules].

The optimizer module available in mini tab 17 has been used to get the optimal formulation of nano powder mixture, which is expected to give the best strength(UTS) and energy absorbed in the impact test, and the optimal composition is shown in Table 1.

Table .1. The optimal composition of nanoparticles

Variables	CNT	Al_2O_3	SiO_2
Percentages	88 %	12 %	0 %

A confirmation test was conducted based on the optimum flux composition obtained by the Mixing Design method available in the Minitab software. The experimental values of tensile strength and energy absorbed during the impact test of the optimal combination were reported in Table 2.

Table 2. Strength and absorbed energy in the case of optimal composition

Responses	Experimental values
UTS(MPa)	35
Energy absorbed (joules)	4

CONCLUSIONS

Ultimate tensile strength is obtained for the hybrid composite containing 50% GF and 50% of DPF with a value of 23.00 MPa, the maximum total absorbed energy, which is obtained for a 100% GF (3.76 J). The composite laminate doped by the optimal combination composed of 88% CNT and 12% Al_2O_3 shows the highest strength up to 35 MPa, and the energy absorbed increases up to 4 joules. Adding nanoparticles in glass and date palm fronds fibers- polyester reinforced hybrid composite improves the mechanical properties, such as strength and resistance to sudden loads

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Green Manufacturing for Fabricating Environmentally Friendly Products

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Abstract: This project focuses on implementing green manufacturing practices to fabricate environmentally friendly tiles using recycled tires. The objective is to design and optimize the manufacturing process to produce high-quality tiles while minimizing environmental impact. The effects of temperature, pressure, and holding time on the production process were explored through systematic experimentation with molds of varying sizes. After rigorous testing, the optimal parameters were determined: a pressure of 5 tons at 350°C for 60 minutes. This resulted in the production of durable tiles that meet environmental and performance standards. The success of this project not only demonstrates the feasibility of repurposing discarded tires but underscores the potential of green manufacturing in promoting sustainability and responsible resource management. There are opportunities for further optimization and expansion, including scaling up production. Overall, this project exemplifies the intersection of innovation, sustainability, and social responsibility, showcasing the transformative potential of green manufacturing practices.

Keywords: tires upcycling, green manufacturing, Rubber tiles, mold development, environmentally friendly product.

1. INTRODUCTION

Saudi Arabia confronts a critical challenge in effectively managing the surge in waste volume, primarily originating from vehicles and industries, and is expected to escalate with a projected population of 35 million by 2030. The absence of efficient waste management strategies, mainly for automotive waste and industrial by-products, severely threatens environmental sustainability and public health. This pressing issue is exacerbated by the absence of structured recycling programs, innovative technologies, and regulatory frameworks, intensifying environmental degradation through air and water pollution, soil contamination, and increased proliferation of disease vectors. The urgent need for a comprehensive solution is underscored by the current lack of green manufacturing principles, leading to detrimental consequences for the Kingdom's ecological balance and the well-being of its populace.

As shown in Fig. 1, the previous studies of GTs focused on sustainable technologies, environmental technologies, adverse effects of traditional manufacturing technologies, and green investments concerning firm performance. Research on GT adoption is gradually gaining traction as a potential solution for a better environment. This shift is attributed to the heightened public awareness regarding

environmental quality, making the outdated "treatment after pollution" approach obsolete. Furthermore, enhancing the sustainability of manufacturing technologies could contribute to sustainable development, a phenomenon currently lacking in existing manufacturing practices [1]. Also, Figure 2 shows that most countries focus on green technology, and unfortunately, Saudi Arabia has low efforts [2]

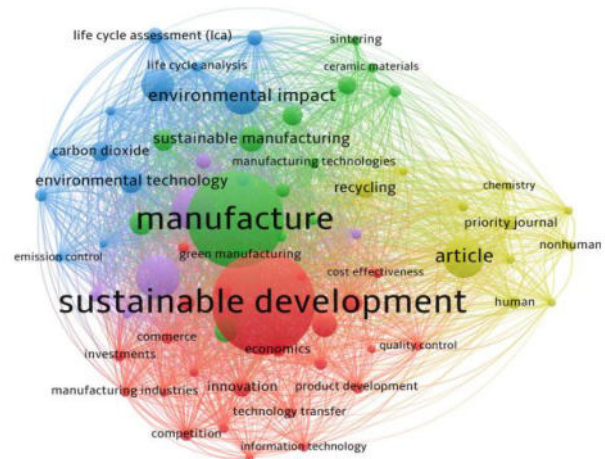


Fig. 1. VOS diagram for the most related topics in GTs [1].

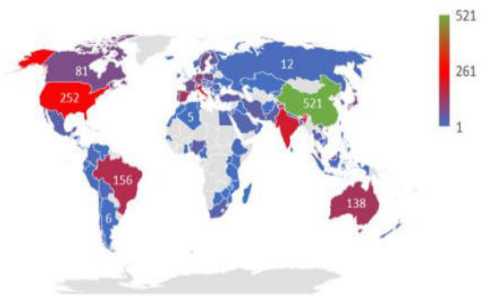


Fig. 2. The most countries focusing on green technology [1]

Thus, the objectives of this project based on the aforementioned discussion are to implement green manufacturing to fabricate environment-friendly products (tiles) from recycled tires, propose a detailed design of the mold used to fabricate environment-friendly tiles and determine the optimum process parameters to manufacture the environment-friendly tiles.

2. EXPERIMENTAL WORK

We visited Ahmed Hammoud Al-Jawir for rubber production in Riyadh to gain first-hand insight into their manufacturing process. Figure 3 illustrates the recycling process used in this

project. This study used rubber powder (less than 1 mm) and coarse size (1-5 mm).



Fig. 3. The stage of recycling the rubes at ambient temperature.

Fabricating environmentally friendly tiles from recycled tires is essential in designing and manufacturing the model and the ejection mechanisms. Mold design is crucial for making things precisely, like in the compression molding process. It's all about creating molds that match the product perfectly. But even with a great mold, you need a good ejection mechanism to get the product out smoothly and safely for the part and the operator. The project aims to improve both aspects to make manufacturing easier and products better.

2.1. Design and Finite element (FE) analysis of the mold.

During the design phase, we developed three concepts with distinct approaches until we reached the final design, as depicted in Fig. 4, where Figs. 4a and b describe the final designs and FE analysis of the proposed environmentally friendly tiles. Comprehensive simulations of the proposed mold designs were accomplished to meticulously analyse stress distribution and ascertain its compliance with our specifications.

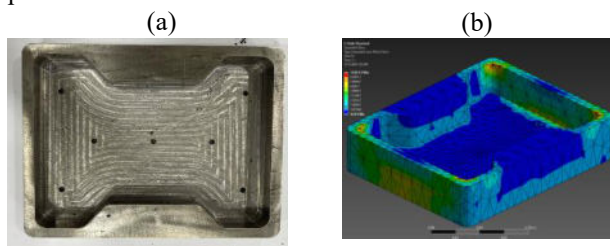


Fig. 4. The mold's initial and final design and FE analysis.

2.2. Design and FE analysis of Ejection mechanism.

The ejection mechanism employs a sophisticated scissors mechanism to facilitate efficient ejection. This mechanism comprises several key components, including an ejection plate, ejection pins, an upper plate, a lower plate, and links. Each component plays a crucial role in the smooth operation of the ejection process. Fig. 5 provides a comprehensive overview of how these elements form the assembly coupling with FE analysis, ensuring optimal functionality and reliability.

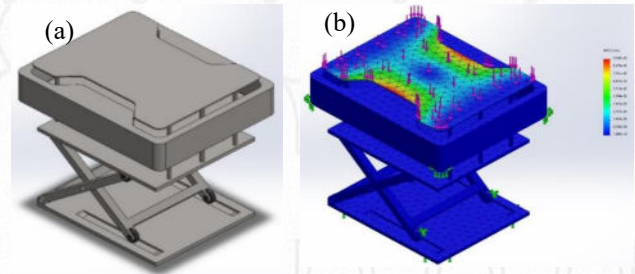


Fig. 5. The design and FE analysis of the Ejection mechanism

3. RESULTS AND DISCUSSION

After completing previous experiments and finite element analysis on the final mold design, we commenced experimental trials with the following parameters: applying pressure ranging from 2 to 5 tons, accompanied by holding times varying from 20 to 60 minutes. The mold was filled with fine rubber powder up to the brim to ensure consistent testing conditions, as depicted in Fig. 6. These experiments aim to investigate the effects of varying pressure levels systematically and holding times on the molding process and the resultant part quality. By meticulously controlling these parameters, we seek to optimize the manufacturing process and achieve the desired characteristics in the molded parts.

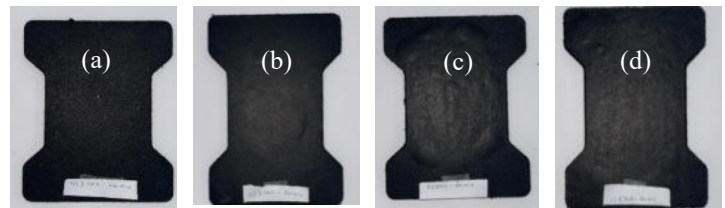


Fig. 6. The tiles are manufactured from recycled tires at a working temperature of 350 °C, and (a) 2 tons for 20 mins., (b) 3 tons for 20 mins., (c) 4 tons for a holding time of 60 mins., and (d) 5 tons for a holding time of 60 mins. temperature 350c

4. CONCLUSIONS

We successfully produce environmentally friendly products by applying green technologies in manufacturing, which resulted in the design, analysis, and manufacturing of a mold and an ejection system.

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Performance Enhancement of Cylindrical Solar Still by Water Spraying Unit and Air Bubble Injection

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Abstract: Solar stills, the most fundamental technology for harnessing solar energy for freshwater acquisition, utilizes a straightforward process. Sunlight directly evaporates fresh water from seawater or brackish water sources. This study investigated the potential for augmenting solar stills' productivity and thermal performance. To achieve this objective, a novel design, the cylindrical solar still (CYSS), was employed. The multi stages absorber serves the dual purpose of significantly increasing the surface area dedicated to evaporation while concurrently reducing the thickness of the brine layer. This innovative design resulted in a remarkable enhancement in freshwater production. The cylindrical SS generally exhibits a higher average temperature of glass compared to the conventional SS. This results from the significantly larger surface area of glass cover of the cylindrical SS (2.35 m²) compared to the conventional SS (0.61 m²). This difference translates to a 482% improve in the cylindrical SS surface area.

Keywords: desalination, solar energy, cylindrical solar still, Water Spray, air bubble.

1. INTRODUCTION

The scarcity of fresh water is a growing global challenge, particularly in arid and semi-arid regions [1]. Desalination technologies offer a promising solution to address this issue. Among them, solar stills present a sustainable and low-energy approach for water desalination, utilizing solar energy to evaporate saline water and condense the clean vapor.

However, conventional solar stills often suffer from limitations in efficiency. This research project aims to overcome these limitations by developing a novel prototype. The multi stages absorber surface area increases solar energy absorption compared to a flat plate, enhancing water evaporation rates.

This project investigates this innovative solar still prototype's design, fabrication, and performance evaluation. We anticipate that the cylindrical solar still shape with multi stages absorber will significantly improve water production compared to traditional solar stills. The successful development of this prototype could contribute significantly to advancing sustainable desalination technologies, particularly in regions with abundant solar resources and limited access to fresh water.

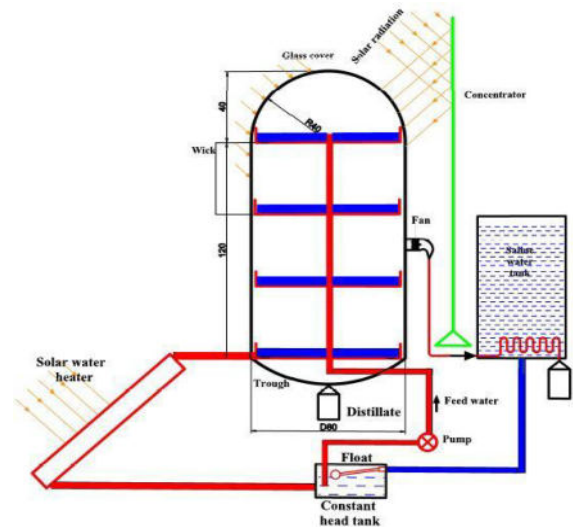
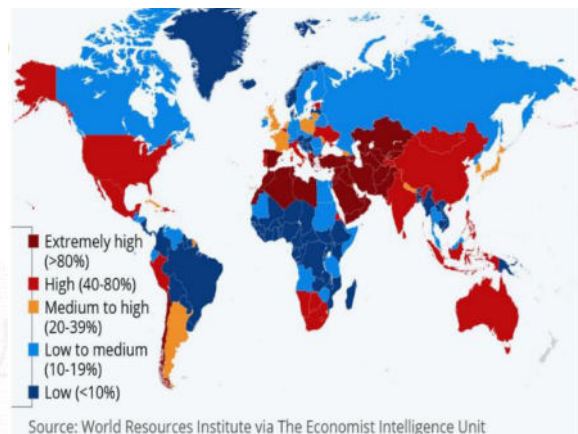


Figure 1. Schematic diagram of cylindrical solar still shape with multi stages absorber.

A growing number of people, urbanization, and economic development are the main factors contributing to the depletion of world water supplies and their increasing demand. By 2050, it is anticipated that the amount of water required globally for home consumption, power production, and manufacturing would rise by 406%, 144%, and 126%, respectively. The major sources of the world's water consumption in 2000 and 2050 are depicted in the graphic below, which is taken from the OECD publication "Environmental Outlook to 2050: The consequences of inaction".[2]



Source: World Resources Institute via The Economist Intelligence Unit

Figure 2: levels of water stress in different countries around the world [3].

Thus, the objectives of this project based on the above discussion are to investigate a compact solar design with a cylindrical solar still shape with multi stages absorber to significantly increase freshwater production, improve efficiency, and reduce heat loss.

2. MULTI STAGES ABSORBER DESIGN

The core component of this solar still is the multi stages absorber, which is crucial for desalination. This innovative design features a cylindrical-shape that significantly increases its surface area compared to traditional flat-plate absorbers. This expanded area effectively captures more incoming solar radiation, which is then transferred to the saline water within the basin. The chosen material for the absorber is cold-rolled steel, ensuring compatibility with the final design and offering superior advantages. This combination of increased surface area and optimal material selection maximizes sunlight absorption for efficient water evaporation.

3. A CYLINDRICAL-SHAPE SOLAR STILL

The meticulous fabrication of each component – the absorber, freshwater collection basin, and cylindrical polycarbonate cover– culminated in a final assembly stage meticulously integrated into a functional solar energy collection system. This process involved careful adherence to a pre-defined assembly plan to ensure proper alignment and secure attachment of each element. This rigorous approach ensured the cylindrical solar still shape with multi stages absorber system functioned optimally and delivered exceptional solar energy collection efficiency.

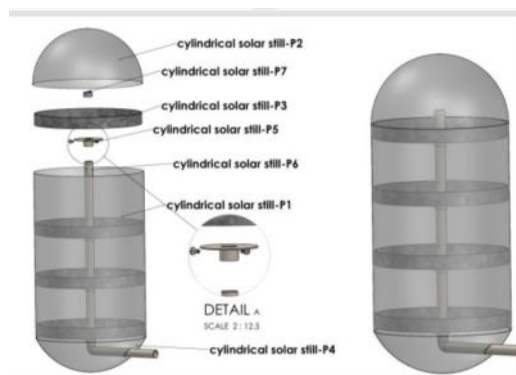


Fig. 3. cylindrical solar still shape with multi stages absorber design.

4. EXPERIMENTAL WORK

The experiment tested a new solar still design (CYSS) in a natural setting at the University of Prince Sattam (KSA) on May 2nd, 2025, from 8 AM to 9 PM. The focus was on how well the CYSS captured sunlight and produced freshwater compared to a traditional design (CSS) under identical conditions. Data on solar radiation, temperatures, and freshwater output was collected throughout the day. Fig. 4.

5. RESULTS AND DISCUSSION

The SS and multi-stage cylindrical SS are displayed in Fig. 5. The findings unequivocally show that, in terms of overall yield, cylindrical SS consistently outperformed conventional SS. The conventional SS reaches 470 mL/m²h at this peak, but

the cylindrical SS reaches a maximum yield of 1450 mL/m²h. Additionally, the traditional SS produced 3050 mL/m² every day, whereas the cylindrical SS produced 10600 mL/m². This corresponds to a noteworthy 248% increase in production that the cylindrical SS attained.



Fig. 4. Experiment Setup

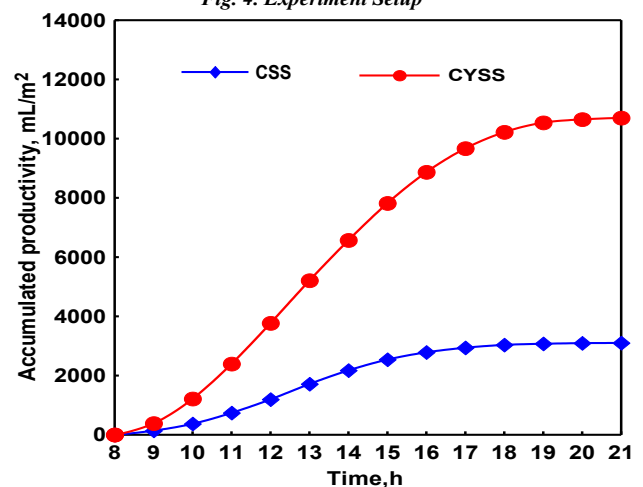


Fig. 6. Accumulated productivity conventional SS and multi-stage cylindrical SS.

CONCLUSIONS

Experiments with a cylindrical solar still shape with multi stages absorber (CYSS) showed impressive results. CYSS produced 248 % more fresh water than a conventional still, this configuration optimizes solar radiation utilization across the cylinder's longitudinal axis and hemispherical cover while reducing internal air volume by 36% relative to the CYSS without absorber chambers. The compact chamber design lowers thermal inertia, enabling faster heating of trapped air and enhancing vapor generation rates.

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Design and Fabrication of a diurnal radiative cooler

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Abstract: This project explores the design and fabrication of a diurnal radiative cooler, employing the principles of radiative cooling to achieve efficient thermal management. A comprehensive literature review was conducted to analyze the fundamental mechanisms and recent advancements in radiative cooling technologies, emphasizing the selection of materials and system configurations. Using energy balance equations, the project developed an optimized design with high solar reflectivity and thermal emissivity within the atmospheric transparency window (8–13 μm). The prototype incorporates advanced materials, such as the 3M Vikuiti ESR film, and was modeled using CAD software to enhance its performance. Experimental tests were conducted to evaluate the cooler's efficiency in controlled environments, comparing its performance with conventional cooling systems. This work aims to contribute to the development of sustainable cooling technologies for diverse applications, including residential, industrial, and agricultural sectors..

Keywords: radiative cooling, solar energy, thermal emission, passive cooling, optical materials.

1. INTRODUCTION

Radiative cooling is a passive cooling technique that utilizes the sky as a natural heat sink by emitting thermal radiation through the atmospheric window (8–13 μm) [1], allowing heat to escape into outer space without warming the atmosphere. This phenomenon has gained increasing attention due to the global demand for sustainable and energy-efficient solutions, particularly in the building sector. However, the effectiveness of radiative cooling is influenced by several factors, including material properties, device design, and environmental conditions. Despite a long history of research, much of the literature remains scattered, making it challenging to identify research gaps and practical advancements. This study presents a comprehensive investigation into radiative cooling systems, focusing on material selection, environmental variables, simulation techniques, and experimental prototypes. The goal of this work is to design and fabricate a diurnal radiative cooler, test the designed cooler under outdoor conditions, and propose and validate a CAD model.

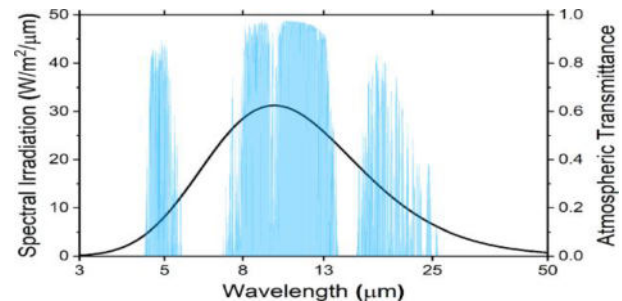


Fig. 1. The spectrum of a blackbody surface with a temperature 300K

2. PRINCIPLE OF RADIATIVE COOLING

Radiative cooling is a passive thermal management process where the Earth's surface emits infrared radiation directly into outer space, particularly within the 8–13 μm atmospheric transparency window. While traditionally limited to nighttime applications, recent innovations in nanophotonics and metamaterials have made it possible to achieve sub-ambient temperatures even during the day. The significant temperature gap between Earth (~300K) and the cosmic background (~2.7K) enables effective heat dissipation without energy input. Unlike conventional cooling systems that transfer heat to air or water, radiative cooling transfers energy directly to the cold sky, making it a sustainable and energy-free solution. This study highlights the core principles of radiative sky cooling, recent material advancements, and the influence of solar and atmospheric radiation on surface temperature regulation. [2]

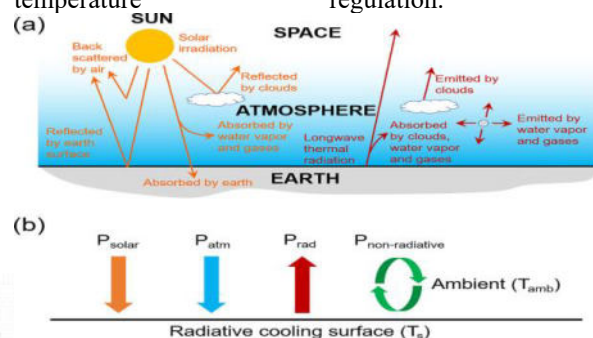


Fig. 2. Fundamentals of radiative sky cooling

3. SYSTEM CONFIGURATION AND MODELING

The diurnal radiative cooler was designed using thermal analysis based on the energy balance equation, considering solar input, radiative emission, and convective losses. Materials with high infrared emissivity and low solar absorptivity, such as 3M Vikuiti ESR film and polycarbonate—were selected to optimize performance. The prototype was modeled in CAD software and built using 3D-printed supports and layered materials. Design constraints like thermal conductivity, durability, and optical properties were addressed. CFD simulations were performed in ANSYS Fluent, using simplified geometry and structured meshing to optimize accuracy and speed. The model simulated heat transfer under varying solar and ambient conditions, enabling comparison with physical results.

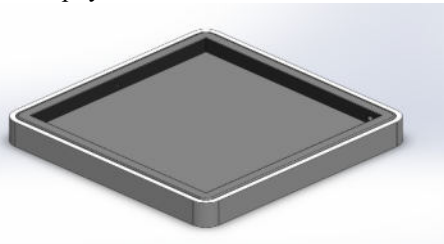


Fig. 3. CAD final design

This multi-layered prototype is designed to achieve sub-ambient cooling of the water layer through passive radiative cooling principles. Each component plays a specific role in enhancing heat dissipation while minimizing external thermal gain. The arrangement was optimized to support effective radiative emission under real-world environmental conditions.



Fig. 4. Material arrangement diagram

4. SYSTEM SCHEMATIC AND EXPERIMENTAL WORK

The system was built as a closed-loop setup including a 2L water tank, a submersible pump, PVC piping, and a radiative surface. Digital sensors and infrared thermometers were used to monitor temperatures during testing. Environmental data was obtained from NASA POWER to match real conditions.

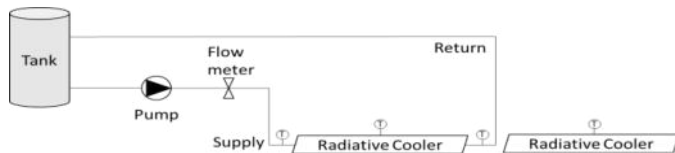


Fig. 5. System schematic illustration

5. MATHEMATICAL MODEL

An energy balance was performed on each layer of the radiative cooler:

$$\frac{(c_w m_w + c_p m_p) \partial T}{\partial t} = P_{rad} - P_{atm} - P_{solar} - P_{conv+cond}$$

Where:

$$P_{rad} = \epsilon_s \sigma T_s^4$$

$$P_{atm} = \epsilon_{sky} \sigma T_a^4$$

$$P_{solar} = \alpha_s I_{solar}$$

$$P_{conv+cond} = h(T_s - T_a)$$

5. RESULTS AND CONCLUSION

Experimental results confirmed the cooler's ability to maintain sub-ambient temperatures under high ambient conditions, with peaks reaching up to 42 °C. The static water setup achieved lower surface temperatures than the reference polycarbonate-only configuration. The temperature profile of the cooler is shown in Figure 6. Simulations closely matched the experimental results, though they slightly overestimated the surface temperature. Figure 7 shows that the simulated temperature of the water inside the cooler follows the experimental results with an error of less than 0.5 °C. However, a larger error was observed in predicting the surface temperature of the radiative cooler, with a maximum deviation of 2 °C, suggesting that a refined simulation model is needed. Future work will refine the CFD model and explore better materials with low solar absorptivity and high infrared emissivity.

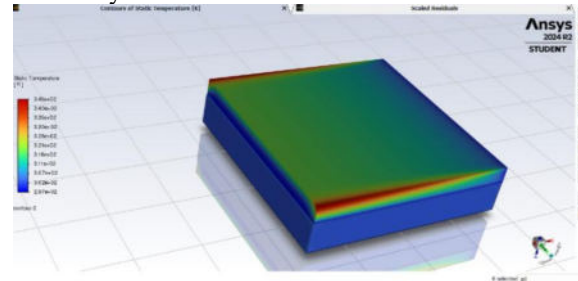
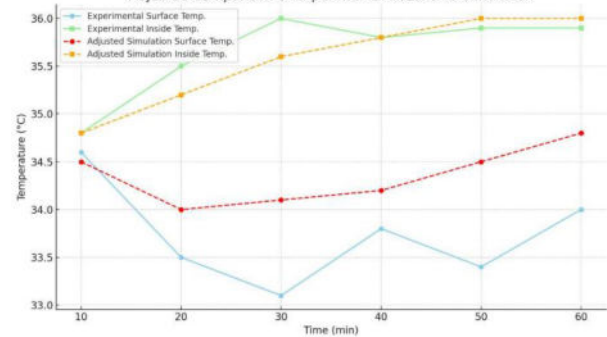


Fig. 6. Simulation temperature results

Fig. 7. Comparison between Experimental and simulation results



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Design and Development of Renewable Energy Actuated Car

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Abstract: This project focuses on the design and development of a renewable energy actuated car, a solar-powered unmanned ground vehicle (UGV) that integrates renewable energy systems with intelligent control and navigation capabilities. The project demonstrates how sustainable energy solutions can be applied in mobile robotic systems to achieve autonomous operation. The designed prototype uses solar panels, Li-ion batteries, Arduino-based control, and sensor modules for line following and obstacle avoidance. Aerodynamic simulation, fabrication, and programming stages were carried out to ensure performance and efficiency. The results confirm that renewable energy integration can enhance endurance and sustainability of robotic systems, aligning with Saudi Vision 2030 goals for green and smart technologies.

Keywords: Solar energy, Renewable energy vehicle, Unmanned ground vehicle (UGV).

1. INTRODUCTION

The global rise in energy demand, coupled with the depletion of fossil fuels and the adverse effects of greenhouse gas emissions, has intensified the need for sustainable and renewable energy solutions. Among various renewable sources, solar energy stands out as one of the most promising due to its abundance, reliability, and environmental friendliness. The Kingdom of Saudi Arabia, situated within the global “Sun Belt,” possesses one of the highest solar irradiance levels in the world—averaging more than 2,200 kWh/m² annually. This makes solar energy not only a viable alternative but also a strategic resource to support the nation’s energy diversification and sustainability goals under Vision 2030.

Harnessing solar power in engineering applications can significantly reduce carbon emissions and operational costs while promoting innovation in sustainable mobility. The Renewable Energy Actuated Car project aims to design and develop a solar-powered unmanned ground vehicle (UGV) that demonstrates the integration of clean energy with intelligent control systems. The vehicle is capable of autonomous movement using solar-charged batteries and sensors for navigation and obstacle avoidance.

This project aligns with Saudi Arabia’s commitment to transition toward a circular carbon economy by employing renewable technologies to achieve carbon neutrality and energy efficiency. By developing a small-scale, solar-powered robotic system, this research contributes to the advancement of green mobility technologies and provides a

model for future sustainable transportation systems suited for the climatic and geographical conditions of Saudi Arabia.

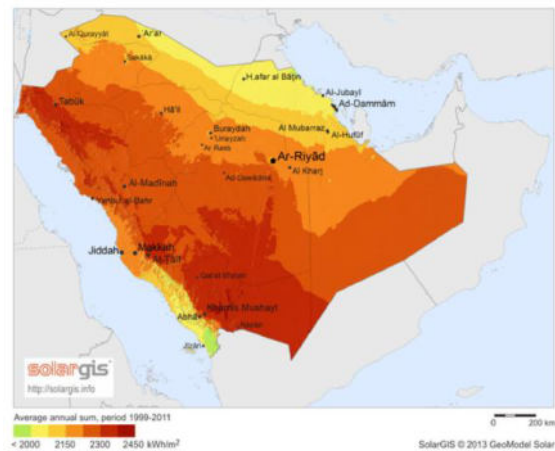


Fig. 1. Map of direct normal irradiation in Saudi Arabia (~2000-2450 kWh/m² yr) [1]

As shown in Fig 1, Saudi Arabia has very high solar-irradiation levels — with annual sums exceeding 2400 kWh/m² in many regions and daily averages up to ~6.7 kWh/m²/day — making solar energy a highly viable option for mobile and stationary renewable-energy systems in the Kingdom.

Thus, the objective of this project is to design and develop a solar-powered unmanned ground vehicle (UGV) utilizing renewable energy for sustainable and autonomous mobility by integration of mechanical, electrical, and control systems for efficient energy conversion and intelligent navigation using solar power.

2. EXPERIMENTAL WORK

The experimental work comprised materials selection, mechanical fabrication, electrical integration, and functional validation of the solar-powered unmanned ground vehicle (UGV). The platform employed a 6 V, 660 mA photovoltaic panel (≈170 mm × 170 mm), a 2-cell Li-ion pack (2 × 18650, nominal 7.4 V, 2000 mAh) with on-board USB-C charging, four TT DC gear motors, an Arduino R3 controller, an ESP32-CAM for vision, and ultrasonic plus IR obstacle sensors interfaced via a multi-port motor/sensor shield. Power sizing followed the report’s calculations: estimated solar output ≈5.08 W under full sun, battery energy ≈24 Wh, and traction demand established from friction and drag estimates at 3 km·h⁻¹.project.

2.1. Mechanical fabrication.

Mechanical fabrication used 2 mm aluminum-cladding sheets as upper/lower decks. Plates were dimensioned ($\approx 18.5 \text{ cm} \times 9.5 \text{ cm}$), laser-cut to ensure clean edges and repeatability, then deburred and mounted to a metal frame with machine screws and spacers to maintain stiffness and service access. Motors and battery were mounted on the lower deck; the shield, Arduino, ESP32-CAM, and sensors were arranged on the upper deck for cable discipline and airflow.



Fig. 2. Steps of Cutting plate.

2.2. Electrical integration.

The electrical integration connected the panel to the shield's SOLAR port for regulated charging of the Li-ion pack; motor channels were mapped and labeled; sensor trigger/echo and IR outputs were assigned to digital I/O; the ESP32-CAM was wired to its dedicated header with mode-switch considerations for sketch upload vs run. Fig. 3 shows the schematic representation of circuit diagram.

2.3. Software and test protocol.

Arduino IDE sketches implemented (i) line following (dual-IR feedback with differential motor duty) and (ii) obstacle avoidance (HC-SR04 range thresholding with stop/turn logic) were used. Complementary aerodynamic studies (SolidWorks Flow Simulation; ANSYS CFD snapshots) were used to visualize pressure/velocity fields and reason about body shaping, though mechanical implications were modest at the low operating speed. Overall, the integrated experiments verified energy harvesting, control robustness, and repeatable autonomous motion.

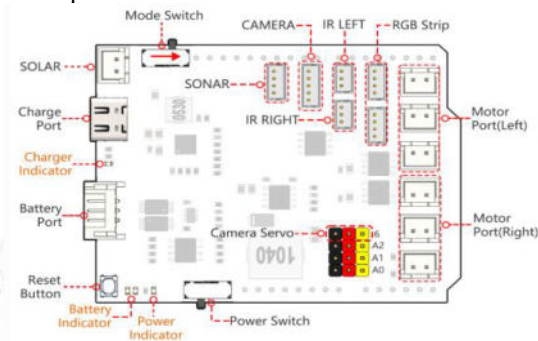
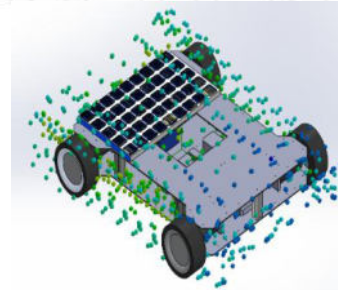


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Fig. 4. The design of the robot.

3. RESULTS AND DISCUSSION

The aerodynamic analysis revealed stable airflow distribution around the vehicle body, reducing drag and improving efficiency. The solar panel generated an average of 5.08 W under full sunlight, providing sufficient energy to sustain operation for approximately 2 hours. Fabrication involved cutting lightweight aluminum cladding panels with high precision using laser technology. Assembly was completed with a four-wheel drive system supported by a metal frame.



Programming enabled successful line-following and obstacle-avoidance functionalities during testing, validating the control system's reliability.

Fig. 5. Final prototype

4. CONCLUSIONS

The Renewable Energy Actuated Car demonstrates an effective integration of solar energy and autonomous robotics. Through systematic mechanical design, energy management, and control system programming, the vehicle achieved self-powered motion and autonomous navigation system.

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