**Design and Implementation of Battery-Operated Brush Cutter with Improved DC Motor Control System**

Abstract:

This research aims to contribute to the advancement of brush cutter technology and drive innovation in the agricultural and landscaping sectors. A rechargeable battery-operated brush cutter with DC motor control was proposed for efficient management of lawns, gardens and farmlands. The study involved the design, development, testing, and validation of the speed control system of the brush cutter. The work represents a significant advancement in lawn and farmland maintenance technology. It offered an environmentally friendly alternative to traditional gasoline-powered machines, which often contribute to noise pollution and greenhouse gas emissions. By utilizing a rechargeable battery and efficient Direct Current (DC) motor, the system design not only minimizes environmental impact but also enhances operational efficiency. The integration of speed control allowed users to adjust the cutting power based on specific needs, ensuring optimal performance across various terrains. Moreover, the ability to operate with reduced emissions and noise pollution makes the brush cutter particularly delightful. The study was successfully implemented as exemplified by the developed prototype that demonstrated satisfactory results in performance. This achievement underscored the effectiveness of leveraging locally sourced components and materials, which not only allowed for sustainability but also supported local economies. The design process emphasized reverse engineering, allowing for a deeper understanding of existing systems and facilitating the adaptation of proven technologies for broader societal benefit. Put differently, it allows for the dissection of existing technologies to identify their strengths and weaknesses, fostering iterative improvements that align with local needs. Finally, the successful prototype development underscored how integrating local materials with innovative design processes yielded significant advancements in sustainable technology application.

**Keywords:** DC Motor, Brush Cutter, Microcontroller, Speed Control, Battery Management

1. **Introduction**

Brush cutters are essential tools used for cutting dense vegetation, thick grass, weeds, undergrowth, and small trees in areas where a lawnmower or handheld grass trimmer may not be effective. It is commonly employed in landscaping, agriculture, forestry, and grounds maintenance for clearing and maintaining large areas with rough terrain. The design of brush cutters typically consists of a powerful engine mounted on a shaft with a cutting head at the end. The cutting head can be equipped with various types of cutting attachments, such as metal blades or nylon lines, depending on the vegetation being cleared.

Brush cutters are typically, powered by gasoline engines (2-stroke or 4-stroke) or electric motors. Gasoline-powered brush cutters are noisy and emit exhaust fumes but this is not the case with electric motors. The cutting head of a brush cutter rotates rapidly to cut through thick vegetation. It can be equipped with a blade for tackling dense brush and saplings or a nylon line for trimming grass and light vegetation. Presently, engine-operated brush cutters are well popular among farmers for various operations like paddy harvesting, grass cutting, etc (Arya & James, (2022). The portable harvester (brush cutter) developed for wheat worked satisfactorily with an average value of 1.23% for post-harvesting losses with the actual field capacity of 0.038 ha/h and the field efficiency was 62.99%. Many researchers are modifying the brush cutter ergonomically for multipurpose operations (Dhimate et al., 2024; Mali et al., 2022). Direct Current (DC) motors are power actuator which transforms electrical energy into mechanical energy. DC motor is widely used in many industrial applications where wide speed ranges are required. The variable speed control of DC motors is suitable for a wide range of applications which include brush cutter systems (Khillare, *et al,* 2020; Siddhartha, et al, 2018). DC motors are often preferred over other types of motors due to their precise speed control, which is crucial for industrial machinery. They can start, stop, and reverse instantly, providing essential control over the operation of production equipment. DC motor consists of two main components such as the stator, which remains stationary, and the rotor, or armature, which rotates. The speed at which a DC motor rotates is influenced by the interaction between the magnetic fields created by the stator stationary permanent magnets and the armature rotating electromagnets. By managing this interaction, the motor rotational speed can easily be controlled (Sachin *et al*, 2019; (Khillare, *et al,* 2020; Hariya, et al, 2017). Traditional brush cutters are often operated at a constant motor speed, regardless of the load or vegetation density, are energy inefficient, and have limited user control. Additionally, manual adjustment of motor speed can be inconvenient and unsafe during operation. To address these limitations, this research aims to design and develop a rechargeable battery-operated brush cutter with adjustable speed DC motor control for improved performance and energy efficiency. The successful implementation of a variable DC motor speed control system for a brush cutter has the potential to revolutionize cutting operations, offering improved efficiency, precision, and user control.

**2.0 Literature Review**

In recent years, the demand for sustainable energy solutions has surged, driven by industrial growth and an increasing reliance on electrical gadgets. Aponte et al. (2021) responded to this challenge by developing a grass-cutting machine that operates on both battery and solar energy. This innovative work not only addresses the environmental impact of traditional gas-powered mowers but also aligns with global efforts to reduce carbon footprints in daily activities such as lawn maintenance. Cutting grass traditionally necessitates significant human effort and time, often resulting in inconsistent grass lengths and uneven lawns. Bulski et al. (2021) emphasize the importance of developing an automated system that mitigates these challenges by utilizing a solar-powered lawn mower. This innovation not only reduces the labour required for lawn maintenance but also offers a sustainable solution through renewable energy sources.

The process of grass cutting, as explained by Baluprithviraj et al. (2021), is traditionally time-consuming and labour-intensive, primarily relying on manually operated diesel cutters. These conventional machines pose significant environmental concerns due to their reliance on non-renewable energy sources, which contribute to greenhouse gas emissions and exacerbate climate change. The operation of diesel-powered equipment not only pollutes the air but also generates noise pollution, adversely affecting both the health of operators and nearby residents. As highlighted in recent literature, there is a pressing need for more sustainable alternatives in agricultural practices. In response to these challenges, innovative solutions such as solar-powered automatic brush cutters have been developed. These modern devices provide an eco-friendly option that mitigates the adverse effects associated with diesel-operated machinery. The research conducted by Akinola, et al. (2019) underscores the critical role of agriculture in society, identifying it as the largest and most diverse sector demographic-wise. Agriculture not only sustains a significant portion of the population but also plays a pivotal role in contributing to national growth. This shift is essential for enhancing productivity and output across various agricultural practices. One of the innovative approaches discussed involves utilizing DC battery-powered systems for operational efficiency. These systems serve as reliable energy sources while enabling farmers to operate machinery in standby mode effectively.

The advancement of robotic technology has led to the development of innovative solutions for everyday tasks, such as lawn maintenance. Arunmozhiselvi et al. (2022) successfully introduced the Automated Lawn Brush Cutter Machine, a DC-powered robotic vehicle designed to cut grass with minimal human assistance. The integration of the microcontroller as the central processing unit is pivotal in controlling both the vehicle and lawn cutter motors, enhancing operational efficiency and reliability. One of the standout features of this machine is its use of an infrared (IR) sensor for obstacle detection. This technology allows the device to navigate complex environments while avoiding potential hazards, thus mitigating risks associated with traditional grass-cutting methods.

Meng and Ahmad (2018) assert that the Sun has been a critical source of energy for life on Earth since time immemorial. This perspective highlights the historical significance of solar energy, illustrating its early applications in everyday tasks such as drying clothes, curing agricultural produce, and preserving food. These practices underscore humanity's reliance on solar energy long before the advent of modern technology, indicating that our relationship with this renewable resource is deeply rooted in our survival and daily activities. Pai, et al. (2020) have made significant advancements in the design of lawn care technology through their innovative grass-cutting machine, which features tempered blades for enhanced durability and performance. This machine not only optimizes efficiency but also integrates computerized controls that allow for precision in operation. The dual functionality of being operable both manually and via computer increases its versatility, catering to various user preferences and operational contexts. The construction materials utilized in this design, such as GI sheet, aluminium sheet, motor components, wheels, switches, cables, and rectangular tubes, have been selected for their suitability in ensuring longevity and ease of use. The choice of these materials contributes to the overall robustness of the machine while maintaining a lightweight profile that facilitates manoeuvrability. Furthermore, incorporating inert materials minimizes wear and tear during operation.

The development of an IoT-based DC lawn mower, as proposed by Khemnar, et al (2020), represents a significant advancement in automated gardening technology. This innovative mower integrates Internet of Things (IoT) principles, connecting digital machines and users to enhance functionality and efficiency in lawn maintenance. By utilizing smartphones for control, the system aligns with contemporary user habits, enabling convenient operation from a distance. The programming framework is based on Arduino software, which facilitates ease of use and customization for various user needs. Moreover, the incorporation of ultrasonic sensors allows the mower to detect obstacles and navigate accordingly, employing DC motors to adjust its movement dynamically. This feature not only improves operational efficiency but also minimizes potential damage to both the equipment and the surrounding landscape. A critical aspect of this system is its reliance on solar energy sourced from integrated solar panels. This renewable energy solution ensures that the mower remains functional year-round, promoting sustainability while reducing dependence on fossil fuels.

The innovative work by Meng et al. (2020) presents a significant advancement in lawn care technology through the development of a DC-powered grass-cutting device. This machine incorporates tempered blades attached to a brush cutter, allowing for both manual and automatic operation. The materials utilized, including GI sheets, aluminium sheets, motors, wheels, transfer cords, and insulating components, emphasize practicality and accessibility in design. The integration of a rechargeable battery and various sensors enhances operational efficiency while ensuring safety during use. Furthermore, the device's solar-powered feature enables it to harness renewable energy effectively. The voltage generated by the solar panel is displayed on Dipin's LCD device, providing real-time feedback on power levels. Using Matlab programming alongside a digital camera positioned above the robot shape allows for precise robotic motions based on predetermined samples. This capability not only reduces human effort but also incorporates an object detection system that identifies both humans and obstacles in its path.

Sachin et al. (2019) successfully developed a solar-powered brush cutter machine that significantly reduces human labour and minimizes reliance on non-renewable energy sources. This innovative device harnesses solar energy by capturing sunlight, storing it in batteries, and utilizing it as needed for efficient operation. The implementation of adequate monitoring systems ensures that all features function according to schedule, thereby enhancing the machine's reliability and efficiency. The study exemplifies a growing trend toward sustainable technology solutions in agricultural practices. A unique aspect of Sachin et al.'s design is its protective system for the battery, which prevents excessive charging and prolongs battery life. This feature not only enhances the sustainability of the device but also underscores its suitability for gardening applications on a smaller scale.

The innovative design presented by Kumar et al. (2016) introduces a solar-powered, vision-based robotic lawn mower that significantly reduces human effort in maintaining lawns. This self-sufficient device distinguishes itself from traditional robotic mowers by eliminating the need for perimeter wires, allowing for greater flexibility and ease of use. Utilizing a 12V, 310mA solar panel comprised of 24 cells, the mower harnesses solar energy efficiently while employing a lead-acid rechargeable battery rated at 12V 1.2Ah to prevent overcharging. The integration of an array of sensors enables the robot to navigate autonomously, detecting obstacles and humans with precision while adapting its movement based on environmental feedback. Furthermore, the design incorporates infrared sensors paired with a 555 IC circuit to facilitate boundary detection and obstacle avoidance. This technology allows the mower to manoeuvre seamlessly within garden spaces while responding dynamically to its surroundings. The proposed mower represents a significant advancement in automated gardening solutions that align with contemporary ecological values (Patil & Patil, 2017).

Akinola et al. (2019) developed an advanced automated sun brush cutter that integrates several innovative features aimed at improving the efficiency of lawn maintenance. This device is powered by a combination of a rechargeable battery and a solar panel, which are strategically positioned on top to mitigate power issues commonly associated with robotic devices. The automation capabilities include self-docking and rain sensors, significantly reducing the need for human intervention in lawn care tasks. The operational mechanism of this automated mower relies on infrared sensors that differentiate between cut and uncut grass. Once activated in automatic mode, it systematically executes its cutting routine until completion. To enhance functionality further, Akinola et al.'s design incorporates an 8051 microcontroller that manages all vehicle operations while interfacing with ultrasonic sensors to detect obstacles. This ensures that if any impediment is encountered, the brush cutter motor halts immediately, thus safeguarding both the equipment and nearby entities from potential harm (Sujendran and Vanitha,2020).

Ismail et al. (2019) have successfully introduced a solar-powered battery brush cutter designed for efficient grass-cutting in various environments, including gardens and school fields. The growing emphasis on sustainable energy solutions makes such innovations particularly relevant today, as power consumption continues to be a critical concern for the future. This device not only reduces reliance on traditional fossil fuels but also minimizes environmental impact by harnessing solar energy (Sorvig, et al, 2018). The design improvements made to this machine contribute significantly to its user-friendliness and safety. Even individuals lacking technical expertise can operate the solar-powered brush cutter with ease, ensuring a well-maintained lawn appearance without undue risk. The versatility of this tool further enhances its practicality; it can serve various applications beyond gardening, making it an essential asset in promoting eco-friendly practices in landscaping and agricultural maintenance (Penchant, et al, 2021).

The evolution of lawn mowing technology has seen significant advancements, particularly highlighted by the work of Ulhe et al. (2016), who introduced a hand brush cutter equipped with spiral roller blades designed to enhance slicing efficiency. This innovative mower features a height-adjustable loop trimming element, allowing for versatility in cutting various grass types uniformly. Such developments reflect a growing emphasis on efficiency and adaptability in landscaping tools. The operation of these early machines often required workers to have prior experience with large animal-drawn devices, indicating the transitional nature of agricultural practices during this period. The innovative design of a battery brush cutter by Dong et al. (2018) integrates a linear blade mechanism with a scotch yoke, enhancing efficiency in cutting applications. This configuration allows the cutter to convert rotational motion into linear movement effectively, thereby optimizing the cutting process and reducing energy consumption. The incorporation of this mechanism not only improves performance but also offers a more compact design compared to traditional cutters, making it suitable for various landscaping tasks. Furthermore, the integration of photovoltaic (PV) panels installed at a 45-degree angle serves as an essential feature in this design. By harnessing solar energy, these panels provide an eco-friendly power source that complements the lithium-ion battery used in the cutter. This combination ensures that users can operate the device sustainably while minimizing reliance on fossil fuels.

The development of automated lawn maintenance technology has gained momentum, particularly with innovations such as the fully automated DC-powered brush cutter designed by Bulskiet et al. (2018). This system utilizes battery energy sourced from solar panels to operate a robotic mover that effectively performs grass-cutting without human intervention. The integration of 10V batteries not only powers the movement motors but also drives the brush cutter motor, making it an energy-efficient alternative to traditional gas-powered mowers. Moreover, the proposed system design emphasized obstacle avoidance capabilities, which enhance operational safety and efficiency. This feature is crucial in ensuring that the robotic mower can navigate various terrains without risking damage to itself or surrounding objects. In a notable study, Pai et al. (2017) successfully determined that the sound produced by brush cutter machines significantly contributes to noise pollution. Their investigation into the acoustic output of these machines highlights the adverse effects of such noise on both human health and environmental quality. The findings underscore the necessity for innovative solutions aimed at mitigating this sound while effectively managing vegetation in fields and on various terrains. Given that traditional motor-operated equipment is a source of both auditory and environmental pollution, it is imperative to consider alternatives that align with sustainable practices. One viable solution is to transition towards electric lawnmowers, which generate considerably less noise compared to their gas-powered counterparts. Electric mowers not only operate more quietly but also reduce air pollution associated with gasoline engines, thus promoting a healthier ecosystem (Kaufmann, et al., 2021).

The advancement of technology in agriculture is crucial for enhancing efficiency and sustainability. Niazi et al. (2019) highlight the need for environmentally friendly grass-cutting machines, which can be further innovated to serve agricultural purposes effectively. A promising direction would be the development of a smart solar-powered grass-cutting robot. This robot utilizes solar energy, significantly reducing reliance on fossil fuels and minimizing environmental pollution while offering a cost-effective solution for crop harvesting. Unlike conventional brush cutters that face restrictions on cutting height, this robotic system can be designed to adapt to various crop types and field conditions. The design proposed by Akinyemi & Damilare, (2020) for an automatic DC grass-cutting machine embodies a significant advancement in agricultural technology. This innovative prototype is not only remotely controlled but also incorporates the ability to charge its batteries while operating, utilizing solar power during daylight hours. Such features underscore the growing trend towards sustainable practices in agriculture, as they leverage renewable energy sources, thereby reducing reliance on fossil fuels (Thangavel et al., 2024).

Revi et al., (2016) introduced an innovative programmable robot designed for lawn care, which operates autonomously or via wireless control using an Android smartphone. This dual-functionality enhances user convenience and safety, allowing operators to manage the robot from a distance through Bluetooth technology. The brush cutter's ability to create pre-set shapes while adjusting blade height for varying grass lengths exemplifies its versatility and precision in landscaping. The innovative work of Smith et al. (2012) in designing and fabricating a DC-powered brush cutter with an integrated water-spraying system represents a significant advancement in gardening technology. This dual-function device utilizes RF technology to operate both grass-cutting and water-spraying applications simultaneously, thereby minimizing the need for manual labour while enhancing efficiency. The implications of this development are profound, particularly in light of the increasing global electricity demand driven by commercial growth and the proliferation of electrical devices. As urbanization continues to rise, so does the strain on electrical resources, leading to heightened environmental concerns regarding pollution and energy consumption. Smith et al.'s brush cutter addresses these issues by employing a DC power source that not only reduces electricity usage but also mitigates pollution associated with traditional gardening equipment (Chi, 2012).

**3.0 Methodology**

A variable control architecture is developed that interfaces with the DC motor and is embedded in the brush cutter's control system. Appropriate components, such as microcontrollers, motor drivers, sensors, and user interfaces were selected for the hardware implementation. Software Program was developed to execute the speed control algorithm, user interface, and feedback mechanisms for seamless operation and user interaction. Finally, rigorous testing of the performance of the brush cutter was conducted in controlled environments and field tests to validate system performance.

This work is motivated to design and fabricate an automatic brush cutter machine-based DC motor speed control using a microcontroller. Moreover, the circuit would be capable of generating a pulse width modulation (PWM) signal to regulate motor speed. By triggering interrupt signals to the microcontroller through push buttons, identified as up- and down-buttons in the circuit, the DC motor speed can be increased or decreased. The variations in motor speed would be monitored using a tachometer attached to the motor shaft, and the results matched our expectations.

The feedback control system block diagram for the adjustment of DC motor speed is presented in Figure 3.1 below. The desired speed of DC would be set to 1500rpm at 415VAC on Load and No Load. The input part of the system includes the setting of the desired speed valuer. The rotational speed of DC in revolutions per minute (rpm) would be determined by the adjustment of the applied voltage in order to achieve the desired speed. The feedback control measured actual speed and compared it with the desired motor speed until they were equal.



FIG 1 Feedback control for adjustment of DC motor speed.

The circuit diagram shown in Figure 2 depicts the DC motor speed control using the ATMEGA 328P microcontroller. The whole assembly is composed of three main units namely; the power source with its power-on reset switch sub-unit, the main circuit (control unit) which obtains signals through the interrupt input switches, and the switching unit, incorporating the interrupt input switches and the switching power transistor for the DC motor.

The power supply to the circuit assembly is made up of a transformer labelled TRF which steps down, the mains 220 V alternating current, AC to deliver a secondary output of 12 V, 500 mA output which is further processed for delivery to relevant components. This the transformer secondary voltage is rectified by a full-wave bridge rectifier circuit made up of four IN4001 diodes labelled D1, D2, D3 and D4, filtered by a 1000μF, 25 V electrolytic capacitor, labelled C1. The circuit regulator is a 7805, 5 V, integrated circuit IC, labelled IC1 in the circuit diagram. This acts as a power-on reset for the ATMEGA 328P microcontroller. From the output terminal of IC1, 0.1μF capacitor labelled C2 is connected in series, which serves as a filter for the output from IC1. Across C2 is connected to a 330Ω resistor labelled R1 which regulates the current passing to the LED1. Switch, S1 serves as the power-on-off for the circuit providing a manual control from this power supply unit, the connection was made to the main circuit via switch S2. The oscillator circuit served to generate a pulse width modulation signal and connected to the 8-bit microcontroller, ATMEGA 328P labelled IC2, and its control algorithm was programmed using the ARDUINO C++ program.

From the power supply pin, (1 of the microcontroller) connection is made to the power source using a 10 KΩ resistor, labelled R2, in series as a current limiter. Inputs to the appropriate pins of this microcontroller are made as shown in Figure 2. The actuating signal from the microcontroller was used to drive 16 × 2 liquid crystal display, LCD which serves as a user interface, having a total of 32 characters (16 on each line).



Figure 2: Circuit Diagram of DC Motor Speed Control Using ATMEGA 328P Microcontroller

Figure 3. shows the functional block diagram of the proposed system depicting the different components of the system from the input power supply, power electronics circuit, battery management, input and output of the feedback control component that drives the DC motor of the brush cutter.

Figure 3.: Block diagram of an Adjustable DC Motor Speed Control System

The battery management system and power electronics block illustrate the functions of the battery charger, rectifier circuit, battery bank and voltage regulation of the system. In the battery-operated brush cutter, the Battery Management System (BMS) oversees the health and performance of the battery bank. It monitors key parameters such as voltage, current, and temperature to ensure the battery operates within safe limits. The BMS prevents overcharging, over-discharging, short circuit, overheating, and excessive current draw, which can damage the battery or reduce its lifespan. Besides, providing real-time data to the microcontroller, the BMS helps manage power consumption efficiently, ensuring reliable operation of the brush cutter machine. Additionally, it monitors and detects when the battery needs recharging or replacement, contributing to overall system safety and performance. The BMS plays a critical role in extending battery life, maintaining operational efficiency, and ensuring the brush cutter performs effectively throughout its runtime.

The microcontroller, on the other hand, serves as the central processing unit, driving the device’s operations and ensuring efficient performance. It processes input from various sensors, such as the current sensor and then actuates appropriate action. By interpreting these inputs, the microcontroller makes real-time decisions about the cutter’s actions. The microcontroller generates Pulse Width Modulation (PWM) signals to regulate the DC motor's speed, which controls the cutting performance. It adjusts the motor speed based on the load, cutting conditions, and user settings to ensure efficient grass-cutting. Additionally, it interfaces with the input button to control the brush cutter’s start/stop functions and select different operational modes. It also monitors the battery management system, tracking battery voltage, current, and state of charge. This data helps in optimizing power consumption and ensuring the device operates within safe limits. The microcontroller’s role in processing sensor data, controlling motor speed, and managing power usage makes it essential for the brush cutter’s automation, efficiency, and reliability, ultimately enhancing the user experience and performance of the device.

A battery charger, also known as a recharger or simply a charger, is a device that stores energy in an electric battery by passing current through it. The charging process including voltage levels, current rates, duration, and procedures for completion varies based on the battery's size and type. Some batteries can tolerate overcharging once fully charged and may be recharged using either a constant voltage or constant current source, depending on their specific requirements. In an automatic brush cutter speed control, the battery charger replenishes the battery bank's energy after use. It converts AC power from a wall outlet or another power source into DC power suitable for the battery at the rate of 24V to 25V. The charger regulates the charging voltage and current to ensure safe and efficient recharging, preventing overcharging which can damage the battery or reduce its lifespan and also depends on the total number of batteries connected in parallel. It typically includes features such as automatic cut-off to stop charging when the battery reaches full capacity and monitoring systems to ensure correct charging parameters. By maintaining optimal charge levels, the battery charger ensures that the brush cutter remains operational and performs effectively for subsequent use. It helps maximize battery life by providing controlled and accurate charging and ensures the brush cutter is ready for operation when needed, enhancing the reliability and efficiency of the cutting system. The circuit diagram is shown in Figure 4.



Figure 4: Detailed circuit diagram of the proposed system.

The hardware system implementation of the proposed system involved the integration of various components to enable automatic speed control of the brush cutter's motor based on different cutting conditions. A suitable microcontroller unit (MCU) that can efficiently process speed control algorithms and interface with the motor driver and sensors was selected. The Atmega 386P was used. The motor driver that can handle the power requirements of the brush cutter's motor was also selected. The motor driver will receive control signals from the MCU and regulate the motor's speed accordingly. Speed sensors to provide feedback on the motor's speed were also integrated. The user interface for adjusting the desired speed settings was embedded in the system. A stable and adequate power supply scheme for the MCU, motor driver, sensors, and dc motor was also implemented. This was followed by the implementation of control algorithms on the MCU to regulate the speed of the brush cutter's motor based on input from the speed sensors and user settings. Safety features such as emergency stop buttons, overcurrent protection, and motor stall detection to ensure the safe operation of the brush cutter and prevent accidents were also incorporated. To ensure that the hardware components are securely housed in an enclosure to protect them from environmental factors such as dust, moisture, and vibration, proper mounting of the components on the brush cutter was done for reliable operation. A printed circuit board (PCB) was used to provide mechanical support and electrical connections for electronic components through conductive pathways etched from copper sheets onto a nonconductive board for the automatic brush cutter machine system.

**4.0 RESULT AND DISCUSSION**

The testing of the DC speed-controlled brush cutter with a microcontroller on different types of grass provided valuable insights into its performance characteristics and effectiveness in real-world cutting applications. The results of this testing informed further refinements to the brush cutter system to enhance its efficiency. A variety of grass types commonly encountered in landscaping and grounds maintenance, including but not limited to tall grass, thick grass, weeds, and fine grass were identified. A controlled testing environment that simulated typical cutting conditions, ensuring that each grass type is represented in separate test areas selected. The speed control system of the brush cutter was calibrated using the microcontroller to ensure accurate speed adjustments based on the grass type being cut. Performance metrics for evaluation were defined as cutting speed, cutting precision, and energy consumption. Tests at varying speed settings to determine the optimal speed for each grass type were carried out. Overall, the test results were satisfactory.

**5.0 Conclusion**

In conclusion, the presented battery-operated automatic brush cutters equipped with DC motor speed control represent a significant advancement in lawn and farmland maintenance technology. These devices offer an environmentally friendly alternative to traditional gas-powered equipment, which often contributes to noise pollution and greenhouse gas emissions. By utilizing rechargeable batteries and efficient DC motors, these brush cutters not only minimize environmental impact but also enhance operational efficiency. The integration of speed control allows users to adjust the cutting power based on specific needs, ensuring optimal performance across various terrains. Moreover, the ability to operate silently and with reduced emissions makes these brush cutters particularly suitable for residential areas and sensitive environments where traditional machinery may be disruptive.

The study has been successfully designed and developed, exemplified by a prototype module that demonstrates satisfactory results. This achievement underscores the effectiveness of leveraging locally sourced components and materials, which not only enhances sustainability but also supports local economies. The design process emphasized reverse engineering, allowing for a deeper understanding of existing systems and facilitating the adaptation of proven technologies for broader societal benefit. Moreover, reverse engineering serves as a crucial mechanism for sustainable technology diffusion within society. It allows innovators to dissect existing technologies to identify their strengths and weaknesses, fostering iterative improvements that align with local needs. As such, this approach not only accelerates technological adoption but also encourages knowledge transfer among communities. Ultimately, the successful prototype illustrates how integrating local materials with innovative design processes can yield significant advancements in sustainable technology application.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Authors hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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