International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 10 Issue 3 March - 2026, Pages: 20-25

Performance Evaluation of a Battery-Electric Propulsion System of a Locally Fabricated Small Boat

Robert Poku, Ernest Appresai, Favour Chinomso Onyia, Emmanuel Malachi Daniel, Abraham Mugan Warri, Hope Love Roya, & Oyinkepreye Lucky Bebeteidoh

Department of Marine and Offshore Engineering, Niger Delta University, Nigeria
Corresponding Author: engrpreye@ndu.edu.ng

Abstract: *The increasing environmental impacts associated with conventional propulsion systems utilizing fuel-based energy sources have created the need for cleaner and more sustainable alternatives for small boats. This research presents the design, fabrication, and experimental evaluation of a battery-electric propulsion system for a small wooden boat intended for inland waterway applications. Materials used for the boat fabrication were sourced locally. The propulsion system comprised a 60W AC motor, powered by a 12 V, 90 Ah sealed lead-acid battery through a 500 W inverter and capacitor arrangement. The design was validated in a river in order to assess the performance, battery discharge behavior, power consumption, stability, and operational characteristics. The results showed that the boat achieved a steady speed of approximately 5.5–5.6 knots with only a small fraction of the available battery energy. The findings demonstrate that battery-electric propulsion is technically feasible for small boats operating at low speeds and offers significant advantages in terms of environmental sustainability, noise reduction, and operational simplicity.*

Keywords: Batteries, electric, performance, propulsion system, small boat.

1.0 Introduction

Report by the International Maritime Organization (IMO) shows that in 2018, the global anthropogenic emissions from the shipping industries increased from 2.76% to 2.89% [1], [2], signifying an upward trend in emissions. In fact, studies have shown that the highest share of this emission comes from ships that uses the conventional fossil-fuel-based propulsion system [3], [4]. In response to growing demands to decarbonize the maritime transportation sector and improve energy utilization efficiency [5], the IMO has implemented tougher emissions regulation, aiming to mitigate emissions from ships by at least 50% by 2050 [4], [6]. As a solution to providing efficient and low source of environmental pollution, many shipping companies are focusing on research in the direction of environmentally clean propulsion systems [7], [5] for maritime vessels.

As against the conventional propulsion drives, the electric propulsion system uses a more efficient system that derives its energy directly from diesel generator sets, gas turbine generator sets, batteries, fuel cells, or hybrid arrangement through an electric motor [8], [9]. This type of propulsion system has many advantages. First, it reduces the transmission device as it converts the mechanical energy of the prime mover into electric energy and uses it to directly drive the propeller [10] and second, it contributes significantly to the reduction of fuel consumption and air pollution [11], [12], [7].

A number of researchers have demonstrated the feasibility of electric propulsion drives for small craft, particularly at low to moderate speeds [13], in naval vessels [9], in cruise ships [10]. Larsson and Raven [14] highlighted that electric motors provide superior controllability and efficiency at low speeds compared to internal combustion engines. Molland et al. [15] emphasized the environmental and acoustic benefits of electric propulsion in sensitive waterways.

Although, the battery-electric propulsion system is fraught with challenges such as high battery cost, limited battery energy density [16] and river electromobility problem in respect to charging infrastructure [11], it offers a viable alternative and distinct advantages due to its high torque at low speeds, low noise, zero operational emissions [17], [10] and compatibility with renewable energy sources [18]. Recent experimental works by Kim et al. [19] and Choi et al. [20] further confirmed that battery-powered boats can achieve acceptable endurance and speed when properly matched with hull resistance characteristics.

Lithium ion and lead acid batteries are the two types of battery widely used in power applications. Recent developments in lithium-ion battery technologies, inverter efficiency, and motor control strategies have significantly improved performance reliability and energy conversion efficiency, thereby enhancing the feasibility of electric propulsion in small craft applications [16], [9]. In spite of the superior energy density and longer life cycle of lithium-based battery, lead-acid batteries continue to be widely adopted due to their lower initial and maintenance costs, rechargeable capabilities, availability in developing regions and the ease of installation [21]. Lead-acid batteries are presently used as the main propulsion and auxiliary power sources for submersible vehicles [22], [23].

The aim of this research is to evaluate the performance of an environmentally friendly boat propulsion system suitable for coastal and inland water application. To achieve this, a prototype of a small boat using a battery-electric propulsion system was designed and fabricated. All materials for the fabrication of the boats were sourced locally and the boat was test run in a river to ensure it performs safely and according to specification.

2.0 Materials and Methods

2.1 Boat specifications

A miniature wooden-hull boat designed for inland water operation was constructed with specifications as in the table 1 and instrumented as shown in Figure 1.

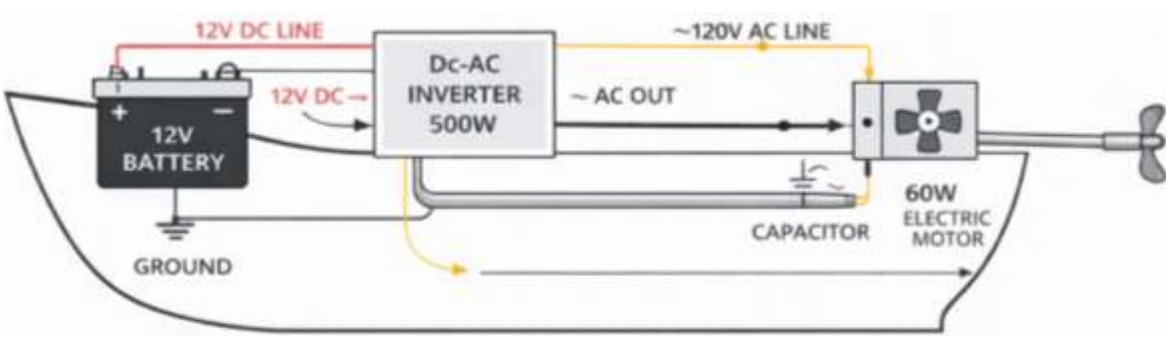
Table 1: Boat Specifications

Parameter	Symbol	Value
|Length Overall	L	1.83m
Beam	B	0.61 m
Draft	T	0.18 m
Freeboard height	-	0.10 – 0.16 m
Block coefficient	C_b	0.45
Material	-	Wooden planks with aluminum edge sealing
Motor	-	60 W, 1325 rpm, 5o Hz
Battery	-	12 V, 90 Ah (lead-Acid)
Inverter	-	500 W DC - AC
Expected Speed	-	1.5 knots

Figure 1: Schematic overview of the electric propulsion system of a small boat.

2.2. Boat Instrumentation

The hull was fabricated from wooden planks with aluminum edge sealing for waterproofing. Hydrostatic and hydrodynamic calculations were performed to estimate displacement volume, buoyancy force, resistance, power requirement, endurance, and range. Archimedes' principle was used to determine buoyancy. The fabricated wooden hull model constructed for this study has the dimensions as shown in table 1. The buoyancy of the hull was analysed with Archimedes' principle as in equation 1:



$$F_b = \rho \times g \times V_{disp} \quad (1)$$

Where:

F_b = buoyant force (N)

ρ = density of water (kg/m³)

g = gravitational acceleration (9.81 m/s²)

V_{disp} = volume of displaced water (m³)

The volume of displaced water was calculated as:

$$V_{disp} = \frac{W_{total}}{\rho} \quad (2)$$

Where:

$$\text{The the total weight } (\mathrm{W_{total}}) = \text{weight of boat, battery, motor, inverter}$$

The total weight was determined by placing the boat and its components such as the battery, motor, inverter and shafting system on a 150kg Camry electronic digital platform weighing scale. An additional load capacity of the boat which represents the weight of one operator and an additional load was estimated as:

$$W_{load} = \rho\left(LBTC_b - V_{disp}\right) \quad 3$$

Where:
W_{load}: is an additional load capacity
The propulsion system comprised a power generation system, power distribution system, a propulsion motor, propeller and control system. This study employed a 60 W AC electric motor that was powered by a 12 V, 90 Ah sealed lead-acid battery through a 500 W DC–AC inverter. A capacitor was connected between the inverter and motor to improve voltage stability and assist during motor startup. Battery endurance was estimated from available energy and motor power, accounting for system efficiency losses due to the inverter, motor, and propeller.
Endurance was determined by dividing available battery energy by the motor power as in equation 4:

$$Endurance = \frac{E_{battery}}{P_{motor}} \quad 4$$

In practice, considering 60 – 70% system efficiency (motor, inverter, propeller shaft losses), the endurance is calculated from:

$$Endurance_{\ real} = Endurance \times 0.68 \quad 5$$

The distance the boat could cover at 1.5 knot speed considered for the design is calculated from:

$$Range = Speed \times Endurance_{real} \quad (nautical\ miles) \quad 6$$

The energy consumption per nautical mile is:

$$Energy_{consumption} = \frac{E_{battery}}{Range} \quad 7$$

During the test, the boat carried an operator of 87 kg and an additional load of 60 kg. The vessel was allowed to accelerate for approximately two minutes before steady-state observations were recorded. Throughout the period of the experiment, the speed, test duration, and battery voltage were monitored.

2.3 Performance Testing and Data Acquisition

Testing was planned in two stages. Shore-based trials were conducted to confirm the efficiency of the wiring system, inverter, and the motor. This included running the motor without load to evaluate speed and torque response. Thereafter, water trials were performed to assess real-world performance. Performance parameters evaluated included the boat speed, endurance, thrust, noise level, and energy consumption. The speed was measured using a stopwatch and GPS and the thrust was assessed with a spring balance attached to the hull during the motor operation. Energy efficiency was calculated by measuring the battery voltage drop and operating duration. Noise reduction was assessed using a decibel meter, comparing the results to conventional small petrol outboard engines.

3.0 Results and Discussion

3.1 Speed Performance

Figure 2 shows the performance of the electric boat with respect to time for the period the boat was subjected to trial in the river. This was done to verify the functionality and performance of the boat. As it can be observed, the boat achieved a steady cruising speed of approximately 5.5–5.6 knots after the initial and rapid acceleration. This rapid acceleration is caused by instant torque being a feature of an electric propulsion system. The speed of the boat remained relatively stable for most of the test duration, with a slight decline toward the end due to battery voltage reduction. This drop in speed performance with time can be explained by the low energy density of the battery which became more pronounced as the speed increases. This performance confirms the high initial torque characteristic of electric propulsion systems reported in earlier study by Larsson and Raven [14].

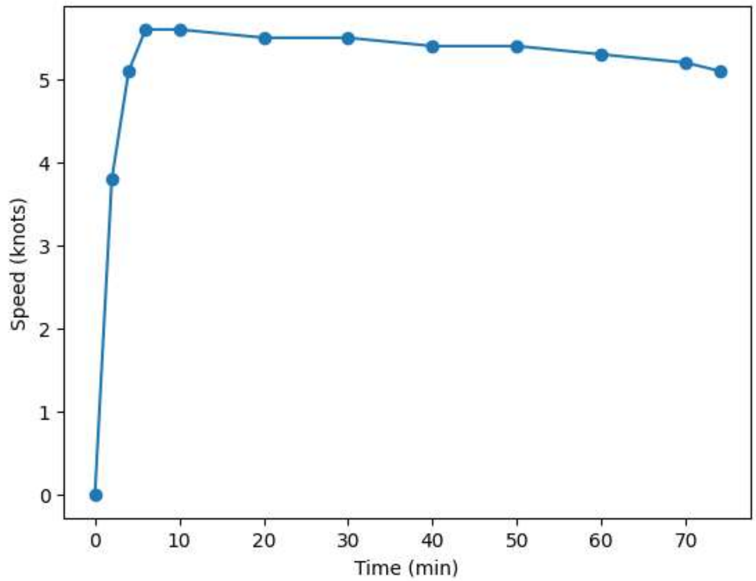


Figure 2: Boat speed performance against time for the test duration.

3.2 Battery Discharge Behavior

Battery voltage decreased gradually from 12.6 V at the start of the test to approximately 11.5 V at shutdown, indicating controlled discharge well within safe operating limits for lead-acid batteries. The smooth discharge profile agrees with observations by Linden and Reddy [24], confirming effective electrical system integration.

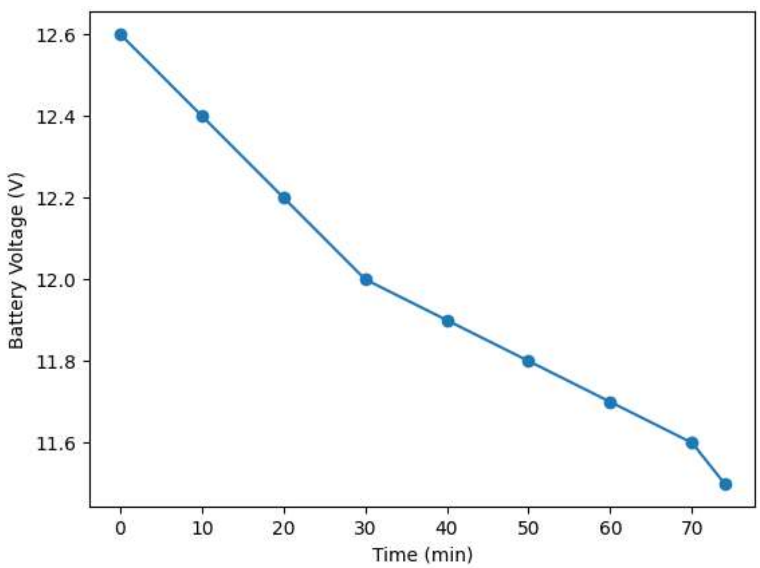


Figure 3: Battery Voltage versus Time

3.3 Power Consumption and Energy Utilization

Figure 3 represents the power consumption of the propulsion system with time. The average power consumption during the test was estimated as 60 W. Over a test duration of 1.23 hours, total energy consumption was estimated at 74 Wh, and this represents less than 7% of the available battery capacity.

International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 10 Issue 3 March - 2026, Pages: 20-25

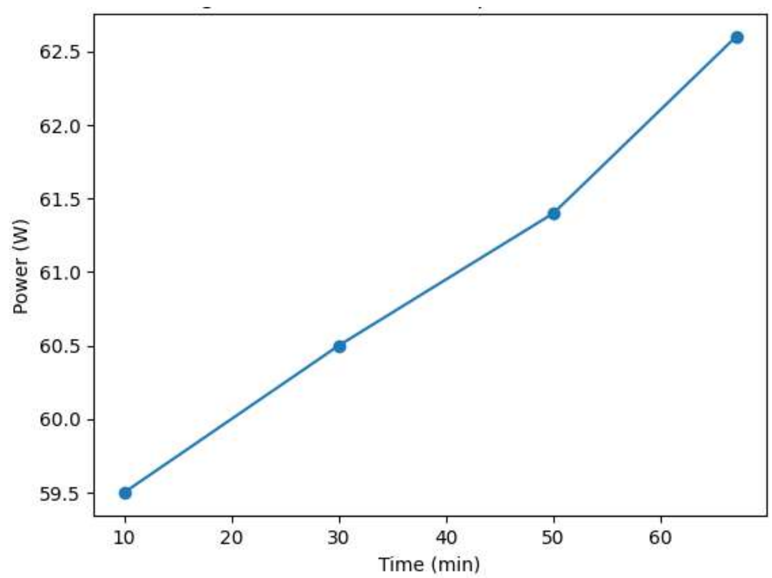


Figure 4 Power Consumption versus Time

3.4 Thrust and Propulsive Efficiency

Figure 4 shows the effect of power on thrust. The estimated thrust and power analysis yielded a propulsive efficiency of approximately 1%. Although low compared to full-scale vessels, this value is consistent with prototype-scale experiments where motors and propellers are not optimally matched. Similar scale-related efficiency limitations have been reported by Carlton [25].

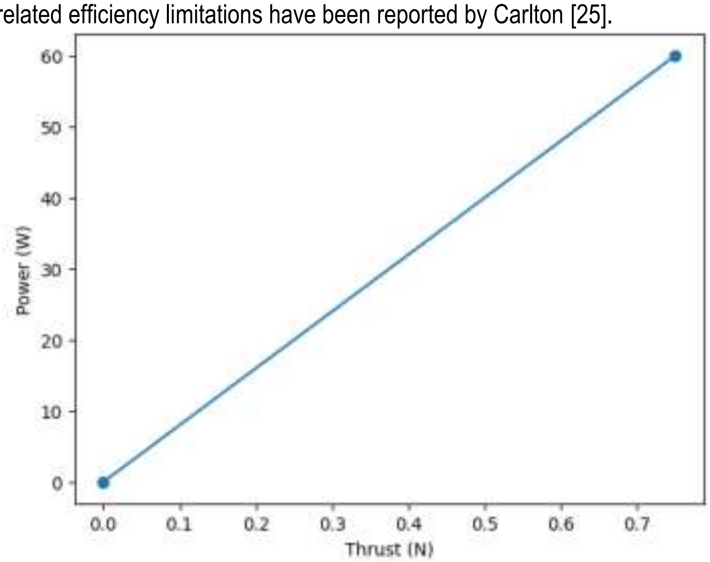


Figure 5: Power versus Thrust Relationship

3.5 Stability, Noise, and Operational Observations

Minor tilting was observed when the operator boarded the vessel. However, the boat stabilized quickly once in motion. Noise and vibration levels were very low, confirming one of the major advantages of electric propulsion for inland waterways.

These observations align with findings by Molland et al. [15] regarding reduced acoustic impact of electric boats.

Conclusion

This study successfully demonstrated the design, fabrication, and experimental evaluation of a small-scale battery-electric propulsion system for inland watercraft. River trials results of the boat and propulsion system showed stable speed performance, predictable battery discharge behavior, low noise emission, and satisfactory stability under practical loading conditions. Although propulsive efficiency was low due to scale and component mismatch, the system effectively validated the theoretical design assumptions. The results confirm that battery-electric propulsion is a viable and environmentally friendly alternative for small boats operating at low speeds.

References

[1] IMO (2020). Reduction of GHG emissions from ships. Fourth IMO GHG Study 2020 – *Final report. In: MEPC 75/7/15.*

[2] Xie, W., Li, Y., Yang, Y., Wang, P., Wang, Z., Li, Z., Mei, Q. and Sun, Y. (2023). Maritime greenhouse gas emission estimation and forecasting through AIS data analytics: a case study of Tianjin port in the context of sustainable development. *Front. Mar. Sci. 10:1308981*. *https:// doi.org/ 10.3389/fmars.2023.1308981*

[3] Ammar, N., R. and Seddiek, I. S. (2021). Evaluation of the environmental and economic impacts of electric propulsion systems onboard ships: case study passenger vessel. *Environmental Science Pollution Research, 28:37851–37866.*

[4] Aksöz, A., Asal, B., Golestan, S., Gençtürk, M., Oyucu, S. and Biçer, E. (2015). Electrification in Maritime Vessels: Reviewing Storage Solutions and Long-Term Energy Management. *Applied Sciences, 15, 5259.*

[5] Zhang, J. (2025). Electric Propulsion Systems for Ships: Technological Advances and Application Prospects. *Journal of Education and Educational Research, vol. 13, No. 2., pp. 57 – 59.*

[6] Hong, S. H., Kim, D. M., and Kim, S. J. (2024). Power Control Strategy Optimization to Improve Energy Efficiency. *IEEE, vol. 12, 22534.*

[7] Kolodziejski, M. and Michalska-Pozoga, I. (2023). Battery Energy Storage Systems in Ships' Hybrid/Electric Propulsion Systems. *Energies, 16, 1122.*

[8] Hassan, S. R., Zakaria, M., Arshad, M. R., and Aziz, Z. A. (2012). *Evaluation of Propulsion System Used in URRG- Autonomous Surface Vessel (ASV). Procedia Engineering, 41, pp. 606 – 613.*

[9] Park, Y. and Kim, H. (2024). Advanced Design of Naval Ship Propulsion Systems Utilizing Battery-Diesel Generator Hybrid Electric Propulsion Systems. *Journal of Marine Science and Engineering, 12*, 2034.

[10] Zhemin, J. and Yuxin, Y. (2020). Research on Ship Electric Propulsion. IOP *Conf. Ser.: Earth Environ. Sci. 446 042057.*

[11] Candelo-Beccera, J. E., Maldonado, L. B., Sanabria, E. P., Pestana, H. V., and Garcia, J. J. (2023). Technological Alternatives for Electric Propulsion Systems in the Waterway Sector. *Energies, 16*, 7700.

[12] Geertsma, R. D., Negenborn, R. R., Visser, K., and Hopman, J. J. (2017). Design and control of hybrid power and propulsion systems for smart ships: A review of developments. *Applied Energy, 194*, pp. 30–54.

[13] Maydison, Zhang, H., Han, N., Oh, D and Jang, J. (2025). Optimized Diesel–Battery Hybrid Electric Propulsion System for Fast Patrol Boats with Global Warming Potential Reduction. *Journal of Marine Science and Engineering*, *13*(6), 1071.

[14] Larsson, L., and Raven, H. C. (2010). *Ship Resistance and Flow*. Society of Naval Architects and Marine Engineers.

[15] Molland, A. F., Turnock, S. R., and Hudson, D. A. (2011). *Ship Resistance and Propulsion*. Cambridge University Press.

[16] Zhang, H., Maydison, Kang H., Kim, Y., Jang, J., Han, Z. and Oh, D. (2025). Effective energy density in small vessels: a comparative study of diesel engines and battery electric propulsion systems. *International Journal of Naval Architecture and Ocean Engineering, vol. 17, 100681.*

[17] Kumar, L. and Jain, S. K. (2014). A Comprehensive Study of Electric Propulsion System for Vehicular Application. *Journal of Renewable and Sustainable Energy, 6(2): 022701*

[18] Perera, L. P. and Mo, B. (2016). Electric and hybrid propulsion systems for marine vessels: Emerging technologies. *Ocean Engineering, 120*, pp. 140–150. https://doi.org/10.1016/j.oceaneng.2016.04.008

[19] Kim, J., Park, S., and Lee, J. (2018). Performance analysis of small electric boats. *Journal of Marine Science and Technology*, *23(4), pp. 567–575*.

[20] Choi, Y., Lee, H., and Kim, D. (2019). Experimental study on battery-powered vessels. *Ocean Engineering*, *182, pp. 17–26.*

[21] Phogat, P., Dey, S. and Wan M. (2025). Powering the sustainable future: a review of emerging battery technologies and their environmental impact. *RSC Sustainability, 3, 3266.*

[22] Kamenev, Y., Lushina, M. and Yakovlev, V. (2009). New lead-acid battery for susmersible vehicles. *Journal of Power Sources, vol. 188, issue 2, pp. 613-616*.

[23] Szymborski, J. (2002). Lead-acid batteries for use in submarine applications. *Proceedings of the 2002 Workshop on Autonomous Underwater Vehicles, 2002.*, San Antonio, TX, USA, 2002, pp. 11-17.

[24] Linden, D., and Reddy, T. B. (2011). *Handbook of Batteries*. McGraw-Hill.

[25] Carlton, J. (2012). *Marine Propellers and Propulsion*. Butterworth-Heinemann.