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Innovative Design and Fabrication of a Solar-Powered Boat Prototype Using 3D Printing Technology: Improving Sustainable Marine Transportation

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Powerboat prototype solar system design and fabrication are the focus of this research. The research on solar energy-powered boats contributes significantly to the Sustainable Development Goals by promoting sustainable transportation and reducing environmental impact. Solar-powered boats made using 3D printing technology are a major step towards sustainable marine transportation. This innovative prototype addresses environmental issues associated with maritime fuel sources with solar energy. The solar-powered boat's core is a sophisticated circuit system. The main power source is a high-efficiency 6 V, 200 mA, 1 W solar panel. It is strategically linked to the solar panel lithium-ion battery charger charging controller module to maximise 18650 4,200 mAh 3.7 V battery charging efficiency. A battery holder secures the battery, which stores solar energy. This project relies on the bes23288-rx board to connect stored energy to the boat's propulsion system. This board connects to the battery and powers the two propeller-equipped motors. This novel design propels the boat along waterways using renewable energy. Solar-powered boats can reduce air and sea pollution by replacing or supplementing traditional fuel sources with solar energy. This solar-powered boat project is a pioneering maritime sustainability initiative. Due to its advanced technology and commitment to environmental sustainability, this prototype sets a new standard for marine transportation.

Keywords: Powerboats, solar, 3D boat, 3D Printer, Parent hull.

1. Introduction

This research delves into the creation and significance of a solar-powered boat aimed at mitigating the environmental impact of traditional maritime fuel sources. Solar energy-powered boats is a main focus of this research and it contributes significantly to the Sustainable

Development Goals by promoting sustainable transportation and reducing environmental impact [1].

By utilising cutting-edge 3D printing methodologies, the prototype boat stands out as a symbol of innovation and sustainability within marine transportation as well as a significant step towards greener maritime practices. The solar-powered vessel boasts a meticulously designed circuit system. It features components such as the CN3791 Maximum Power Point Tracking (MPPT) solar panel lithium-ion battery charger controller module, a high-efficiency solar panel, and a custom battery holder for the 4,200 mAh battery used in solar charging [2]. Therefore, the board expediates the transfer of solar energy to the boat's dual motors and propellers.

The prototype boat's solar system effectively integrates renewable energy technology by focusing on optimal component selection and arrangement to ensure a sustainable power supply for the vessel [3]. By providing clean and renewable propulsion, this solar system demonstrates the transformative potential of solar technology in the maritime sector. The research focuses on the intricate interactions of the components, highlighting the technical intricacies that underpin the viability and eco-friendliness of solar-powered marine transportation.

2. Design A 3D Powerboat

Hull Design

The hull design for the 3D powerboat is according to the parent hull. All design variations of parent hall is generated and stored in the hull database in advance as a way to develop the design framework. Correspondingly, for designers to retrieve the hulls required and modify them, designers will be using the introduced shape modifiers.

The parent hull of the series, the C01 model, was derived from a pre-existing model, the C954, that had demonstrated good performance and was registered by an intensive experimental programme in a towing tank [4]–[6]. The C954, was designed in 1995, was also frequently chosen as a working boat hull to ensure good performance in still and rough waters as well as short-sea conditions exclusively [7]. To simplify the building of the hulls, the C954 hull form was changed to obtain the plating as developable surfaces.

The Shapr 3D software was utilised to create the hull design for 3D printing [8]–[10]. This is essential for ensuring the reliability and smooth functioning of boats on the water. It also enables the creation of detailed 3D models of the boat's structure. Using the software, fine-tuning design elements like hull’s shape and size can optimise performance attributes like stability and performance.

Create 3D Design

The first step in creating or acquiring a 3D model is by using Computer Aided Design (CAD) software. CAD software serves as the architectural plan for producing the model through printing. A comprehensive 3D model of the boat’s hull structure is the result by the hull design process in Shapr3D software. The process of the boat’s hull design involves exact representing the vessel's design. The vessel’s design includes defining the shape, dimensions, and features of the hull. In addition, with a wide range of features and tools in Shapr3D, proves the capabilities of Shapr3D as a valuable and helpful tool for creating detailed hull designs.

The parameters of the C01 model are presented in Table 1. Construct the C01 model to resemble the parent hull C954, as depicted in Figure 1. The C01 model features a hull design that incorporates chine.

Table 1: Parameters C01 Model

Parameters	C01 Model (mm)
Length	240
Width	75
Depth	45
Draft	22.5

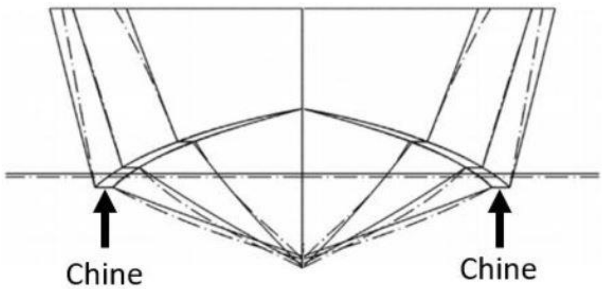

Figure 1: Body plan of parent hull C954

There are several steps in the modelling process including adding up the surface, keying in the size surface, merging in the surface, and smoothening the hull using the control point positions for each column to obtain the desired shape, as displayed in Figure 2.

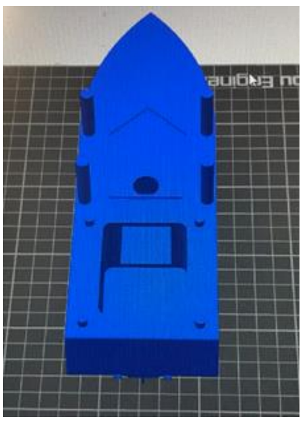

Figure 2: Hull design

After the modelling process has been completed, as in Figure 3, then the subsequent step is involved by generating a file in either Stereolithography (STL) or 3MF format. An STL file exclusively encompasses the surface geometry of a 3D object, whereas a 3MF file encompasses additional data such as textures, materials, and colours.

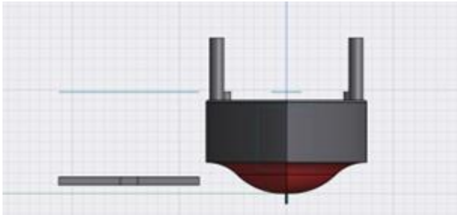

Figure 3: C01 Model

3D Printing

The Bambu Lab X1 Series is used to perform 3D printing. The solar boat prototype was simply produced using this app within a short period. Then, the printer creates the object layer by layer using heated plastic or hardening liquid resin, following the instructions given in the design.

In order to provide precise instructions for the 3D printer, the Shapr 3D model is converted to the STL or 3MF file into G-code. It is necessary to slice the model using specialised slicing software, as illustrated in Figure 4. This procedure shows how the printer will construct the object, progressing one layer at a time.

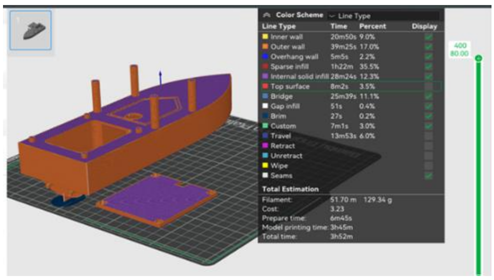

Figure 4: Setting C01 model into 3D Printer.

Once the slicing process is completed and the G-code is generated, the 3D printer is ready to receive the file. Next, the printing process will begin creating the touchable and tangible 3D object.

The 3D printer set-up offers high-speed 3D printing with up to 20,000 mm/s² acceleration. It can achieve speeds of up to 500 mm/s, with rapid acceleration from zero to 500 mm/s in just 0.025 seconds for the printing process.

As shown Figure 5, the printer features of active vibration compensation, extrusion compensation for smooth prints, and automatic bed levelling produced optimal first-layer calibration. The material filaments used are Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA).

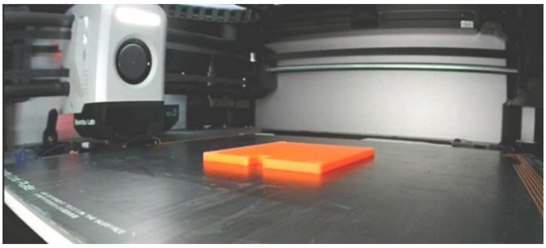

Figure 5: Panel system 3D

Fabrication For Solar Panel

To build an impressive, eco-friendly and sustainable solar-powered boat, the devices and components used play a crucial role. The main device of this composition is the 6 V 200 mA 1 W high-efficiency solar panel. This shows the project's dedication to environmental stewardship through its effective energy harvesting capabilities with a meticulous calibration of its 6 V voltage, 200 mA current, and 1 W power rating. It also shows perfect integration of energy efficiency and spatial limitations.

The boat's high-efficiency design highlights the incredible potential of renewable energy by utilising the available sunlight [11]. The solar panel's powerhouse is the CN3791 MPPT solar panel lithium-ion battery charger charging controller module for the energy conversion process

Solar panels are typically constructed using silicon or other semiconductor materials and are mounted within a sturdy metal frame protected by a glass casing. This metal frame releases electrons and generates an electric charge when it is exposed to photons of sunlight.

For technical evaluation of solar system components, the performance of each component within the solar system will be analysed. This includes the 3D printed boat structure, the 6 V 200 mA 1 W solar panel, the CN3791 MPPT solar panel lithium-ion battery charger charging controller module, the 18650 4,200 mAh 3.7 V battery, the battery holder, the bes23288-rx board, motors, and propellers. The overall integration of these components will be evaluated to ensure smooth functionality and efficient energy utilisation as in Figure 6.

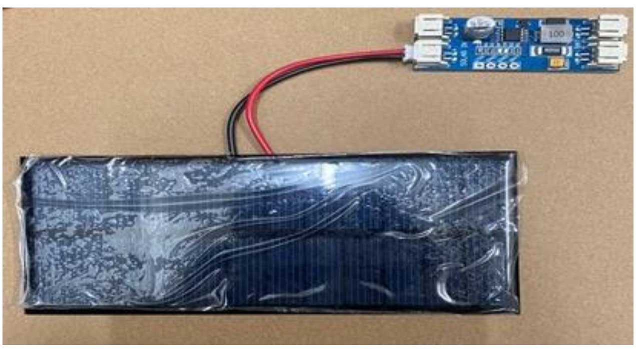

Figure 6: Solar panel integration

3. Results and Discussion

3D Powerboat

The 3D design solar powerboat, which incorporates modifications to the C01 model derived from the parent hull C954, has exhibited impressive manoeuvring capabilities. The vessel demonstrates efficient hydrodynamic characteristics and favourable resistance properties, as evidenced by its achieved block coefficient (CB) of 0.7133. The findings indicate that the solar powerboat design incorporating the C01 model derived from the C954 hull has great potential in manoeuvrability and hydrodynamic efficiency.

The achievement of a CB value of 0.7133 for the solar powerboat design indicates a well-balanced hull form. It enhances manoeuvrability and ensures optimal performance. It is also observed that the changes made from the parent hull C954 to the C01 model have positively impacted the vessel's hydrodynamic performance. This leads to better handling and manoeuvrability in the water.

The CB value is an essential factor that indicates the boat's resistance characteristics and overall efficiency in navigating through water. A higher CB value indicates a more complete hull form, which can improve stability and manoeuvrability [12]. In addition, it also has the potential to affect speed and fuel efficiency. Meanwhile, the CB value of 0.7133 demonstrates an optimised hull design that effectively balances stability and performance. This result proves that solar powerboat is a promising choice for sustainable marine transportation.

In summary, the findings emphasise the seamless incorporation of the adapted C01 model from the original hull C954 in the development of a solar-powered boat that exhibits excellent manoeuvrability and efficient hydrodynamic characteristics. This discussion highlights the significance of hull design in attaining maximum performance and manoeuvrability in solar-powered vessels, opening up possibilities for progress in eco-friendly marine transportation in future.

Solar Panel System

The solar panel system incorporated into the powerboat has effectively utilises light energy to propel the vessel. The energy absorption process begins with the solar panel capturing light energy. Then, it is directed to the CN3791 MPPT battery controller board to efficiently charge the 18650 batteries. Next, the wire is connected from the bes23288-rx board, equipped with a switch, to the CN3791 MPPT battery controller to ensure the circuit functions properly.

To confirm the circuit is working properly, the light-emitting diodes (LED) indicator on the bes23288-rx board will be lighted up wheb the switch is turned on. This verification step ensures the efficient operation of the energy transfer process within the solar panel system. Activating the remote control to evaluate the DC motor's movement and the propeller's activation is further testing to showcase the system's efficient solar energy conversion into mechanical propulsion.

In addition, the system's charging capability is emphasised by the estimated duration for a full charge on a hot day. This suggests that, in ideal circumstances, the solar panel system can fully charge the battery within 4 to 5 hours [13], [14] as shown in Table 2. The data demonstrates the system's ability to efficiently charge, thus proves its reliability and effectiveness in harnessing solar energy to power the boat.

Table 2: Duration for charging battery 18650 (100%)

DURATION (HOURS)	WEATHER CONDITION
10	CLOUDY
6	HOT
4	SCORCHING HOT

The solar panel system's ability to convert light energy into electrical power for propulsion is highlighted by the successful operation of the system on the powerboat. Hence, the smooth and efficient transfer of energy within the circuit is ensured by the sequential flow from the solar panel to the CN3791 MPPT battery controller and then to the bes23288-rx board.

The LED indicator on the bes23288-rx board is important for verifying the circuit's functionality. Besides, it confirms the successful transmission of energy from the solar panel to the battery. Additionally, the real-time feedback mechanism improves the system's reliability and enables quick troubleshooting for any operational issues.

Its remarkable effectiveness in utilising solar energy for continuous operation is shown when the system's impressive capability to fully charge the 18650 batteries within a day, even under optimal conditions. Moreover, the solar panel system's rapid charging capability greatly improves the practicality and usability of the solar-powered boat, making it an efficient and viable power source.

In general, the results and discussion emphasise the effectiveness of the implementation and performance of the solar panel system in the powerboat. Thus, the results demonstrate its dependability, effectiveness, and potential for eco-friendly marine transportation fueled by renewable energy sources.

4. Conclusion

Based on the abstract, this summary highlights the main discoveries and implications of a research project focused on creating a solar-powered boat prototype using 3D printing technology. The research delves into the development of a solar-powered boat prototype aimed at improving sustainable marine transportation by reducing the ecological consequences of conventional fuel sources. Through the implementation of state-of-the-art 3D printing methods, we have successfully reached a significant breakthrough in the realm of eco-friendly marine transportation. It has been developed into a revolutionary and environmentally conscious vessel that sets new standards for sustainability.

The solar-powered boat highlights a thoroughly designed circuit system that integrates cutting-edge components. This includes the CN3791 MPPT solar panel lithium-ion battery charger controller module and a highly efficient solar panel. In addition, incorporating renewable energy technology in the vessel's power supply highlights the promising prospects of clean and sustainable propulsion in the maritime sector.

The research emphasises the practicality and environmental benefits of solar-powered marine transportation by examining the technical aspects and interactions of its components. The detailed curation and organisation of components exemplify the potential of solar technology to revolutionise the maritime sector, leading it towards a more environmentally friendly and sustainable future. Finally, the solar-powered boat prototype showcases a groundbreaking approach to greener marine transportation. It also highlights the immense potential of solar energy to revolutionise the maritime industry in a more sustainable and eco-friendly manner.

References

1. R. Sampedro, "The Sustainable Development Goals (SDG)," Carreteras, vol. 4, no. 232, 2021.
2. A. Nasirudin, R. M. Chao, and I. K. A. P. Utama, "Solar powered boat design optimization," Procedia Eng., vol. 194, pp. 260–267, 2017.
3. A. Kurniawan, "A Review of Solar-Powered Boat Development," IPTEK J. Technol. Sci., vol. 27, no. 1, 2016.
4. F. De Luca, S. Mancini, S. Miranda, and C. Pensa, "An extended verification and validation study of CFD simulations for planing hulls," J. Sh. Res., vol. 60, no. 2, pp. 101–118, 2016.
5. F. De Luca, "Experimental Study on Interceptor ' s Effectiveness," no. November, 2011.
6. R. Ramli, M. H. Mohd Hashim, A. Alisibramulisi, S. Mohamed Noor, and M. F. Abdul Razak, "Tensile Strength Testing of +45° Isotropic FRP Laminate on Different Universal Testing Machines," in Advanced Structured Materials, vol. 167, 2022.
7. F. De Luca and C. Pensa, "The Naples warped hard chine hulls systematic series," Ocean Eng., vol. 139, no. December 2016, pp. 205–236, 2017.
8. B. A. Praveena, N. Lokesh, A. Buradi, N. Santhosh, B. L. Praveena, and R. Vignesh, "A comprehensive review of emerging additive manufacturing (3D printing technology): Methods, materials, applications, challenges, trends and future potential," in Materials Today: Proceedings, 2022, vol. 52.
9. V. J. Kharat et al., "Additive manufacturing (3D printing): A review of materials, methods, applications and challenges," Mater. Today Proc., 2023.
10. T. D. Ngo, A. Kashani, G. Imbalzano, K. T. Q. Nguyen, and D. Hui, "Additive manufacturing (3D printing): A review of materials, methods, applications and challenges," Composites Part B: Engineering, vol. 143. 2018.
11. G. Minak, "Solar Energy-Powered Boats: State of the Art and Perspectives," Journal of Marine Science and Engineering, vol. 11, no. 8. 2023.
12. M. Khosravi Babadi and H. Ghassemi, "Optimization of ship hull forms by changing CM and CB coefficients to obtain optimal seakeeping performance.," PLoS One, vol. 19, no. 5, p. e0302054, 2024.
13. A. Gurung and Q. Qiao, "Solar Charging Batteries: Advances, Challenges, and Opportunities," Joule, vol. 2, no. 7. 2018.
14. R. Romero, "Battery Charging Performance Using 12 Volts Solar Power Line Source," Eng. Technol. J., vol. 08, 2023.