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Titanium-Based Artificial Heart

Author: Yashpal Aniruddha Gajbhiye
M-Tech (CAD/CAM), B.E. (Mechanical)

Abstract This paper presents the design and analysis of a titanium-based artificial heart that functions as a complete replacement for the human heart. The proposed design incorporates a compact motor for blood circulation and is powered by a combination of solar energy and a backup battery system to ensure continuous operation. By adopting advanced materials and design principles, with modifications in dimensions and energy integration, this study aims to offer a sustainable and durable solution for patients requiring total heart replacement. Computational analyses assess hemodynamic performance, structural integrity, and energy efficiency, providing a foundation for future research and clinical implementation.

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1. Introduction Heart failure remains a leading cause of mortality worldwide, with the limited availability of donor hearts constraining treatment options. The development of total artificial hearts (TAHs) offers a viable alternative for patients ineligible for transplants. This paper introduces a novel artificial heart design featuring modifications in dimensions and integrating renewable energy sources to enhance functionality and patient quality of life.

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2. Design Approach

2.1. Material Selection The primary materials selected for the artificial heart include:

- **Titanium:** Chosen for the casing due to its high strength-to-weight ratio, corrosion resistance, and biocompatibility.
- **Polyether Urethane:** Utilized for all blood-contacting surfaces, including the tricuspid valves, to ensure flexibility and hemocompatibility.

2.2. Pump Mechanism The heart employs a compact motor-driven pump system to replicate the natural systolic and diastolic phases:

- **Systolic Function:** The motor contracts the artificial ventricles, propelling blood into the systemic circulation.
- **Diastolic Function:** The ventricles relax, allowing passive filling with blood, facilitated by the tricuspid valves.

2.3. Renewable Energy Integration To ensure continuous operation, the artificial heart incorporates a dual-energy system:

- **Solar Panels:** Flexible photovoltaic cells are integrated into the external surface to harness ambient light.
- **Backup Battery:** A lithium-ion battery provides power during low-light conditions and stores excess energy generated by the solar panels.

2.4. Dimensional Modifications The dimensions have been adjusted to accommodate a broader patient population, including individuals with smaller thoracic cavities. The overall size has been reduced by approximately 10%, and the shape has been contoured to fit more comfortably within the chest cavity.

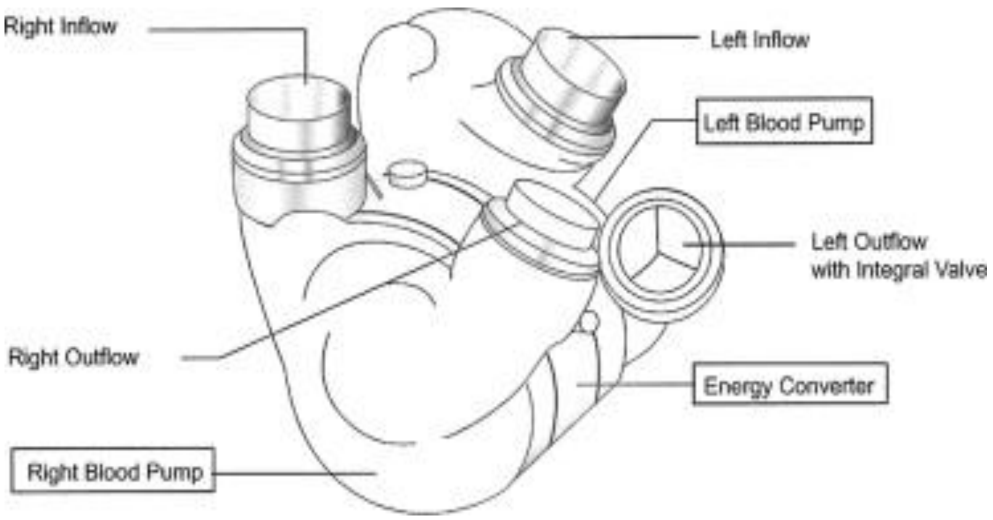
2.5. Functional Design The device comprises:

- **Two Titanium Chambers:** Serving as artificial atria and ventricles, lined with polyether urethane to promote biocompatibility.
- **Motorized Pump:** Capable of adjusting pumping rates in response to physiological demands, ensuring adequate cardiac output.
- **Energy Management System:** Regulates the distribution of power between the solar panels and the backup battery, optimizing energy utilization.

Diagram of the Artificial Heart Design

The following figures illustrate key aspects of the proposed design:

Figure 1: Detailed schematic of the artificial heart, showing the titanium chambers, motorized pump, and energy integration components.



3. Computational Analysis

3.1. Hemodynamic Performance Computational Fluid Dynamics (CFD) simulations were conducted to evaluate blood flow patterns, pressure gradients, and shear stresses within the artificial heart. The results indicate smooth flow dynamics, minimizing the risk of hemolysis and thrombosis.

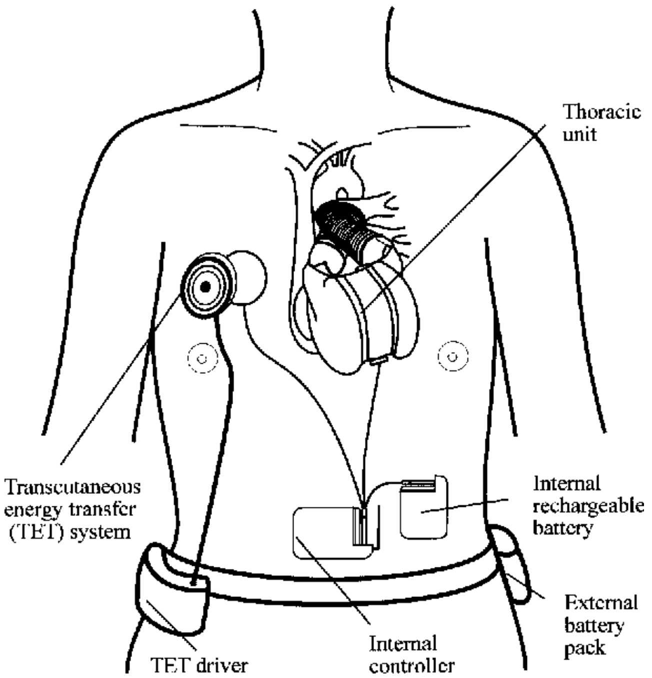
3.2. Structural Analysis Finite Element Analysis (FEA) assessed the mechanical integrity of the titanium casing and polyether urethane-lined components under cyclic loading conditions. The materials demonstrated excellent durability, with minimal deformation over extended use.

3.3. Energy Efficiency Simulations of the energy management system revealed that, under optimal conditions, the solar panels could supply up to 70% of the device's power needs, with the backup battery providing reliable support during periods of insufficient light exposure.

Diagram of the Artificial Heart Design

The following figures illustrate key aspects of the proposed design:

Figure 2: Placement and components of the artificial heart within the human thoracic cavity.



4. Results and Discussion

4.1. Hemodynamic Efficacy The artificial heart successfully replicated physiological blood flow rates and pressures, closely mimicking natural cardiac function and ensuring adequate tissue perfusion.

4.2. Structural Durability The combination of titanium and polyether urethane provided a robust and biocompatible structure, capable of withstanding the mechanical stresses associated with continuous operation.

4.3. Energy Sustainability The integration of solar energy and a backup battery system proved effective in maintaining uninterrupted device operation, highlighting the feasibility of incorporating renewable energy sources into implantable medical devices.

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5. Challenges and Limitations

- **Energy Harvesting Efficiency:** The reliance on ambient light for solar energy generation may limit effectiveness in low-light environments, necessitating further optimization of photovoltaic technology.
- **Patient Selection Criteria:** Despite dimensional modifications, the device may still be unsuitable for patients with very small thoracic cavities, underscoring the need for customizable sizing options.
- **Long-Term Biocompatibility:** While initial results are promising, extended clinical trials are required to fully assess the long-term biocompatibility and durability of the materials used.

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6. Conclusion This study presents a novel design for a titanium-based artificial heart, incorporating dimensional adjustments and renewable energy integration to enhance patient compatibility and device sustainability. The computational analyses support the feasibility of the proposed design, laying the groundwork for future experimental validation and clinical application.

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7. References

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