Manufacturing of Titanium Power Cell Enclosures for High-Performance Applications

Mr.G.Selvakumar[1], R.Harishwar[2], K.Hariharan[3], P.Aswinkumar[4]
[1]Assistant Professor, Dept of Mechanical Engineering
[2, 3, 4]Dept of Mechanical Engineering
[1, 2] Kongunadu College of Engineering & Technology

Abstract- *Titanium has become the preferred material for power cell enclosures due to its exceptional strength-to-weight ratio, corrosion resistance, and thermal stability. Previously, materials like aluminium and steel were widely used, but they had significant limitations in high-performance environments such as aerospace, defences, and energy storage applications. Aluminium, though lightweight, lacked the required mechanical strength and thermal resistance, whereas steel, despite being strong, was heavy and susceptible to corrosion over time. The transition to titanium has been driven by its ability to withstand extreme conditions while maintaining structural integrity. This paper explores the manufacturing processes involved in producing titanium power cell enclosures, including CNC machining, deep drawing, and laser welding. It also discusses the advantages, challenges, and solutions associated with using titanium in power cell applications. By leveraging advanced fabrication techniques, titanium enclosures provide superior durability, efficiency, and safety, making them essential for modern energy storage solutions.*

Keywords- Titanium enclosures, power cell casing, high-performance materials, aerospace applications, CNC machining, deep drawing, laser welding, corrosion resistance, thermal stability.

I. INTRODUCTION

The demand for high-performance energy storage solutions has increased significantly in industries such as aerospace, defences, and advanced battery technologies. Power cell enclosures are critical components that protect energy storage devices from mechanical damage, temperature variations, and environmental factors. Selecting the appropriate material for these enclosures is crucial to ensure long-term performance, reliability, and efficiency. Historically, aluminium and steel were the primary materials used for power cell enclosures. Aluminium was preferred for its lightweight nature, but its low mechanical strength and poor thermal stability limited its use in extreme conditions. Steel, on the other hand, offered high strength, but its heavy weight and susceptibility to corrosion made it less suitable for modern high-performance applications. Titanium has emerged as an ideal alternative due to its high strength-to-weight ratio, corrosion resistance, and ability to withstand high temperatures. These properties make it particularly valuable for applications where weight reduction, durability, and reliability are critical factors. Recent advancements in manufacturing technologies, such as CNC machining, deep drawing, and laser welding, have made it feasible to mass-produce titanium power cell enclosures with high precision and efficiency. This paper examines the transition from traditional materials to titanium, focusing on material properties, manufacturing techniques, advantages, challenges, and future applications.

II. MATERIAL PROPERTIES OF TITANIUM

Titanium possesses unique characteristics that make it an ideal material for power cell enclosures in demanding environments.

2.1 Strength-to-Weight Ratio

Titanium offers a superior strength-to-weight ratio compared to steel and aluminium, making it ideal for weight-sensitive applications such as aerospace and military power storage systems.

2.2 Corrosion Resistance

Titanium naturally forms a protective oxide layer, preventing corrosion even in harsh environments such as high humidity, saltwater, and chemically reactive conditions.

2.3 Thermal Stability

Titanium can withstand extreme temperature variations without losing its structural integrity, making it ideal for applications requiring high thermal resistance and minimal expansion.

2.4 Chemical Inertness

Titanium does not react with most battery electrolytes, ensuring the safety and longevity of power cell enclosures.

III. MANUFACTURING TECHNIQUES FOR TITANIUM POWER CELL ENCLOSURES

Producing titanium enclosures requires specialized manufacturing techniques due to its high strength and low mach inability compared to aluminium and steel. The following techniques are commonly used to manufacture titanium power cell enclosures:

3.1 CNC Machining

Provides precision shaping and finishing for complex enclosure designs. Ensures tight tolerances and high durability. Utilizes high-speed cutting tools and coolant-based lubrication to minimize wear.

3.2 Deep Drawing

Allows for the formation of thin-walled titanium enclosures with a uniform structure. Reduces material waste compared to traditional machining. Enhances mechanical strength by work-hardening the material during forming.

3.3 Laser Welding

Enables high-precision joining of titanium components. Provides a hermetic seal, ensuring leak-proof enclosures for power cells. Reduces thermal distortion compared to conventional welding methods.

3.4 Additive Manufacturing (3D Printing)

Enables customized and lightweight designs for power cell enclosures. Reduces material wastage and enhances complexity in design. Offers rapid prototyping for new enclosure designs.

IV. ADVANTAGES OF TITANIUM POWER CELL ENCLOSURES

Titanium enclosures offer several advantages over traditional materials:

Lightweight yet strong, reducing the overall system weight. Corrosion-resistant, ensuring long-term durability in extreme environments. High-temperature resistance, preventing thermal degradation. Electromagnetic shielding, protecting power cells from external interference. Non-reactive with electrolytes, enhancing battery safety and reliability.

V. CHALLENGES AND SOLUTIONS IN TITANIUM ENCLOSURE MANUFACTURING

Despite its benefits, titanium presents certain manufacturing challenges:

5.1 High Processing Costs

Titanium is more expensive than aluminium or steel.
Solution: Adoption of recycling techniques and bulk production to reduce costs.

5.2 Machining Difficulty

Titanium has low thermal conductivity, leading to tool wear during machining.
Solution: Use of coated cutting tools, high-speed machining, and cryogenic cooling.

5.3 Welding Complexity

Traditional welding techniques cause oxidation in titanium.
Solution: Use of laser welding in an inert gas environment to ensure clean joints.

VI. APPLICATIONS IN HIGH-PERFORMANCE INDUSTRIES

Titanium enclosures are widely used in aerospace, defences, and energy storage sectors.

6.1 Aerospace & Defence

Used in satellites, military drones, and missile systems due to its strength and lightweight properties. Ensures battery longevity in extreme altitudes and temperatures.

6.2 Energy Storage & Electric Vehicles

Enhances battery safety in lithium-ion and solid-state batteries. Reduces thermal runaway risks, improving overall battery life.

6.3 Medical & Industrial Applications

Used in implantable medical devices requiring biocompatibility and durability. Provides corrosion-resistant enclosures for industrial power storage units.

VII. CONCLUSION

Titanium has revolutionized power cell enclosures by offering unmatched strength, corrosion resistance, and thermal stability. The adoption of advanced manufacturing techniques, such as CNC machining, deep drawing, and laser welding, has enabled the mass production of durable titanium enclosures. While challenges such as high processing costs exist, advancements in automation, tool coatings, and material recycling are making titanium more viable for large-scale use. Titanium's unique properties make it an essential material for aerospace, defences, and energy storage industries, ensuring long-term performance, safety, and reliability. As manufacturing technologies advance, titanium power cell enclosures will continue to be a key component in next-generation energy storage solutions.

Appendix

A. Manufacturing Process Flow

1. Material Selection – Titanium Grade 5 (Ti-6Al-4V).
2. Design & Modeling – CAD-based enclosure design.
3. Machining & Forming – CNC machining and deep drawing.
4. Heat Treatment – Stress relief and strength enhancement.
5. Surface Finishing – Anodizing for corrosion resistance.
6. Laser Welding – Precision joining for durability.
7. Quality Testing – Strength, corrosion, and thermal analysis.

B. Key Properties of Titanium Grade 5

- Density: 4.43 g/cm³
- Tensile Strength: 895 MPa
- Corrosion Resistance: Excellent
- Melting Point: 1668°C

C. Performance Comparison

Property	Titanium	Aluminum	Steel
Strenght (MPa)	895	310	520
Corrosion Rasistance	High	Moderate	Low
Thermal Expansion (µm/m°C)	8.6	23.1	11.7

D. Future Scope

- 3D printing for improved design flexibility.
- Cost-effective titanium alloy development.
- Smart coatings for enhanced performance.

Acknowledgment

We express our sincere gratitude to our guide, Mr.G.Selvakumar.,M.E.,(Ph.D)., for their invaluable guidance, support, and encouragement throughout this research on Manufacturing of Titanium Power Cell Enclosures for High-Performance Applications. Their insights and expertise have been instrumental in shaping this study.

We would also like to thank **Kongunadu College of Engineering & Technology, Department of Mechanical Engineering** for providing the necessary resources and facilities. Special appreciation goes to my colleagues and family for their continuous motivation and support.

Finally, We acknowledge all the researchers whose work has contributed to the foundation of this study.

R.HARISHWAR, K.HARIHARAN , P.ASWINKUMAR
Kongunadu College of Engineering & Technology

REFERENCES

[1] Md Hosne Mobarak a, Md. Aminul Islam a, Nayem Hossain a, Md. Zobair Al Mahmud a, Md. Thohid Rayhan a, Nushrat Jahan Nishi a, Mohammad Asaduzzaman Chowdhury b Volume 18, December 2023
[2] Anketa Jandyal, Ikshita Chaturvedi, Ishika Wazir, Ankush Raina PhD, Mir Irfan Ul Haq PhD Volume 3, 2022, Pages 33-42
[3] Shangqing Chen, Zishen Chen, Zhenwei Wei, Jiayin Hu, Yafei Guo, Tianlong Deng Volume 410, 15 April 2021
[4] N. Kolsch; A. Seidel; T. Finaske; F. Brueckner; J. Gumpinger; M. Bavdaz; T. Rohr; T. Ghidini; C. Leyens Volume 32, May 2020
[5] M. Grandi a 1, S. Rohde b 1, D.J. Liu c, B. Gollas b, V. Hacker a Volume 562, 1 April 2023