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**Review Article**

# Studies on features, physical, mechanical, tribological properties and applications of Ti-6Al-4V in aerospace industry

**Roopsandeep Bammidi[1]*, K. Siva Prasad[1], P. S. Rao[2]**

Department of Mechanical Engineering, [1]Anil Neerukonda Institute of Technology and Engineering, Visakhapatnam, [2]Centurion University, Parlakhemundi, Odisha, India

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***Correspondence:**
Roopsandeep Bammidi,
E-mail: rsb.research@gmail.com

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## ABSTRACT

This research article gives an overview of the extensive research of Ti-6Al-4V from past few decades helped in studying about the features, properties, characteristics and application of aerospace industries. The final objective of study is to obtain the inherent advantages of Ti-6Al-4V like low elasticity modulus, high strength, low density and more resistant to fatigue and corrosion that leads to rely on the required knowledge for the employment of application which improves all physical and mechanical properties.

**Keywords:** UTM, Ti-6Al-4V, Corrosion, Fatigue, Properties

## INTRODUCTION

The development and applications of various new materials in the industries of aerospace plays a vital role since 19th century. In 1954, the alloy of titanium named Ti-6Al-4V and called work horse of titanium alloys. In recent decades, the different alloys of titanium have been developed but special attention given to Ti-6Al-4V for aerospace applications due to their outstanding corrosion resistance and high strength. The subject of utility of this titanium alloy had been limited in addressing the best possible applications. This titanium alloy can be used in various applications because of its excellent nature of corrosion resistant, strength to weight ratio. The use of Ti-6Al-4V in aerospace industries is increasing gradually with best combinations of physical and mechanical properties but relative features and characteristics are required. The machining of Ti-6Al-4V occupies one of the crucial challenges for the application in aerospace industries. From literature we can probably say there is no material other than titanium which is very close to the industries of aerospace. The aerospace components are manufactured majorly with titanium but most of the part shares with aero engine. The physical properties of titanium are shown in following Table 1.

## PHYSICAL AND MECHANICAL PROPERTIES

The Ti-6Al-4V was applied to many industrial sectors such as automotive, aerospace and biomedical etc, but high impact of emphasis is given to aerospace sector.[1] The aerospace is the major field for the application of titanium materials with concern to airframe components and engine systems comprising of 7 and 11 percentages respectively. The critical challenge covered in the development of new material alloys of titanium with temperatures of high service and high improved strength that describes principle governing design of Ti-6Al-4V for the applications of airframe and aero engines. By understanding these principles, application of this titanium alloy is a critical concern for the research labs.[2] The titanium alloy performs a outstanding design with excellent characteristics that includes ductility, fracture toughness, higher strength and resistant to corrosion. It is

applicable to mainly components of aeronautical industry with attention towards the reliable requirements. The Figure 1 shows the names of Japanese companies that had joined the development of A380, which is the biggest aircraft manufactured by Airbus.[3] The mechanical properties generally include tensile and compressive properties and hardness of the material. These properties were tested using Instron UTM, Universal Testing Machine and Vicker's Hardness Testing Machines respectively. The Table 3 shows the exact properties of Ti-6Al-4V of these mechanical testing.

**Table 1: Physical properties of titanium.**

| Property | Titanium |
|---|---|
| **Metal price** | High++ |
| **Reactivity with oxygen** | High++ |
| **Melting point, °C** | Around 1670 |
| **Density, g/cm$^3$** | 4.50 |
| **Modulus of elasticity, GPa** | 115-145 |
| **Corrosion resistance** | High+++ |
| **Thermal conductivity, W/mK** | 15-22 |
| **Hardness, HV** | 300-400 |
| **Yield strength, Mpa** | 800-1100 |
| **Tensile strength, Mpa** | 900-1200 |
| **Beta transus temperature, $T_\beta$, °C** | 995 |

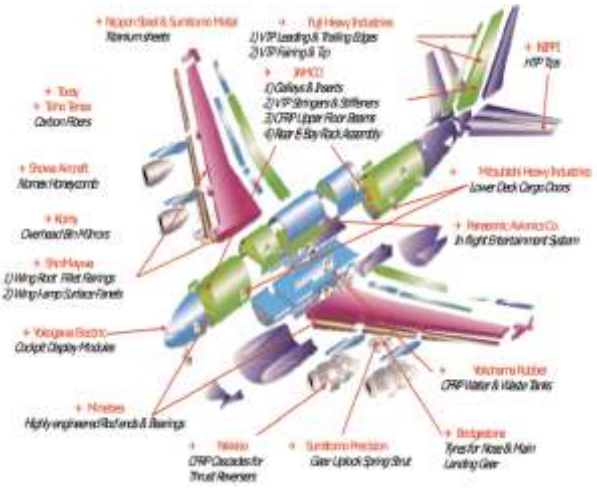

**Figure 1: A380 Japanese partners (Airbus).[3]**

**Table 2: Purpose of Ti-6Al-4V in aerospace industries.**

| S. No. | Purpose of Ti-6Al-4V |
|---|---|
| **1.** | High corrosion resistance |
| **2.** | Heat resistance |
| **3.** | Low thermal expansion |
| **4.** | Resistance to embrittlement at low temperatures |
| **5.** | Weight saving |

**Table 3: Mechanical properties of Ti-6Al-4V.**

| Mechanical properties | Value |
|---|---|
| **Percentage elongation, %** | 15.5-16.5 |
| **Yield strength, MPa** | 975-985 |
| **Ultimate tensile strength, MPa** | 1105-1125 |
| **Ultimate compressive strength, MPa** | 1650-1675 |
| **Compressive yield strength** | 1065-1080 |
| **Hardness, VHN** | 178-185 |

## TRIBOLOGICAL PROPERTIES

The Ti-6Al-4V exhibits an excellent property that leads to commercial utility of the material for various applications with special attention in aerospace. Different methods are introduced and used for the improvement of tribological properties and wear resistance of Ti-6Al-4V. The researchers' investigated the tribological behaviour of Ti-6Al-4V in different approaches for their applications and many publications take place in the path of wear behaviour. The wear mechanisms with different loads and speeds have been studied and dry sliding mechanisms against different materials in atmosphere and vaccum conditions are also considered during the study of Ti-6Al-4V.[4-6] The wear mechanisms are adopted using different techniques.[7] The mechanical properties and tribological behaviour of Ti-6Al-4V are improved using surface treatments and different techniques are adopted for achieving the reduction of material porosity. Due to very low surface oxides and shearing of the plastics, Ti-6Al-4V exhibits very poor wear resistance and tribological properties.[8] Under different conditions for highlighting mechanisms which are responsible for poor wear resistance, researchers are investigated the wear behaviour of Ti-6Al-4V.[9] The tool wear is a serious problem in machining of Ti-6Al-4V and coating makes it effective for machining of the material.

## CONCLUSION

The aerospace industries are trend setters for the developments and introducing new type of material systems and latest technologies of the production. The application of this Ti-6Al-4V brings a tremendous impact on the several issues such as ecological and economical with involvement of advancement of materials and production technologies. The study of this article concludes the features and applications with framing together the physical, mechanical and tribological properties of Ti-6Al-4V paying special attention towards aerospace industries.

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## REFERENCES


1. Veiga C, Davim JP, Loureiro AJR. Properties and applications of alloys: a brief review, Rev Adv Mater Sci. 2012;32:133-48.
2. Banerjee D, Krishnan RV. Challenges in alloy design: titanium for the aerospace industry. Prec Indian Acad Sci (Engg Sei). 1981;4:21-39.
3. Inagaki I, Takechi T, Shirai Y, Ariyasu N. Application and Features of Titanium for the Aerospace Industry, A technical review. Nippon steel & sumitomo metal technical report no. 106, 2014.
4. Yong L, Yang DZ, He SY, Wu WL. Dry Sliding Wear of Ti-6Al-4V Alloy in Air and Vaccum. Transactions Nonferrous Soci China. 2003;13:1137–40.
5. Guleryuz H, Cimenoglu H. Surface Modification of a Ti- 6Al-4V Alloy by Thermal Oxidation. Surface Coatings Technol. 2005;192:164–70.
6. Ming Q, Yongzhen Z, Jun Z, Jianheng Y. Dry Friction Characteristics of Ti-6Al- 4V Alloy under High Sliding Velocity. J Wuhan Univ Technol-Mater. Sci. 2007;22:582–5.
7. Majumdar P, Singh SB, Chakraborty M. Wear response of heat-treated ti-13zr-13nb alloy in dry condition and simulated body fluid. Wear. 2008;264(11–12):1015–25.
8. Narayanan B, Rajamanickam A. A review on tribological behaviour of titanium alloys, International Journal of Pure and Applied Mathematics, 2018;119:2225-9.
9. Chauhan SR, Dass K. Dry sliding wear behaviour of titanium (grade 5) alloy by using response surface methodology. Advances in Tribology. Hindawi Publishing Corporation; 2013;2013:272106.


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