# A Review In Analysis The Corrosion And Wear Properties Of Titanium Alloy

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**Abstract:** The most commonly used material for aerospace and biomedical application is titanium alloy due to its high strength to weight ratio, corrosion resistance properties. The wear resistance properties matters for longevity of the component and avoids failure. In the present study, different types of methodology are discussed, analyzed and compared. The Nanostructured coating found to be fruitful in infusing new properties and also improves existing properties of titanium alloy.

***Keywords*:** wear; titanium alloys; medical implants; surface modification methods

**1. Introduction*:***Titanium alloys are workhorse and abundantly available structural metal. Three major categories of titanium alloys are α alloy, β alloy and (α+β) alloy. Microstructure of these alloys defines their properties. Pure Titanium is not as strong as its different alloys. The high strength, low weight ratio, and excellent corrosion resistance immanent to titanium and its alloys. Ti6Al4V is the commonly used titanium alloy. It features low friction coefficient, wear resistance and other improved mechanical properties has led to wide range of successful applications which demand high level of reliability in biomedical performance as well as aerospace, automobile, agricultural industries, chemical plants, power generations, sports and other major industries .SandeepYadav [1] and AnoopKumar[2] investigated. The surfaces of titanium and of all of its alloys relatively inferior wear properties, huge unstable coefficient of friction, excessive adhesive wear and tendency to seize. In particular, titanium surfaces in contact with each other or with other metals readily gall under conditions of sliding contact. Even with little relative movement under light loading, complete seizure of surfaces can occur. This situation is caused by adhesive wear in which microscopic asperities on the metal surfaces come into contact because of relative sliding and they tend to weld together forming a bond at the junction, which can have a rupture strength greater than the strength of the underlying metal. Fracture then takes place at one of the asperities causing metal to be transferred from one surface to the other. The debris so formed gives rise to the accelerated wear that occurs with titanium and its alloys . It is essential that use be made of one of a number of ways to improve wear resistance of Ti6Al4V that are available for the material. There are number of ways to enhance wear resistance properties of Ti alloy such as enhanced surface films including plasma coatings, flame coatings, shot peening, conversion coating etc. as well as thermal oxidation, Nano-composite coatings, ball burnishing process etc. Each process has their own advantages and limitations. In the present study, a comparative study is done to find out the enhancement of wear resistance properties of Ti6Al4V.SandeepYadav will explained

## 2. *Selection of Titanium Alloys for Service*

MJ Donachie observed Primary Aspects. Titanium and its alloys are used primarily in two areas of application where the unique characteristics of these metals justify their selection: corrosion-resistant service and strength-efficient structures. For these two diverse areas, selection criteria differ markedly. Corrosion applications normally use lower-strength "unalloyed" titanium mill products fabricated into tanks, heat exchangers, or reactor vessels for chemical-processing, desalination, or power-generation plants. In contrast, high-performance applications such as gas turbines, aircraft structures, drilling equipment, and submersibles, or even applications such as biomedical implants, bicycle frames, and so on, typically use higher-strength titanium alloys. However, this use is in a very selective manner that depends on factors such as thermal environment, loading parameters, corrosion environment, available product forms, fabrication characteristics, and inspection and/or reliability requirements . Alloys for high-performance applications in strength-efficient structures normally are processed to more stringent and costly requirements than "unalloyed" titanium for corrosion service. As examples of use, alloys such as Ti-6Al-4V and Ti-3Al-8V-6Cr-4Mo-4Zr are being used for offshore drilling applications and geothermal piping, while alloys such as Ti-6Al-4V, Ti-6Al-2Sn-4Zr-2Mo+Si, Ti-10V-2Fe-3Al, and Ti-6V-2Sn-2Zr-2Cr-2Mo+Si are used or planned for use in aircraft or in gas turbine engines for aerospace applications. Desired mechanical properties such as yield or ultimate strength to density (strength efficiency), fatigue crack growth rate, and fracture toughness, as well as manufacturing considerations such as welding and forming requirements, are extremely important. These factors normally provide the criteria that determine the alloy composition, structure (alpha, alpha-beta, or beta), heat treatment (some variant of either annealing or solution treating and aging), and level of process control selected or prescribed for structural titanium alloy applications. A summary of some commercial and semicommercial titanium grades and alloys For lightly loaded structures, where titanium normally is selected because it offers greater resistance to the effects of temperature than aluminum offers, commercial availability of required mill products, along with ease of fabrication, may dictate selection. Here, one of the grades of unalloyed titanium usually is chosen. In some cases, corrosion resistance, not strength or temperature resistance, may be the major factor in selection of a titanium alloy

***3. Corrosion***is the deterioration or destruction of metals and alloys in the presence of an environment by chemical or electrochemical means. In simple terminology, corrosion processes involve reaction of metals with environmental species. "Corrosion is an irreversible interfacial reaction of a material (metal, ceramic, polymer) with its environment which results in its consumption or dissolution into the material of a component of the environment. Often, but not necessarily, corrosion results in effects detrimental to the usage of the material considered. Exclusively physical or mechanical processes such as melting and evaporation, abrasion or mechanical fracture are not included in the term corrosion" With the knowledge of the role of various microorganisms present in soil and water bodies, the definition for corrosion need be further widened to include microbiallyinfluenced factors. Corrosion can be classified in different ways, such as

- Chemical and electrochemical
- High temperature and low temperature
- Wet corrosion and dry corrosion.

***EFFECTS OF CORROSION:***The economic and social consequences of corrosion include i) Due to formation of corrosion product over the machinery, the efficiency of the machine gets failure leads to plant shut down. ii) The products contamination or loss of products due to corrosion. iii) The corroded equipment ~~must be replaced iv) Preventive maintenance like metallic coating or organic coating is required. v) Corrosion~~ releases the toxic products. vi) Health (eg., from pollution due to a corrosion product or due to the escaping chemical from a corroded equipment) S.S. Dara explained.

***CAUSES OF CORROSION:***

In nature, metals occur in two different forms.

1) Native State (2) Combined State

***Native State:***The metals exist as such in the earth crust then the metals are present in a native state. Native state means free or uncombined state. These metals are non-reactive in nature. They are noble metals which have very good corrosion resistance. Example: Au, Pt, Ag, etc.,

***Combined State*:**Except noble metals, all other metals are highly reactive in nature which undergoes reaction with their environment to form stable compounds called ores and minerals. This is the combined state of metals. Example: Fe2O3, ZnO, PbS, CaCO3, etc.,

***Metallic Corrosion:***The metals are extracted from their metallic compounds (ores). During the extraction, ores are reduced to their metallic states by applying energy in the form of various processes. In the pure metallic state, the metals are unstable as they are considered in excited state (higher energy state). Therefore as soon as the metals are extracted from their ores, the reverse process begins and form metallic compounds, which are thermodynamically stable (lower energy state). Hence, when metals are used in various forms, they are exposed to environment, the exposed metal surface begin to decay (conversion to more stable compound). This is the basic reason for metallic corrosion.

***4. Wear Behavior***of Ti Alloys (Without Surface Modifications) Generally, a poor tribological performance with low surface hardness has been reported for titanium alloys that are used in biomedical implants . High coefficients of friction (COF), intense adhesive wear, and low abrasion resistance are regarded as the adverse effects of their tribologicalbehavior. Mechanical sliding between titanium alloys (or a titanium alloy and another material) may lead to wear damage over the surface by disrupting the protective oxide layer, mainly in the presence of a third body at the interface. High reactivity of titanium alloys causes a rapid change of the oxide surface layer to oxidative environment; consequently, it may lead to a removal during the sliding of the two contacting surfaces . After investigation of wear behavior by ball-on-disc and pin-on-disc tribometers, it was reported that the volume loss of titanium alloys increases with rising sliding speed. Higher wear resistance of Ti-6Al-4V alloy was also compared with Ti-6Al-7Nb alloy. This study listed Ti-6Al-7Nb and Ti-6Al4V in a decreasing order based on their estimated wear values at any specific sliding speed . The results of a study performed by De Viteri and Fuentes the protective oxide layer can be removed from the surface of metals. This phenomenon occurs by applying contact loads which allows metals to have interaction with the surrounding environment (or the adjacent material). It can cause adverse effects including high friction and corrosion, and also premature failure of implants. Narayanana and Rajamanickambreviewed the mechanical and tribologicalbehavior of titanium alloys. Poor tribological properties of titanium alloys were concluded in this study due to low plastic strain and unsuited surface reaction of titanium alloys to form oxides. Geetha et al.found that the wear resistance of Ti-6Al-4V is lower than that of Co-Cr-Mo alloy and 316L stainless steel. In addition, higher metal concentrations were reported in the tissue that was removed from the area around the Ti-alloy prosthesis when compared with the Co-Cr alloy and stainless-steel prostheses. Long et al. described the process of wear by performing wear and fretting wear investigations on Ti-35Nb-6Zr-5Ta alloy. A correlation was found between the wear mechanism and both the plastic deformation and tribological transformation of surface (TTS) layers which included α-Ti grains (free from β phases). The fretting studies on two α+β alloys (Ti-6Al-4V and Ti-5V-3Al3Cr-3Sn), and β alloy (Ti-15V-3Al-3Cr) in air showed the formation of TTS layers. The resulting wear particles caused third body abrasive wear. The lowest COF was reported for Ti-5Al-2.5Fe and the highest for commercially pure (CP) titanium, according to the investigations on the fretting wear rate of CP titanium, Ti-6Al-4V, Ti-5Al-2.5Fe, Ti-13Nb-13Zr, and Co-28Cr-6Mo alloys against a steel ball in Hank's solution Yoneyama et al. demonstrated a correlation between wear rate and hardness; when the hardness increases, the wear rate decreases. It was also pointed out that the wear rate of Ti-6Al-4V alloy was significantly less than that of Ti-6Al-7Nb alloy because of the higher hardness of Ti-6Al-4V. Higher hardness and the friction coefficient of Ti-6Al-4V caused reduced material removal specifically in higher sliding speeds. However, no significant change of material removal was identified for Ti-6Al-7Nb [28]. Titanium alloys have an adhesion ability because they are chemically active and ductile. The large wear loss or removal of material is contributed by adhesion; therefore, the wear rate is found out by adding the adhesive wear to the total wear. The differences between the wear rates that were investigated in the body fluid environment and under normal atmosphere were reported by Ganesh et al. and Ren et al. Higher wear rates and material losses were shown in the body fluid environment compared to the normal atmospheric condition which may be due to the corrosive nature of the body fluid environment Dursunetal.pointed out some information about the plastic deformation occurring during the initial phases of wear; and found that there is a positive correlation between this level of wear and the sliding distance. In another study, Choubey et al. performed the tribological testing in Hank's solution and reported that the cracks were created on all Ti alloy samples (e.g., Ti-6Al-4V and Ti-5Al-2.5Fe) because of abrasive wear. A liquid environment was also considered in this wear test to investigate the lubricant effect in reducing the friction; and the temperature remained the same at the contact area of the samples. A comparative study between untreated and β-annealed Ti-10V-2Fe-3Al alloy by Mehdi et al. [33] showed that the β-annealed alloy has a higher wear resistance at loads $\leq 2$ N because of the superelasticityeffect. Besides, a significant transition of the wear rates was seen in the loads over 2 N.

Adhesion phenomenon and material transferring from Ti-alloy to steel were listed as the important reasons of these changes. The super-elasticity effect did not make any increase in the wear resistance level because of the changes in the adhesion behavior of the Ti-alloy. Some other studies reported that there are several wear mechanisms while only a few of them can occur simultaneously. The basic wear mechanism in Ti alloys is abrasion followed by adhesion and transfer layer. The transfer of material is found important in case of tribology .Alam and Haseeb simulated the Ti-alloy pin-on-disc (steel) wear test and acknowledged that the adhesion occurs based on the transferred layer effect. But if no transfer layer exists, it means abrasive wear is dominant. Likewise, Majumdar et al. found that the dominant wear is abrasive in Ti-13Zr-13Nb alloy by performing the wear test in Hank's solution and Bovine serum. Cvijović-Alagić et al. found that Ti-6Al-4V has a higher wear resistance than Ti-Nb-Zr alloy in Ringer's solution, independent of the microstructure. It was concluded that the wear decreases when the hardness increases. More wear loss also occurred in Ti-13Nb-13Zr. The amount of wear was lower in case of Ti-6Al-4V.

***PROPERTIES***

- Tensile strength of titanium materials varies normally from about 200 MPa for pure titanium to about 1400 MPa for near-alloys, while for Ti- 6Al-4V the values vary between 900 and 1200 MPa.
- Thermal conductivity varies from about 5.5 to 25 W/mK when temperature varies from near room at 200˚C.
- Flow stress of Ti-6Al-4V increases substantially with increasing strain and with increasing strain rate, but decreases with increasing temperature.
- Titanium alloys are used in several fields, systems, and parts and their selection is based essentially on corrosion resistance and/or strength, but in the case of biomedical application, the biocompatibility is also an important requisite.

***AEROSPACE APPLICATION***

- Aerospace has been the major field of application of titanium materials, particularly in the engine and airframe systems where it comprises 36% and 7% respectively.

- In parts subjected to aggressive conditions of corrosion, but not submitted to high mechanical and thermal demands, as are the cases of support structure under the kitchens and lavatories, the CP-Ti is usually used.
- The major challenge has been to develop new alloys with improved strength and higher service temperature.Automotive application
- Recently, titanium and its alloys are actively used for intake and exhaust valves, connecting rods, retainers, and others, being the weight saving the major benefits of such applications.
- The major need is the development of new alloys with higher service temperature motor cycle exhaust value application, and new surface treatment to improve wear resistance.

### *BIOMEDICAL APPLICATION*

- The use of titanium alloys as biomaterials has growing due to their reduced elastic modulus, good biocompatibility, excellent strength to weight ratio, and enhanced corrosion resistance when compared to conventional stainless steel and Co- Cr alloys.
- Improving the biocompatibility through the elimination of potential toxic elements such as Al and V, and lowering the elastic modulus to a value similar of the bone are among the major problems on development of new titanium alloys for biomedical applications.

### *CONCLUSIONS*

This paper addressed the review on titanium alloys. The main topics discussed were the properties and the applications, but additional subjects such as elemental titanium, alloying elements and titanium categories were also briefly described. The classic alloy, Ti-6Al-4V, received special attention. With regard to application, the emphasis was given to the aerospace, automotive and biomedical fields. Below are presented the main conclusions obtained.

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