Improved performance of Ti6Al4V alloy in Biomedical applications - Review.

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Abstract. The advantages of Ti6Al4v alloy are high strength, low density, and the advantage of it being non-toxic and the human body does not reject it. Because of these properties, Ti6Al4v are distinguished by their unique properties. To manufacture high strength and lightweight components for biomedical applications, Ti6Al4v alloy is suitable for purpose because of its properties necessary for manufacture. The properties of TiAl4v alloy about its mechanical properties, its corrosion resistance, wear testing, biocompatibility, and bone fusion in biomedical applications, are discussed in the paper. Although TiAl4v alloy has desirable properties, studies have proven to release the two elements of aluminum and vanadium. These two elements are toxic and affect the biocompatibility of Ti6Al4v despite its unique properties. To avoid that, researchers are looking for a way to solve the problem by addition alloy elements that are less toxic and have good mechanical properties. Examples of these elements are zirconium and tantalum.

1. Introduction

Material Science witnessed in the last century a significant development, and a few substances were used effectively for assisting, replacing, and repairing some of the body functions and places. These materials can be vital substances on a large scale. Several definitions of biological substances can be added by different means. Scientists define some unknown or discovered range, and the following are several definitions: Biomaterials Williams in 1987 is a substance used in the medical device and has the advantage of being non-viable, and its purpose is interacting with the biological systems [1]. Williams had defined bio-compatibility in 1999, as a substance. Specific its capability of performing with suitable host response to a specific situation [2]. Other than this definition has been largely a bird's view of vital materials to that time, these successful vital substances have played inert roles in the human body to a large extent as well as concerning the above definition, these vital substances not only provide some functions only It also stimulates some biological responses to understand the various considerations that we have mentioned above. [3] Titanium and Its alloys, specifically Ti6Al4v, are among the best examples of biomaterials considered biocompatible because of its advantage of being non-toxic, and the human body does not reject it, can stay for more than 20 years in The patient's body, in addition to what titanium and Ti6Al4v alloy possess of the potential for bone fusion and Ti6Al4v. Titanium and Ti6Al4v alloy also have low elastic modulus, which is matching (closely) the bone, and because of this feature, it is possible to distribute. The loads from the skeleton
are evenly distributed between the bone and implants; this results in a decrease in the bone deterioration rate and is due to [4] protection from stress and [5] and the occurrence of a fracture of the bone Bones around prostheses[6]. Even though titanium has a hardness that is more than twice the hardness of the bone and thus may cause deterioration to the adjacent bone due to the decrease in the load that has been emphasized on the bone[7].

2. Ternary Phase Diagram of Ti6Al4V Alloy

2.1. Preparation of the Powder Alloy

An alloy \((\alpha + \beta)\) is a Ti6Al4V alloy. A schematic biphasic diagram of Ti-6Al-V alloys is shown in Fig. 1. The \(\alpha\) phase transforms into the \(\beta\) phase with increasing temperature, from about 955-1020 °C, i.e. even higher. From the transition temperature (\(T_B\)), from the high-temperature \(\beta\) phase the entire structure is formed [8-9-10-11]. In the phase diagram these \((\alpha+\beta)\) alloys have a figure-1 range, with room temperature from the \(\beta + \alpha\) phase boundary, until the \(sM\) line junction so the \((\alpha+\beta)\) alloys transform. Martensially upon.

![Figure 1](image-url)

**Figure - 1.** Schematic binary phase diagram of Ti-6Al-V alloy, (MS: martensite start temperature) [8-9-10-11] .

3. Types of Ti6Al4V Alloys

There are two types of crystal structure. Titanium is in the form of a hexagonal crystal representing a phase \((\alpha)\) at room temperature and transforming into a cube crystal representing a phase \((\beta)\) at a temperature of 883 degrees Celsius (equivalent to 1621 degrees Fahrenheit) where to thermomechanical processes and the addition of elements Alloys This diversity is due to crystalline compositions in alloys and properties, which is the basis and basis for this great development as for the classification of titanium products that pave a comfortable path are these phases and therefore titanium alloys are classified into \(\alpha\) alloys, \(\alpha +\) alloys and \(\beta\) alloys

3.1- Alloy(\(\alpha\))

It contains stabilizing elements for \(\alpha\)-alloys, and alloy elements such as aluminum and tin either cause it to increase or work by changing the phase conversion temperature [12]. One of its characteristics is sufficient toughness [13] with heat treatment, it cannot be strengthened.
3.2- Alloy (β)

They contain vanadium, meldenium and niobium, which are transition elements for phase conversion that reduce the α phase temperature, and this promotes development in and phase and are subjected to thermal treatment

3.3- Alloy (β + α)

At room temperature it can contain from 10% to 50% of (β) phase, containing compounds that aid a mixture of α and phases. Ti6Al4v is the most commonly used alloy [14].

4. Corrosion Behavior of Ti6Al4V Alloys

In the early 1950s, extensive research into titanium alloy systems resulted in the discovery of several alloys, the most important of which is Ti-6Al-4V [15]. On the surface of these alloys the presence of passive non-reactive films is an important factor in their resistance to corrosion. Titanium alloys' corrosion resistance is superior to other implant materials such as stainless steel and cobalt-chromium-based alloys [16-17]. Ti-6Al-4V alloy has good weight ratio, mechanical properties and exceptional strength Mineral biomaterials main disadvantage is their degradation upon interaction with body fluids [18]. Thus, the resistance to these traditional metal implant materials for corrosion is according to their ability to produce negative protective films and according to this, these materials are chosen. Due to the thermodynamic stability of TiO2, Ti-6Al-4V alloy shows excellent corrosion resistance. Various other oxides have also been reported to form on a surface. Ti-6Al-4V [19]. However, it suffers from high reactivity despite many advantages to Ti6Al4v alloy. However, by means of different surface treatments, its surface properties can be improved. There are a variety of heat treatments to which Ti-6Al-4V alloy responds as in some previous studies [20-21]. It has been observed that the corrosion resistance properties of Ti-6Al-4V have improved with heat treatment, both in a body fluid solution (SBF). And Ringer's lotion.

5. Mechanical Behavior of Ti6Al4V Alloys

Due to its relatively high specific strength, toughness properties, excellent corrosion resistance, and good creep resistance [22-23] titanium alloys for lightweight structural applications are attractive for such applications as the chemical industry and, as the high-value aviation industry, the large use of titanium is largely limited to the relatively high costs of Final titanium [24]. The main manufacturing process is powder metallurgy (PM) which has the potential to reduce material loss and manufacturing costs associated with wrought shapes and processing steps. In the late 1940's by Kroll [25] for the first time the PM method for making sintered titanium presses was reported the presence of residual impurities in the alloy led to a severe deterioration in the mechanical properties of the alloy. [26-27] Abkowitz et al. [27] A study of PM Ti-6Al-4V alloys in terms of the effect of chlorine on mechanical properties when the chloride content decreased from 0.16 to 0.016 wt% showed significant improvement in mechanical properties, especially fatigue strength and density. Since Kroll's work, many studies have focused on developing the PM approach to titanium. The first and main goal was to reduce material loss in manufacturing, reduce costs, and to improve mechanical properties. This was necessary. In order to create PM for titanium alloys, an approach to manufacturing was followed as a low-cost manufacturing method. It is the mixed element method [28-29] using PM. The components of the prototype were manufactured from titanium [30-31] and it was done by cold pressing of the powder and at a high temperature the sintering was done above the temperature of b-transus. By mechanically mixing primary titanium powder and alloying element powders, the desired alloy composition is obtained, after which the powder is pressed according to the required shape and then sintered to achieve homogeneity of the microstructure. This is for high melting point elements such as
vanadium. Large pre-laminate colonies with beta-grains and large residual porosity have a relative density of 94 percent and from primary powders are impurities [26-32] in this approach. The main disadvantage of titanium PM alloys is the microstructure without any additional mechanical work that cannot be further refined and this increases its cost. PM Ti-6Al-4V possesses substandard mechanical properties Compared with wrought Ti-6Al-4V.

6. Effects of Alloying Elements on Ti6Al4V Alloys

In the recent period, numerous researches were advanced in European Union and the United States of America, in particular, in Japan and China, on the effect of the existence of the elements of the Ti6Al4v alloy on the cells that make up bone and fibroblasts in the surrounding implanted tissues with the implantation of the facet tissue. This study proves that vanadium and aluminum are toxic matters, whereas aluminum may be a cause of neurotoxicity and aging conditions of the type of Alzheimer's. For the purpose of avoiding it, the research looks for alloys and metals with very good corrosion resistance, excellent bio-compatibility, and sufficient mechanical characteristics where elements like tantalum and Zirconum are nontoxic for cells and has good mechanical properties [33-34], it can perform additions of alloying elements; and what it has of significant influences on mechanical properties and phase formation. Research has shown that the values related to the elastic modulus of (alpha + beta) and type (alpha) alloys were relative to titanium-based alloys, where this modulus of elasticity has been considerably higher than the elasticity modulus of human bones that may result in causing a shielding impact against stress [35-36]. The speech proposes a new development based on titanium-based alloys with the existence of nontoxic elements and to reduce the values of elastic modulus to avoid the stress protection effects. Some of the elements such as Zirconum and tantalum were chosen to design a new Ti6Al4v alloy type with a lower value of the elastic modulus, corrosion resistance, and sufficient bio-compatibility [37]. Ti6Al4v shows many characteristics which depend on chemical composition. Knowing the phase shift to a metallic biomaterial is very important, such as titanium and its alloys such as Ti6Al4v, in order to control mechanical characteristics and corrosion resistance [33-35]. The stability regarding the (beta) phase is related. Directly with mechanical properties, titanium alloys, in general, are based on what the research found is that the (beta) phase has a low modulus of elasticity compared to the alloys of the (alpha) phase or the alloy (alpha + beta). The elasticity of the alloy is small closer to the human bone for avoiding the effects protection from stress [3-38] The results of the Vickers hardness test are presented, as the hardness values obtained for titanium alloys containing zirconium and tantalum 402,91 HV it is much higher than the hardness values of Vickers for pure titanium160 HV it is also much higher than the hardness values of Ti6Al4v alloy 294 HV [34-35-39]. The development of new biomaterial is characterized by being with mechanical characteristics that are closer to the human bone properties. The topic for all researchers around the world is considered a difficult problem.

7. Application

In recent period Ti6Al4v titanium alloys are receiving great interest in the medical area in many considerable medical applications like the cardiovascular devices and Dental, orthopedic, and other material types and Valves, orthopedic implants, dental implants, prosthetic limbs, braces, orthodontic wires, screws and plates [40-41]. Ti6Al4v alloy was utilized in many different areas, including petrochemical, automotive, aerospace, medical and marine equipment [42].. In various medical applications, examples of these applications are dentistry, brushes, and surgical tools such as prostheses, braces, and orthodontic wires [5] use of Ti6Al4v alloy in bone implantation applications [43], and for these reasons, Ti6Al4v alloy is used as well as hip balls and sockets,[44] which are made as an alternative to the joint made of titanium metal or Ti6Al4v alloy,
Conclusions

1. The one that affects the mechanical properties of the PM alloy Ti-6Al-4V is the porosity where the required relative density is > 98% which gives mechanical properties similar to those of the ductile Ti-6Al-4V alloy. Porosity causes concentration of stress and the initiation of premature fissures, thus reducing the achievement of uniform elongation in tension.

2. The heat treatment of Ti-6Al-4V alloy has a positive effect on corrosion resistance. There was no improvement in the E value though. The improvement in (current i value) was noticeable due to thermal treatment, and the Ecorr value did not improve. The presence of the beta phase is the reason for the improvement in the corrosion resistance. After Ringer's long-term immersion in Ti-6Al-4V alloys, the negative film that formed on the surface was found to be intact, providing resistance to corrosion and great passivation.

3. The properties of titanium alloys are affected in Addition of elements such as Ta and Zr by increasing the wear resistance and reducing the modulus of elasticity. That is, the addition of these elements makes the microstructure consisting of specific laminate structures of the type of martensite and of granules placed inside the granules. In terms of the mechanical properties of the titanium alloys to which the element Zr or Ta was added, the results obtained are closer to the human bone where the value of the elastic modulus of the alloy is closer to the value of the human bone modulus, where it is of 51.69, which is a low value. To determine cytotoxic behavior it is necessary to continue future studies.

4. As for the phases, the presence of /α transformation means a variety of combinations of properties and fine structures through heat treatment that can be achieved in the alloy, allowing the properties to be adapted according to new applications.

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