Muthanna Journal of Engineering and Technology, Vol. (11), Issue (1), Year (2023)

Muthanna Journal of Engineering and Technology

Website: https://muthjet.mu.edu.iq/

Submitted 13 October 2022, Accepted 27 January 2023, Published online 27 January 2023

Effect of niobium oxide on titanium aluminum alloy

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DOI:10.52113/3/eng/mjet/2023-11-01/11-15

Abstract

Titanium - Aluminum niobium oxide composite was fabricated by powder metallurgy technique. The effect of Nb_2O_5 ratio addition with (1, 1.5, 2, 2.5 wt %) on their mechanical, thermal, and microstructure were investigated. By introducing 2.5 % of Nb_2O_5 the hardness and compressive strength were increased approximately 20% and 46% respectively more than that of pure sample. while weight loss decreased to 4 2% at same ratio. Thermal Conductivity of composite in different temperatures (25, 50, 75 and 100 °C) was decreased 39, 43, 49, and 53 % respectively. Ti-6Al- 2.5 % Nb_2O_5 composite formed porous shape with niobium oxide. This kind of composite could be a promising candidate for implant material.

***Keywords**: Titanium aluminum Alloys; Niobium Oxide; composite Materials; Dental Implants*

1. Introduction

Titanium -Aluminum alloys are representing a light weight metal, malleable and often, high melting point metals ≈ 1655 °C, highly deterioration resistant and high conductivity with excellent resistant to corrosion and erosion. In addition, not affected by chemicals solution and it has high mechanical properties [1, 2]. Titanium – Aluminum alloy is an expensive metal and consider important alloy

This is because it is used in a number of important industrial fields, including space applications, power generation applications, chemicals, automotive applications, many sports applications, especially in general medical industries and dental applications. The main reason for the many applications of titanium alloys is the high strength compared to its low density [3, 4]. This is very desirable in medical applications, especially for devices implanted inside the human body to replace injured hard tissues. The most important of these applications are bone plates, artificial hip joints, heart valves, artificial knee joints, artificial hearts, and prostheses. Since titanium - aluminum is passive in human body and it is a nontoxic alloy, therefore it is also used in teeth and teeth abstraction clamps roots screws connecting and plates bones, that need to be immovable for very a long time [5, 6]. The effect of metals adding like vanadium and niobium in properties of titanium – aluminum alloy has been studied [7-9]. However, the effect of oxides adding like (Nb_2O_5) in mechanical properties and microstructure of titanium – aluminum alloy was scarcely reported. So, the purpose of this study is to evaluate the effect of (Nb_2O_5) on the properties of titanium – aluminum alloy.

2. Procedure and Experimental

2.1. Powders and methods

Titanium Aluminum alloy / Niobium Oxide composite was synthesized by mixing of Ti-6Al and niobium oxide powders (Nb_2O_5) with different ratio (0, 1, 1.5, 2, 2.5) % in blender at (100 r.p.m) for two hours. The mixture was pressed at (110 MPa). The compresses prepared were then the samples are sintered at 650 ℃ for four hours. The purity and size of titanium aluminum alloys and niobium oxide show in table (1).

Table 1: Characterization of Titanium alloys and Niobium Oxide powderS

powder	size	purity %
Ti–6AL	10-50 µm	95%
Nb_2O_5	≈ 100 nm	99.98

2.2. Tests and examinations

2.2.1. X-Ray diffraction

The phase formation behavior of the alloy is revealed by an XRD method X.R.D diffraction was carried in order to revision composition of titanium aluminum alloy and its composite with niobium oxide.

2.2.2. Micro-hardness

Micro - hardness was achieved as mention in (A.S.T.M - E 92 - 82) by Vickers device. This device was applied (1000) g load for twenty second on specimens by a 136° diamond pyramid indenter.

2.2.3. Compressive strength

It was achieved by universal tester as mention in (A.S.T.M. C 623 – 92).

2.2.4. Weight of loss (wear)

This test is very important for titanium alloys because their resistance to wear is medium when friction with materials of higher hardness, so this test was used for the purpose of examining samples before and after addition using a pin method on the disc.

2.2.5. Thermal conductivity

The thermal conductivity inspection achieved for titanium aluminum alloy composites with changed in temperature 25 °C, 50 °C, 75 °C and 100 °C to illustration the effect of niobium oxide by hot disk device.

2.2.6. Field emission SEM (FESEM)

Crystalline structure and Morphology, of (Titanium Aluminum alloy) and composite with Nb_2O_5 nanowires samples were examined by scanning microscope.

3. Results and discussions

3.1. X.R.D

Figure 1 shows the X Ray Diffraction shape for Ti-6Al- 2.5% Nb_2O_5 composite. The (Ti- 6 Al-2.5% Nb_2O_5) composites showed by mainly peaks attributable to Ti α while Ti β phase is evidently considered only by the (011) and (101). The observations were consistent with those of earlier research [9, 10].

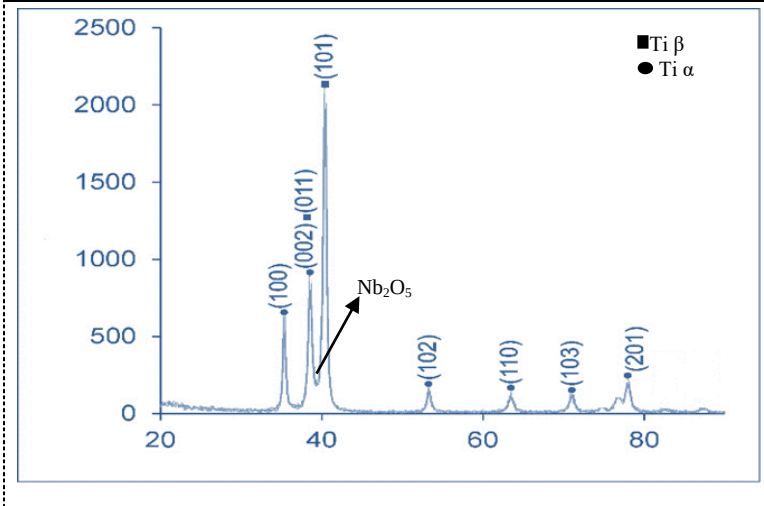


Fig. 1: XRD patterns of titanium – aluminum -2.5% niobium composite

3.2. Vickers -Hardness

Vickers –Hardness values of titanium aluminum with addition of (1, 1.5, 2, 2.5 wt%) of Nb_2O_5 are shown in Figure 2. Hardness values were increased with increasing (Nb_2O_5) ratio. The hardness reached to ≈ 8.2 Kg / mm^2 with the addition 2.5 % of Nb_2O_5 approximately 20% more than that of pure sample.

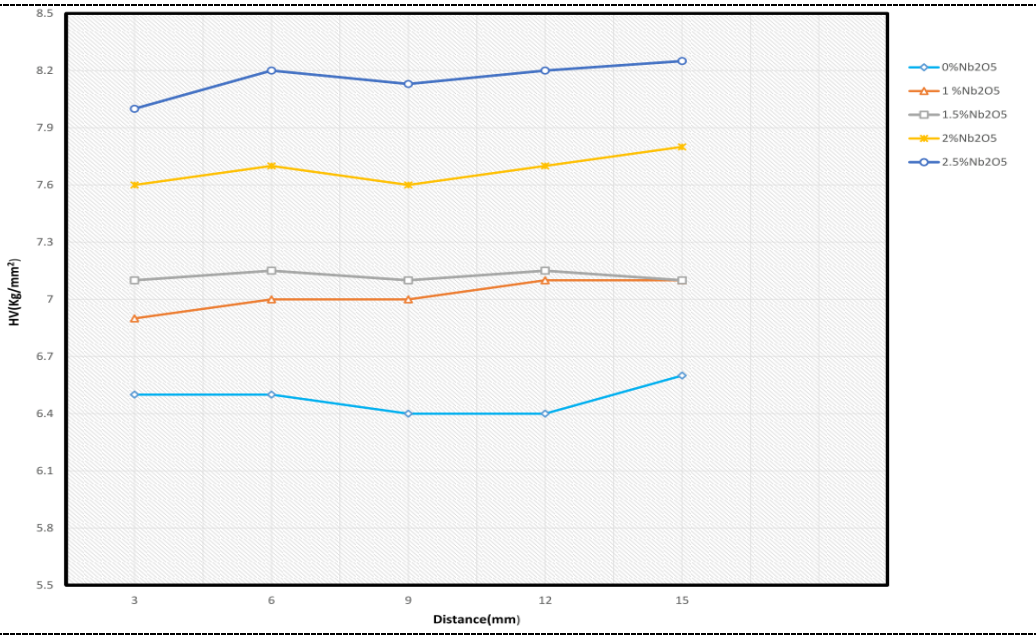


Fig. 2: Variation of Hardness of titanium aluminum at different niobium oxide ratio

3.3. Compressive strength

The Compressive properties of the titanium aluminum composite is shown in Figure 3. It can be noted the compressive strengths of the composite with (1,1.5, 2, 2.5wt%) of Nb_2O_5 additions are approximately 180, 200, 220 and 240 MPa, correspondingly, which are higher than that of titanium aluminum fabricated by powder metallurgy 152 MPa the compressive strength of the Ti- 6Al-Nb_2O_5 composites increased with increasing Nb_2O_5 addition because (Nb_2O_5) addition reduced ductility and toughness of the Ti - 6Al alloy, many previous works have reported similar behavior [9, 11].

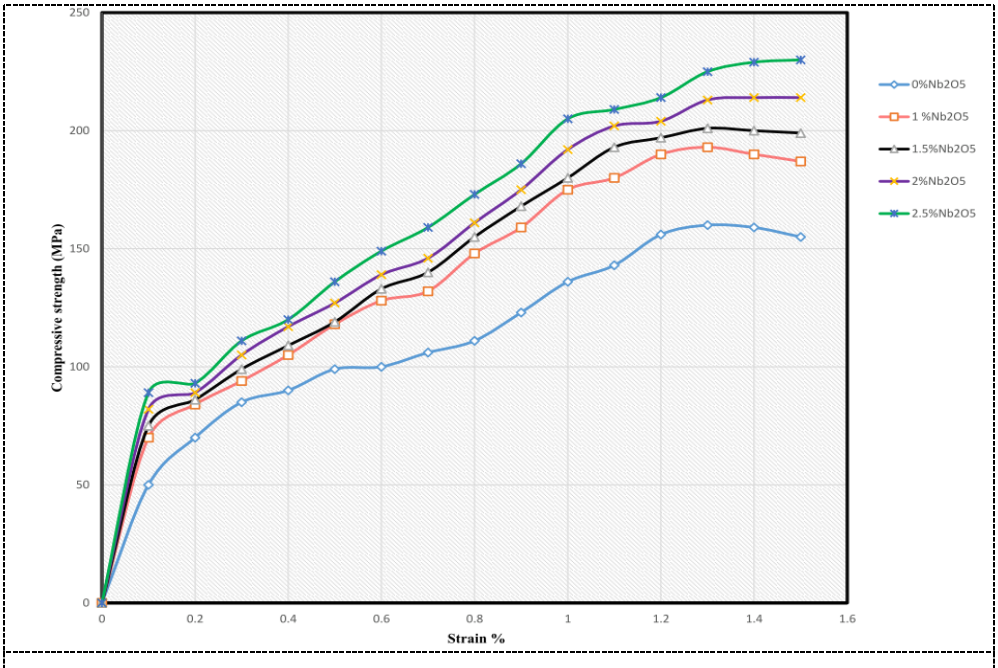


Fig. 3: Compressive strength of titanium – aluminum - niobium oxide composite

3.4. Weight loss

Weight loss of samples with addition of (1,1.5, 2, 2.5wt%) of Nb_2O_5 are shown in Figure 4. The results revealed that the weight loss was decreased sharply with increasing Nb_2O_5 ratio with increasing of Nb_2O_5 ratio to 2.5% a decrease in weight loss reached to (42%) ≈ 4.5 gm as compared with pure titanium aluminum alloy which was 8.2 gm because of addition of Nb_2O_5 accelerated the densification parameters, reinforced and toughened the obtained samples. These results agree with earlier report [10, 12].

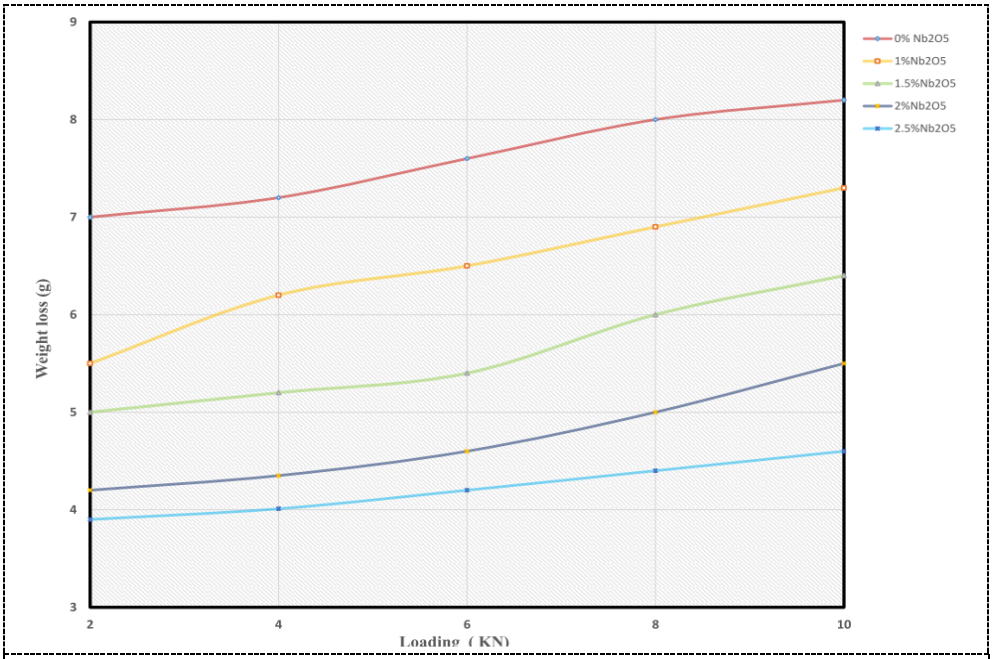


Fig. 4: weight loss of titanium – aluminum – niobium oxide.

3.5 Thermal conductivity

The changes of thermal conductivity with the increase of niobium oxide ratio are presented in Figure 5. When Nb_2O_5 ratio was increased from 1% to 2.5% the thermal Conductivity of Ti-6Al- Nb_2O_5 composite in different temperatures was decreased 39, 43, 49, and 53 % respectively because generally, ceramics have very low thermal conductivity, as compared to metals. The observations were consistent with those of earlier research [13, 14].

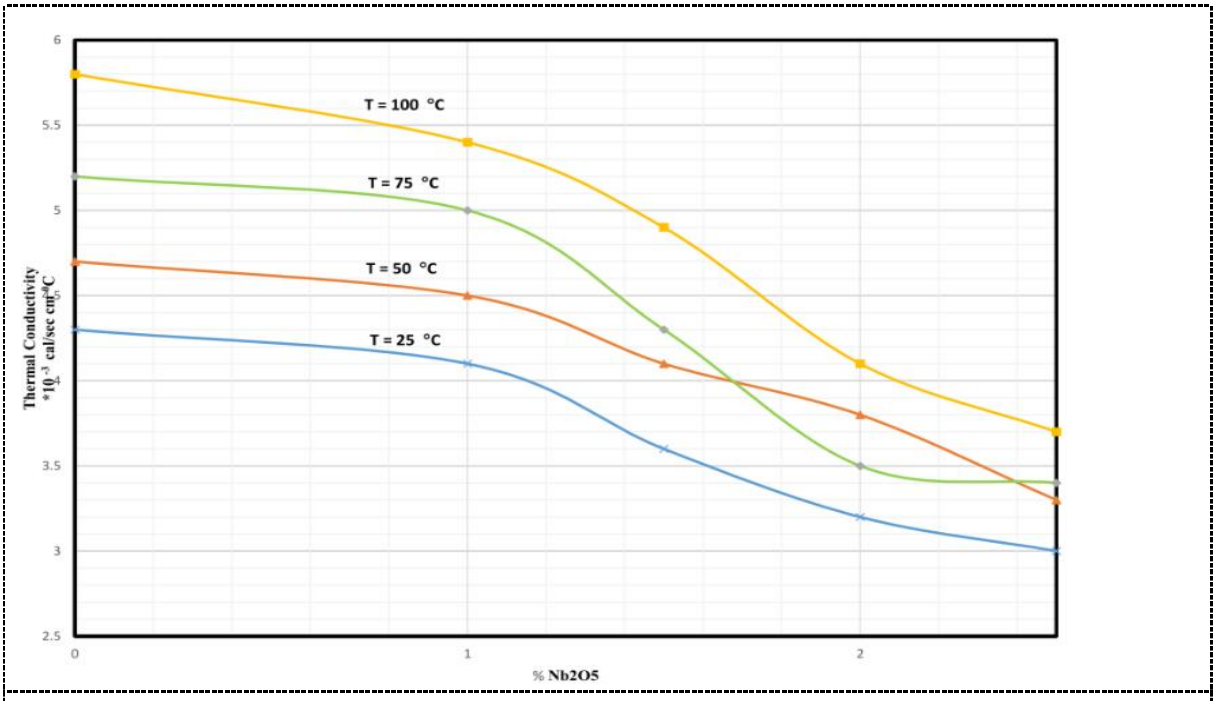
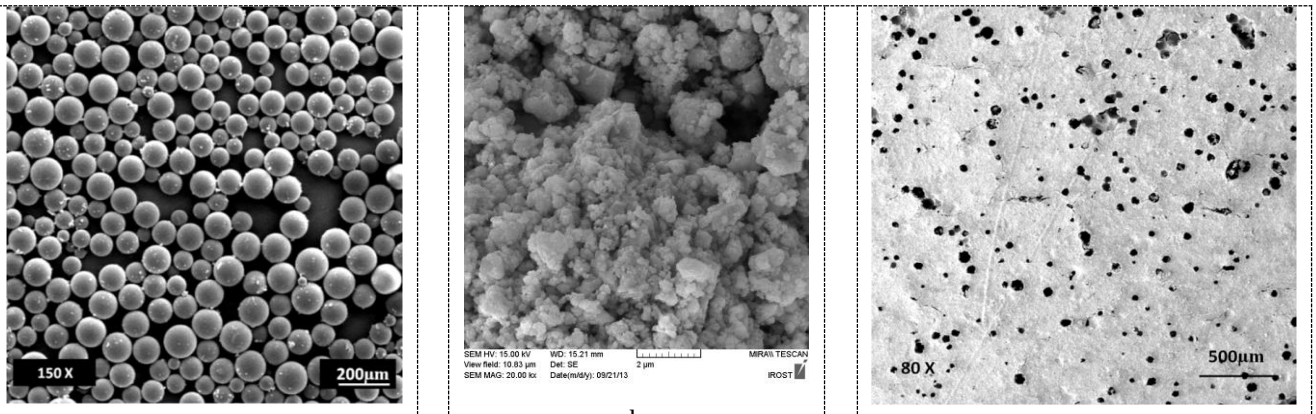


Fig.5: Thermal conductivity of titanium - aluminum – niobium oxide composite at (25, 50, 75 and 100 ˚C).

3.6 Microstructure

Morphologies of starting materials illustrated by FESEM images of the Ti 6 Al and Nb_2O_5 commercial powders are shown in Figure 6 (a and b). The Ti6Al powders have spherical morphologies and size distribution of 10-50μm and Nb_2O_5 powder appears as an extremely fine powder as nanoparticles with diameters of approximately 100nm Titanium Aluminum / Niobium oxide composite appeared as rough surface and formed porous shape with niobium oxide and its pores extended to the internal with a diameter of about 10-50 μm as illustrated in Figure 6 (c).



a b c

Fig. 6: FESEM micrograph of the a) Ti-6Al powder b) Nb_2O_5 powder c) Ti- 6Al -2.5% Nb_2O_5 composite

4. Conclusions

Ti- 6Al -Nb_2O_5 composites were produced by powder metallurgy. Beta titanium was observed in investigation of x-ray diffraction of composite sample. The composite was investigated as a function of (Nb_2O_5) addition with different ratio (0, 1, 1.5, 2, 2.5) %. The hardness increased approximately 20% more than that of pure sample with the addition 2.5 % of Nb_2O_5. Compressive strength was increased 46% and weight loss decreased to 42% at same ratio. The adding of Nb_2O_5.to titanium - aluminum alloys also reduced the thermal conductivity in different temperatures by 39 % , 43 % , 49 % , and 53 % respectively. Ti- 6Al -Nb_2O_5 composite formed porous shape with niobium oxide and its pores extended to the internal with a diameter of about 10-50 µm. The results agreed with the theoretical predictions

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