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Effects Of The Boriding Time at 800°C on Ti6Al4V Alloy

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Öz

Bu çalışma, 800 derece Ti6Al4V alaşımının farklı sürelerde borlanması araştırmaktadır. Ti6Al4V alaşımı, hafiflik, yüksek mukavemet ve korozyon direnci gibi özellikleri nedeniyle geniş bir endüstriyel uygulama alanına sahiptir. Borlama, alaşımın yüzey özelliklerini iyileştirmek için kullanılan bir yüzey modifikasyon yöntemidir. Çalışmanın amacı, 800 derece sıcaklıkta gerçekleştirilen borlama sürecinin Ti6Al4V alaşımının yapısal ve mekanik özelliklerine etkisini değerlendirmektir. Bu çalışmada, borlama işleminin etkisini belirlemek için çeşitli analiz yöntemleri kullanılmıştır. İncelenen örneklerin mikroyapısal analizi, taramalı elektron mikroskobu (SEM) ve X-ışını difraksiyonu (XRD) ile gerçekleştirilmiştir. Ayrıca, borlanmış örneklerin mekanik özellikleri, sertlik testleri ve aşınma direnci testleri ile değerlendirilmiştir. Elde edilen sonuçlar, 800 derece Ti6Al4V borlanmasının alaşımın yüzey özelliklerini önemli ölçüde iyileştirdiğini göstermektedir. Borlama işlemi sonucunda yüzey sertliği artar ve aşınma direnci gelişir. Mikroyapısal analiz, borlama sıcaklığının artmasıyla birlikte TiB2 gibi borür fazlarının oluştuğunu ortaya koymuştur. Bu fazlar, alaşımın yüzeyinin sertliğini ve aşınma direncini artıran önemli faktörlerdir. Sonuç olarak, bu çalışma Ti6Al4V alaşımının 800 derece borlanması sürecinin önemli sonuçlarını sunmaktadır. Bu bilgiler, endüstriyel uygulamalarda Ti6Al4V alaşımının dayanıklılığını artırmak için yüzey modifikasyonunun optimize edilmesinde kullanılabilir. Üretilmiş olan borlanmış Ti6Al4V numunelerinin aşınma dayanımı ve sertlik değerleri arttırılmıştır. Bu sayede daha uygun maliyetlerde daha yüksek dayanım değerlerine sahip Ti6Al4V alaşımı üretilmiş olacaktır.

Anahtar Kelimeler

"Borlama, Aşınma,XRD"

Abstract

This study investigates boronization of 800 degree Ti6Al4V alloy at different times. Ti6Al4V alloy has a wide range of industrial applications due to its light weight, high strength and corrosion resistance. Boronizing is a surface modification method used to improve the surface properties of the alloy. The aim of the study is to evaluate the effect of boriding process carried out at 800 degrees on the structural and mechanical properties of Ti6Al4V alloy. In this study, various analysis methods were used to determine the effect of boriding process. Microstructural analysis of the examined samples was carried out by scanning electron microscopy (SEM) and X-ray diffraction (XRD). In addition, the mechanical properties of boronized samples were evaluated by hardness tests and abrasion resistance tests. The results show that 800 degree Ti6Al4V boronizing significantly improves the surface properties of the alloy. As a result of boriding process, surface hardness increases and wear resistance improves. Microstructural analysis revealed that boride phases such as TiB2 were formed with the increase of boriding temperature. These phases are important factors that increase the hardness and wear resistance of the surface of the alloy. In conclusion, this study presents the important results of the 800 degree boronizing process of Ti6Al4V alloy. This information can be used to optimize the surface modification to increase the durability of the Ti6Al4V alloy in industrial applications. The wear resistance and hardness values of the boronized Ti6Al4V samples were increased. In this way, Ti6Al4V alloy with higher strength values will be produced at more affordable costs.

Key Words

"Boriding,wear, XRD"

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1. Introduction

Ti6Al4V alloy is a metal matrix composite formed by the combination of elements such as titanium, aluminum and vanadium. This alloy has become a preferred material in many industrial applications with its advantages such as excellent mechanical properties, low density and high corrosion resistance Yao (2016). It is frequently encountered in components used in sectors such as aviation, space and medicine.

The surface properties of the Ti6Al4V alloy are a critical factor affecting the performance and durability of the component Paretti (2018). Therefore, surface modification methods are of great importance to improve the properties and prolong the life of the alloy. One of these methods is known as boriding Li(2018).

Boronizing is the process of forming a boride layer by diffusion of the element boron onto the surface of a material. This layer increases surface hardness, improves wear resistance and creates a more resistant surface against corrosion. Therefore, boronizing the Ti6Al4V alloy can provide significant improvements in the mechanical and surface properties of the alloy Atar(2008).

Boring temperature and time have a great influence on the structural and mechanical properties of the alloy. In this way, it is ensured that the alloy is used at higher strength values in a wider area of use Atar (2009).

2. Experimental

2.1 Sample Preparation

Commercially available Ti6Al4V alloy was used for boriding and 20mm×5mm cylindrical samples were prepared. The samples were obtained by cutting Ti6Al4V cylindrical material. Struers accutom cutting -10/-100 precision cutting device was used in the preparation of the samples.

Figure 1. Struers accutom cutting -10/-100 precision cutting device

2.2 Boriding

Boriding process can be done in solid, liquid, gas and plasma environment. In this study, boriding in solid medium (box) was preferred because it is preferred widely and more stable results are obtained with relatively easier facilities. Stainless steel crucibles were used for boriding the samples. The crucible is precision machined and designed to minimize air intake. Figure 2 gives a schematic representation of the crucible..

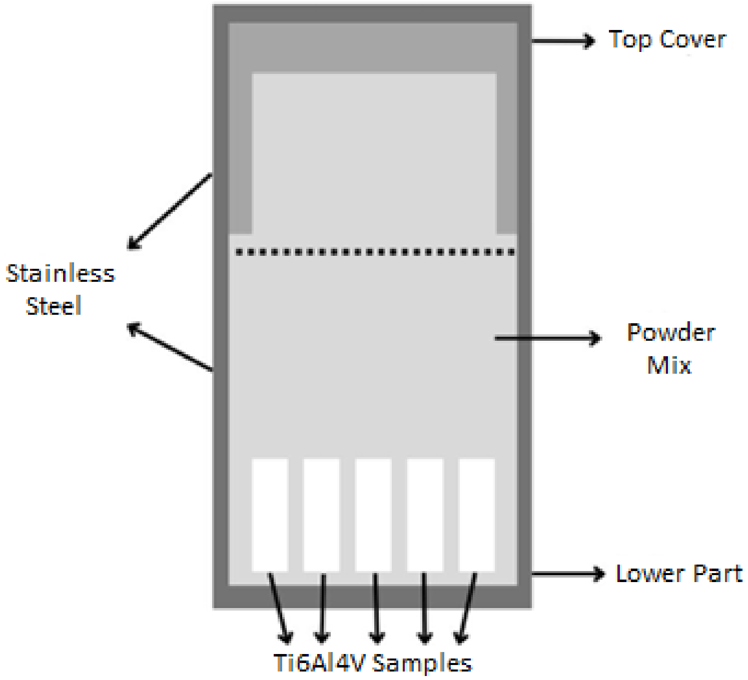


Figure 2. Schematic representation of the ladle for pack boriding

2.3 Wear

Abrasion tests of boronized specimens were carried out in the UTS Tribometer T10 Tester in accordance with ASTM G133 standard for linear back-and-forth reciporating wear test under dry sliding conditions.

Figure 3. (a) UTS Tribometer T10 abrasion tester (b) Sample test section

For the wear test, 3 different loads as 10N, 20N and 40N were used. As a result of the test, the machine automatically gives us the coefficient of friction.

As a result of the wear tests, SEM images of the samples were taken on the device given in the figüre 14.

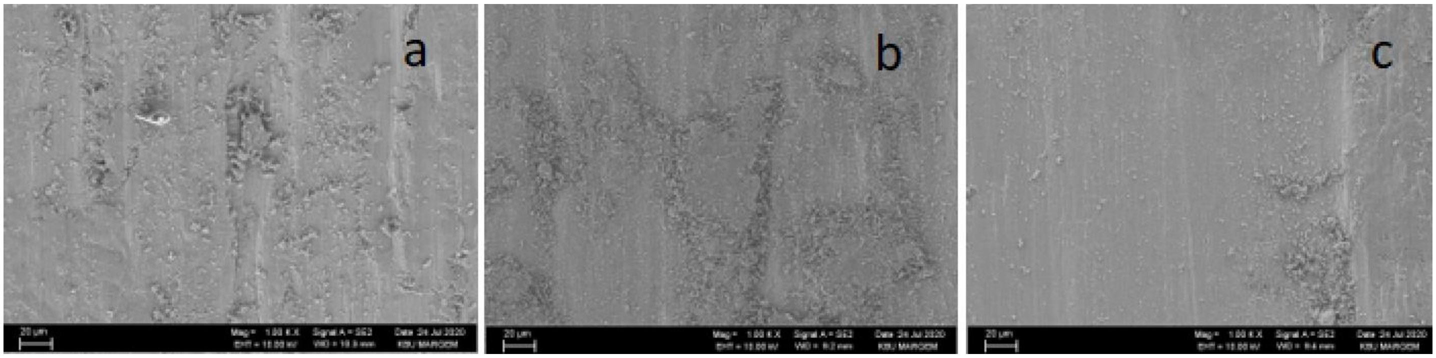


Figure 4. SEM image of boronized samples under 10N load (a) 800°C 2h (b) 800°C 4h (c) 800°C 8h

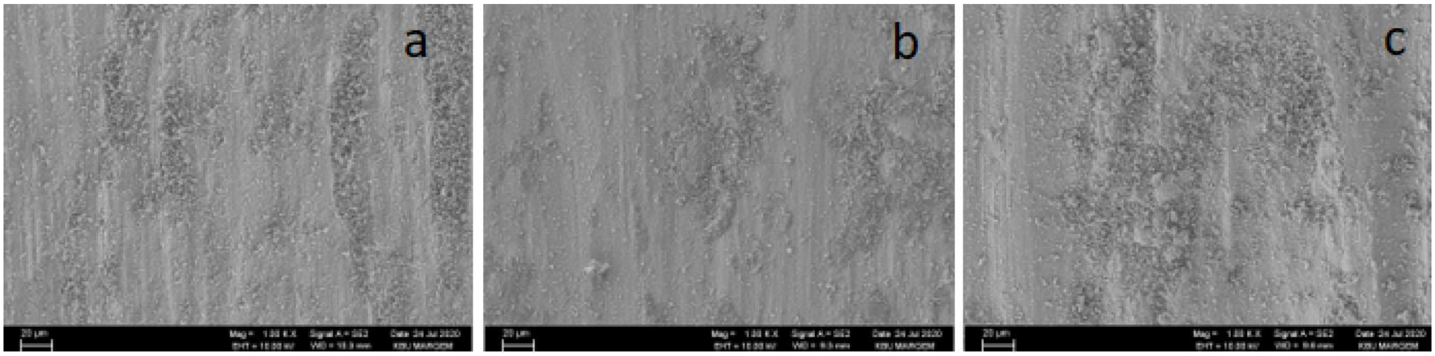


Figure 5. SEM image of boronized samples under 20N load (a) 800°C 2h (b) 800°C 4h (c) 800°C 8h

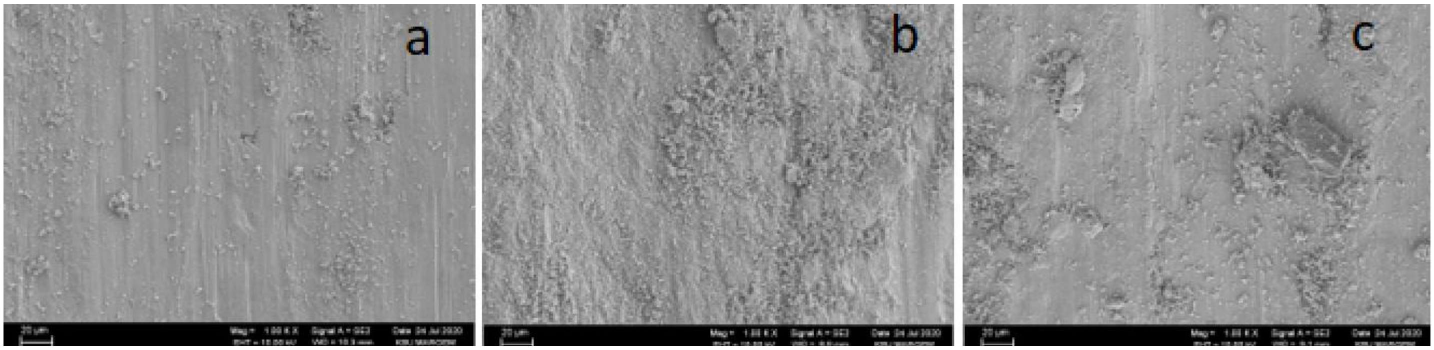


Figure 6. SEM image of boronized samples under 40N load (a) 800°C 2h (b) 800°C 4h (c) 800°C 8h

In addition, in order to control the wear depths of the samples and to calculate the volume losses more clearly, the wear surfaces of the samples were displayed in three dimensions using Nikon shuttlepix, and the wear depths and volume losses were also controlled by the software. Figure 7 shows the three-dimensional image of the device, reduced to 2 dimensions.

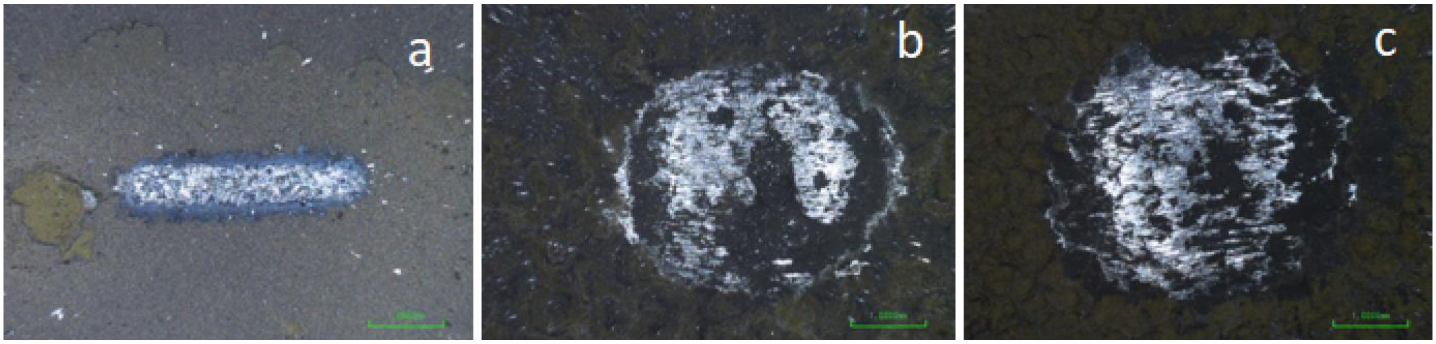


Figure 7. Nikon shuttlepix 3d microscope image of boronized samples under 20N load (a) 800°C 2h (b) 800°C 4h (c) 800°C 8h

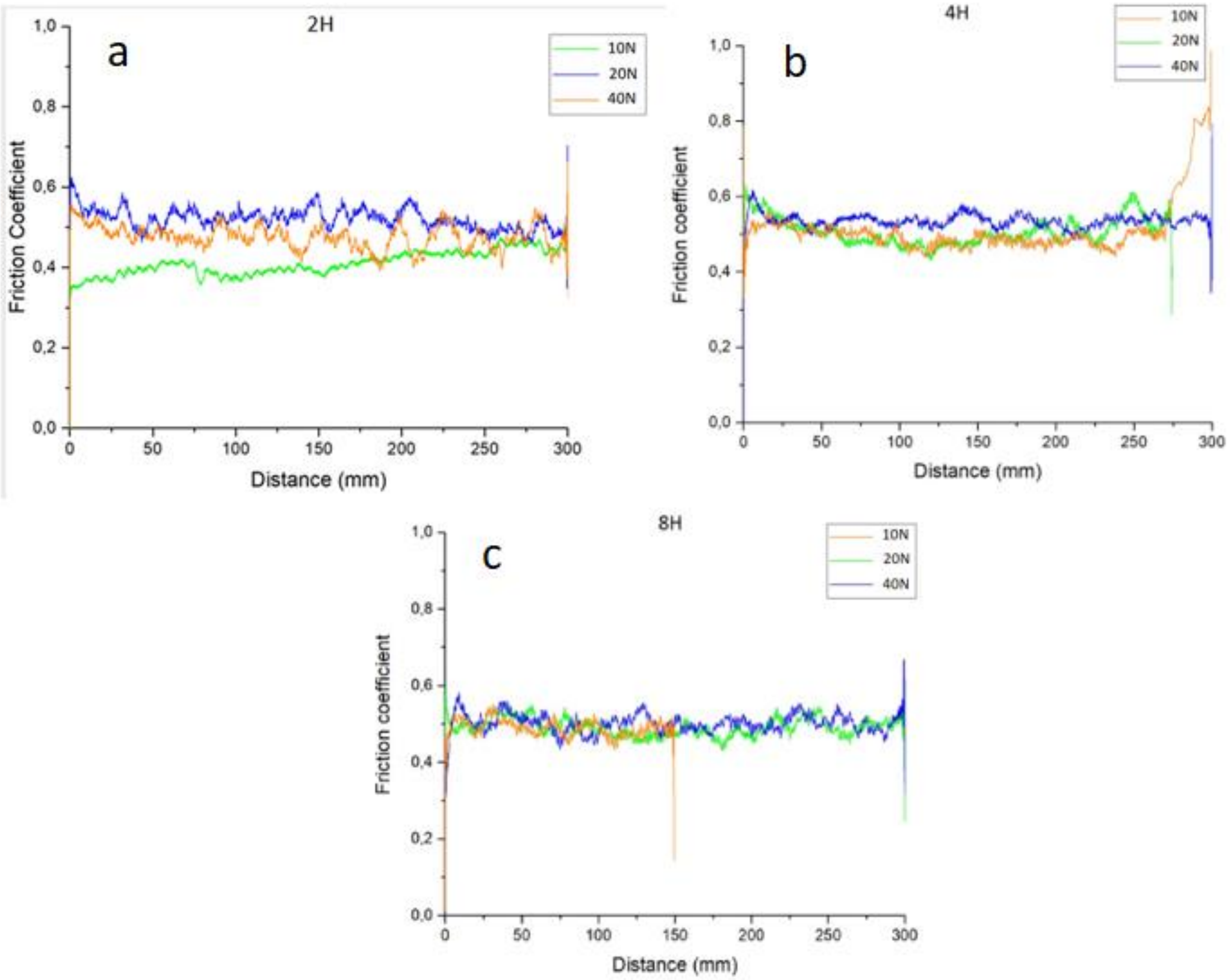


Figure 8. Friction coefficent distance plots of boronized samples at 10N, 20N and 40N (a) 800°C 2h (b) 800°C 4h (c) 800°C 8h

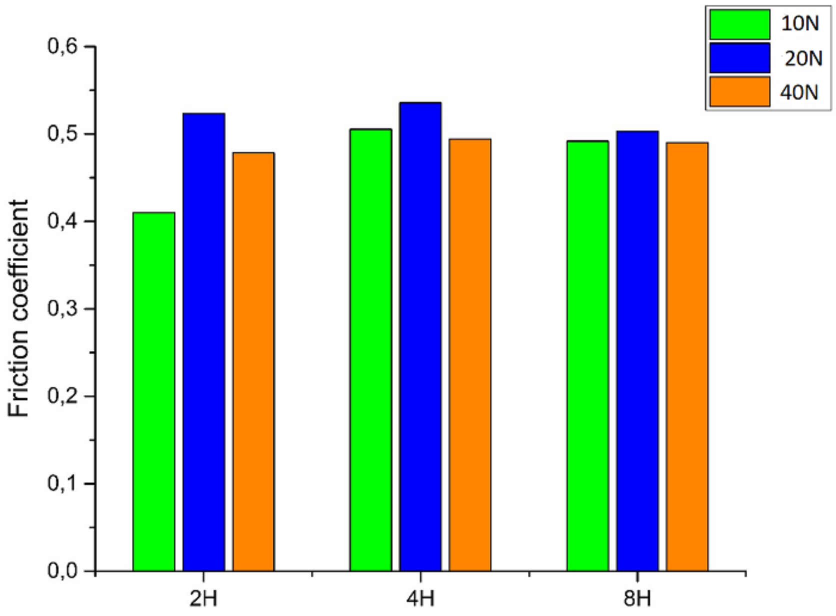


Figure 9. Friction Coefficent

2.4 Hardness

Hardness test measurements were made on the Qness Q10 A+ micro hardness measuring device. The hardness measurement results are given in the figure.

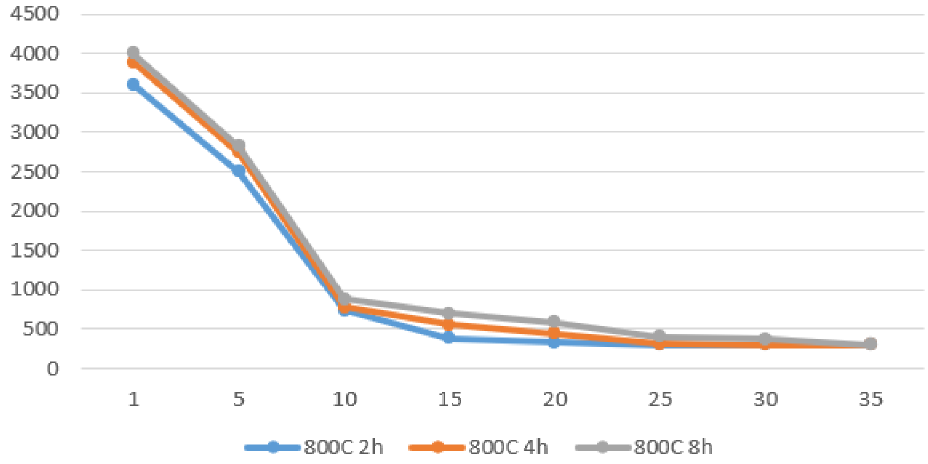


Figure 10. Distance from the surface (µm) hardness measurement results

Figure 11. Qness Q10A+ microhardness tester

2.5 Material Characterization

After boriding, the samples were subjected to XRD measurement. XRD measurements were made with the Rigaku ultima IV X Ray diffraction spectrometer device.

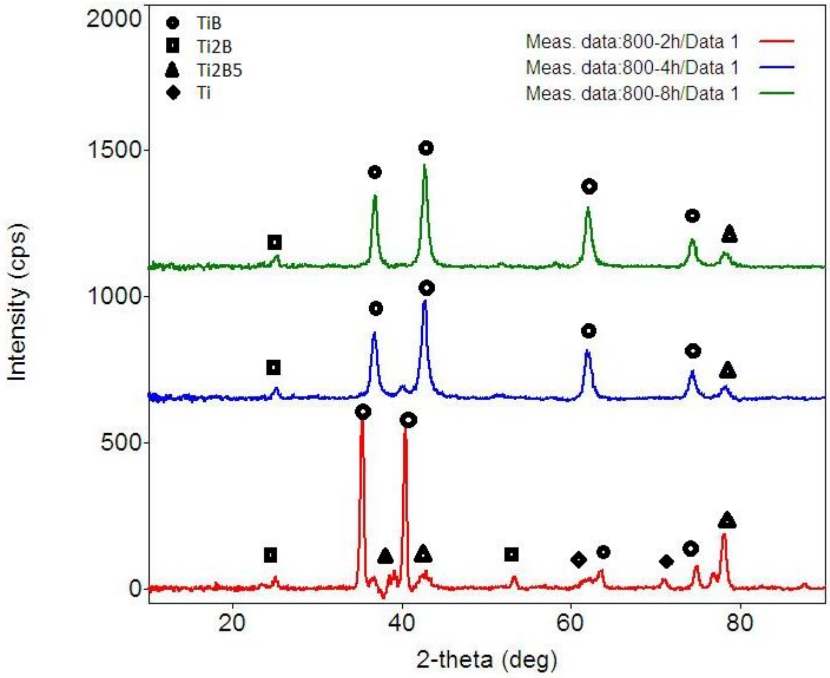
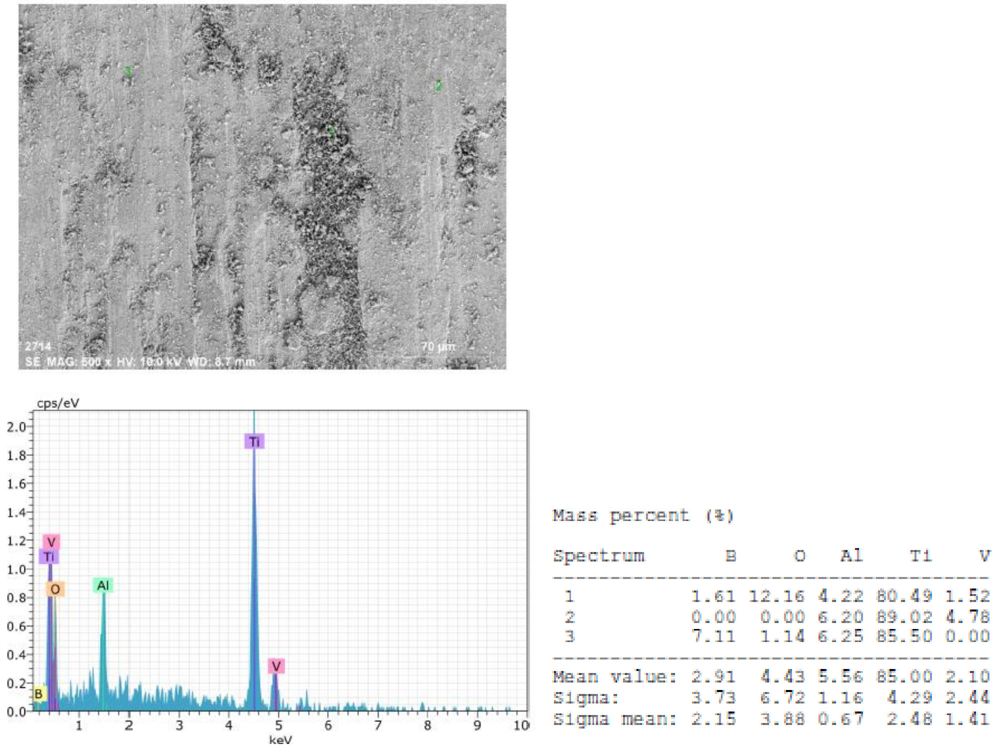


Figure 12. XRD analyzes of 800°C 2h, 4h, and 8h samples

Figure 13. Rigaku ultimate IV X-Ray diffraction spectrometer

After boronization, EDX analyzes were made and sem images were taken on Carl Zeiss Ultra Plus Gemini Fesem device. In addition, wear images of the worn samples were also taken on the same device.

Figure 14. Carl Zeiss Ultra Plus Gemini Fesem cihazı



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Mass percent (%)

Spectrum          B     O    Al    Ti    V
-------------------------------------------
 1             1.61 12.16 4.22 80.49 1.52
 2             0.00  0.00 6.20 89.02 4.78
 3             7.11  1.14 6.25 85.50 0.00
-------------------------------------------
Mean value:    2.91  4.43 5.56 85.00 2.10
Sigma:         3.73  6.72 1.16  4.29 2.44
Sigma mean:    2.15  3.88 0.67  2.48 1.41
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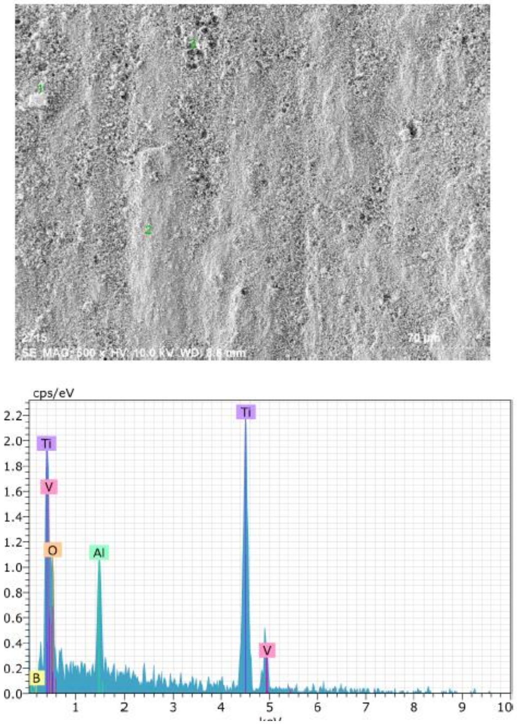
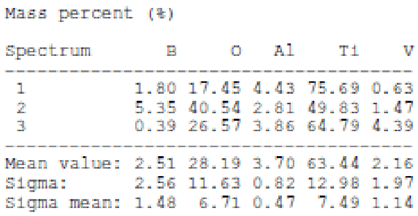
Figure 15. 800°C de 2h borlanmış numunenin SEM görüntüsü ve EDX analizleri





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Mass percent (%)

Spectrum       B     O    Al    Ti    V
-----------------------------------------------
 1          1.80 17.45 4.43 75.69 0.63
 2          5.35 40.54 2.81 49.83 1.47
 3          0.39 26.57 3.86 64.79 4.39
-----------------------------------------------
Mean value: 2.51 28.19 3.70 63.44 2.16
Sigma:      2.56 11.63 0.82 12.98 1.97
Sigma mean: 1.48  6.71 0.47  7.49 1.14
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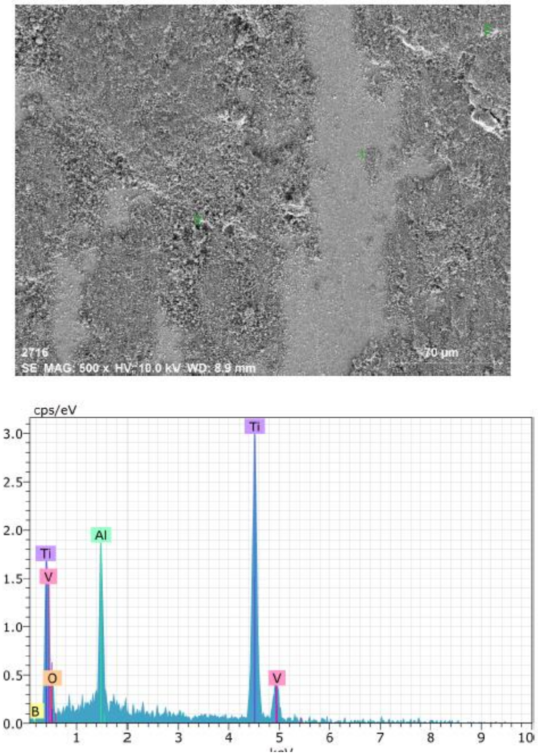
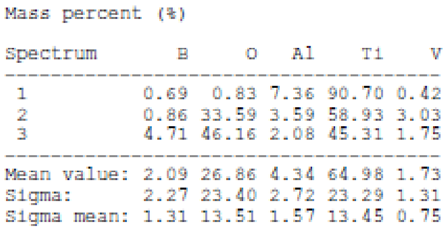
Figure 16. SEM image and EDX analysis of the 2h boronized sample at 800°C





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Mass percent (%)

Spectrum       B     O    Al    Ti    V
-----------------------------------------------
 1          0.69  0.83 7.36 90.70 0.42
 2          0.86 33.59 3.59 58.93 3.03
 3          4.71 46.16 2.08 45.31 1.75
-----------------------------------------------
Mean value: 2.09 26.86 4.34 64.98 1.73
Sigma:      2.27 23.40 2.72 23.29 1.31
Sigma mean: 1.31 13.51 1.57 13.45 0.75
```

Figure 17. SEM image and EDX analysis of the 2h boronized sample at 800°C

When the SEM images and XRD analyzes are examined, it is seen that the samples boronized for a longer time reach higher peak values, which is evident in the microstructure.

3. Conclusion

Commercial usage areas of Ti6Al4V alloy are increasing day by day. We do some additional processes to make the different properties of the materials used better according to the area needed. When we perform these operations, we want to obtain higher mechanical properties without decreasing values such as biocompatibility, corrosion resistance, toughness and wear resistance. Boriding process allows us to obtain better wear resistance, hardness resistance and corrosion properties without sacrificing the material's own properties. When the tests and analyzes are examined, we see that the TiB and Ti2B layers formed in the structure have different peaks at different temperatures. This situation emerges when we examine the microstructure of the material and EDX analysis. However, with the wear test, we see how effective the boron layer on the surface is. When the hardness values of the materials are examined from the surface, this gives us information about the thickness of the layer. Here, while the layer thickness is thinner at lower waiting times, the increase in the waiting time ensures that the layer is thicker. Another situation that should not be overlooked here is the adjustment of the boriding time of the material under optimum conditions. Since the high-thickness layer will have a brittle structure, it may not provide the desired mechanical properties.

When Figure 15, Figure 16 and Figure 17 are examined, it is seen that the microstructure of the samples changes with the increase of the boriding time. The increase in the boron layer shows this to us with XRD graphics. The hardness values of the samples changing from the surface indicate that the boriding process time is proportional to the hardness. In addition, the hardness values from the surface also increase in the samples boronized for a longer time.

In general, Ti6Al4V is a suitable material for boriding. Box boriding process is preferred especially because of its low cost and ease. As a result of the boriding process, the hardness value increased as the layer thickness and penetration depth increased with the increase in the time of the material. We see this increase in hardness values in the wear test results. Abrasion depths and wear rates resulting from wear gave better results with increasing coating thickness.

The study shows that box boriding process is a simple process for application and control of parameters. Ti6Al4V samples produced by boriding process reached the desired wear and hardness values. By increasing the boriding time, these properties can be preserved up to the inner parts of the alloy. Wear test results show us this.

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