IMPROVEMENTS IN WEAR PROPERTIES OF TI-6AL-4V ALLOY BY THERMAL OXIDATION PROCESS

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Introduction:

Ti-6Al-4V alloy is a versatile titanium alloy finding large scale applications in aerospace, bio-medical and automotive fields. Its strength, toughness and ductility can be manipulated by thermo-mechanical treatments to the required levels. But, it exhibits a poor wear resistance[1] due to which its versatility has not been completely exploited.

Thermal oxidation has been proposed by many workers in order to improve its wear resistance by increasing the surface hardness of Ti-6Al-4V alloy. Recent studies have been conducted by Dong et al[2], Hideki Fujii et al[3], Broglie etal [4]and Sivarama Krishnan et al[5], at a few chosen temperatures and durations of thermal oxidation.

The present investigation is carried out to explore the influence of thermal oxidation process and its parameters on sliding wear properties of Ti-6Al-4V alloy.

Experimental Work:

The nominal composition of the Ti-6Al-4V alloy used in the present investigation is given in Table 1.

Table1 Nominal Composition of Ti-6Al-4V alloy used in this investigation

Al	V	Fe	O	Ti
5.6-6.3	3.6-4.4	0.25 max	0.12max	Rem.

The alloy was first subjected to the standard STA treatment of solutionising at 950ºC and aging at 540ºC for 6 hours. It had a hardness of 358 KHN in this condition. Thermal oxidation process was carried out on the samples at 600ºC for 6hours, 15 hours and 24 hours in a resistance furnace with free air circulation. These samples were subjected to x-ray diffraction on a Rigaku X-ray Diffractometer. Microstructural studies were carried out on a Leica Vertical Metallurgical Microscope.

The micro-hardness tests at the surface and at different depths from the surface were determined using Buehler Micromet 2103-93as per ASTM 0384-9. Pin-on-disc wear tests were conducted as per ASTM G99-95a standards, on the oxidised and the STA treated samples, at 200 rpm for 10 minutes duration on an EN31 steel disc of 100 mm diameter and Hardness 63HRC. The load used was 2 kgf. The worn out surfaces of the samples were studied under a JEOL JSM 6490LV Scanning Electron Microscope, at an accelerating voltage of 20kV in SEI mode.

Results and Discussions:

X-ray diffraction pattern from a sample oxidised 600ºC for 24 hours, is shown in Fig 1(a). Microstructures of the edge of the sample oxidized at 600ºC are shown in Fig 1(b). The X-ray and Microstructural studies reveal a thin layer of oxides TiO_2 and/or TiO formed at the surface of the alloy. A layer of α–Ti rich in oxygen is formed underneath the oxide layer

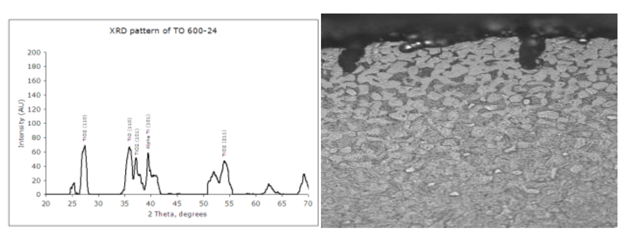

Fig 1(a): X-Ray Diffraction pattern (b): Microstructure of the sample oxidised at 600ºC for 24 hours

The microhardness – depth profiles for the three durations of oxidation are shown in Fig 2. The microhardness at the surface in a thermally oxidized sample is found to be increasing with increase in duration of thermal oxidation. It is found to be 114 to 125 % higher than the property for the alloy in STA condition. This is due to the formation of hard oxides of titanium at the surface. The microhardness-depth profile decreases gradually up to a depth of about 100 microns, after which it is found to reach a steady value in each case of the oxidation temperature

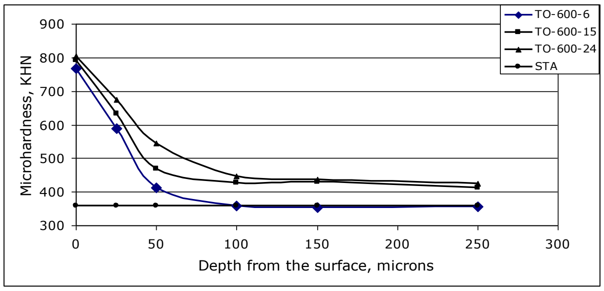

Fig 2: Microhardness-depth profile of the samples oxidised at 600°C for different durations

Variation of wear volume loss/unit sliding distance with duration of thermal oxidation is shown in Fig 3, as determined in the pin-on-wear tests. A comparison of the wear volume loss is shown with that for a sample in STA condition in Fig 4.

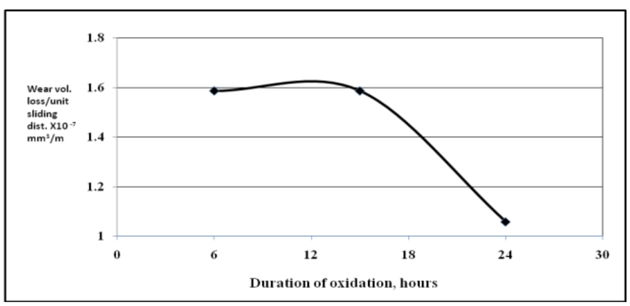

Fig 3: Variation of wear volume loss/unit sliding distance with the duration of thermal oxidation

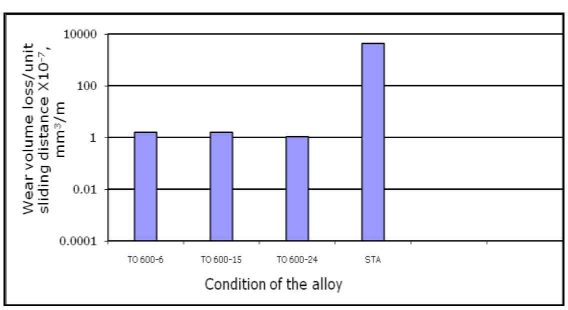

Fig 4: A comparison of the wear volume loss in various thermal oxidation conditions with that for a sample in STA condition

The wear volume loss is found to decrease with increase in oxidizing temperature. This is in good agreement with the increases found in surface microhardness with temperature. Further it is found to decrease significantly in comparison with the value for the alloy in STA condition (Fig 4).

Typical SEM Micrographs of the worn surfaces are shown in Fig 5; for the sample treated at 600°C for 24 hours The SEM micrograph reveals that the oxidized layer wears off layer by layer, in the sliding wear conditions.

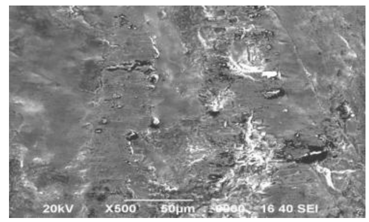

Fig 5: Worn out surface of the thermally oxidised sample after the sliding wear test

Conclusions:

The thermal oxidation treatment has a significant effect in improving the surface hardness of Ti-6Al-4V alloy. There has been an decrease in the wear volume loss with the duration of thermal oxidation. Further it has been found that the wear of the surface takes place by layer by layer removal of material.

References:

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