ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 5, pp. 10862-10866, May, 2016

International Journal of Recent Scientific Research

Research Article

WEAR RESISTANCE IMPROVEMENT OF THE Ti6Al4V/2.5%TiB2-2.5%TiC COMPOSITESFABRICATED BY POWDER METALLURGY

Anandajothi M[1]* and Ramanathan S[2]

[1,2]Department of Manufacturing Engineering, Annamalai University, Annamalainagar, Tamil Nadu-608002, India

ARTICLE INFO

Article History:

Received 29th February, 2016
Received in revised form 19th March, 2016
Accepted 25th April, 2016
Published online 28th May, 2016

Keywords:

Dry sliding wear, Ti6Al4V/ TiB_2-TiC Composites, Wear, FE-SEM, EDS.

ABSTRACT

Titanium Matrix Composites (TMCs) have consists of attractive features whereas, it may tendency to high temperature properties and oxidation resistance respectively. Though, these applications of its alloys and titanium were under the severe friction and wear surroundings are highly limited because of poor tribological properties and low hardness. Dry sliding behaviour on Ti6Al4V alloy and Ti6Al4V/2.5%TiB_2-2.5%TiC composite fabricated by powder metallurgy method was investigated. While, its wear and the friction behaviour of TMCs are examined by means of a pin-on-disk wear tester under various conditions. The results show that the specific wear rate rises with an increasing in the sliding speed simultaneously. Effects of TiB_2 and TiC addition on the microstructure and the wear characteristics of titanium alloy specimens were analysed with the help of Field Emission-Scanning Electron Microscope (FE-SEM), Energy Dispersive Spectroscopy (EDS). It was found that the wear resistance of the Ti6Al4V matrix was improved due to the addition of TiB_2 and TiC associated to that sterilized Ti6Al4V.

INTRODUCTION

Titanium and its alloys have gained by the acceptance in all over years for an automobile, aerospace, marine, medicine, chemical and energy industries. These have been driven by a number of issues, such as its high strength-to-weight ratio, excellent corrosion resistance, high temperature strength, high Young's modulus (Junqiang *et al*.,2009; Mathew *et al*., 2000; Yang *et al*., 2008;Wang *et al*.,2006) and high cycle fatigue properties (Choe *et al*., 2006) Among titanium alloys, Ti6Al4V alloy are mostly used as a general-purpose alloy (Mathew *et al*., 2000) But, (Yun *et al*., 2005) despite has various uses for their general usages are frequently constrained because of insufficient wear, hardness and poor antifriction properties are exhibited in selected service conditions. Titanium and its alloys exhibit high specific strength, oxidation resistance and corrosion resistance.

Hence, by using the titanium and its alloys under the severe friction and wear conditions are highly limited because of poor tribological properties and little resistance (Tian *et al*., 2005). In the present work, dry sliding wear behaviors of Ti6Al4V alloy and Ti6Al4V/TiB_2-TiC composite. It has been investigated by using a pin-on disc type wear apparatus against an EN31 steel counter face. The investigational work was considered to study the properties of their applied load and sliding velocity on the wear transitions in this alloy. The friction and wear behavior of Ti6Al4V alloy and Ti6Al4V/2.5%TiB_2-2.5%TiC composite were investigated using a pin-on-disk wear test under various conditions and assessed by consuming the Field Emission-Scanning Electron Microscope (FE-SEM) analysis respectively.

MATERIALS AND METHODS

Specimen preparations

Mixing of powder was made in a high-energy ball mill (Fritch-pulveriselt-6) at 50 rpm for 4hrs. to obtain a homogenous mixture. The stainless steel balls are used to mix the powder. Ball to powder weight ratio of 20:1 was used. Toluene was used to prevent oxidation, at different weight fraction of 2.5% TiB_2 and 2.5% TiC reinforcements was Ti6Al4V matrix alloy powder was mixed in the high energy ball mill. The mixed powders were pressed uniaxial at a pressure of 950 MPa by using a hydraulic pressing machine with a suitable punch and die. Green compacts having diameter at 10 mm with a height of 30 mm (Zeng *et al*., 2014). Before each run, die wall was lubricated with zinc stearate. The green compacts, sintered at 1250 ^{o}C for 2 hrs. in a high temperature tubular furnace with argon atmosphere used by cooling to room temperature in the

**Corresponding author: Anandajothi M*

Department of Manufacturing Engineering, Annamalai University, Annamalainagar, Tamil Nadu-608002, India

furnace itself (Zhu *et al*., 1999). Hence the Similar procedure was adopted for the preparation of Ti6Al4V /2.5% TiB_2-2.5% TiC composite specimens.

Dry Sliding wear test

The dry sliding wear tests are based on the ASTM G99-(reapproved 2010) standards in pin-on- disc wear test (Ducom, Model No: TR-20LE, Bangalore, India) for a pin-on-disc form these wear apparatus against EN31 steel counter-face (Ravindran*et al*., 2013). Hence, these wear testers cutting-edge in the form of cylinder-shaped pin by using means of 30 mm its length and 10 mm for diameter were prepared by using sintered method. Contact surfaces were prepared by grinding against 600-grid silicon carbide paper and cleaned ultrasonically in an acetone solution. The counter-face undergone for EN31 steel disc as 160 mm diameter and its 8 mm width having surface roughness of 0.02µm on which the test specimen slide. The tests were carried out by applying load range of 100 N and a sliding velocity range at 1-5 m/s. The constant sliding distance was about 1770 m. The quantity of indemnities is measured since the dissimilarities in weight of specimens measured before and after the sliding test (after removing any loose debris) using a precision stability (0.01 g). Wear rate has been calculated. Each test was repeated four times, and the average results were taken.

Metallography

Microstructure of the specimen along with its elemental composition was observed by using Field emission scanning electron microscope (FE-SEM) (SEM-ZEISS SIGMA) with energy dispersive spectrometer (EDS-BRUKER). The sinteredTi6Al4V alloy andTi6Al4V/2.5%TiB_2-2.5%TiC compositessamples were ground, polished and chemically etched using Kroll's reagent (a mixture of 10 ml HF, 5 ml HNO_3 and 85 ml H_2O). Then the microstructures of the samples were observed using FE-SEM, and the chemical composition of elements was observed by using EDS.

RESULTS AND DISCUSSION

The wear rates of the Ti6Al4V alloy are against the constant applied 100 N load for the tests conducted at various sliding speeds 1-5m/s. The Fig.1, indicates wear rate is improved with the applied load has been detected at all sliding speeds respectively. Hence, at low sliding speeds of 1 m/s these wear rates are also greater than before with the applied load. At high sliding speeds (e.g. V >2 m/s) enormous variations in the inclines of the wear rate curves followed at a certain load range 100N. The slope variations point out their transitions from minor to severe wear. At 100 N applied load, the wear rate increased with increasing sliding velocity. While, sliding velocity rises, the contact temperature also rises due to developed their frictional heat and will cause increase in wear rate (Anbuselvan *et al*., 2010). The line indicates that steady state takes place at remained achieved (mild wear) at high applied loads huge fluctuations seen in the slopes of wear rates occurred at a constant sliding distance range (1770 m/s).

Wear mechanisms

While, there are four different wear mechanisms are identified to worn out the pin in various sliding situations. They consist of abrasion, oxidation, delamination and plastic distortion. hence, these are observed by wear mechanisms and those are discussed in their relation for a sliding conditions. The wear rates for better understanding of the tribological methods are distinguished by consuming theTi6Al4V alloy and Ti6Al4V with 2.5%TiB_2-2.5% TiC composites.

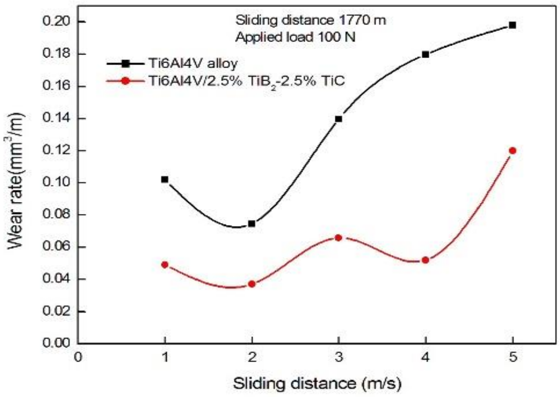

Fig.1 Wear rate of Ti6Al4V alloy and Ti6Al4V/2.5%TiB_2-2.5% TiC composite

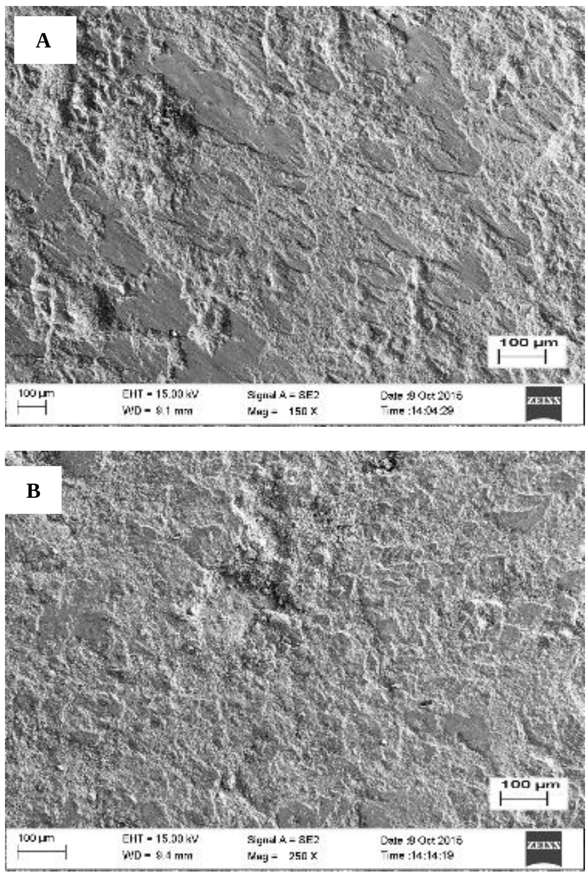

Fig.2 SEM micrographs showing grooves and scratch marks on the pin surfaces, indicating abrasion (a) Ti-6Al-4Valloy at 50 N and 1m/s; (b) Ti-6Al-4V alloy with 5% (TiB_2 +TiC) at 100 N and 2 m/s.

Abrasion

Abrasion wear occurred in the Ti6Al4Valloy and Ti6Al4V/2.5%TiB_2-2.5%TiC composites worn surfaces at 100

N and 2 m/s worn surfaces at 100N and 2m/s as shows at, Fig. 2(a-b), respectively. From the Fig 2a, shows that several hollows and abrasion grades, are mostly parallel to the sliding direction are evident for all the worn pins compared than Fig2 (b) Ti6Al4V/2.5%TiB_2-2.5%TiC.

Hence, these structures are characteristics for scrape, in which the solid particles in the middle of the contacting surfaces, plough or cut into the pin, causing wear by the removal of slight garbage. While in this proposes the scrape took place at primarily by investing, the material is moved on either side of the abrasion groove without being removed, or wedge forming, anywhere small wedge designed fragments are damaged during the primary interaction with an abrasive particle respectively. This is well agreed with earlier investigation (Mao *et al*., 2013; Choi *et al*., 2014)

Oxidation

From the Fig. 3(a) shows FE-SEM image of oxidation wear for Ti6Al4V alloy sample at 100N and 4m/s. Fig. 3(b) shows the FE-SEM image of oxidation wear for Ti6Al4V alloy with 2.5%TiB_2 -2.5%TiC composite at 100 N and 4m/s. Under SEM, the black surfaces are found to be covered extensively by a thin layer of fine particles as shown in Fig. 3.

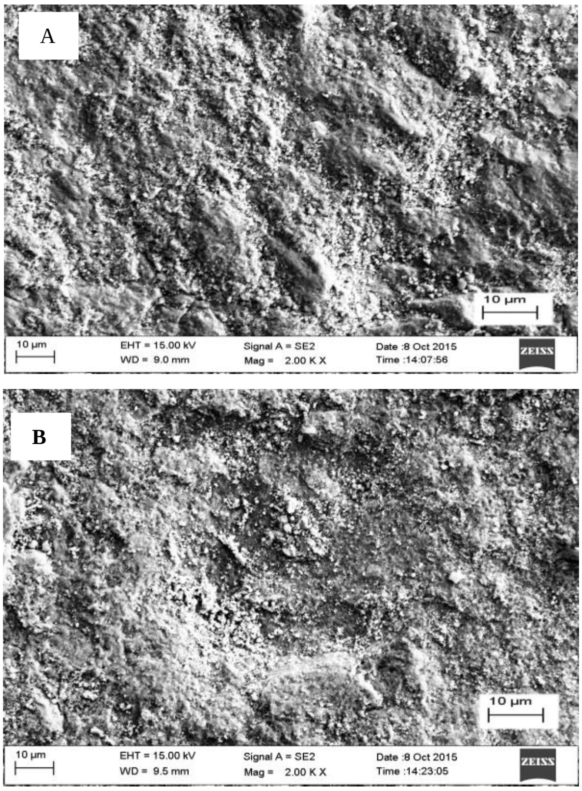

Fig.3. SEM micrographs showing oxidation (a) Ti-6Al-4V alloy (b) Ti-6Al-4V - 2.5% TiB_2-2.5% TiC at100 and 4 m/s.

The EDS analysis Fig. 4(a) Ti6Al4V alloy shows the presence of oxygen peak in addition to the titanium peak, Fig. 4(b) Ti6Al4V-2.5% TiB_2-2.5% TiC presence of oxygen peak addition to the Titanium, Boride and carbide peak. These physical appearances are diagnostic in order to oxidative wear, in which their frictional reheating takes place during sliding causes oxidation of the surface (Degnan *et al*.,2002), with wear occurring through the deduction of oxide garbage. While, over frequent sliding, the oxide wear debris fills obtainable on the pin surface, converts compacted in to a protective layer. So metallic contact is prevented and minimum wear rates are occurred (Ohidul Alam *et al*., 2002).

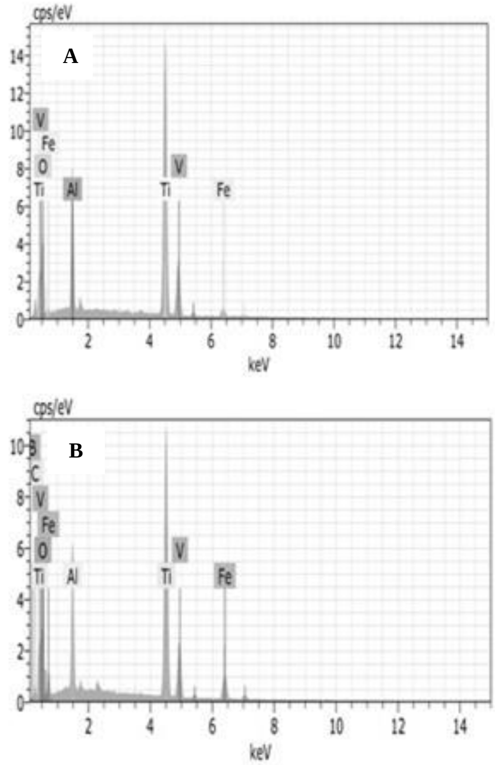

Fig.4 EDS spectrum of the worn surface under an applied load 100N at 4 m/s (a) Ti6Al4V alloy, (b)Ti6Al4V/2.5TiB_2-2.5TiC composite.

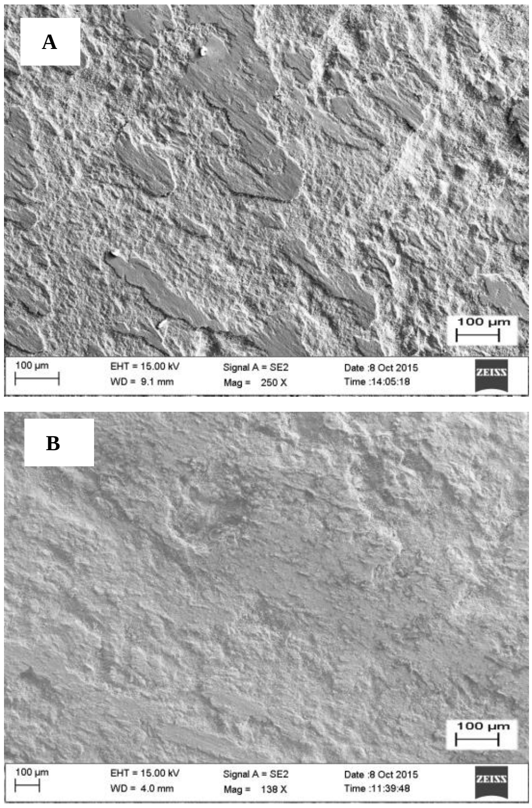

Fig.5 SEM micrographs showing series of cracks roughly perpendicular to the sliding direction on the pin surface, indicating delamination at 100N and 4 m/s; (a)Ti-6Al-4Valloy (b)Ti6Al4V/2.5TiB_2

Delamination

Fig. 5(a) shows the FE-SEM image of delamination wear for Ti-6Al-4Valloy at 100 N and 4 m/s. Fig.5(b) shows the FE-SEM image of delamination wear for Ti6Al4V/2.5TiB_2-2.5TiC composite at 100N and 4m/s. As the applied load is increased in the mild wear regime, a gradual transition in the wear behavior of the alloy occurred from an oxidational wear to a delamination wear (Molinari *et al*., 1997). In delamination wear, short cracks occur roughly perpendicular to the sliding direction. Hence, the connection of these cracks effects in the impartiality of sheet-like wear particles.

Plastic deformation

Fig.6 (a) shows the plastic deformation layer on the worn surface of Ti-6Al-4Valloy tested at 100N and 4 m/s. Fig. 6(b) shows the plastic deformation layer on the worn surface of Ti6Al4V/2.5TiB2-2.5TiC composites tested at 100N and 4 m/s. While they association takes place between the external in main wear mechanism and they applied load whereas sliding velocity resulted was increases in plastic deformation, which resulted in high level of structural disruption and destruction for the material.

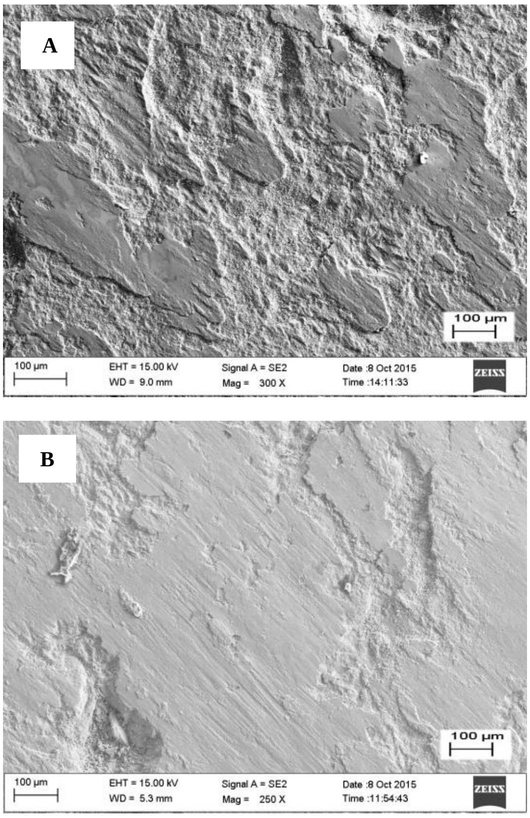

Fig.6. (a) SEM micrographs showing plastic deformation of worn surfaces (a) Ti6Al4Valloy at 100N and 4 m/s; (b) Ti6Al4V/2.5% TiB_2-2.5% TiC at 100 N and 4 m/s.

As the temperature increases the yield strength of both Ti6Al4V/Ti6Al4V/2.5TiB2-2.5TiC composite decreases sharply and gets softened. As a result, they become prone to easy plastic deformation and spread out of the contact surface in the direction of sliding as well as by moving sideways.

CONCLUSION

In this study, Ti6Al4V/2.5%TiB_2-2.5%TiC composites improved more than the matrix alloy. Wear rate reduced by the addition of TiB_2 and TiC reinforcements in the matrix. Ti6Al4V/2.5%TiB_2-2.5%TiC shows the ultimate improvement in the tribological performance. The FE-SEM micrograph of the worn surface of different composites indicates the major Wear mechanisms. The Ti6Al4V/2.55TiB_2-2.5TiC rich tribological properties improve the wear resistance and reduce the friction co-efficient.

References

Junqiang, Lu., JiningQin., Weijie.Lu., Di Zhang., Hongliang Hou, and Zhiqiang Li. (2009). Effect of hydrogen on microstructure and high temperature deformation of (TiB + TiC)/Ti-6Al-4V composite. Mat Sci &Engg. A 500: 1-7.

Mathew, J., Donachie J.: Titanium: a technical guide. (2000). ASM International: 1–50.

Yang, Z., Lu, W., Zhao, L. Qin, J., Zhang, D. (2008). Microstructure and Mechanical Property of in Situ Synthesized Multiple-Reinforced (TiB + TiC + La_2O_3)/Ti Composites. J. Alloy sand Com 455: 210-214.

Wang, M., Lu, W., Qin, J., Ma, F., Lu, J., and Zhang., D. (2006). Effect of volume fraction of reinforcement on room temperature tensile property of in situ (TiB + TiC)/Ti matrix composites. Mat & Des 27:494-498.

Choe, Heeman., (2005). Effect of tungsten additions on the mechanical properties of Ti–6Al–4V. Mat Sci Engg. A 396 :99-106.

Yun, E., Lee, K., and Lee. S. (2005). Correlation of microstructure with high-temperature hardness of (TiC, TiN)/Ti-6Al-4V surface composites fabricated by high-energy electron-beam irradiation, Sur. Coat. Tech 191 :83-89.

Y.S. Tian, C.Z. Chen, L.B. Chen, J.H. Liu. (2005). Wear properties of alloyed layers produced by laser surface alloying of pure titanium with B_4C and Ti mixed powders. J Mat Sci 40 :4387-4390

Zeng SW, Zhao AM, Jiang HT, Yan XQ, Liu JX, Duan XG. (2014). High-temperature deformation behavior of titanium clad steel plate. Rare Met 34(11):764-769.

Zhu JH, Liaw PK, Corum JM, McCoy HE. (1999). High-temperature mechanical behavior of Ti-6Al-4V alloy and TiC_p /Ti-6Al-4V composite. Metall Mater Trans A. 30A (6):1569-1578.

P Ravindran, K Manisekar, R Narayanasamy, P Narayanasamy.(2013). Tribological behaviour of powder metallurgy-processed aluminium hybrid composites with the addition of graphite solid lubricant 39 (2): 1169-1182.

S. Anbuselvan and Ramanathan, S. (2010). Dry sliding wear behavior of hot extruded ZE41A magnesium alloy. Mat Sci Engg A 527 :1815-1820.

Y.S. Mao, L. Wang, K.M. Chen n, S.Q. Wang n, X.H. Cui.(2013). Tribo-layer and its role in dry sliding wear of Ti–6Al–4V alloy, Wear 297:1032-1039.

B. Choi, I. Kim, Y. Lee, and Y. Kim. (2014). Microstructure and friction / wear behavior of (TiB + TiC) particulate-reinforced titanium matrix composites, Wear 318: 68-77.

Degnan, C.C., P.H. Shipway. (2002). A comparison of the reciprocating sliding wear behaviour of steel based metal matrix composites processed from self-propagating high-temperature synthesised Fe-TiC and Fe-TiB_2 master alloys. Wear 252: 832-841.

Md.Ohidul Alam, A.S.M.A. (2002). Haseeb Response of Ti-6Al-4V and Ti-24Al-11Nb alloys to dry sliding wear against hardened steel, Tribology International 35:357-362.

Molinari, A., G. Straffelini, B., Tesi, T. Bacci. (1997). Dry sliding wear mechanisms of the Ti6Al4V alloy. Wear 208: 105-112.

****

How to cite this article:

Anandajothi M and Ramanathan S.2016, Wear Resistance Improvement of the Ti6al4v/2.5%Tib2-2.5%Tic Composites Fabricated By Powder Metallurgy. *Int J Recent Sci Res.* 7(5), pp. 10862-10866.