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Effects of high temperature wear and corrosion behaviour of sintered titanium reinforced with vanadium particle

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The present investigation deals the high temperature wear and corrosion behavior of sintered Titanium (Ti) reinforced with vanadium (V) particles with various wt. % such as 3, 6 and 9. The surface morphology followed to that elemental confirmation of the sintered composites were identified using Scanning Electron Microscope (SEM) embedded with Electron Dispersive Spectroscopy (EDS). The high temperature wear behavior of the sintered composites was evaluated using pin on disc apparatus with varying the operating temperature (50°, 100° and 150°C). By using TAFEL exploration the corrosion behavior of the composites were assessed. The results revealed that Ti reinforced with 6 % of V possessed better wear resistant and corrosion resistance properties. Furthermore, the surface morphological changes of wear and corrosion behavior after experimentation were viewed using SEM.

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1. Introduction

Titanium and its alloys are commonly used in aero engines and airframe industries because of low relative density, excellent strength to density ratio and better corrosion resistance at high temperature [1]. But, due to its low thermal conductivity and high chemical activity, it is difficult to cut materials. However, during machining process titanium and its alloys are observe the tool surfaces and it creates adhesive wear.

But, titanium and its alloys are having poor tribological properties, because of its low plastic shearing resistance. The poor wear resistance strictly obstructs the applications of titanium alloys. By adding the secondary particles like hard ceramics, led to improve the wear resistance of the titanium [2]. The extensively accepted views on the wear properties of titanium and it alloys are mainly grounded on the room temperature. Fairly, some of the researchers only reported the high temperature wear behavior of titanium and its alloys. One of the researcher reported that Ti-6Al-4V alloy shows excellent wear resistant properties at the temperature range of 400°C. But, it does not mean that the titanium alloy possessed high temperature wear resistance properties [3-4]. In-order to explore the titanium alloys wear related problems, a detailed study on high temperature wear is essential.

Titanium is generally known as high corrosion resistance in wide variety of environments. This was happen, during its different environmental conditions, titanium are spontaneously formed stable and generate oxide film over the surfaces. The oxide films provides better resistance to corrosion for as long as the reliability of the film. Corrosion can be characterized by a quite uniform attack over the surface. At passive condition, the corrosion are takes place very rapidly on the titanium surfaces [5].

Many researchers are done their research on titanium alloy and the detail experimental results are summarized. Yu Liu et al. (2020) studied the instability of titanium during corrosion at

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acidic hydrometallurgical slurries and the results directs that electrochemical noise was increased for localized instability of the passive film in the mixing of slurry. Sebastien Dubent et al. (2019) deliberate the corrosion behavior of titanium grade 2 in electrolyzes for hydrogen production and it reveals that it is free potential in a sulfuric medium. However, in actual operating conditions the electrolyzes are making slightly greater than 20 mm/year. Though, many literatures are available, but it is not very informative are high temperature wear conditions of titanium and its alloy. Hence, the present study is to analyze the high temperature wear behavior Ti-V composites at elevated temperature conditions such as 50°, 100° and 150°C. Further, the corrosion behavior of the composites was also evaluated using TAFEL exploration. Later on, the surface morphological changes of wear and corrosion behavior after experimentation were viewed using SEM.

2. Materials and methods

The elemental powders such as Ti and V are purchased from M/S. Sigma Aldrich Germany. Initially the powders sizes were < 44 µm and it has a hexagonally closed pack and body centre cubic structure. The secondary particle vanadium such as 3 %, 6 % and 9 % are mixed with titanium (wt. %). respectively. The desired amount of powders was kept in a WC vial and blend for a 1 hr. in order to attain a proper mixing. The mixing was carried out in an inert medium to avoid oxidation. After mixing the powders were compacted using Compression Testing Machine (CTM) having an applied load of 2 GPa. Afterwards the green compact was sintered using muffle furnace at a temperature of 900^{o}C and following to that the samples was annealed.

The high temperature wear test was conducted for the samples having an applied load of 5 N to 20 N with the increment of 5 N and the sliding velocity such as 10 m/s and 25 m/s with the increment of 5 m/s and pin temperature 30°, 50°, 100° and 150°C. Throughout the experimentation the sliding distance should kept constant (1500 m) and following to that the samples were heated continuously till the experimentation was completed. By using the following relations, the specific wear rate and coefficient of friction was calculated. Volume loss partition by the product of load and sliding distance is the relation to find specific wear rate and the partition of frictional force and load is the relation to find coefficient of friction. For an accuracy purpose the test was repeated for 3 times and the average value was reported.

Specific wear rate = Volume loss/ Load *Sliding distance

Coefficient of friction = Frictional force/Applied load

In-order to assess the corrosion behavior of the sintered samples current density (Icorr) and corrosion potential (Ecorr) are the best way to found the Tafel polarization according to ASTM G3-14. For a corrosion studies the samples was cut at a size of 10 x 10 x 10 mm^3 in neutral chloride solution (3.5 % NaCl). Before conducting the experiment, the specimen surface was polished and degreased using acetone solution. Ag/AgCl was taken as reference and counter electrode.

3. Results and discussion

3.1. Microstructural examination

Fig. 1 shows the SEM micrographs of Ti-6V sintered composites and the corresponding EDS spectrum. It illustrates that the secondary particles such as vanadium was homogenously distributed throughout the matrix and the corresponding EDS spectrum shows that the titanium intensity is high when compare to V. It also illustrates that amount of titanium is high when compare to vanadium. Some of the foreign materials were found due to environmental error.

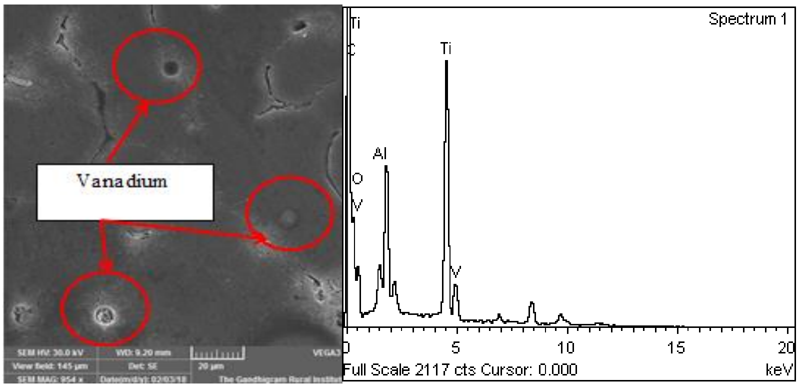


Fig. 1. SEM micrograph of a) sintered Ti-6V composites and b) and the equivalent EDAX spectrum.

3.2. Specific wear rate and coefficient of friction for high temperature condition

Fig. 2 (a) shows the specific wear rate for Ti-V composites under various sample temperatures such as 50°, 100° and 150°C and load of 20 N and sliding velocity of 25 m/s was displayed. It clarifies that that increasing the pin temperature led to increase in specific wear rate irrespective of load and wt. % of secondary particles. According to the concern, of wt. % of V, increasing the wt. % of V led to decrease in specific wear rate. However, during high temperature condition, V acts as very vigorous manner in-order to resist the specific wear rate. This was happened because of during high temperature, V particles are extremely penetrated to the matrix and it reduces specific wear rate. But Ti-6V possessed minimum specific wear rate when compared to other composites [6-8].

Fig. 2 (b) shows the coefficient of friction for Ti-V composites under various sample temperatures such as 50°, 100° and 150°C for an applied load of 20 N and sliding velocity of 25 m/s and it illustrates that while adding V, the coefficient of friction was gradually decreased irrespective of all temperature conditions. For at high temperature condition enormous amount of heat was generated between disc and pin. So that the higher adhesion was created and it led to increase in coefficient of friction. On other hand, it reveals that hard asperities such as V is act as a shielding between the sample and the counterpart, it led to decrease in coefficient of friction [9-11]. But Ti-6V possessed minimum coefficient of friction when compared to other composites.

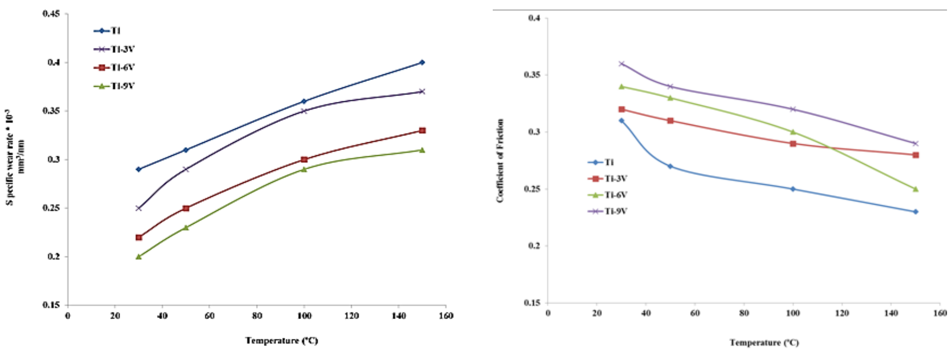
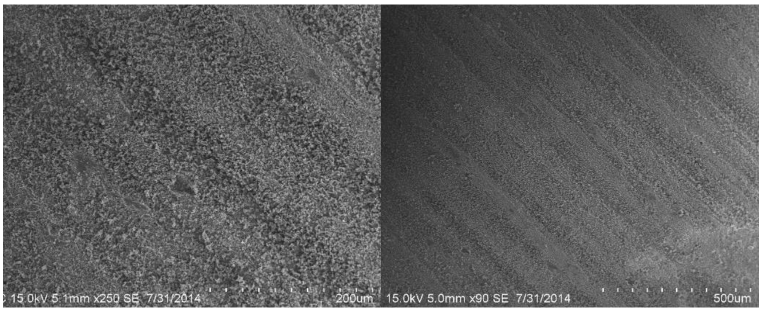


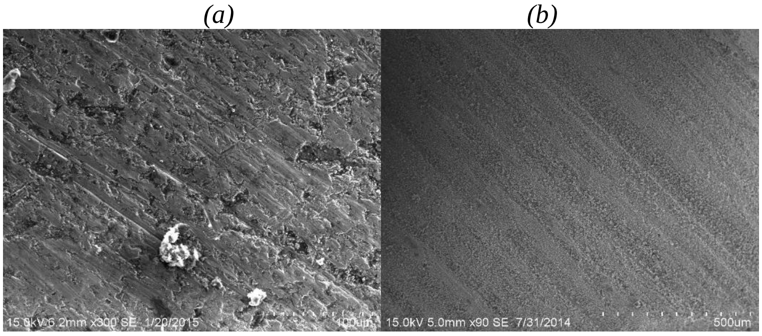
Fig. 2. (a) Specific wear rate and b) Coefficient of friction for various Pin temperatures.

3.3. Surface morphological analysis for high temperature condition

Figs. 3, 4 and 5 (a-d) shows the worn surface morphology of Ti, Ti-3V, Ti-6V and Ti-9V composites for different pin temperatures such as 50°, 100° and 150°C. Fig. 3 (a-d) shows the worn surfaces of the Ti-V composites for 50° C and it illustrates that adhesive wear was identified; it was happen because of direct metal contact between each other. However, from the SEM image, it clearly viewed that the ploughing of metals was happen for pure Ti. Though, the surface morphology under the conditions are 100° and 150°C and following to that various concentration such as Ti-(3, 6 & 9) Wt.% of V are revealed in figs. 4 (b-d) and 5 (b-d). During this temperature condition, the atmosphere air plays a vital role and it creates oxides layer on the sample surfaces. The oxide layer is also acts a shielding between the sample and counter disc and thus it reduces specific wear rate and coefficient of friction. Moreover, some of the micro pits was also viewed on the Ti-6V composites, irrespective of the temperature condition. It also reduces the specific wear rate and coefficient of friction [12].

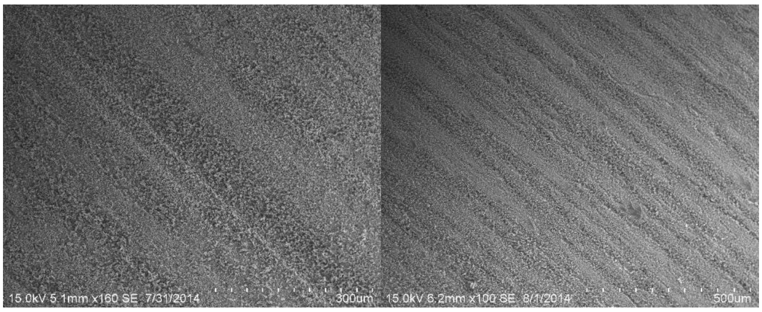


(a) *(b)*

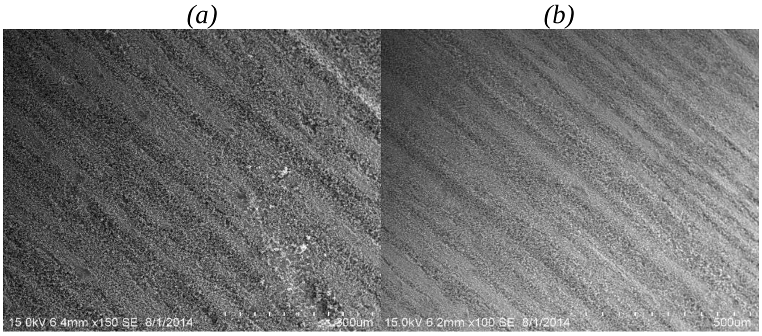


(c) *(d)*

Fig. 3. Micrograph of Wear test SEM of a worn surface of various composites for 50°C a) Ti, b) Ti-3V, c) Ti-6V and d) Ti-9V.

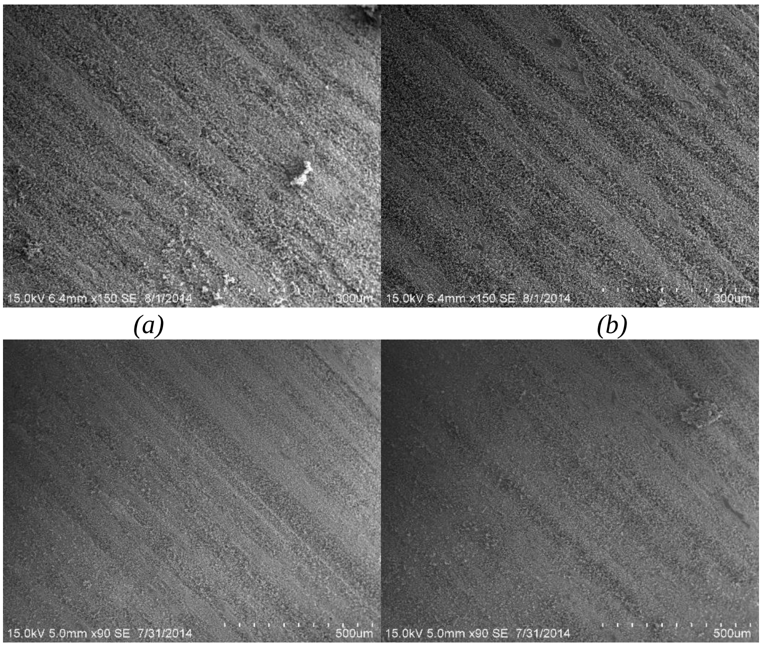


(a) *(b)*



(c) *(d)*

Fig. 4. Micrograph of Wear test SEM of a worn surface of various composites for 100°C a) Ti, b) Ti-3V, c) Ti-6V and d) Ti-9V.



(a) (b)

(c) (d)

Fig. 5. Micrograph of Wear test SEM of a worn surface of various composites for 150°C a) Ti, b) Ti-3V, c) Ti-6V and d) Ti-9V.

3.4. Corrosion Behavior

Table 1 displays the lesser Ecorr value shows greater exposure while higher Ecorr values (towards positive side) indicate inertness towards the corrosive ion medium. The corresponding tafel exploration is shown in fig. 6 (a-d) and it illustrates that dominant cathodic reaction was created for all the specimens. Moreover, the curves shows that the active-passive behavior for all the composites [13-15]. While increasing the V particles to the titanium, the current density was fluctuating. In this case, Ti-6V composite possessed higher corrosion rate than the other composites. Furthermore, the Icorr value of Ti was $1.18*10^{-13}$ mpy which is monotonically increased to i$6.81*10^{-13}$ mpy to Ti-9V composites [16].

Fig. 7. (a-d) shows the SEM micrograph of after corrosion exploration and it observed that severe pitting was observed for pure Ti. While reinforcing V, minor cracks and pits were observed, and it illustrates that reduction of corrosion. Furthermore, for Ti-6V composites, possessed small pits and it is sprinkled over the surfaces, and it shows that the minimum corrosion was occurred [17].

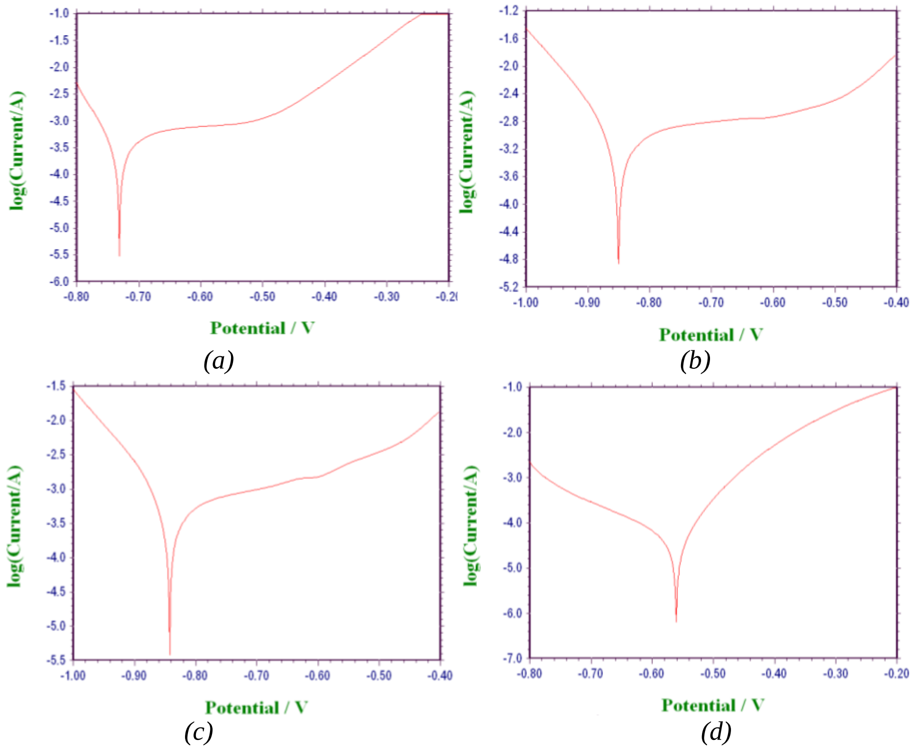


Fig. 6. Tafel Polarization For Ti-V Composites a) Ti, b) Ti-3V, c) Ti-6V and d) Ti-9V.

Table 1. Corrosion behavior of Ti-V composites at 3.5% NaCl solution.

Samples	Corrosion Potential Ecorr (-mv)	Corrosion current density Icorr (μA/cm^2)	Corrosion rate in (mpy)
Ti	251.0	2.0 *10^{-5}	1.18*10^{-13}
Ti-3V	267.0	1.65 *10^{-5}	6.18*10^{-13}
Ti-6V	350.0	2.25 *10^{-5}	5.20*10^{-13}
Ti-9V	601.0	2.05 *10^{-5}	6.81*10^{-13}

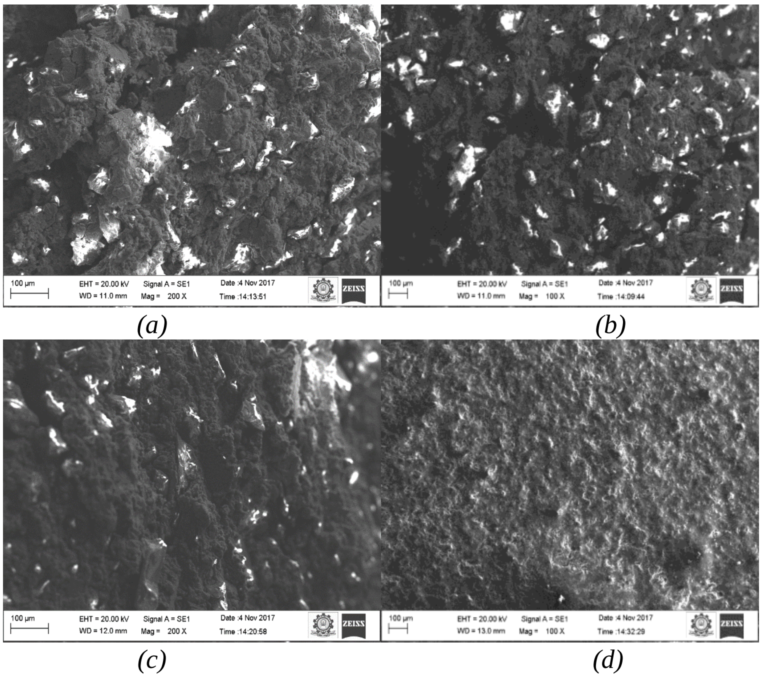


Fig. 7. SEM micrograph of corroded samples a) Ti, b) Ti-3V, c) Ti-6V and d) Ti-9V.

4. Conclusion

Increasing the wt. % of V led to decrease in specific wear rate and coefficient of friction. However, during high temperature condition, V acts as very vigorous manner in-order to minimize the SWR and CoF. Minimum SWR and CoF were obtained for Ti-6V composite samples.

Micro pits are viewed on the Ti-6V composites, irrespective of the temperature condition. It also reduces the specific wear rate and coefficient of friction.

Ti-6V composite possessed higher corrosion rate than the other composites. Furthermore, the Icorr value of Ti was $1.18*10^{-13}$ mpy which is monotonically increased to $6.81*10^{-13}$ mpy to Ti-9V composites.

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