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The effects of Sliding Parameters on Dry Wear Characteristics of Ti-6Al-4V Alloy

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Abstract. Titanium (*Ti-6Al-4V*) alloy is very attractive for many applications due to its high strength-to-weight ratio and high corrosion resistance. Even then, with these attractive properties, it has poor shear strength and surface wear properties. This study is therefore undertaken to investigate the effect of sliding parameters on the surface wear behavior of *Ti-6Al-4V* alloy. Pin-like specimens of the alloy were produced and subjected to sliding motion on a pin-on-disk apparatus using different speeds, loads and sliding distances. The surface and specific wear rates of the alloy were evaluated as the main output of the study. Results indicate that the most severe surface wear rate of over 0.008 mm^3/sec is experienced under conditions of low disk speed (50 rpm) with high input weight (46.5 N). Higher sliding distance is also found to affect the severity of the surface wear rate. All results of specific wear rates evaluated indicate that *Ti-6Al-4V* alloy can be classified as a low surface wear resistance material when operated under sliding counterface.

Introduction

Titanium (*Ti-6Al-4V*) belongs to the grade of α-β alloys and is termed the "workhorse" of the titanium industry being the most commonly used. The combination of high strength-to-weight ratio, good formability and high corrosion resistance make the alloy very attractive for many applications. Although *Ti-6Al-4V* alloy is used in several critical areas including aerospace and automotive industries, it has poor shear strength and surface wear properties, and thus tends to seize under relative sliding contact with either itself or other metals [1-4].

Much as designers would wish to avoid using it in such sliding systems, there are situations that their application becomes inevitable. In systems like valves, piping connections, bone plates it is becomes necessary to use the alloy parts in the assembly of its components. Premature failure is then bound to occur with regular disassembly and reassembly of these parts in the component [5].

The main objective of this study therefore is to investigate the dry wear behavior of *Ti-6Al-4V* alloy under various loading and sliding conditions. The behavior of wear rate is studied with input load, disk speed and sliding distance.

Experimentations: Materials and Procedures

The equipment used is a pin-on-disk apparatus on whose counterface the Ø5mm pin-type specimens were cut from the blank of *Ti-6Al-4V* alloy were subjected to sliding motion. The surface wear rate and specific wear rate were investigated under varying conditions of disk speed (V), input load (F_n),

and sliding distance (D). The disk speed is varied between 50 and 150 rpm, input load in the range of 21.5 to 46.5N while the sliding distance ranges between 100 and 300m.
The wear rate is evaluated using Eq. (1).

$$W_r = \frac{\Delta W}{\rho t} \quad (1)$$

Where W_r is the surface wear rate (mm^3/sec); ΔW is the weight loss during sliding (kg); ρ is the density of the alloy and t is the sliding time (sec). The specific wear rate on the other hand is computed from Eq. (2).

$$W_s = \frac{V}{F_n\, l} \quad \left(\frac{m^3}{Nm}\right) \quad (2)$$

Where V is the wear volume (m^3); F_n is the normal load (N) and the sliding distance is l (m). The specifications used in the Pin-on-disk apparatus for the sliding experiment are presented in Table 1.

Table 1: Specifications used for the wear test condition

S/N	Specification	Value
1	Radius from the disk centre [mm]	60
2	Pin diameter [mm]	5.00
3	Disk diameter [mm]	216
4	Disk thickness [mm]	15.00
5	Density of the pin [g/cm^3]	4.42

Results and Discussions

Observations. The surface of the parent titanium alloy used in this investigation is made up of well-structured fine grains as can be seen from the SEM micrograph of Fig. 1. But when it is subjected to counterface sliding (rubbing), abrasion wear of the surface occurs and micro-debris such as that found in Fig. 2 is experienced on the worn surface. The wear behavior of computed from Eq. (1) for various conditions are presented in Figs. 3 to 5.

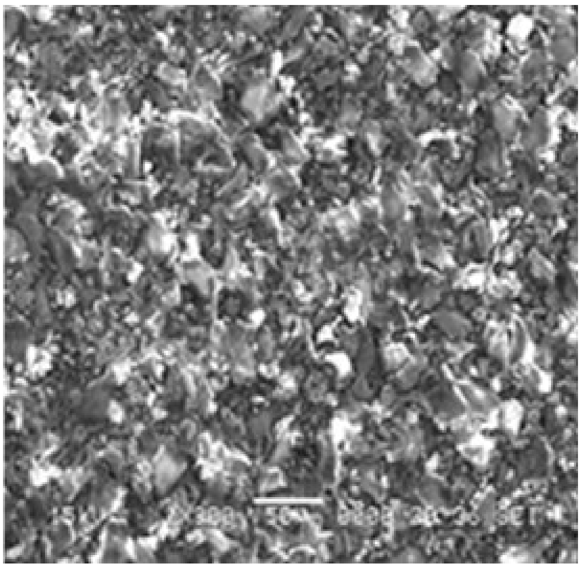

Fig. 1: Micrograph of the *Ti-6Al-4V* surface

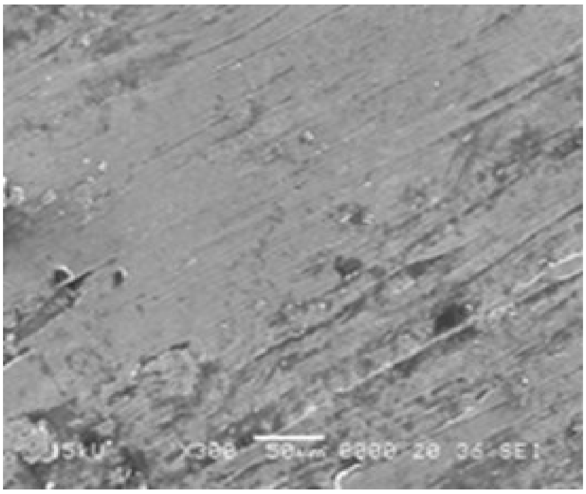

Fig. 2: SEM micrograph of a worn surface (3.00kg, 150rpm)

Wear Rate of *Ti-6Al-4V* Alloy. In Fig. 3, the wear rates are generally observed to increase with input weight, but it is more severe under 50 rpm with the highest being over 0.008mm^3/sec at 46.5N. However, when varied with speed (Fig. 4), the wear rate generally decreases with increasing speed. The lowest wear rate in this case is 0.0015mm^3/sec at the input weight of 30N. Higher sliding distance of about 300m is also found to affect the severity of the surface wear rate (Fig. 5). It can be concluded that low disk speed coupled with high input weight and longer sliding distances increase the severity of wear rate of *Ti-6Al-4V* alloy.

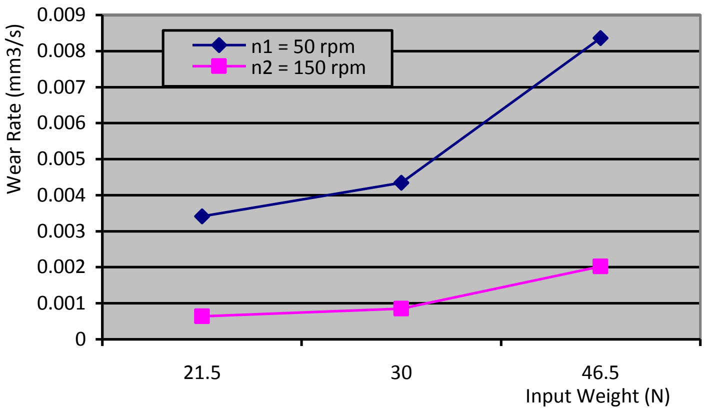

Fig. 3: Effect of input weight on wear rate at D = 200m

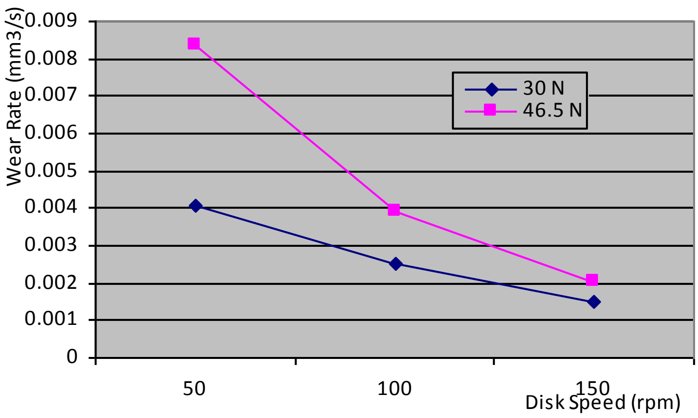

Fig. 4: Wear rate with rotating disk speed at D = 200m

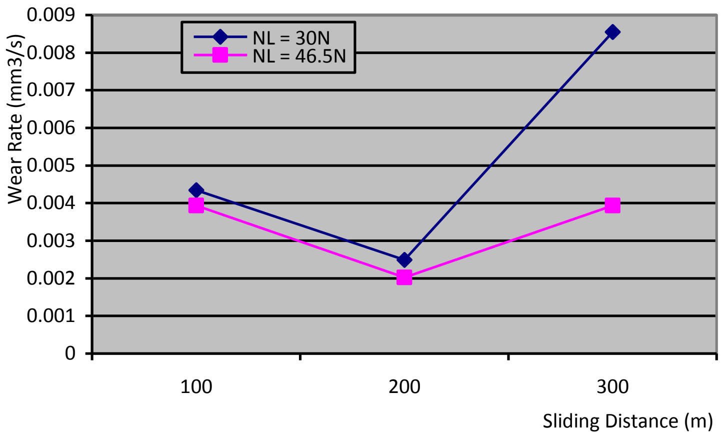

Fig. 5: Wear rate with sliding distance at V = 100rpm

Specific Wear Rate of the Alloy. Computation of the equivalent specific wear rates with Eq. (2) for all the sliding conditions show that they fall in the range of 4.00 x 10^{-14} to 5.8 x 10^{-13} m^3/Nm. These values are very high compared to normal values for materials categorized under mild wear. The mild wear materials should exhibit specific wear rate which is not more the 10^{-16} m^3/Nm [6, 7]. Based on this therefore, *Ti-6Al-4V* alloy can be categorized as a low surface wear resistance material when operated under the given sliding counterface conditions.

Conclusions

The following conclusions can be drawn from the discussion:

1. When *Ti-6Al-4V* is subjected to counterface sliding, abrasion wear is observed to occur on its surface.
2. Low disk speed coupled with high input weight and longer sliding distances increase the severity of wear rate of the alloy
3. The alloy can be categorized as a low surface wear resistance material in comparison to standards.

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References

[1] B.H. Yan, H.C. Tsai and F.Y. Huang: Int. J. Mach. Tools and Manu. Vol. 45 (2005), pp. 194-200.

[2] M.B. Ndaliman, A.A. Khan and M.Y. Ali: Adv. Mater. Res. 2012; Vol. 576 (2012), p. 7.

[3] ASM-Data-Sheet: http: //asm.matweb.com/search/SpecificMaterial.asp? retrieved 27/02/2011.

[4] M.B. Ndaliman, A.A. Khan and M.Y. Ali: Proc. IMechE Part B: J. Engineering Manufacture Vol. 227 (2013), p. 460.

[5] K.G. Budinski: Tribological Properties of Titanium Alloys. Proc. Int. Conf. Wear of Materials, Orlando, Florida. 1991, April 7-11

[6] S.M. Hsu and M.C. Shen in: *Wear - Materials, Mechanisms and Practice*, edited by G.W. Stachowiak, John Wiley and Sons, Ltd, England (2005)

[7] G.W. Stachowiak and A.W. Batchelor: *Engineering Tribology*, Elsevier Butterworth-Heinemann, Burlington (2005).

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[1] B.H. Yan, H.C. Tsai and F.Y. Huang: Int. J. Mach. Tools and Manu. Vol. 45 (2005), pp.194-200.
10.1016/j.ijmachtools.2004.07.006
[2] M.B. Ndaliman, A.A. Khan and M.Y. Ali: Adv. Mater. Res. 2012; Vol. 576 (2012), p.7.
10.4028/www.scientific.net/AMR.576.7
[4] M.B. Ndaliman, A.A. Khan and M.Y. Ali: Proc. IMechE Part B: J. Engineering Manufacture Vol. 227 (2013), p.460.
10.1177/0954405412470443