Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals & Proceedings of DAAAM International 2011

WEAR BEHAVIOR OF TI6AL4V ALLOY UNDER DRY RECIPROCATING SLIDING

DONI, Z[inaida]; BUCIUMEANU, M[ihaela] & PALAGHIAN, L[iviu]

Abstract: *The experiments were conducted to investigate the reciprocating wear behavior of an aerospace material (Ti-6Al-4V alloy) under pin/ball-on-plate contact configuration. Results obtained from dry reciprocating wear tests of Ti6Al4V/34CrNiMo6 and Ti6Al4V/AISI420 contact pairs are presented. The results presented in this work show the wear modification via varying normal load. The results provide a comparison between fretting and reciprocating sliding situation.*
Key words: *titanium, reciprocating wear, fretting*

1. INTRODUCTION

It is well known, that fretting arises wherever two components in contact are subjected to small relative displacement amplitude, whereas the reciprocating sliding wear is known to occur at much larger displacement amplitude.

Normal contact load is a significant variable on the situations where the components slide against each other with oscillatory movements, being important to look at its effect on the component lifetime.

In general, if normal contact load increases the component lifetime should decrease because of the monotonous increase in frictional stress amplitude with contact pressure. For example, some researches state that normal contact loads have a significant influence on fretting life (Lee, 2004) while others consider that its influence is insignificant (Fouvryet al., 2004).

Some researchers observed that the normal load has a very close relation with the tribological condition in the contact – wear. Experimental research of Magaziner et al. (Magazineret al., 2004) demonstrated that the wear volume is related with the magnitude of the normal load. It was concluded that there is a linear relation between normal load and wear volume.Sarkar el at. (Sarkaret al., 2006) also examined the effect of normal load on the wear mechanism, under fretting wear tests. It was noted a transition in the wear mechanism by increasing the normal load from 8 to 10 N.There are also contradictory results regarding the relation between normal load and wear. For instance, according to Bryggman (Bryggman&Soderberg, 1988) the overall wear scar is little affected by the variation of the normal load.

The results presented in this work show the wear modification via varying normal load. The results provide a comparison between fretting and reciprocating sliding situation.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

Reciprocating pin/ball-on-plate wear and fretting tests has been carried out. The specimens used in the tests were machined from Ti6Al4V alloy bars. The pins were machined from 34CrNiMo6 steel and the balls were from AISI420 steel. The mechanical properties of these alloys are given in Table 1.

	Mechanical properties				
	E (GPa)	$\sigma_{0.2}$ (MPa)	σ_r (MPa)	ε_r (%)	HV
Ti6Al4V	115	989	1055	16.1	360
34CrNiMo6	210	1101	1204	21.6	309
AISI420	200	690	760	20	540

Tab. 1. Mechanical properties of the materials

2.2 Details of the tests conditions

The specimen used in the reciprocating wear tests has a simple cylindrical shape (Ø20x3mm). The pin has a cylindrical shape with 4 mm radius and spherical contact surface, and the ball has 4 mm radius. A reciprocating pin-on-plate tribometer (nano-micro tribometer UMT-2) was used to evaluate the wear characteristics of Ti6Al4V/34CrNiMo6 (pin) and Ti6Al4V/AISI420 (ball) contact pairs. Figure 1 shows schematically the tests performed in this work: i) applied normal load (Fn) on the pin/ball and alternative displacement (d) of the specimen.

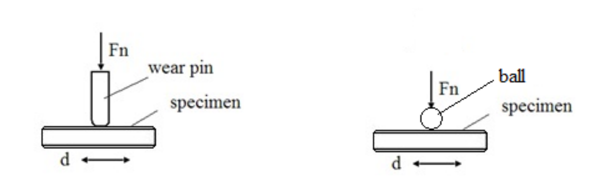

Fig. 1. Schematic test configurations.Fn – Normal load applied on pin; d – alternated displacement amplitude

The pin is pressed against the specimen by applying a normal load which induces the contact pressure between the pin and the specimen.

The surface of specimens and pins were polished with abrasive paper, finished with diamond spray (1 µm), and then cleaned ultrasonically in alcohol as to provide a standard surface.

Two series of reciprocating wear tests were carried out: Ti6Al4V/34CrNiMo6 and Ti6Al4V/AISI420 contact pairs. Experiments were carried out with three different normal loads of 100N, 120N and 140 N and relative displacement amplitude of 3 mm. All tests have been stopped after 4 h. The frequency of the tests was kept constant for all tests at 1 Hz. All the tests were performed in laboratory environment.

A detailed descripition of the fretting tests is presented elsewhere (Buciumeanu, 2009).

3. RESULTS AND DISCUSSION

Figures 2 and 3 show the evolution of the material loss in reciprocating wear case as a function of normal load for both contact pairs. It can be seen that for both material combinations the material loss increases with increasing the normal load.

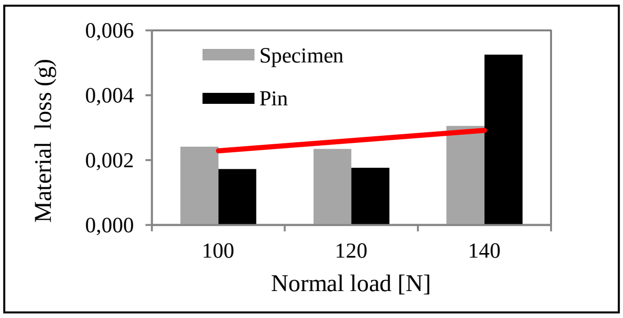

Fig. 2. Evolution of the material loss as o function of the normal load (Ti6Al4V/34CrNiMo6 - pin)

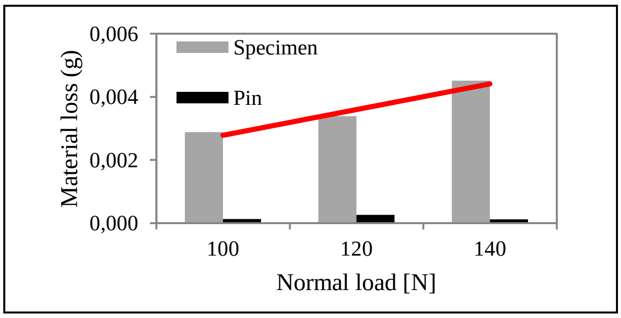

Fig. 3. Evolution of the material loss as o function of the normal load (Ti6Al4V/AISI420 - ball)

In reciprocating sliding situation with increasing normal load the material removal will become faster and the elimination of the surface layers will be accelerated. Regarding the contact material pairs response it can be seen that the intensity of the reciprocating wear process (the material loss) is much more prominent for Ti6Al4V/AISI420 material pair compared with Ti6Al4V/34CrNiMo6 material pair.

Regarding the wear behavior in fretting situation, from figure 4 can be depicted that the overall size of the contact area increases with increasing the normal load.

Figure 5 shows the variation of the depth of the contact zone with normal contact load.

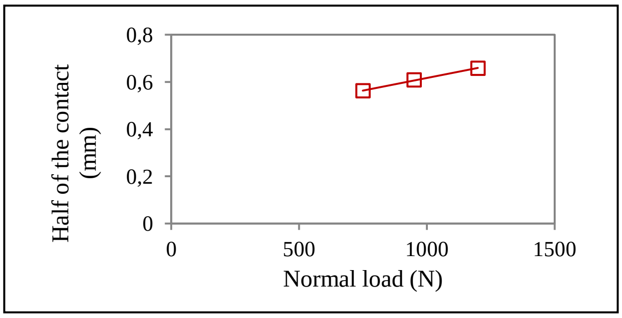

Fig. 4.Variation of the half of contact with normal load (Ti6Al4V/34CrNiMo6 contact pair) (Buciumeanu, 2009)

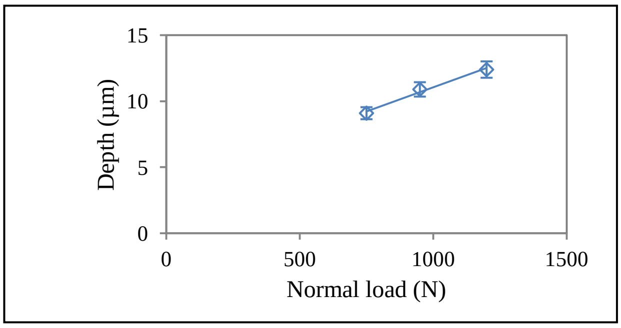

Fig. 5. Variation of the depth with normal load (Ti6Al4V/34CrNiMo6 contact pair) (Buciumeanu, 2009)

It can be observed that with increasing the normal load, the wear behavior in fretting and reciprocating wear situation is similar. These are expected results because according to Bowder and Tabor theory (Halling, 1987), the real area of contact between two surfaces is directly proportional to the applied normal load. So, it is expected an increase on the area of contact with increasing the normal load. However in the fretting case the increase in the contact area cannot be attributed only to normal load, because there is an inter-relation between several parameters (normal load, tangential load, relative displacement amplitude, material combination, environment etc.). As it is known solid materials subjected to loads deform in either elastic or plastic manner. In most contact situation we find a mixture of both elastic and plastic deformation. The load applied to the solids in contact may induce a general elastic behaviour in the bulk of the solid bodies, but since the actual contact must occur at the tips of the surface asperities these may be subjected to localized plastic deformation at their tips. The amount of plastic/elastic deformation must obviously depend on the value of the applied load and the degree of plastic deformation increases with increasing the load.

This study is part of an overall research regarding the behavior of the materials used in aerospace and automobile engines where both fretting and reciprocating sliding conditions are present.

4. CONCLUSION

From the present investigation of the wear behaviour of the Ti6Al4V alloy, the following conclusion can be drawn:

- The wear behaviour with increasing normal load seems to be similar behaviour in both cases fretting and reciprocating sliding;
- The materials loss increases with increasing on the normal load, under the same conditions;
- The intensity of the reciprocating wear process (the material loss) is much more prominent for Ti6Al4V/AISI420 material pair compared with Ti6Al4V/34CrNiMo6 material pair.

5. REFERENCES

Lee, H. (2004) Effect of dissimilar mating materials and contact force on fretting fatigue behavior of Ti-6Al-4V, *Tribology International* Vol. 37, No. 1, (January, 2004)(35-44), ISSN 0301-679X

Fouvry, S.; Duó P. &Perruchaut, Ph. (2004). A quantitative approach of Ti-6Al-4V fretting damage: friction, wear and crack nucleation, *Wear* Vol. 257, No. 9-10, (November, 2004)(916-929), ISSN 0043-1648

Magaziner, R.; Jin,O. &Mall,(2004).S. Slip regime explanation of observed size effects in fretting, *Wear*Vol. 257 No. (July, 2004) (190-197), ISSN 0043-1648

Sarkar, D.; Kumar, B.V.M. &Basu B. (2006).Understanding the fretting wear of Ti3SiC2, *Journal of the European Ceramic Society* Vol. 26, No. 13, (May, 2005)(2441–2452), ISSN 0955-2219

Bryggman, U. &Soderberg S. (1988). Contact conditions and surface degradation mechanisms in low amplitude fretting, *Wear* Vol. 125, No.1-2, (July, 1988)(39–52), ISSN 0043-1648

Buciumeanu, M.; Crudu, I.; Palaghian, L.; Miranda, A.S. & Silva, F.S. (2009).Influence of wear damage on the fretting fatigue life prediction of an Al7175 alloy, *International Journal of Fatigue*Vol. 31 No. 8-9, (August-September, 2009) (1278–1285), ISSN 0142-1123

Halling, J. (1987). *Principles of Tribology*, MacMillan Education Ltd, ISBN 0333246861, Hampshire-London