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The Effects of Counterparts on the Wear Properties and Surface Microstructure of TC4 Alloy

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Abstract: The wear properties and wear surfaces microstructure of TC4 alloy were studied with GCr15 and SiC counterparts, respectively. The results show that the friction coefficients of TC4 alloy with GCr15 was higher and the mass loss was lower compared with those of SiC. The wear mechanisms of TC4 alloy with GCr15 and SiC could be concluded as grinding abrasion, adhesion abrasion and oxidation abrasion. However, adhesion abrasion and oxidation abrasion mechanisms were predominant with GCr15 counterpart.

Keywords: TC4 Alloy, Counterparts; Wear Property, Surface Microstructure

1. Introduction

Titanium alloy has been used in the in the aerospace, shipbuilding industry, petroleum chemical industry, biological medicine, and other fields due to its high strength, low density and good corrosion resistance. TC4 alloy is used widely, and it is more than 50% in the total titanium alloy[see 1,2]. Since 1960's, the alloy has been used widely in various fields. However the friction and wear resistant properties of TC4 alloy is poor due to the adhesion and scuffing. So the improvements of the wear resistance and wear behavior of TC4 alloy surface have been becoming a hot research.

At present, the study of TC4 alloy is developing towards the high-performance and low cost[see 3,4]. Therefore, it is necessary to study the mechanism of the wear failure and metallo-graphy phenomenon of wear microstructure in order to optimize the TC4 alloy surface treatment technology and reduce the cost[see 5,6]. The different counterparts were influenced on the wear behavior of TC4 alloy[see 7~10]. The paper is to study the mechanism of TC4 alloy with the different fraction counterparts as the GCr15 and the SiC, and the friction coefficient and the wear weightlessness evaluation is to study.

2. The Experimental Procedures

A multi-component TC4 alloy with nominal composition of Ti-6Al-4V (wt.%) was prepared in a high vacuum consumable arc-melting furnace with master-cooled copper crucible under argon atmosphere. The samples were cut into cubes with dimension of 10mm×10mm×3mm by an electro-discharge machine. After being polished to an 800-grit finish using SiC paper, the samples were cleaned in an ultrasonic acetone bath and then dried.

The wear test was carried out by a ball on disk tester under a load of 4.5N. The counterparts were GCr15 and SiC sphere with 4.76mm in diameter. The sliding velocity was 224r/min, and wear time was 60 min.

The mass loss was weighed by the precision electronic analytical balance, and each group of samples were carried out three times. The wear surface morphology and the microstructure were observed by the scanning electron microscope with JMS-6360 and the chemical composition of grinding crack was analyzed.

3. The Results and Discussion

3.1. The Friction Coefficient and Wear Mass Loss with Different Friction Counterparts

The friction coefficients of TC4 alloy with GCr15 and SiC counterparts can be seen from Fig.1. It can be seen that the average friction coefficient of GCr15 is higher than that of SiC, and the friction coefficient of GCr15 was varied from 0.5 to 0.6. The friction coefficient of SiC was ranged from 0.4 to

0.55. At the beginning, the friction coefficients have an increasing trend because the contact area between the matrix alloy and the corresponding counterparts is much less than that of the nominal area of contact due to the macro surface rugged(sample surface has many tiny bumps and potholes). Under the rated load, there is the proportionality between the friction force and real friction area. Furthermore, there is a layer of pollution film between surface of matrix alloy and the air, and the film plays a role of lubrication, then reduce the friction coefficient. But the boundary film would be destroyed quickly, the Mico-bulge between the matrix alloy and the counterparts plays a role, which lead to the friction coefficients and friction force increase due to the increasing of local contact stress. As the wear, the tough between the matrix and the counterparts is grinding gradually, then the friction coefficient start to level out.

The wear mass losses of TC4 alloy with GCr15 and SiC can be seen from Figure 2. It can be seen that the mass loss is 2.61mg with GCr15 after 60min, however the mass loss is 5.56mg with SiC, and the latter is twice than the former. It is seen that wear mass loss with the SiC is more serious than that of SiC.

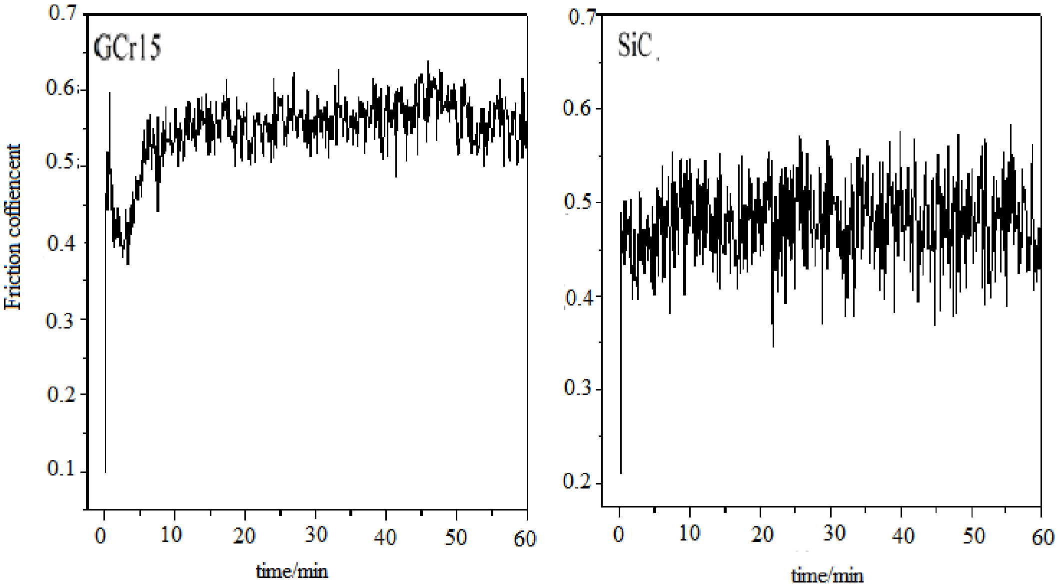

Fig. 1. *Friction coefficients of TC4 alloy with GrCr15 and SiC counterparts.*

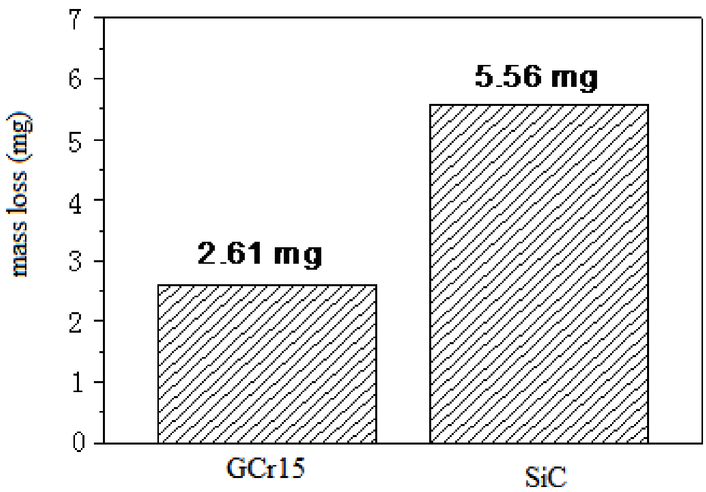

Fig. 2. *Mass losses of TC4 alloy with GCr15 and SiC counterparts.*

3.2. Wear Morphology and the Mechanism of Wear

Figure 3 shows the wear morphology of GCr15 and SiC and Table 1 shows the typical composition of EDS results of surface microstructure, respectively. It can be seen that the wear trace of GCr15 was presented furrow morphology and adhesion a large amount of discontinuous microstructure of TC4 alloy, however, the wear trace of SiC shows a approximate circle morphology. The surface was damage seriously due to the surface covered with a large amount of the microstructure of TC4 alloy. Their high magnification SEM morphology showed that discontinuous microstructure on the GCr15 counterparts was presented plastic deformation characteristic (Seen from point 2), however the microstructure adhesion on SiC showed an island morphology. The composition of microstructure adhesion on the GCr15 is Fe-66.34 Ti-7.53-Al-7.53-0.75 Cr-24.5O (at.%)(Seen as the table 1, point 2) and the composition of microstructure adhesion on the SiC is 26.46Ti-4.01Al-9.25Si-17.05C-43.23O (Seen as the table1, point 4), which suggested that the TC4 alloy would be adhesion on the grinding balls and the alloy was oxidized during the wear experiment.

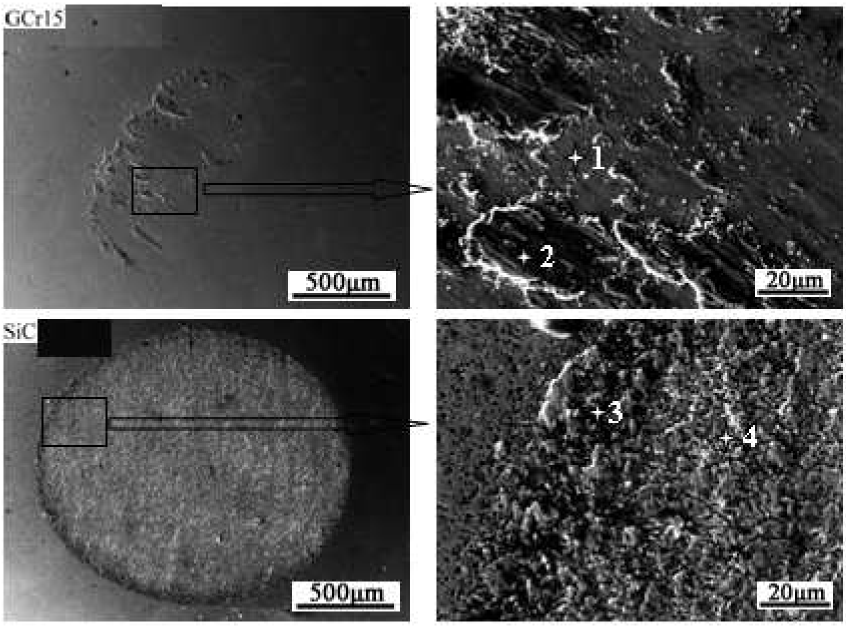

Fig. 3. *SEM images of the wear traces of GCr15 and SiC after wear against TC4 alloy*

Table 1. *Chemical composition of the sites marked by arrows with numbers 1-4 in Fig.3, determined by EDS analysis.*

Sites	Composition, at.%						
	Ti	Al	Fe	Cr	Si	C	O
1	0.80	0.42	88.22	0.42	--	0.80	9.34
2	56.34	7.53	1.60	0.03	--	--	34.50
3	0.33	--	--	--	41.70	51.37	6.61
4	26.46	4.01	--	--	9.25	17.05	43.23

According to the above results, it can be concluded that the above results show that the TC4 alloy was frayed with the GCr15, however the SiC is frayed with TC4 alloy. Because the hardness of GCr15 and SiC were higher than that of TC4 alloy, and they can be broke into the TC4 alloy matrix, then the TC4 alloy was deformed under the tangential force. The SiC particles microstructure is easy to adhesion on TC4 and fall off due to the SiC with loose porous, but the microstructure of GCr15 are more compact and more durable, so the mass loss of GCr15 is more smaller.

Figure 4 shows the wear morphology of the wear trace of TC4 alloy with GCr15 and SiC, respectively. The Table 2 shows the chemical composition determined by EDS. It can be seen that the wear trace width with GCr15 is smaller than that of SiC, and this was agreed well with the results in Figure 2. The wear trace of matrix TC4 alloy shows topography morphology and a large number of bright white microstructures are piled up on the wear trace with GCr15 counterparts. The morphology was presented plastic deformation and adhesive pits on the wear trace according to the magnification SEM. The EDS results show that the O content in the white bright microstructure is high than 49.3at.%, and it was suggested that the wear surface was oxidated.

However, it can be seen that the topography is obvious and the plastic deformation of wear surface is not obvious, and wear trace is not apparent with SiC counterparts. Furthermore, the bright white microstructure of wear surface is smaller and is dispersed in the wear surface. The results of EDS show that there was a small amount of Si and C on the wear surface, which is concluded that the SiC could be grinding out and adhered to the wear surface. This result was agreed with the morphology of wear surface as SiC. The composition determined by EDS show that the white bright microstructure of wear surface is oxidation, which suggested that the SiC could be oxidated.

It is believed that the GCr15 or SiC could be broke into the TC4 alloy matrix under normal force, and the surface is ploughed and bruised under the shear stress because the hardness of GCr15 and SiC is much higher than that of TC4 alloy. Some debris of plough was increased wear.

Some microstructures are piled up on the wear surface, and much microstructure is increased friction force which is resulted in the microstructure torn. It was noticed that much friction heat was happened due to sliding between matrix alloy and friction counterparts, thus wear surface has high temperature. On the one hand, the TC4 alloy surface was soften, on the other hand, the wear surface could be oxidated. The oxide scale was broken into small scale, and increased the degree of wear. Based on the above analysis, it can be concluded that the wear mechanism of TC4 alloy is mainly the plough, adhesive wear and oxidation wear. However, the wear adhesive and oxidation wear are significantly with the GCr15 counterpart, and the plough mechanism is more prominent with SiC counterpart.

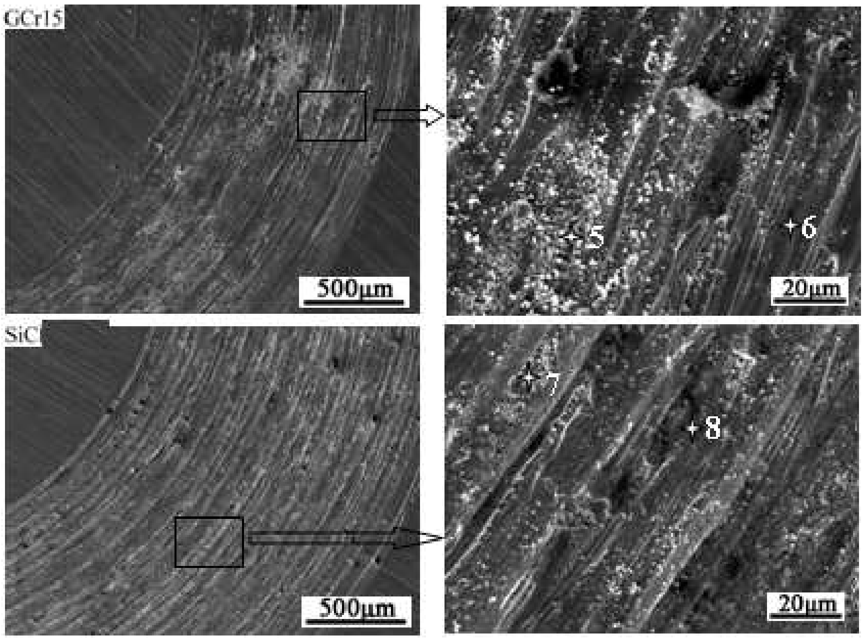

Fig. 4. *Wear morphologies of TC4 alloy wear with GCr15 and SiC counterparts.*

Table 2*. Chemical composition of the sites marked by arrows with numbers 5-8 in Fig.4, determined by EDS analysis.*

Sites	Composition, at.%						
	Ti	Al	V	Fe	Si	C	O
5	45.13	5.24	0.32	0.34	--	--	48.97
6	63.14	7.22	0.26	0.25	--	--	29.13
7	65.28	7.39	0.12	--	0.88	1.83	24.50
8	36.92	3.95	0.17	--	3.64	6.98	48.34

4. Conclusion

(1) At the same load and time, the friction coefficients of TC4 alloy with GCr15 was higher, and the mass losses were lower compared with those of SiC.

(2) The wear mechanisms of TC4 alloy with GCr15 and SiC counterparts could be concluded as grinding abrasion, adhesion abrasion and oxidation abrasion. However, adhesion abrasion and oxidation abrasion mechanisms could be predominant with GCr15 counterpart.

Acknowledgments

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