[Article ID] 1003- 6326(2002)03- 0419- 05

Dry sliding friction and wear behaviors of TiC_p/ZA-12 composites①

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[Abstract] The TiC particle reinforced ZA-12 matrix composites was fabricated by XD™ process combined with stirring casting and its friction and wear properties under dry conditions were investigated using MM-200 wear testing apparatus. The effects of TiC particle content and applied load on the wear resistance properties of the composites were studied. The results show that the friction and wear properties can be greatly improved with an increase in the TiC particle content. The wear mass loss of the composites and the unreinforced ZA-12 matrix alloy increase with increasing applied load, but the increased extent of the former is smaller than that of the latter. Finally the morphologies of worn surface was analyzed using scanning electron microscope(SEM).

[Key words] ZA-12 alloy; TiC_p/ZA-12 composites; friction and wear properties
[CLC number] TB 33 **[Document code]** A

1 INTRODUCTION

Since zinc-aluminum alloys have been widely used in the production of die and bearing for their excellent wear resistance property, their wear resistance mechanism has been studied theoretically by most scholars and researchers[1~3]. The particle reinforced zinc matrix composites have recently been more concerned due to their certain properties superior to zinc based alloys, but studies on the friction and wear properties of the composites are few and some even have incompatible conclusions[4~10]. The complete understanding of friction and wear behaviors and mechanism is important to more reasonable utilization of the composites.

Hence the paper aims at testing the friction and wear properties of the composites under dry conditions, and attempting to study the effects of TiC particle content and applied load on the friction and wear properties of the composites.

2 EXPERIMENTAL

In the present investigation, ZA-12, with its chemical composition shown in Table 1, was used as the matrix alloy. The TiC particle reinforced ZA-12 composites with volume fraction of TiC 5%, 10% and 15% were fabricated by XD™ process combined with stirring casting.

Firstly titanium powder (99.2%, 45 μm) and graphite powder (99.8%, < 0.05 μm) were mixed with aluminum powder (99.6%, 29 μm) according to 40Al+ 30C+ 30Ti (mole fraction), and pressed into d40 mm × 25 mm column with 50%~ 60% theoretical density. Then the column was placed in the vacuum SHS equipment to be heated and reacted to form the preform Al/TiC alloy. The XRD result of Al/TiC alloy is given in Fig. 1. It is shown clearly that the present phases are Al and TiC. Then the Al/TiC alloy was melt in the self-made stirring equipment with zinc and aluminum ingot. Finally the melt was stirred for the uniform distribution of the particles in it and poured for shaping the composites. The microstructures of TiC_p/ZA-12 composites with TiC particle volume fraction 5% and 15% were shown in Fig. 2(a) and (b), respectively. The particles appearing as tiny and circular are nearly globular with average size 1~ 2 μm, and distribute uniformly in the matrix alloy without segregation. The observation using TEM on interface between TiC particles and ZA-12 matrix demonstrates that the interfaces are smooth and bond tightly, and no reaction product exists.

Table 1 Main composition of ZA-12 alloy (mass fraction, %)

Al	Cu	Mg	Zn
11.2	1.23	0.04	Bal.

All the friction and wear tests were carried out under complete sliding condition on MM-200 sliding wear testing machine. The rectangular TiC_p/ZA-12 composites and ZA-12 alloy specimens with the size of 6 mm × 6 mm × 20 mm were used for the investigation. The sliding wheel was a ring of GCr15 with HRC59, the size of which was 40mm in diameter and 10mm in thickness. Wear tests were conducted at a rotating speed of 200 r/min using different applied

① [Received date] 2001- 12- 17; [Accepted date] 2002- 03- 18

load of 50, 100, 150 and 200 N respectively, and in each test the wear time was 20 and 30 min respectively. The wear loss was computed from the mass loss of the specimen weighed by an analysis balance with the sensitivity of ±0.1 mg. The worn surface was observed and analyzed using SEM.

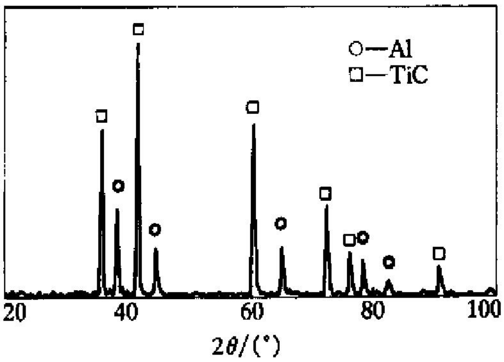

Fig. 1 XRD result of Al/TiC alloy

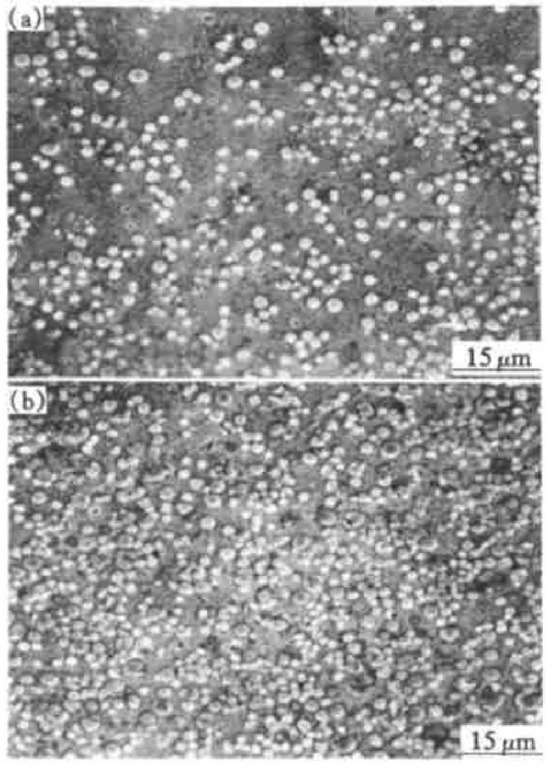

Fig. 2 Microstructures of TiC_p/ZA-12 composites
(a) —5% TiC_p/ZA-12; (b) —15% TiC_p/ZA-12

3 RESULTS AND DISCUSSION

3.1 Effect of TiC particle content

The effect of TiC particle content on mass loss and friction coefficient of the specimens, under a load of 100N and a wearing time of 20 min, is shown in Fig. 3. The curves show that the mass loss as well as the friction coefficient decreases with the increase of particle volume fraction. For example, with the TiC particle volume fraction increasing from 0% to 5%, the mass loss and the friction coefficient decreased by

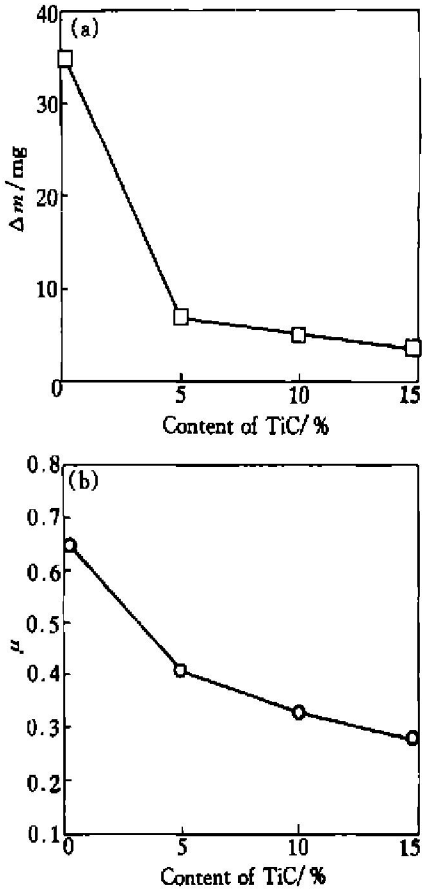

Fig. 3 Effect of TiC particle content on friction and wear properties of TiC_p/ZA-12 composites
(a) —Mass loss(Δm); (b) —Friction coefficient(μ)

83% and 37% respectively.

TiC particle with high hardness distributing in the soft ZA-12 matrix alloy is the main reason why the composite has TiC excellent wear resistance properties. The addition of the particle decreases the effective contact surface between the composite and the sliding wheel, leading to the decrease in the mass loss. And the higher the particle volume fraction is, the higher the hardness of the composites is, as shown in Fig. 4.

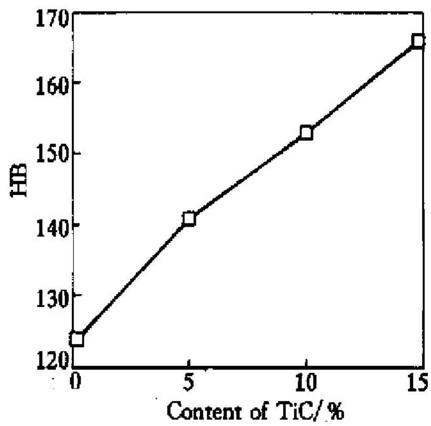

Fig. 4 Effect of TiC_p content on hardness of TiC_p/ZA-12 composites

3.2 Effect of applied load

The friction and wear behaviors of ZA-12 alloy and TiC_p/ ZA-12 composite with 10% (volume fraction) particle, under a wearing time of 20 min and various loads, were investigated, as shown in Fig. 5 (a) and (b) respectively. It shows that the mass loss and friction coefficient of the composite and the matrix alloy increase almost linearly with the load, but the increasing rate of the composite is far smaller than that of the matrix alloy. The greater the applied load is, the more obviously the composite shows its superiority in wear resistance properties.

Since TiC particles play the part as enduring body of the load, and the fracture of the particles takes place in so few quantities during the wear test under any load, the wear resistance property of the composite is improved. It is the role of the particle reinforced that accounts for the superiority of friction and wear properties of the composite over the matrix alloy.

3.3 Morphologies of worn surface

The morphologies of worn surface of ZA-12 alloy and TiC_p/ ZA-12 composites are shown in Fig. 6. Deep worn traces and obvious big grooves are seen on the surface of ZA-12 alloy in the range of test load;

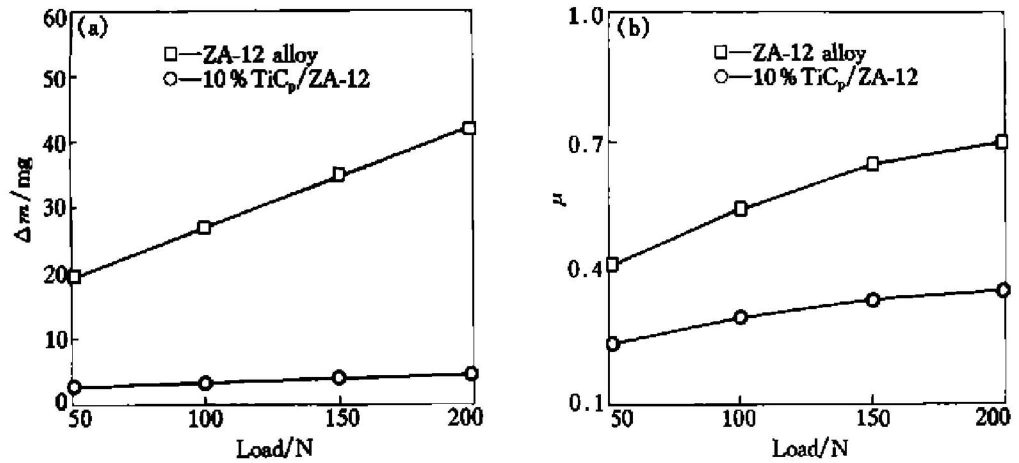

Fig. 5 Effect of load on friction and wear properties of ZA-12 alloy and TiC_p/ ZA-12 composites
(a) —Mass loss; (b) —Friction coefficient

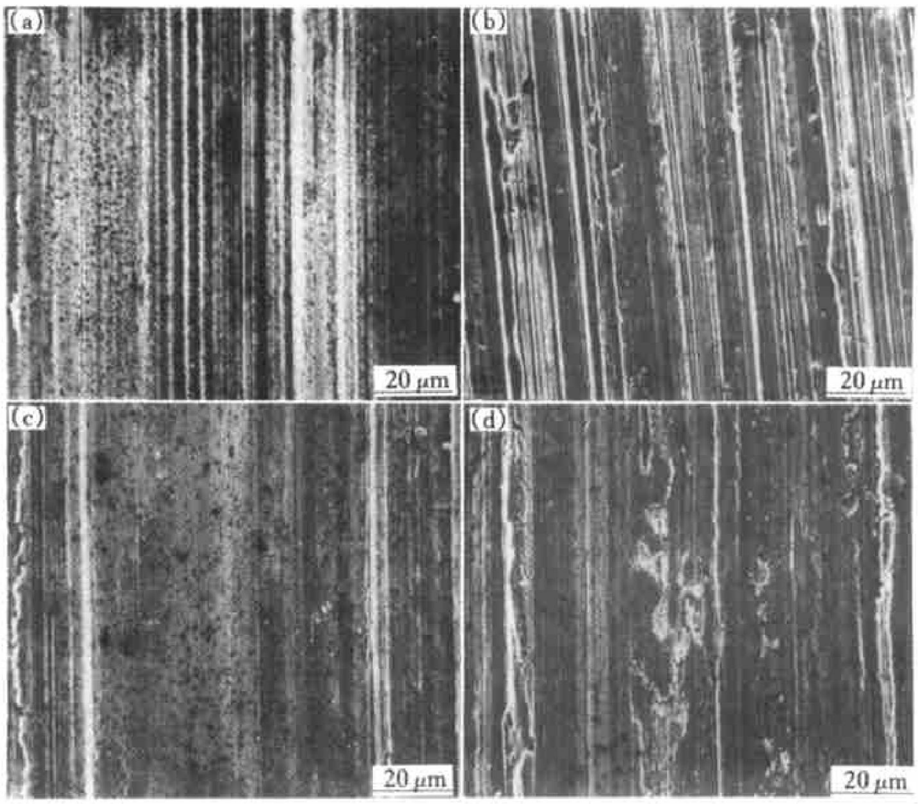

Fig. 6 Friction and wear surface morphologies of ZA-12 alloy and TiC_p/ ZA-12 composites
(a) —ZA-12 alloy, 50 N; (b) —ZA-12 alloy, 150 N; (c) —10% TiC_p/ ZA-12, 50 N; (d) —10% TiC_p/ ZA-12, 150 N

the subsurface is apparent and the worn-off debris are glittering flakes, as shown in Fig. 6(b). The worn surface of the composites under low load is smoother, and there is some tiny granular debris in the grooves between worn layers, as shown in Fig. 6(c). The plastic deformation increases with the applied load increasing, and there are some granular and flaky worn debris out of deep grooves, but the worn surface is still smooth, which can be observed in Fig. 6(d).

It is obvious that the wear resistance property of ZA-12 alloy is significantly improved because of the addition of TiC particles. The reasons can be described as follows: the TiC particles contact with the sliding wheel in place of the matrix alloy as enduring body, so the adhesive wear decreases effectively. At the same time, the combination of interface between TiC particles and matrix alloy is strong enough to keep the particle from dropping from the matrix alloy, thus restrain the tendency of the wear of abrasives. What's more, the combination also improves the capacity of adhesion and deformation resistance.

3.4 Morphologies of worn damaged layer

The morphologies of worn damaged layer of ZA-12 alloy and TiC_p/ZA-12 composites under a load of 200 N and a wearing time of 30 min are shown in Fig. 7. It can be seen that the sub-worn-surface of the specimens has been damaged in different degree. In the worn damaged layer of ZA-12 alloy, there are three zones which are defined as plastic deformation zone(Zone Ⅰ), tiny fracture zone(Zone Ⅱ) closing to the worn surface and sever plastic deformation zone (Zone Ⅲ), as shown in Fig. 7(a). While there are only two zones (Zone Ⅰ and Zone Ⅱ) in the composites with 5% and 10% particle as shown in Fig. 7(b) and (c), and the thickness of Zone Ⅱ decreases with increasing volume fraction of TiC particle. In Fig. 7 (d), only Zone exits in the worn damaged surface of the composite with 15% TiC particle. It can be seen that the fractures vertical to the worn surface connect with the transverse fractures, as shown in Zone Ⅱ of

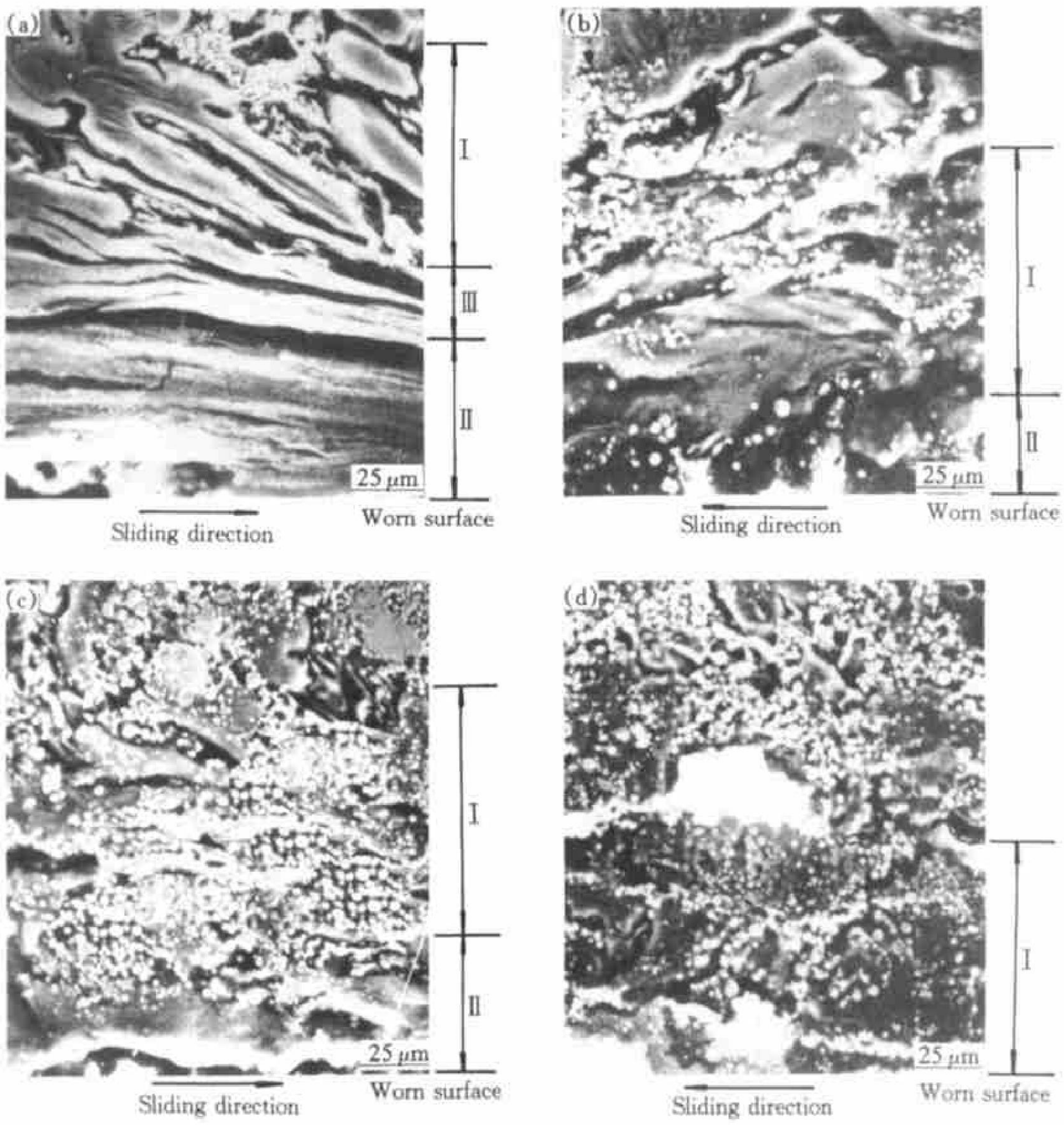

Fig. 7 Worn damaged layers of ZA-12 alloy and TiC_p/ZA-12 composites
(a) —ZA-12 alloy; (b) —5% TiC_p/ZA-12; (c) —10% TiC_p/ZA-12; (d) —15% TiC_p/ZA-12

Fig. 7(a), (b) and (c). So debris will flake off from zone Ⅱ under the effect of friction. The debris is thinner or as thick as Zone Ⅱ, and are equal in length to the longitudinal fracture space of Zone Ⅱ. Therefore the more fractures appear on Zone Ⅱ or the thicker Zone Ⅱ is, the more likely the debris will flake off from the zone, the bigger the debris will be, and the more the mass loss will be. It can be concluded that the addition of TiC particles plays a significant role in preventing plastic flow of ZA-12 matrix alloy.

4 CONCLUSIONS

1) The wear resistance property of ZA-12 alloy is obviously improved due to the addition of TiC particles under dry sliding wear condition. To a certain extent, the higher the particle content is, the better the wear resistance property is.

2) Under dry sliding wear condition, the mass loss of ZA-12 alloy and the composites increases with increasing applied load, but the mass loss of the composites increases by smaller than that of ZA-12 alloy, and the friction coefficient of the composites is much smaller than that of ZA-12 alloy during the wear test under any load.

3) The analysis of morphologies of the worn damaged layer of ZA-12 alloy and TiC_p/ZA-12 composites shows that the addition of TiC particle plays a significant role in preventing plastic flow of ZA-12 matrix alloy.

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(Edited by YUAN Sai-qian)