하이브리드 금속복합재료의 윤활마모특성

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Lubricated Wear Properties of Hybrid Metal Matrix Composites

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Key Words : Hybrid metal matrix composites, Squeeze casting method, Lubricated wear properties, Wear mechanism, Worn surface, Coefficient of friction

ABSTRACT

The purpose of this study is to investigate the lubricated wear properties of Saffil/Al, Saffil/Al_2O_3/Al and Saffil/SiC/Al hybrid metal matrix composites fabricated by squeeze casting method. Wear tests were done on a pin-on-disk friction & wear tester with long sliding distance. The wear properties of the three composites were evaluated in many respects. The effects of Saffil, Al_2O_3 particles and SiC particles on the wear behavior of the composites under lubricated conditions were elucidated. Wear mechanisms were analyzed by observing the worn surfaces of the composites. The variation of coefficient of friction (COF) during the wear process was recorded by using a computer. Comparing with the dry sliding condition, all three composites showed excellent wear resistance when lubricated by liquid paraffin. Under intermediate load, Saffil/Al showed best wear resistance among them, and its COF value is the smallest. The dominant wear mechanism of the composites was microploughing, but microcracking also occurred for them to different extent.

1. Introduction

In recent years, aluminum Metal Matrix Composites (MMCs) used for tribological components have attracted more and more interests. Compared with the corresponding monolithic alloys, aluminum matrix composites are attractive because of their improved strength, stiffness, creep behavior, wear resistance and low thermal expansion [1]. But due to the complexity of wear problems, contrary results could also be found for some composites under certain conditions. Many researches have been carried out on the wear behaviors of aluminum MMCs recently [2-5]. Pan *et al.* found that the main wear mechanism of 2124Al-SiCw composite was abrasive wear though plowing and polishing for lubricated sliding [2]. The liquid paraffin is a good lubricant for aluminum MMCs. Yoshiro Iwai *et al.* found that in paraffin oil, the wear rates of 7004-T6 and 2024-T4 were about 1/10 the wear rates under dry conditions [3]. Delamination was considered to be the controlling wear mechanism for Saffil-reinforced AA6061 composites at intermediate load [4]. Saffil, SiC particles and Al_2O_3 particles are usually used as reinforcements of aluminum alloys. But how do these reinforcements effecting on the wear behavior of aluminum MMCs under lubricated condition? In this research, the lubricated wear properties of Saffil/Al, Saffil/Al_2O_3/Al and Saffil/SiC/Al hybrid MMCs were investigated.

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Table.1. Chemical composition of Al matrix alloy

Material	Chemical composition (wt.%)											
	Si	Cu	Mg	Zn	Fe	Mn	Ni	Ti	Pb	Sn	Cr	Al
AC8A	6.0-18.0	0.8-1.3	0.7-1.3	<0.15	<0.8	<0.15	0.8-1.5	<0.2	<0.05	<0.05	<0.10	rem.

2. Materials and Experimental Details

2.1Materials

The three composites all contain 20vol.% reinforcements. Saffil/Al_2O_3/Al contains 5vol.% Saffil fibers and 15vol.% Al_2O_3 particles. Saffil/SiC/Al contains 5vol.% Saffil fibers and 15vol.% SiC particles. The small fraction of Saffil in Saffil/Al_2O_3/Al and Saffil/SiC/Al is used to reinforce the aluminum matrix and make the composites easier to fabricate, so the wear properties of this two kinds of composites were determined by the particles.

The matrix alloy was AC8A. Table.1 shows the chemical composition of the aluminum matrix alloy.

The SiC particles, which are fabricated by Imperial Polychemical Corp. (U.S.A.), have an average length of 30 μm and average density of 3.2g/cm^3. The size of the Al_2O_3 particle is 40 μm. The Saffil fibers (δ-alumina fibers) are fabricated by ICI (U.K.), having an average length of 150 μm and average density of 3.3g/cm^3. Fig.1 shows the SEM graphes of SiC particles, Al_2O_3 particles and Saffil fibers.

The composites were all fabricated by squeeze casting method. After squeeze casting, cast ingots were treated by T6 heat treatment.

Fig.1. SEM graph of SiC particles (a), Al_2O_3 particles (b) and Saffil fibers (c), 500×

2.2 Experimental Details

The wear behavior of Saffil/Al, Saffil/Al_2O_3/Al and Saffil/SiC/Al hybrid MMCs with lubricant of liquid paraffin was investigated on a pin-on-disk friction and wear tester. Fig.2 shows the schematic diagram of the friction & wear tester.

The specimens were 30mm in diameter and 8mm in thickness. The diameter of the steel pins was 5mm, and the diameter of the pin's top surface was 4.3mm after chamfered. The contact surfaces of the specimens and pins were all smoothed by 1500 grit SiC paper. The rotating diameter of the pin on the specimen's surface was 23mm. The sliding speed and applied load was 0.36m/s and 240N respectively. The tests were done under room temperature, which was around 25°C. The weight losses were measured by using an electronic balance with a sensitivity of 0.1mg. In order to remove the oleaginous organic substances from the specimens' surface, the specimens were cleaned in an acetone bath and dried in hot air before and after the tests. The pins were also cleaned with acetone before the tests. The long sliding distance wear tests were done by an incremental method [6]. The total distance was 8000m and an increment was 2000m. After each increment, the specimen was removed, cleaned by acetone and dried in hot air, then weighted and remounted in the wear tester at the same location, and then the test was continued by using fresh lubricant and started from room temperature.

The wear process was controlled by a computer. Friction force, Coefficient of Friction (COF), wear depth and temperature were recorded as a function of time.

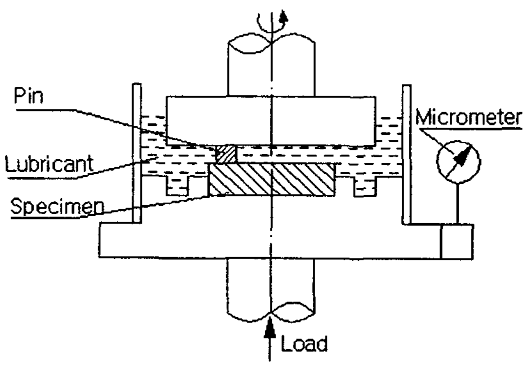

Fig.2. A schematic diagram of the friction & wear tester

3. Results and Discussions

3.1 Results

Fig.3 shows the weight losses and wear depths at different sliding distances. The weight losses of Saffil/SiC/Al and Saffil/Al_2O_3/Al increased abruptly at the early stage of sliding distance, and increased slightly, or even ceased to increase, after sliding distance of 2000m. As for Saffil/Al, the weight loss increased slightly from the beginning of the test. The wear depth of them increased abruptly at the early stage and kept increasing with sliding distance. It was obvious that Saffil/Al showed best wear resistance under lubricated condition.

It was not difficult to find that the weight loss almost ceased to increase after sliding distance of 2000m, while the wear depth increased all the time. This contradiction result might be explained like this. As the particles were pulled out and became debris, pits occurred, but at the same time, some debris trapped into the pits and might form a transfer layer. So the transfer layer prevented the wear of the specimen and the weight loss ceased to increase. It could be concluded that it was the wear of the steel pin, instead of the specimen, that caused the increasing of the wear depth.

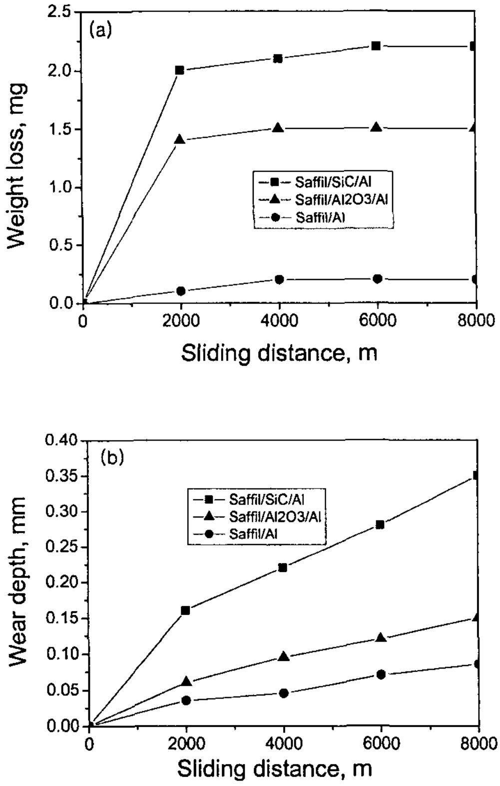

Fig.3. Weight loss (a) and wear depth (b) at different sliding distances

3.2 Worn Surfaces Analysis

The worn surfaces were observed though an image analyzing system. Fig.5 shows the morphologies of the worn surfaces of the composites under load of 240N and sliding distance of 8000m. It was found that the worn surface of Saffil/SiC/Al was filled with grooves paralleling to the sliding direction, while the grooves on the worn surfaces Saffil/Al_2O_3/Al were not so obvious. The grooves occurred here could be thought as a characteristic of microploughing. The grooves in Fig.5 (b) and (c) were discontinuous and cracks were found on the worn surfaces. The occurrence of cracks was due to the pulling-out of some particles. Microcracking of Saffil/SiC/Al was serious than Saffil/Al_2O_3/Al.

As for Saffil/Al, Microcracking was not obvious, and grooves were almost not found on the worn surface. This was because that there were no hard particles served as abrasive, but grooves could be found on the surface of the pin, as shown in Fig.6 (a). Saffil fibers could be found on the worn surface, but they were not pulled out, which suggested a good bonding between the fiber and

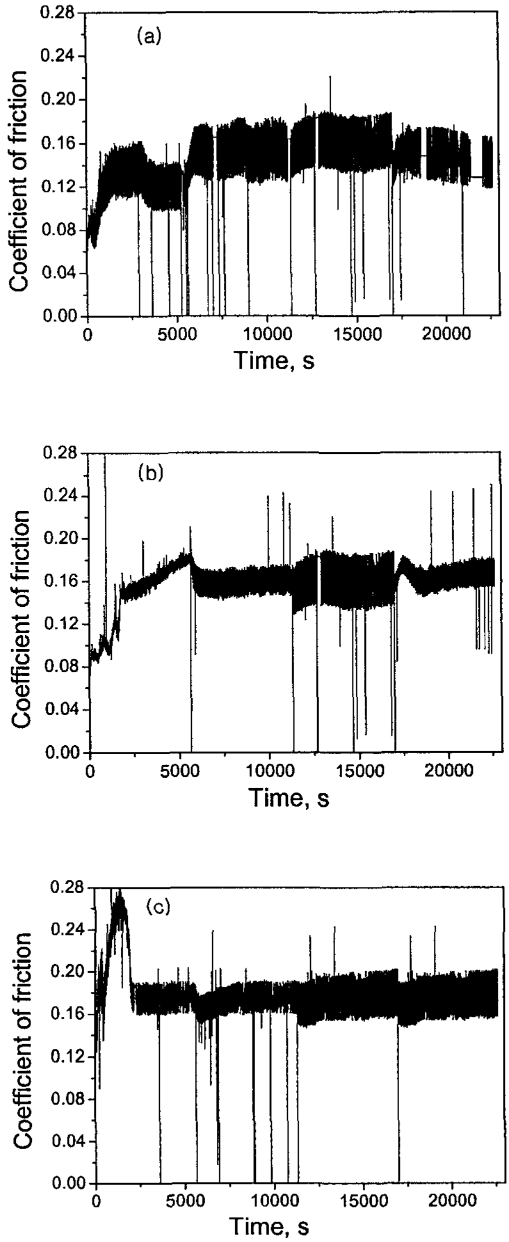

Fig.4. COF characteristics of Saffil/Al (a), Saffil/Al_2O_3/Al (b) and Saffil/SiC/Al (c)

Fig.5. Worn surface images of Saffil/Al (a), Saffil/Al_2O_3/Al (b) and Saffil/SiC/Al (c), 600×

Fig.6. Worn surface images of the pin against Saffil/Al (a), Saffil/Al_2O_3/Al (b) and Saffil/SiC/Al (c), 600×

matrix. The worn surfaces were all very smooth and flat, which was due to the polishing of the surfaces.

It was also found that wear of the pin against Saffil/SiC/Al was serious than that of the pins against Saffil/Al and Saffil/Al_2O_3/Al. The grooves in Fig.6 (c) were deeper and wider than Fig.6 (a) and (b). It was the high strength of Saffil/SiC/Al and the hard SiC particles that caused the serious wear of the pin.

3.3 COF characteristics

The COF characteristics of these three composites are different, as shown in Fig.4. The COF values fluctuated greatly at the early stage, and tended to reach some constant value as sliding distance increased. This constant value was 1.5 for Saffil/Al, 1.6 for Saffil/Al_2O_3/Al and 1.75 for Saffil/SiC/Al. Obviously, Saffil/Al had the minimum COF value at long sliding distance. The COF values of Saffil/Al and Saffil/Al_2O_3/Al at the early stage were not very big value. It was because the materials were soft and the reinforcement cannot resist the plastic deformation of the surface. The COF of Saffil/SiC/Al was biggest. This was due to its greater strength, rendering the composite more difficult to deform.

4. Conclusions

Saffil/Al showed best wear resistance at intermediate load under lubricated sliding. The dominant wear mechanism of the composites was microploughing, but microcracking also occurred for them to different extent. Saffil/Al had the minimum COF value at long sliding distance. Particles, especially hard particles, were destructive to the wear resistance of aluminum MMCs under lubricated sliding.

Acknowledgements

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