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Tribological performance of graphite containing tin lead bronze–steel bimetal under reciprocal sliding test

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ABSTRACT

As a solid self-lubricating material to serve under heavy load and low velocity, graphite containing tin lead bronze–steel bimetal composites were prepared using the powder metallurgy (P/M) technique. Effects of graphite content on tribological performance under reciprocal sliding were studied using the UMT-2MT tribo-meter. The optimal performance of average friction coefficient, maximum friction coefficient, friction coefficient amplitude and wear resistance can be achieved at the graphite content of ~3 wt%. Appropriate graphite content and hardness are the two most crucial factors to achieve a good quality lubricating film on the worn surface and hence the desired solid lubrication performance.

1. Introduction

Metal based self-lubricating composites are a typical solid lubricant material. Some of the most noteworthy properties include low friction coefficient, high melting point, good mechanical strength, improved ductility and elongation, good heat and electrical conductivity, good dimensional stability, good long-term reliability, good moisture resistance, and as well as good machinability [1–3]. Self-lubrication copper based composites, which consists of one of the most important components of this material class, are widely used in many oil-deficiency and even oil-free applications [4,5]. Particularly interesting are tin bronze–steel bimetals, which are not only good at mechanical strength, heat conductivity, abrasive resistance and load bearing capacity, but also save the use of relatively more expensive non-ferrous metals. Tin bronze–steel bimetals have now been employed widely in many industrial fields, such as automotive, aerospace, construction machinery, etc [6]. Powder metallurgy (P/M) technique, which is able to mix non-metallic substances with metals in any proportions to obtain desired performance, is the most preferred method to fabricate such metal based solid self-lubrication materials [7,8].

Graphite, as a solid lubricant, is most often used in self-lubricating copper base composites, due to its good anti-friction performance and chemical–physical stability over a wide temperature range [9–11]. Even though there is an increasing demand for lead-free materials [12], the lead can be still hardly replaced as an additive in load bearing components, particularly under heavy load and low velocity conditions. Furthermore, there exists a good synergic lubrication effect between graphite and lead when they both serve as solid lubricants together [13–15]. In the present work, tin lead bronze–steel bimetal composites have been synthesized using the P/M technique. Effects of graphite content on material hardness, microstructure and tribological performance under reciprocal sliding motion have been investigated and discussed, in order to understand friction and wear mechanisms of such composites under heavy load and low velocity.

2. Experiment details

2.1. Materials

Tin lead bronze–steel bimetal composites were fabricated with −100 mesh (with sizes of less than 154 μm) CuSn10Pb10 (mass fraction) and natural graphite powders. The graphite content of 1%, 2%, 3%, 4%, 5%, 6.5%, and 8% (mass fraction, unless otherwise stated) were used, respectively. The back was made with high-grade carbon steel electroplated with copper.

2.2. Fabricating process

Fig. 1 shows our fabrication process flow of the bimetals. First, bronze and graphite powders were mechanically mixed. Then, the

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mixed powders were laid on the copper-electroplated steel back evenly prior to the first sintering process. The first-stage cold-rolling was then carried out, followed by the second-stage sintering, precision cold-rolling and finally leveling. The sintering temperature was between 750–830 °C. The sintering time is 1 hr. The sintering atmosphere is hydrogen.

2.3. Test and analysis

The Brinell hardness of the bronze coating surface was tested according to Standard GB10453-89 (issued by the Standardization Administration of the People's Republic of China), using a 5.0 kgf load, 30 s dwell time and Φ-1.00 mm steel ball indenter. Friction and wear tests were conducted on the UMT-2MT tribo-meter with a ball-on-disk configuration without lubrication. The ball material was a quenched chromium steel with a Rockwell hardness of 60–63 and a diameter of 9.5 mm. The disk was vertically fixed while the ball was reciprocal sliding on the disk. All tests were performed at room temperature under a fixed load of 100 N. The relative humidity was kept at 50–60%. The reciprocal sliding had an amplitude of 10 mm and a vibrating frequency of 1 HZ. The dimensions of the samples are 20 mm in length, 12 mm in width and 12 mm in height. Every friction and wear test lasted 60 min. The wear data of the bimetal composites was determined by the width of the grinding cracks measured by a scale optical microscope. The microstructures were observed on LEICA optical microscope (Germany). Scanning electron microscopy (SEM, JEOL-6360L Japan) equipped with energy dispersive spectroscopy (EDS) was used to characterize the morphologies and chemical compositions of the worn surfaces.

3. Results and discussions

3.1. Microstructures

During sintering processes, graphite and bronze form a pseudo-alloy on the surface of the bimetal because graphite does not react with any elements of CuSn10Pb10. Fig. 2 compares the unetched optical microstructures of bimetals with graphite content of 1, 3, and 5 wt%, respectively. The bright parts in the pictures are metal base and the grey parts are mainly graphite. Porosities are not obvious under such a low magnification. At the bottom of the pictures shows the steel back. It is clearly seen that the graphite content gradually increases from Fig. 2(a)–(c). Due to the significant difference in weight, graphite segregation in the bronze host can easily occur during the mechanical mixing. This segregation becomes more evident with the increase in content of graphite, and the bimetal with 5 wt% graphite presents the most severe segregation, and possibly related, the lowest adhesion

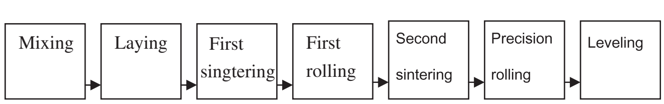

Fig. 1. Fabrication process flow of the bimetals.

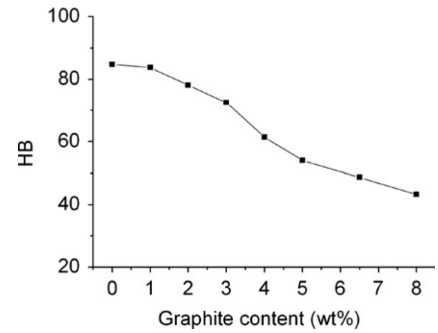

Fig. 3. Effects of graphite content on the hardness.

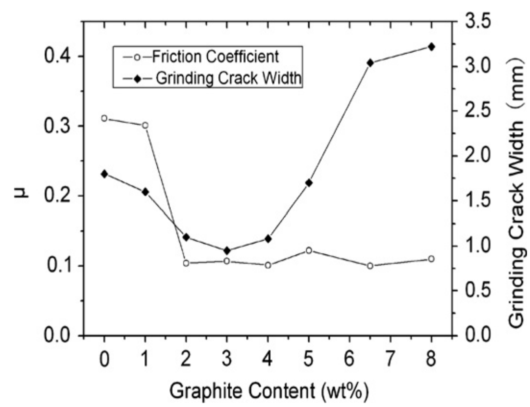

Fig. 4. Curves of average friction coefficient and grinding crack width versus graphite content.

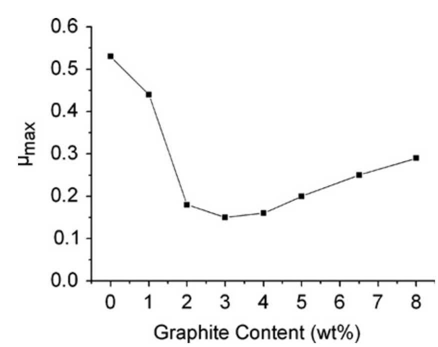

Fig.5. Curves of maximum friction coefficient versus graphite content.

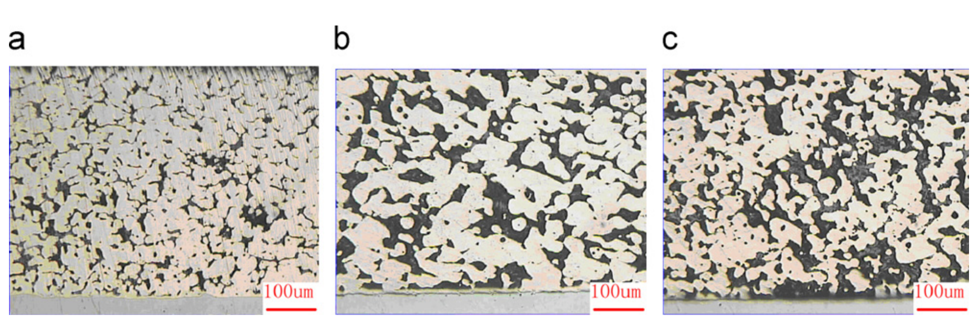

Fig. 2. Metallographic images of the materials. (a) 1 wt% graphite (b) 3 wt% graphite (c) 5 wt% graphite.