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ABRASIVE WEAR OF COMPOSITES BASED ON CuPb30 ALLOY REINFORCED WITH GRAPHITE PARTICLES

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The aim of the study was to assess wear rate and mechanical properties of composites based on CuPb30 copper alloy reinforced with graphite particles and the attempt to replace scarce tin in bearing bronzes with graphite particles. Composites were prepared using the method of mechanical mixing. Composite suspensions, as well as matrix alloy were gravity cast into metal and shell moulds. The effect of sample load on the amount of wear and mechanical properties of the tested materials were determined.

Keywords: casting, composites, graphite, wear, mechanical properties

INTRODUCTION

In the processes of wear and tear of the parts of machines and devices, the most important are parameters such as: sliding speed of rubbing surfaces, load and operating temperature of worn parts. However, the most important factor in friction processes is the material from which the parts working under friction conditions are made. Under the influence of heat, during the wear of working parts, changes in mechanical, physical and chemical properties in the surface layer occur. As the temperature increases, hardness decreases, which significantly affects the course of deformations of the surface layer [1, 2].

Copper and its alloys did not arouse much interest as a matrix material in composites, mainly because of technological difficulties associated with the production of such a composite. The production of these composites is difficult due to the susceptibility of Cu alloys to the so-called hydrogen embrittlement causing microcracks [3].

The properties of metal composite materials are the result or sum of properties of the components from which the composite is built, as well as their volume fractions and their distribution in the reinforced matrix [3 - 5]. Equally important is the selection of a suitable material for the composite matrix as well as the size and shape of ceramic particles [6, 7]. Copper alloys reinforced with ceramic particles exhibit an interesting combination of strength, plastic and abrasive wear resistance properties. Their characteristic feature is also high electrical and thermal conductivity. Copper-based composites are produced by various methods, e.g. powder metallurgy, consisting of mechanical mixing of components, cold compaction and subsequent hot consolidation [8], or with the use of sintering with partial or total share of liquid phase. It is also possible to apply a process of saturation by alloy or metal infiltration, of a porous skeleton previously obtained by pressing and sintering [9]. However, these are expensive and complicated treatments.

A major problem when producing metal composite materials is the lack of wetting of the ceramic particles by the metal matrix. The increase in wetting of non-metallic particles by the liquid matrix of a Cu alloy was attempted to be achieved by introducing vibrations of different frequency or activating non-metallic particles with the use of their annealing, etching and application of metal coatings. However, these methods did not provide the desired results. In the present study, an attempt was made to improve wetting of non-metallic particles by a modification of the liquid alloy with titanium.

METHODOLOGY AND RESEARCH MATERIAL

The aim of this work was to determine the possibility of replacing scarce tin in bearing bronzes with graphite particles arranged in a copper and lead alloy matrix, as well as to determine abrasive wear resistance and the basic mechanical properties of these materials. Composites containing various volume fractions of graphite particles were tested:

1) CuPb30Ti + 5 % Cgr,
2) CuPb30Ti + 10 % Cgr,
3) CuPb30Ti+ 15 % Cgr,
4) CuPb30Ti + 20 % Cgr,

For comparative purposes, tests of abrasive wear of the unreinforced CuPb30 matrix alloy and CuSn5Pb25 bearing bronze were performed. Cu-Pb-graphite composites were modified with titanium (2 %). VA graphite with a carbon content of 99,5-99,9 % was used to make the composites. Graphite particles in the size range of 100-160 μm were used to prepare the composites. To

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remove moisture, the graphite particles were annealed at 250 °C.

The resulting alloy was overheated to a temperature of 1 470 K, and then an appropriate amount of graphite particles was introduced, while stirring the metal bath at a rotational speed of 400 rpm. The mixing time was 120 s. After mixing, the suspension was gravity cast into previously prepared metal and shell moulds. Samples for abrasive wear tests were made in a metal mould, while samples for mechanical tests were cast in a shell mould.

Tribological properties were tested on the T-05 test device. This is a roller-block-type tester.

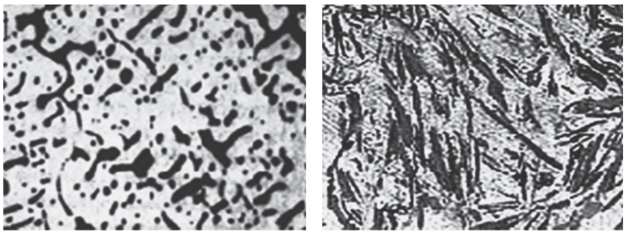
The tests were carried out under the following operating conditions:

- sample load – 10, 20 and 30 N,
- friction path – 3 000 m,
- type of friction – sliding,
- friction velocity – 5 rps
- a sample with concave friction surface, 6,35 mm wide, distributed contact with an area of 100 mm,
- a counter-sample – a steel roll with a diameter of 35 mm, made of NC10 steel with a hardness of 58 - 63 HRC.

The assessment of the abrasive wear of the tested composites was carried out by determining the weight lost by friction. In order to thoroughly examine the abrasion kinetics, weight loss measurements were made every 500 m.

RESULTS OF RESEARCHES

Figure 1a shows the microstructure of the CuPb30 alloy constituting the matrix of the tested composites, while Figure 1b shows an exemplary microstructure of the tested composites.



a) b)

Figure 1 The mikrostructure of: a) CuPb30 alloy, b) CuPb30Ti+ 20 % Cgr composite, magnification100 x.

The obtained results of abrasive wear tests are presented in graphical form in Figures 2 - 4.

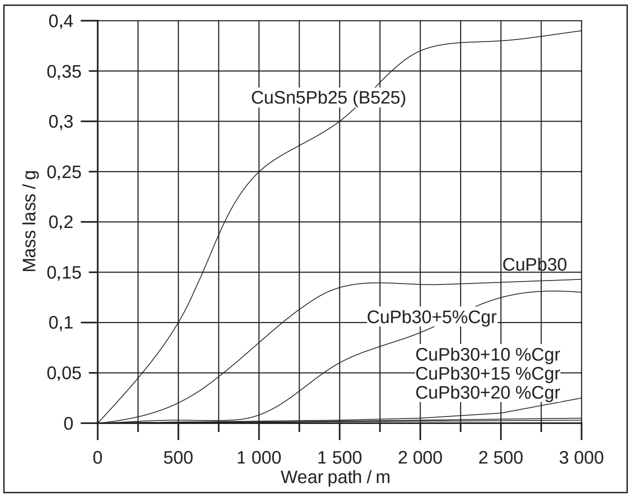


Figure 2 Abrasive wear of the tested composites at 10 N load

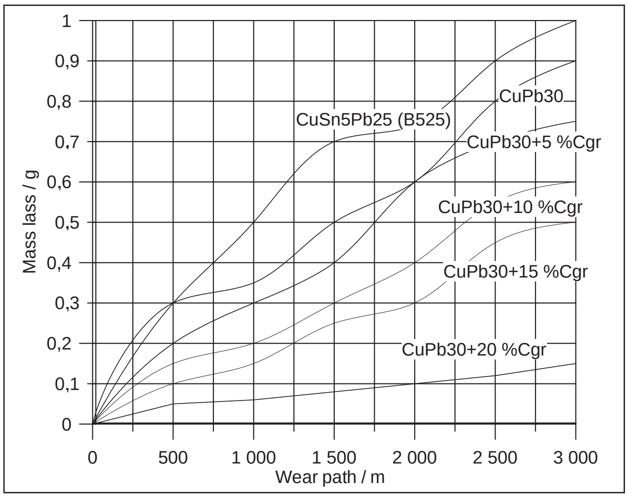


Figure 3 Abrasive wear of the tested composites at 20 N load

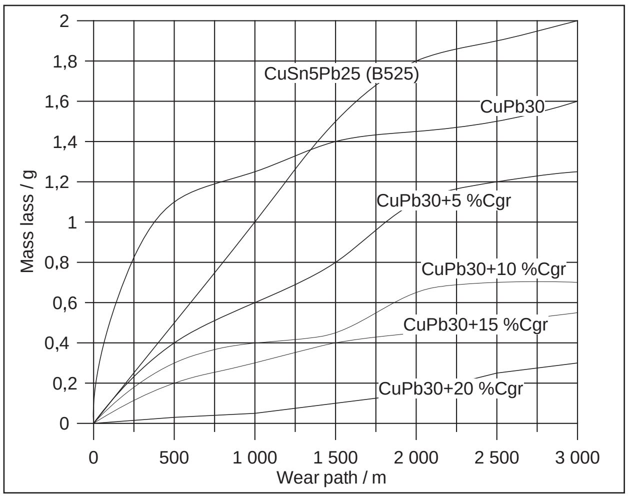


Figure 4 Abrasive wear of the tested composites at 30 N load

Figure 2 shows the abrasive wear of the CuPb30 matrix and composites containing different graphite content at 10 N load. As visible in the drawings, the largest weight loss is characteristic for CuPb30 alloy. The smallest weight loss was observed during wear of the composite containing 20 % Cgr, which proves that the abrasive wear resistance increases with the graphite content. All the curves of the composite reinforced with graphite particles have a characteristic course different from that of the alloy matrix wear curve. The weight loss in case of abrasion under 20 N load looks similar (Figure 3). Figure 4 shows the abrasive wear of composites containing different content of graphite and CuPb30 matrix at 30 N load. At the initial stage of abrasion, the matrix has the largest weight loss. Up to ap-

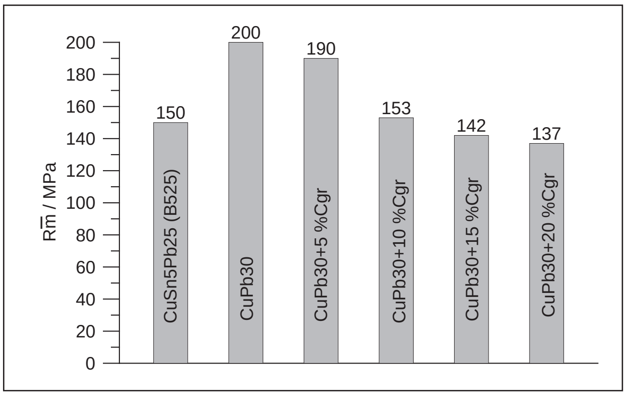


Figure 5 Tensile strength of the tested materials

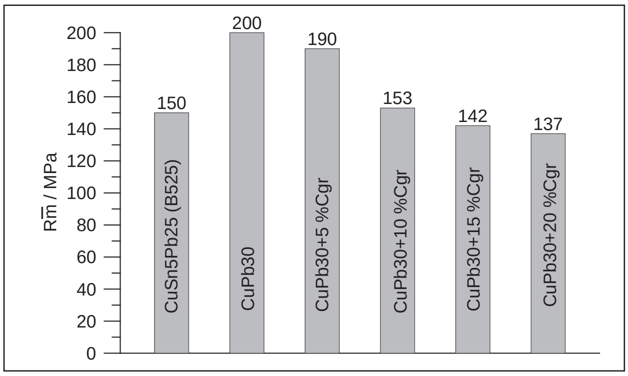


Figure 6 Elongation of the tested materials

proximately 2 000 m, the abrasive wear of composites reinforced with graphite particles is low, but after exceeding this limit it increases in all cases regardless of the graphite content.

The results of the tests of mechanical properties are presented in the following drawings. Figure 5 shows the results of tensile strength tests of the tested materials (average of 5 samples).

The following Figure 6 shows the results of the relative elongation tests. The following Figure 7 shows the results of the hardness tests.

SUMMARY

The conducted tests showed a significant impact of the amount of graphite particles on the mechanical and tribological properties of Cu-Pb-Ti-graphite composites. Even a low content of graphite particles (5 %) to the CuPb30 alloy clearly improves its abrasive wear resistance. As the volume of graphite particles in the composite increases, abrasive wear decreases. The abrasive wear of composites is several times lower than the abrasive wear of bronze B525. In all cases, regardless of the applied load and path of friction, it was observed that the composite containing 20 % graphite is characterised by the highest abrasive wear resistance. Regardless of the type of composite, the largest abrasive wear was observed at the highest load, 30 N.

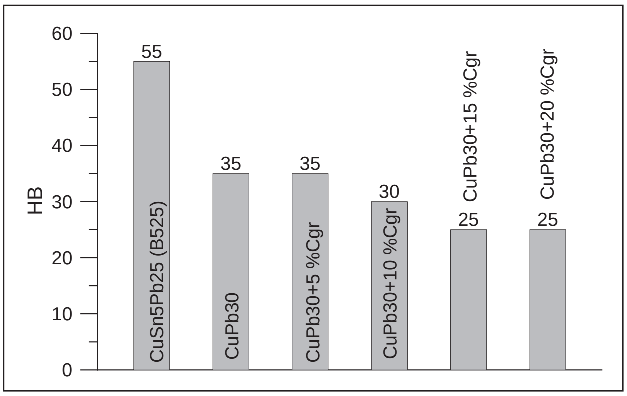


Figure 7 Hardness of the tested materials

Graphite in the composite adversely affects mechanical properties of the CuPb30 alloy. Rm of bronze B525 is comparable to a composite containing 20 % graphite. The hardness and elongation of composites are definitely lower than the hardness and elongation of B525 alloy.

When comprehensively assessing the properties of the tested copper-graphite composites, it can be concluded that this material can be used as a material for components exposed to abrasive wear under dry friction conditions. This composite can therefore become a replacement for commonly used tin bronzes, eliminating expensive and scarce tin.

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Note: The professional translator for English language is Lingua Lab, Weronika Szyszkiewicz, Małgorzata Dembińska, Kraków, Poland