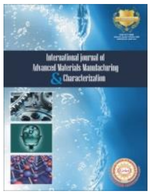

Advanced Materials
Manufacturing & Characterization

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Effect of Pouring Temperature on the Hardness and Wear Resistance of Bronze CuPb10Sn8Zn2

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A B S T R A C T

In the production of engineering parts by casting method, the pouring temperature is an important variable. In this research, the effect of the pouring temperature on the two important characteristics, including the hardness and wear resistance of bronze bearing CuPb10Sn8Zn2 is studied. For this purpose, the melt is produced in a transistor induction furnace and, in the end, the microstructure (by using scanning electron microscope), hardness test (by using Brinell test device) and wear resistance (by using pin-on-disc at 440m and 10N force) of the bronze of CuPb10Sn8Zn2 bearings are compared in sandy mold at pouring temperatures of 950C and 1200C. The results indicated that at high pouring temperatures (1200C); the wear resistance is almost doubled, because the contents of intermetallic compound and solid solution were more and the content of lead was less.

Keywords: Microstructure; Bearing; Pouring; Casting

1. Introduction

Casting is the most common method for producing bronze bearings, which, by melting and pouring into molds, are converted into pieces of the desired shape, size, and type [1].

Bearing alloys have different types, most of which are tin (Babbitt) or bronze-based. Bronze bearings are used when the working conditions of the bearings are difficult (heavy duty operation). According to Table 1, the chemical composition used in this study is bronze containing 10% lead, 1.8% tin, and 2.1% zinc, which is approximately equivalent to bronze SAE660, or C93200, which is widely used to make bronze bearings [2, 3].

Factors affecting the properties of the casting process products (such as the content of elements, mold material, mold cooling velocity, pouring temperature, pouring rate, etc.) are very diverse, affecting the microstructure and, finally, the properties of the pieces [4]. In this study, an important variable i.e. the effect of pouring temperature on the hardness and wear resistance of bronze CuPb10Sn8Zn2 is studied.

There are a lot of casting processes, in each of them, the method of cooling, the type of melting operation, the shape of the mold, the way of molding and so on is different. For example, in gravity die casting or gravity casting in metal molds, permanent and semi-permanent molds are used which, due to the higher cooling rate and metal fine surface, have higher mechanical properties and higher dimensional accuracy, respectively.

One of the methods of producing bronze bearing is soldering. In this method, the molten metal of bearings is cast into steel pre-mold [3, 5, 6]. In other words, casting/melting takes place in metal molds.

Another approach is to use the centrifugal casting process. In this method, casting is done by pouring the melted bearing into the steel centrifugal mold [2, 7]. In this research, casting is done in the sandy mold, because the goal is to study the pouring temperature on the hardness and wear resistance of the bearing metal.

The bearing facilitates the relative rotational or linear motion of the two pieces. On the other hand, the bearing reduces the friction of the involved surfaces. Therefore, two important tasks of bearing in the set of moving parts are [8]:

-To prevent excessive looseness of the axis by restricting radial/axial movement.

-To prevent moving parts contact by restricting lateral movement.

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• Doi: http://dx.doi.org/10.11127/ijammc 2019.02.04

In this way, bearing plays a role as a wearing piece in the set of moving parts of the device. On the other hand, a variety of axial and radial forces are tolerated by the bearing [9]. Therefore, for a good bearing performance, two important characteristics, including hardness and wear resistance, are needed. For this reason, in this study, the hardness and wear resistance properties of bronzeCuPb10Sn8Zn2 are studied.

So far, little research has been done on the effect of the pouring temperature (or casting temperature) on the wear resistance and hardness of the CuPb10Sn8Zn2 bronze bearing in the sand casting condition. In this study, some of these shortcomings are resolved.

2. Materials and Method

In this research, transistor induction furnace in Payvaran Company, including operator panel, electronics and control circuit, oscillator and LC circuit (including tank capacitor, coil, and trans-CT), are used for melting, as shown in Fig. 1a. The frequency (P) of 90Hz and 110Hz are used for a low and high pouring temperature, respectively. As shown in Fig. 1b, the mold is sandy with a steel holder and its shape is cylindrical to a height of 20cm and diameter of 11cm, for a charge of 65 kg. As shown in Fig. 1c, the pouring is carried out at two temperatures, one at a high pouring temperature of 1200C, and the other at a low pouring temperature of 950C. Figure 2 shows the stages of research. Chemical composition, the mold cooling method, and the pouring temperature are according to Table 1.

To ensure the accuracy of the results, the tests were conducted in labs approved by the Iranian Bureau of Standards or at prestigious Universities and to ensure the accuracy of the results, the tests were repeated at least twice. The wear test was carried out with a 3 mm diameter pin of AISI52100 tool steel at a speed of 0.26 m/s (or a rotational speed of 500 rpm) and a force of 10N and a distance of 440m at Tarbiat Modares University according to ASTM G99 [10]. In addition, Brinell hardness test was performed with a 2.5mm diameter ball at 62.5kg force in 10 to 15 seconds, and microstructure study was carried out using a TESCAN VEGA scanning electron microscope at the Razi Metallurgical Research Center (RMRC). The volume percentage of phases was obtained by calculating the occupied area ratio by each phase to the entire field surface by means of three images of an electron microscope at a scale of 200µm (at a magnification of 150).

a: Induction Furnace

b: Sand Mold

c: Pouring

Figure 1: Equipment used in the research, which are available in Payvaran Parsian Company, a: Induction Furnace, b: Sand Mold, c: Pouring

Raw materials were purchased for producing bronze
↓
The melt was prepared in induction furnace. At the same time, the sandy mold was prepared
↓
Bronze casting was carried out in the sandy mold at 1200C and 950C
↓
The chemical composition of the samples was controlled. Microstructure was studied
↓
The hardness and wear resistance of the samples were measured

Figure 2: The stages of research

Table 1: Chemical composition and pouring temperature of bronze bearing metal CuPb10Sn8Zn2

sample	Pouring temperature (C)	Mold cooling environment	Element	Cu	Zn	Sn	Pb	P	S	Ni	Fe
1	1200	air	Wt%	Balance	2.1	8.1	10	0.1	0.019	0.12	0.11
2	950										

3. Results and Discussion

The different production conditions, including the pouring temperature, with the results of the tests including weight loss, hardness, grain size, and phase value and size range for each of the two samples are given in Table 2.

Table 2: Production conditions, Phase value and size range, hardness and weight loss due to CuPb10Sn8Zn2 bronze

Sample	Cooling environment	Pouring temperature (C)	Weight loss (mg)	Hardness (HB)	Grain size (µm)	The phase content (vol.%±10%)			Phase size range in micrometers		
						Solid solution	Lead	Intermetallic compound	Solid solution	Lead	Intermetallic compound
1	air	1200±1%	5.2±1%	86±3%	200±10%	2.4	1.3	0.7	Up to 100	Up to 100	Up to50
2		950±1%	10.1±1%	86±3%	200±10%	2.0	2.0	0.3	Up to 120	Up to 100	Up to 20

3.1. Microstructure evaluation

The microstructure of sample 1, that is, a pouring sample at 1200C, and the microstructure of sample 2, that is, a pouring sample at 950C are shown in Fig. 3 and 4, respectively. By the three similar images of the same electron microscope in each of Figures 3 and 4, the mean of the phase values and the phase size range are determined and listed in Table 2.

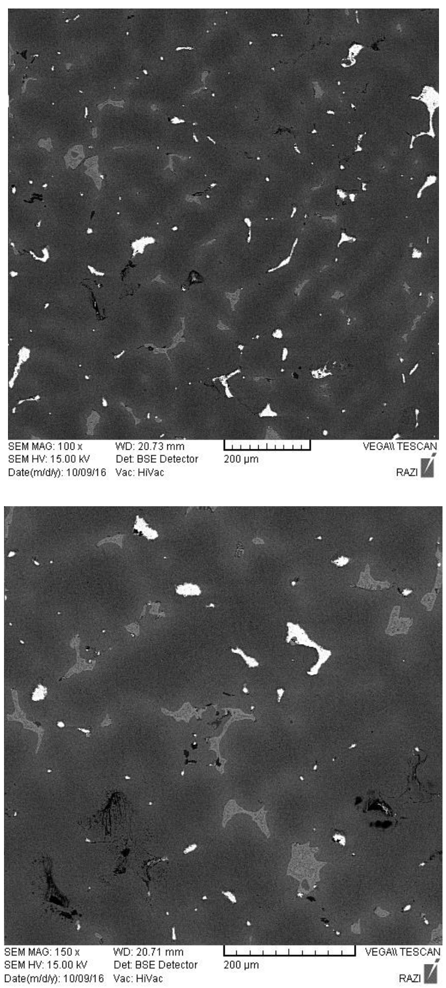


Figure 3: Microstructure of sample 1 at different scales, CuPb10Sn8Zn2 bronze is poured at 1200C

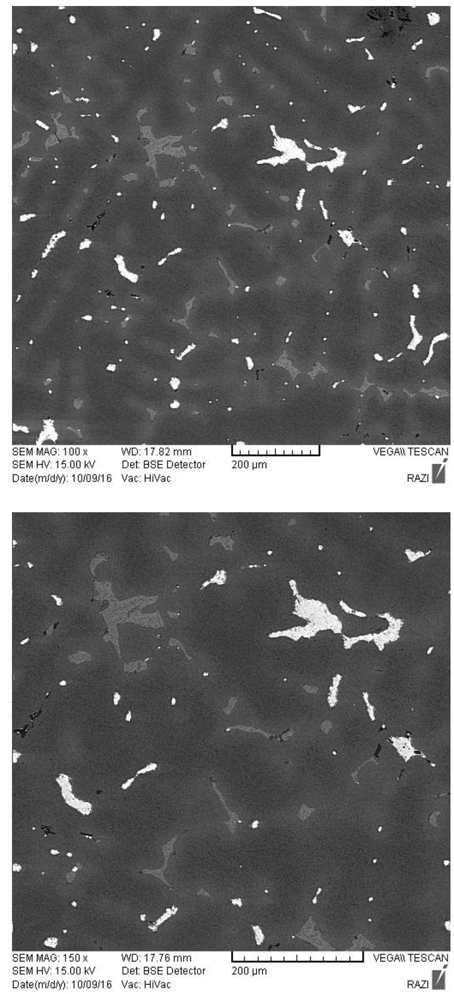


Figure 4: Microstructure of sample 2 at different scales, CuPb10Sn8Zn2 bronze is poured at 950C

According to quantitative and qualitative results of the energy dispersive spectroscopy (EDS), in both production conditions, according to Fig. 5, the gray phase, the solid solution of 86 to 92 At% is copper and the rest (i.e. 8 to 14 At%) is tin. As shown in Fig. 6, the white phase (A) is pure lead.

The black phases, which are usually single or near the lead (C, D), have sharp corners, and according to Fig. 7 and Fig. 8, are impurities such as the intermetallic compound of iron-nickel-phosphorus and zinc sulfide, respectively. According to Fig. 9, the black phase (E), which is located next to the gray phase (solid solution of copper and tin), is an intermetallic compound of copper and phosphorus.

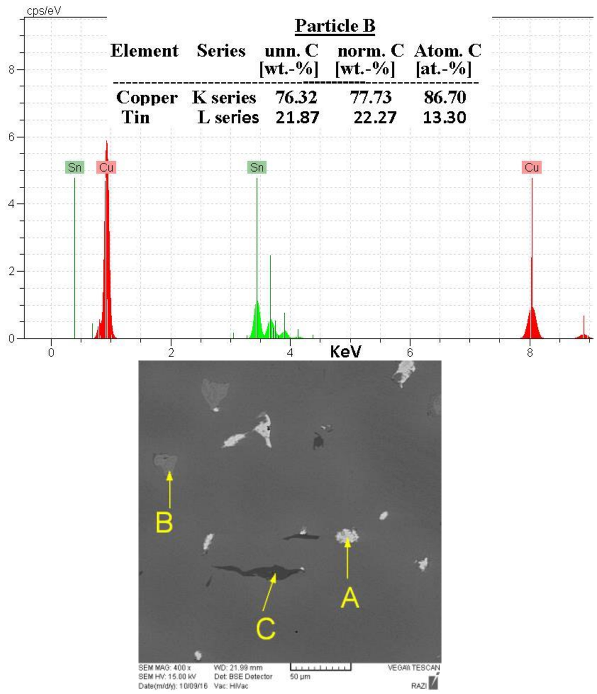


Figure 5: EDS of the solid solution of copper-tin (particle B)

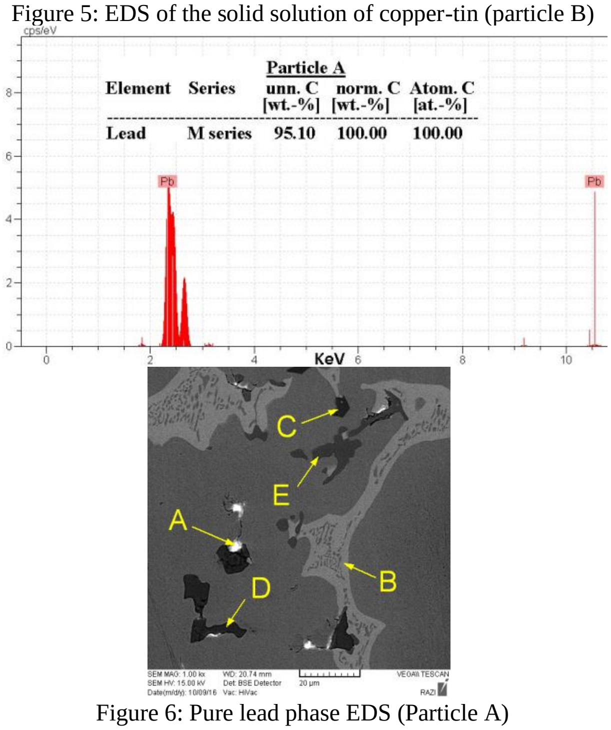


Figure 6: Pure lead phase EDS (Particle A)

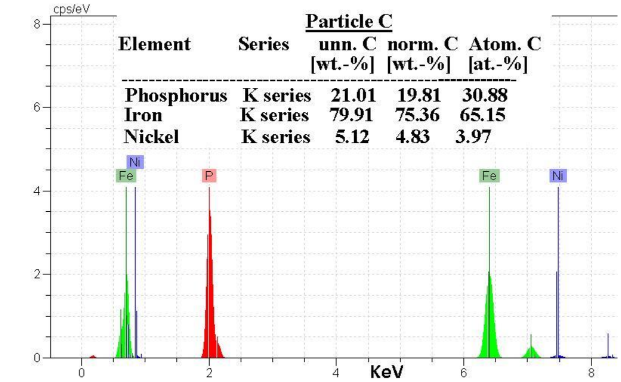


Figure 7: EDS of the intermetallic compound of iron-nickel-phosphorus (particle C)

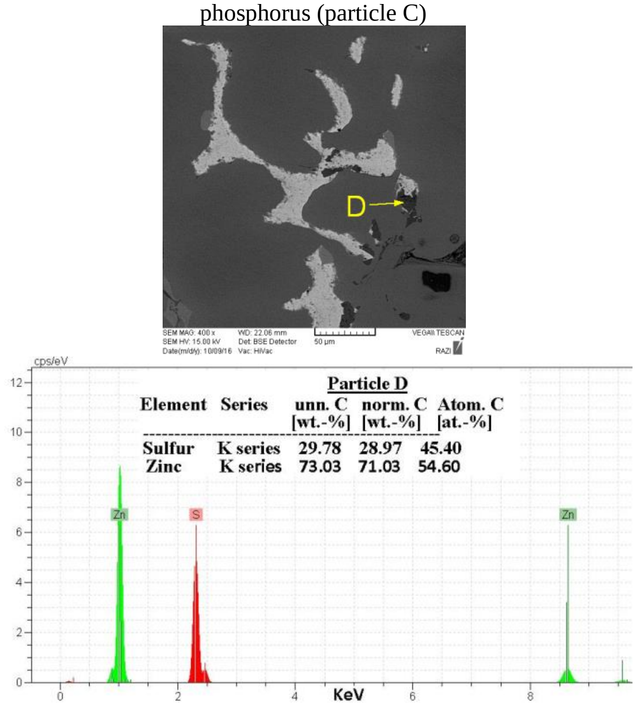
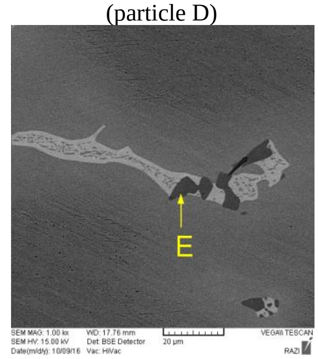


Figure 8: EDS of the intermetallic compound of zinc sulfide (particle D)



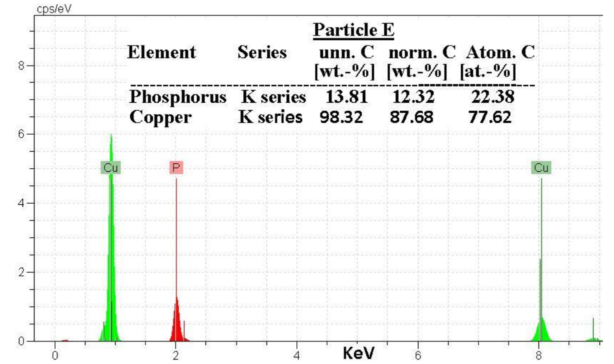


Figure 9: EDS of the intermetallic compound of phosphor-copper (particle E)

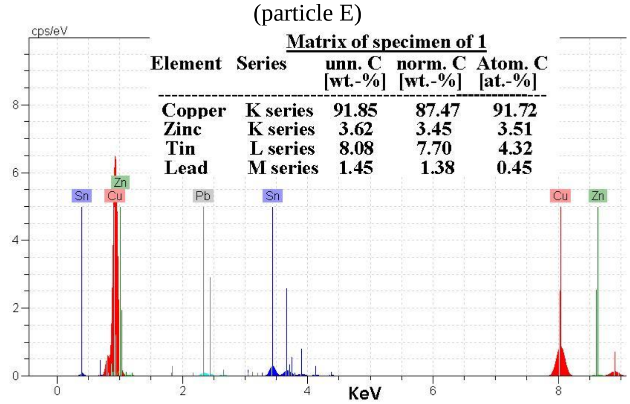


Figure 10: EDS of matrix of sample 1

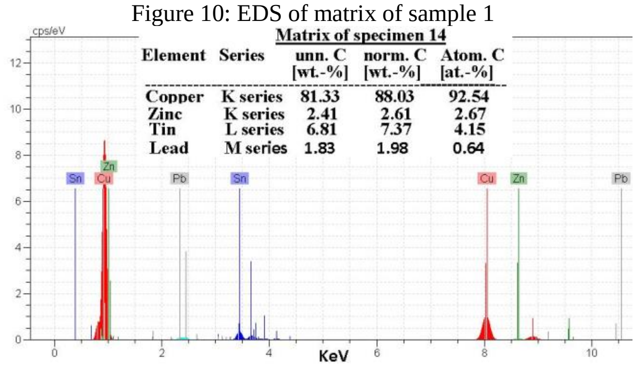


Figure 11: EDS of matrix of sample 2

3.2. Evaluation of hardness and wear resistance

According to Table 2, the hardness of samples 1 and 2 is approximately the same because according to the same table, the grain size, the phase size, and phase value of the two samples are approximately the same - except for the intermetallic compound in sample 1, which its value is approximately 2 times that of sample 2. However, since its value is less than 0.7 vol.%, it does not significantly affect bulk hardness, especially in the Brinell hardness test. But it can affect the wear resistance because the intermetallic compound particles are very hard and can increase wear resistance.

The results of the wear resistance shown in Table 2 or Fig. 12 show that the wear resistance of sample 1 (with a weight loss of 5.2 mg) is approximately 2 times that of sample 2 (with a weight loss of 10.1 mg). According to Table 2, the most important factor is the doubling of the content of intermetallic compound in sample 1 compared to sample 2 (0.7 vol.% for sample 1 and 0.3 vol.% for sample 2). In addition, increasing of copper-tin solid solution, from 2.0 vol.% in sample 2 to 2.4 vol.% in sample 1, can also be effective in increasing wear resistance. In addition, reducing the soft phase of pure lead from 2 vol.% in sample 2 to 1.3 vol.% in sample 1, can also be effective in increasing wear resistance.

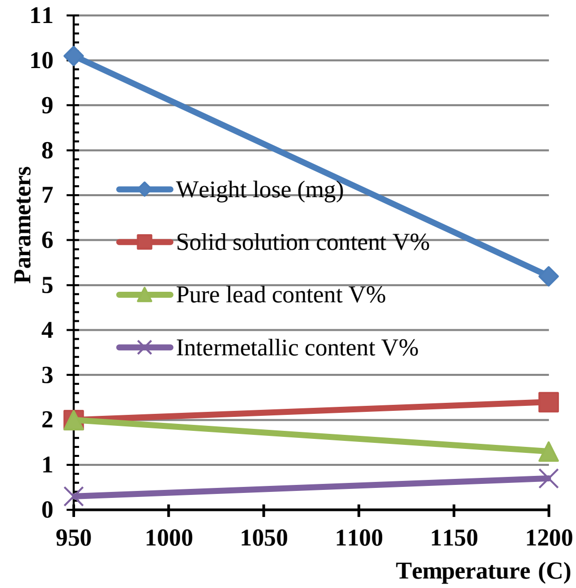


Figure 12: The relationship between the grain size and phase values with weight loss due to wear

4. Conclusion

In this study, microstructure, hardness, and weight loss caused by the bronze CuPb10Sn8Zn2 wear were compared in two different production conditions. So that, samples at 1200C and 950C were poured into the sandy mold.

The results indicate that for the studied alloy, at the above temperature range, the effect of the pouring temperature on the hardness is negligible. However, to achieve maximum wear resistance (the smallest amount of weight loss due to wear), the high pouring temperature of 1200C is recommended, because the weight loss of sample 1 (5.2 mg) is approximately half that of sample 2 (10.1 mg). The reason for this improvement in wear resistance is attributed to the three factors of microstructure, respectively:

1-The amount of phosphor-copper, zinc sulfide, and iron-nickel-phosphorus intermetallic compounds in sample 1 (0.7 vol.%) is more than sample 2 (0.3 vol.%). These compounds are stiff and wear resistant.

2-The copper-tin solid solution content in sample 1 (2.4 vol.%) is more than sample 2 (2.0 vol.%).

3-The soft phase value (almost pure lead), in sample 1 (1.3 vol.%) is less than sample 2 (2 vol.%).

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