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The alloy additions influence on technological properties of fixture brasses

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This paper describes early stages of studies on lead elimination from fixture brasses and synergic influence of some alloy addition on properties and structure of these alloys. Authors showed technological properties comparison for leaded and non-leaded brasses in which lead was replaced with bismuth.

1. INTRODUCTION

The main aim of this work is to present the possibilities of lead elimination from leaded brass Cu59Zn39Pb2. This alloy is used for fixture elements production. Lead is added to this alloy to increase the machinability and castability (technological properties). However, through exploitation of fixture elements made of this material lead can leach out from it and cause crucial damage to human health. Lead is also very dangerous through technological process. All this caused a tendency to eliminate lead from all copper alloys.

First step to eliminate lead without decreasing technological properties of brasses was exchanging it with another addition. Because of similar physical properties first choice was on bismuth. It has low melting point, similar density and like lead does not create any phases with copper and its alloys. Bismuth is non-toxic for human and is widely used in pharmaceutical and cosmetic industry.

2. EXPERIMENTAL AND RESULTS

To compare technological properties and structure of investigated alloys severe casts were conducted. The chemical composition for these casts is shown in table 1. The comparison was made between typical leaded brass with 2% Pb addition and four non-leaded brasses with different bismuth content (in range of 1 – 3%). This allowed to observe changes in technological properties in function of bismuth content and then to describe the optimal quantity of this addition.

Table 1. Chemical composition (in % weight) of investigated alloys

cast no	Cu	Bi	Pb	Zn
1	59.67	1.01	0.01	remainder
2	59.23	1.61	0.03	
3	58.97	2.00	0.02	
4	60.15	3.02	0.01	
5	58.90	0.00	1.90	
6	59.28	0.00	1.70	
7	59.57	0.00	1.60	

To examine main technological properties the fluidity test and machinability analysis were conducted. In fluidity test a special spiral is poured. On base how far the metal will flow the fluidity is determined. The temperature of liquid metal was in all casts the same (1030 ^{o}C). The moulds were dried. For every alloy test was conducted three times in order to reduce measurement uncertainty. Average results are shown in table 2.

Table 2. Results of fluidity test

	MO59	1% Bi	2% Bi	3% Bi
average result, [m]	0.52	0.45	0.37	0.40

As you can see, the leaded brass have slightly higher fluidity than those with bismuth addition. Moreover, with increase of bismuth content the fluidity of bismuth brass first decreases, with minimum in 2% Bi and then slightly rises.

The machinability analysis consisted of cutting force measurement and chip observation. The cutting force measuring system is shown in figure 1. Some of the results are placed in figure 2.

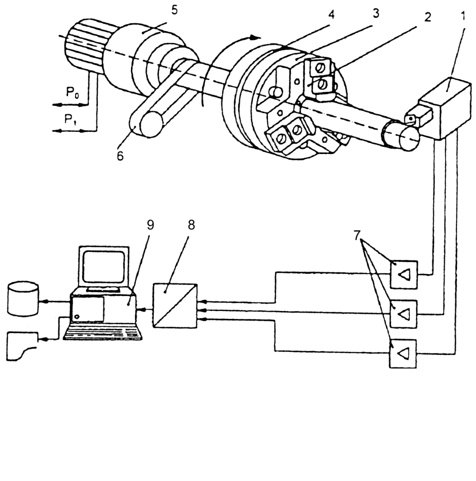

Figure 1. Cutting force measuring system: 1 –force gauge; 2 – measure holder; 3 – three-jaw chuck; 4 – transmitter; 5 – spindle bearing; 6 – spindle drive; 7 – amplifier; 8 – A/C converter; 9 –computer and peripherals [11]

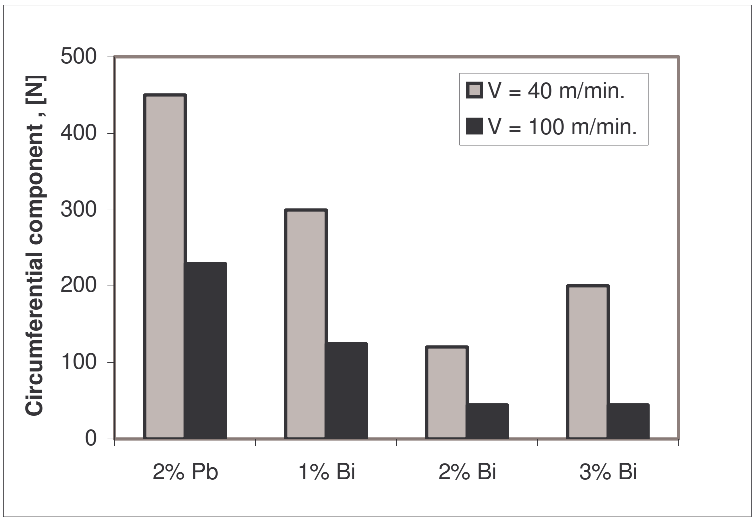

Figure 2. Circumferential component of cutting force for various cutting speed and brasses with different additions

Bismuth addition has stronger effect on cutting resistance of brasses than that of lead. The decrease in cutting resistance rises with bismuth content (figure 2).

The chip shape obtained during machining is a very important factor of a material because it describes the possibility of using automatic machining processes. To do so it is necessary that the chip will be easy to remove and will not wind up on cutting tool what could influence the surface quality and tool life. To fulfill all these demands the chip has to be segmented. Lead is added to brasses and other copper alloys to force chip segmentation. Many classifications [11] show different chip shapes. The most effective are short curved sections – they are easy to remove and do not affect the surface quality or tool life.

Figure 3 shows chip shapes obtained for investigated brasses.

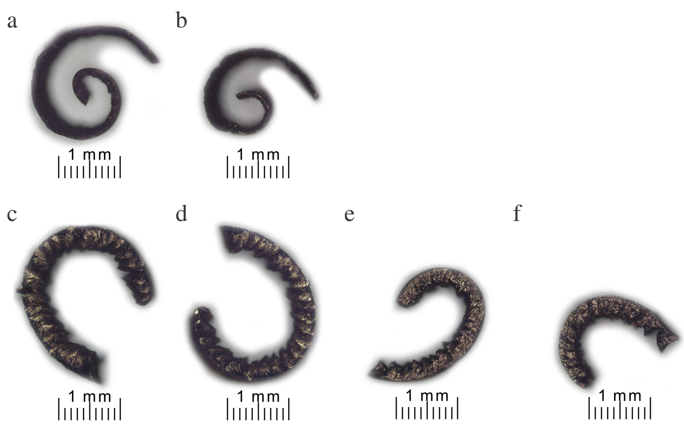

Figure 3. Chip shape for investigated alloys, cutting speed 40 m/min., a, b) CuZnPb2, c) 1%Bi, d) 1.5%Bi, e) 2%Bi, f) 3%Bi

As it can be seen from figure 3 lead as well as bismuth additions cause formation of favourable chip shapes. The addition of bismuth is much more effective in chip segmentation (figure 3c – f) than lead (figure 3a, b). The chip segmentation increases with content of bismuth, which confirms the bismuth influence on copper alloys brittleness [5].

To examine the bismuth influence on microstructure of brasses the metallographic analysis was conducted. Typical structures of CuZnBi and CuZnPb alloys are illustrated on figure 4.

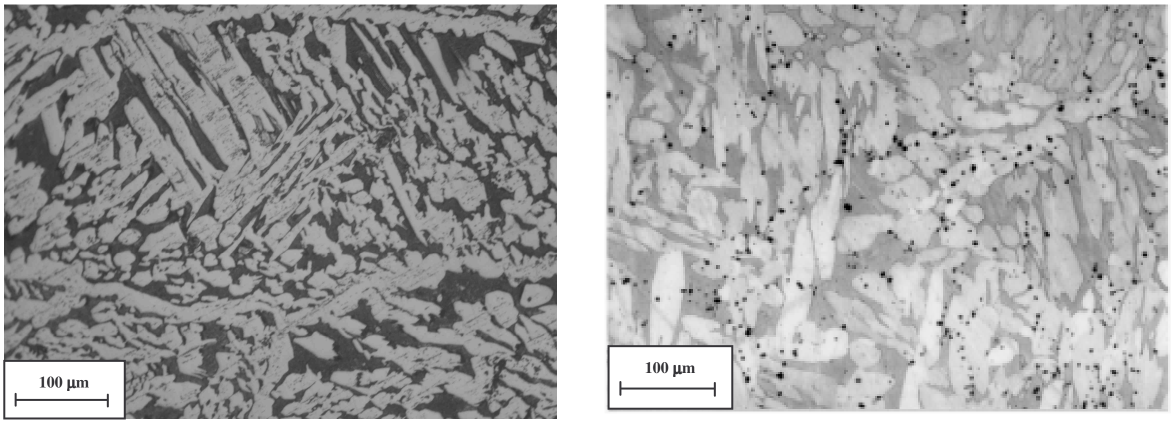

Figure 4. Microstructure for CuZnBi1 alloy (a) bright α phase on dark β' background and CuZnPb2 alloy (b) bright α phase on the β' background, small dark Pb inclusions, sand mould, $FeCl_3$ etched

This group of alloys has a two-phase structure α + β' with Pb or Bi inclusions. As you can see on figure 4 there is no substantial difference in CuZnBi and CuZnPb alloys. Alloys with bismuth addition have resulted in slightly higher α phase fraction (about 10%). Because conventional etching and microscopic examination have not revealed bismuth position the roentgenographic analysis was carried out. Figure 5 shows the measuring area (figure 5a) and bismuth position (figure 5b).

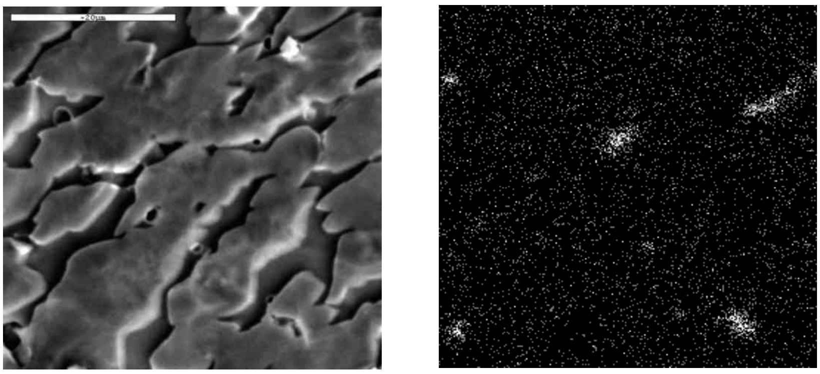

Figure 5. Roentgenographic analysis. Measuring area (a) and bismuth position – bright points (b)

The roentgenographic analysis showed that bismuth can be found mainly in α + β' interface region.

From presented results and other references [10] can be seen that bismuth cannot fully replace lead. The bismuth brasses have inferior castability and corrosion resistance. To preserve the leaded brass properties besides bismuth other elements need to be added to the alloy. Elements which can improve the castability of brasses are: aluminium, silicon and phosphorus. Small amounts of iron can increase the corrosion resistance. However, these elements added together can cause other problems. Even very small amounts (on impurity level) of these elements create hard inclusions, which have strong influence on technological properties. Figure 6 shows structure of leaded brass with these hard inclusions.

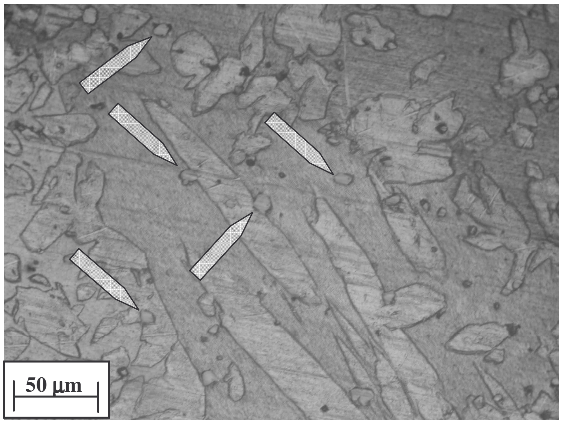

Figure 6. Leaded brass microstructure, sand mould, HNO_3 etched, arrows show some of the hard inclusions

These hard inclusions increase machining resistance of the brass and cause deterioration of polishability which have strong influence on coating quality. The main source of hard inclusions is impure metallic charge and scrap. Problem of hard inclusions is very often experienced in everyday practice. Subject of synergic influence of these elements is now studied by the authors [6, 8].

3. CONCLUSIONS

The leaded brass is an alloy with high technological properties. They are obtained mainly by lead addition. Lead is responsible for high machinability, castability and corrosion resistance. Its major flaw is high toxicity. From above studies can be seen that problem of lead elimination cannot be solved by replacing it with only bismuth. To maintain or improve technological properties of this alloy other elements are needed. Their selection and synergic influence on brass structure and properties are right now studied by the authors.

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