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Y-PbSn10 ANTIFRICTION ALLOYS MICROALLOYED WITH MISCHMETAL

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Antifriction alloys are used for different applications as bearings and bearings rolls. During the time the micro-alloying for this type of alloys was realized with Cd, Ni, As, Mg and P. For this paper we selected YPbSn10 as base alloy and we investigated the changes induced by the micro alloying with mischmetal in amounts of 0.1, 0.2, 0.5 and 1%. The optical microstructure obtained was investigated, in comparison with the original alloy, and the Brinell hardness and compression strength were evaluated. The results obtained are promising the HB hardness being improved with 8% and compression strength with 9%.

Keywords: YPbSn10 antifriction alloy, mischmetal, micro-alloying, hardness

1. Introduction

Lead alloys were considered for antifriction application due to the fact that the tin matrix could be replaced with lead matrix. Tin and antimony are the most important alloying elements for lead. Both lower the melting temperature of lead and improve mechanical properties [1] which might be important for antifriction applications. Having mechanical properties similar to Babbit alloys, antifriction alloy Y-PbSn10 could be used specially as a thin coating layer (0.5 – 1.0 mm) applied on bearing steel for some type of motors. Taking into account the chemical composition Y-PbSn10 is a quaternary alloy where the alloying elements are Sb and Cu: 9.5 – 12%Sn, 14.5 – 16.5 %Sb, 0.5 – 1.5%Cu and balance Pb. From the structural point of view the Y-PbSn10 alloy consists in a relatively soft matrix where the binary or ternary lead solid solution has the lowest hardness. In this matrix we can see the constituents as SnSb and Cu_2Sb [2, 3]. Usually Cu_2Sb crystalizes first and could be observed as needles and had the effect of increasing the hardness of the alloy as well as the effect of structural homogeneity increasing the melting viscosity and blocking the segregation of the hard phases. SnSb phase appears in the structure as being pinned by the Cu_2Sb

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network. In different countries as SUA, Japan a.s.o the hardening elements used in lead antifriction alloys are Ca, Na, Mg, Te, Al and Li [3-6].

Rare earths elements are unanimously recognized in metallurgy as surfactants because they reduce the surface / interface tension energy at the level of crystals / dendrites in formation. They can also lead to the formation of hard compounds but also have the role of modifiers, where they even out the distribution of hard compounds in the soft matrix of the base alloy. They are intensively used to refine the structure of steels and non-ferrous alloys (Al, Cu, etc.) [1-4].

In various forms, the alloying elements will bring properties on the final alloy which are directly related to the lubrication process or contribute to the improvement of metallurgical conditions and their mechanical processing [1-4].In terms of wear, the structure constituents are recommended to be tough, because in this case the abrasive wear will be reduced. The overall hardness of the material is also influenced by the presence of hard phases in the structure [2].

We investigated in this paper a Mm micro alloying of YPbSn10 lead alloy to see the improving brought for the structure and properties by Mm. We tried different amount of Mm micro-alloying: 0.1, 0.2, 0.5 and 1% Mm and investigated each sample in comparison with the base alloy.

2. Materials and Methods

The first step for our paper was the YPbSn10 alloy producing. We prepared this alloy using two master alloys CuSb50 and PbSb50, Sn and Sb. The load is melted and overheated at 600 - 700°C.

Then the slag and the coal layer from the metal surface will be removed and the rest of the tin will be introduced the mixture, the alloy is maintained for 10-15 minutes at 500-550°C, after mixing.

For micro alloying the YPbSn10 antifriction alloy obtained in the sequence prior presented an additional step was considered. We developed the material as described and we introduced the rest of the tin into the metallic bath. After tin introducing the melt will be mixed and maintained for 10-15 minutes at 550-600°C. The master alloy CuSnMm is added, mixed for 1-2 minutes, the slag is removed at a temperature of 425-450°C and it is poured into a metallic shell. After introducing the master alloy with Mm in the metallic bath, for the additional protection of the molten metal bath, a stream of Ar was blown into the oven, which was dried and purified by a CRS purifying cartridge. Ar flow rate: 1-1.5 l / min. Chemical composition of the starting alloy is shown in table 1.

Chemical composition for the alloy produced for these experiments was realized by inductive plasma emission spectroscopy (ICP-OES Spectroflame P, Germany) for Sn, Sb, Cu and Pb and with optical emission spectroscopy with continuum current plasma (DCPSpectraspan V Beckman, Germany) for rare earth elements.

Table 1

Chemical composition of antifriction alloys Y-PbSn10

Alloy Commercial Name	Chemical composition % wt							
	Pb	Sb	Sn	Cu	Zn	Fe	Al	Other elements
YPbSn10	bal	15.32	10.93	1.06	<0.01	<0.01	<0.01	<0.01
	Ce	La	Nd	Pr	Sm	Yt	Fe, Si, P	Other elements
Mm	bal	24.5	11.4	5.6	1.8	1.5	1.4	<0.1

The metallographic analysis of the alloy samples was performed with a metallographic microscope, with polarized light, of AxioImager A1m - Carl Zeiss type.5.6. The microscopic images were obtained by using a Canon Power Shot A 640 digital camera, 10X digital zoom, and processed with specialized PC software AxioVision Release 4.6.3.

The orders of magnifications were x200 and x900. For the study, the samples were embedded in Bakelite-type resin, and then prepared by grinding with abrasive paper and polishing with Lecloth-type cloth soaked with a suspension of α-alumina in water. Nital 5% solution was used for the attack. Dynamic compressive deformation resistance of the YPbSn10 alloy was determined by the repression method. The principle of the method [6 - 9]: the compression test, or the discharge test, involves the use of cylindrical specimens with the help of which both cold and hot plastic properties of metal materials can be determined. The compression test evaluates the "relative plasticity" due to the fact that in the test piece subjected to the discharge, the appeared tensions and deformations are inhomogeneous [9].

The determination of the Brinell hardness of the developed antifriction alloys was performed using a WPM hardness tester model HPO 3000, Germany. The measurements were performed under the following conditions:

Table 2

Measurement conditions

Pressing force [daN]	D [mm]	Holding time [s]	Temperature [ºC]
250	10	60	20, 50±1, 100±2

3. Results and Discussions

The composition of the alloy after micro-alloying is presented in Table 3. The results confirmed the composition we designed, and we obtained after melting, alloying and casting process.

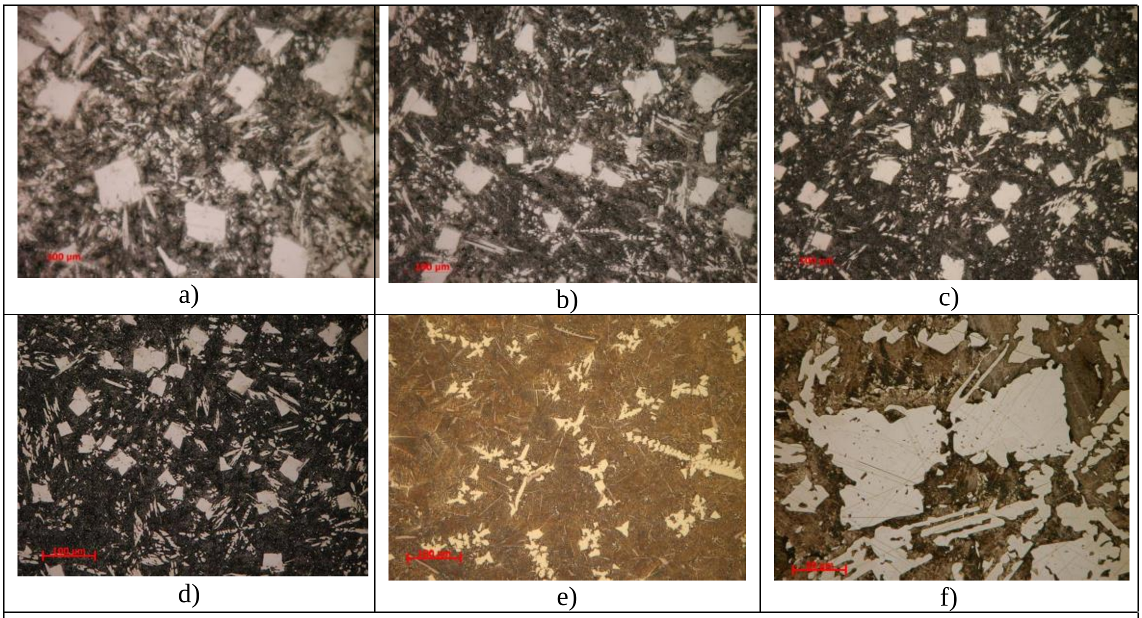
Table 3

Chemical analysis of YPbSn10 alloy samples [% wt]

Sample	Alloying element [%wt]	Pb	Sb	Sn	Cu	Zn	Fe	Al	Mm	Other*
YPM 1	0.1	bal	6.03	11.34	0.93	<0.01	0.01	<0.01	0.09	<0.01
YPM 2	0.2	bal	5.97	11.68	1.08	<0.01	0.01	<0.01	0.21	<0.01
YPM 3	0.5	bal	5.88	11.08	0.92	0.02	0.02	<0.01	0.49	0.02
YPM 4	1.0	bal	5.96	10.85	1.12	0.01	0.02	<0.01	1.05	0.03

***) Other: Bi, Na, Si, P (from Mm)**

In Fig. 1 the optical microscopy analyses was performed on the obtained samples. Samples were denominated YPM1, YPM2, YPM3, YPM4. A detail of the YPM4 sample is presented due to changes in microstructures appeared after adding 1.0 Mm.



a) b) c)

d) e) f)

Fig 1. Microstructure of the alloys produced: a) YPBSn10 cast alloy, b) YPbSn10 with 0.1% Mm (YPM1) c) YPbSn10 with 0.2% Mm (YPM2) d) YPbSn10 with 0.5% Mm (YPM3), e) YPbSn10 with 1.0 % Mm (YPM4)

Fig. 1 a) reveals the structure consisting of needles and pins like structures and of Cu_2Sb and SnSb cuboids embedded in a binary and ternary eutectic mixture phases forming the soft matrix of the alloy. The cuboids are decreasing in their dimensions as the Mm content increases and the matrix become more homogeneous. For 1.0% Mm microalloying (fig 1d) we can observe a totally changed microstructure with lamellar and array of compounds distribute in PbSn matrix. A detail of this changed structure is provided in Fig. 1e to have a clear look on the compounds appearing in this microstructure. The values of the hardness measurements obtained are presented in Table 4.

Table 4

HB Hardness measurements 250/10/60

Sample	20 °C	50 °C	100 °C
YPbSn10	24.87	15.9	8.7
YPM 1	25.23	16.1	9.3
YPM 2	25.42	16.3	9.1
YPM 3	25.56	15.9	9.2
YPM 4	26.03	16.3	9.8

In Fig. 2, it is presented the diagram with the variation of the hardness of the anti-friction alloys depending on the content of the micro-alloy element.

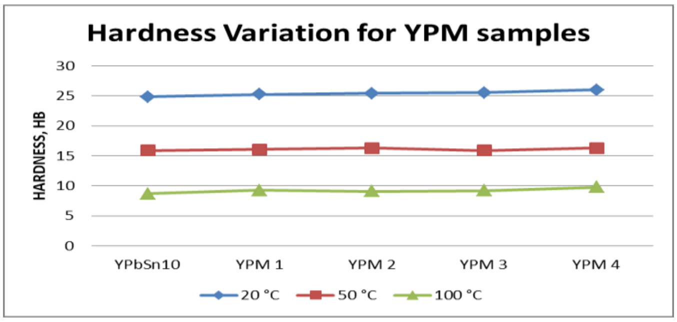


Fig. 2. The hardness of YPbSn10 micro alloyed

In Fig. 2 we can observe that at room temperature the Brinell hardness of the YPbSn10 alloy increased slightly when Mm is added. This trend is changed when the hardness is measured at 50^{o}C. At this temperature, the hardness value decreases and also it reaches a minimum value when Mm is added in proportion of 0.5%. At 100^{o}C we have a variation similar with room temperature variation with a low variation of the hardness value for the base alloy and micro alloyed ones. The Mm adding 1.0% proved to be more efficient for this type of antifriction alloys. The intermediate percentage added had a minor influence on the YPbSn10 antifriction alloy micro alloyed with Mm. So, raising the temperature decrease the Brinell hardness and the variation is dependent on the amount of Mm added. The alloys should be designed according to their purpose and the amount of Mm chosen in accordance with this purpose. The compression value for the 0.5%Mm is lower than the one for 0.2%Mm and also the hardness at 100^{o}C is lower. The microstructure as presented in Fig. 1 d) and e) are not very different so the results suggest that the use of 0.2%Mm is better to be used instead of 0.5%Mm.

The compression strength measured for base alloy and the Mm micro-alloyed samples reveals a increasing for 0.1, 0.2 and 1.0% and an abrupt decrease for 0.5%Mm added.

Table 5

Discharge test results of specimens

Sample	The fall energy of the ram	Unitary degree of deformation ε_u	Deformation resistance (compression) R_d	Sample appearance
	[J]		[daN/mm^2]	
YPbSn10	296352	0.217	13.218	"Barrel" shape, no cracks or visible defects
YPM 1		0.215	13.34	-- , --
YPM 2		0.214	13.41	-- , --
YPM 3		0.216	13.29	-- , --
YPM 4		0.212	13.54	-- , --

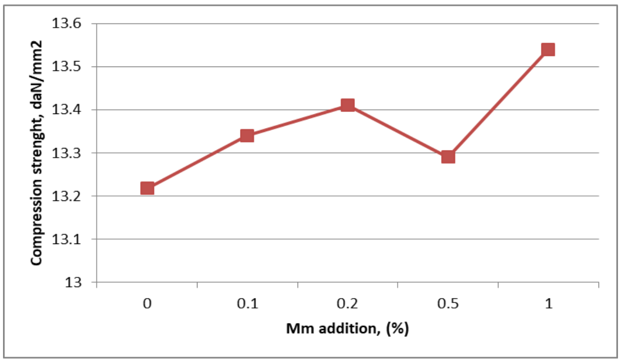


Fig.3. Compression strength of YPbSn10 micro alloyed measured at room temperature

Thus, means that the best results were obtained for 1.0% Mm added and the 0.5% Mm should be avoided when designing new Mm micro alloyed antifriction alloys.

4. Conclusions

Quantitative chemical analysis of developed alloy samples showed that they correspond - within the limits of accuracy given by the methods of analysis - the desired nominal compositions. The use of mischmetal as master alloys, protecting the metal bath resulted in mischmetal losses reducing. The microstructure of the standard alloys modifies during micro-alloying, and for the 1.0%Mm micro-alloying the microstructure is changed and becomes more homogeneous.

The results of the tests performed in this paper, hardness at 20, 50 and 100^{o}C, compression strength and also from the microstructure point of view the best results were obtained for 1%Mm micro alloying for YPbSn10 antifriction alloy as we detailed above. The mechanical properties of the YPbSn10 antifriction alloy micro alloyed with different amounts of Mm were influenced by temperature and the Mm content so the alloy should be designed according to the usage in the future application.

REFERENCES

[1]. *JP Hilger*, J Power Sources 1995 ;53:45.

[2] *K.C. Ludema* (1996), Friction, Wear, Lubrication, A Textbook in tribology, CRC Press LLC, SUA, Chapter 7: Metallic antifriction materials, p.223-25

[3] *Gh Manea*. (1970), Organe de mașini, vol.1. Ed.Tehnică, București, Capitolul Lagăre cu alunecare, p.735-347

[4] *S. Guruswamy* (2000), Engineering properties and applications of lead alloys, Marcel Dekker Inc., NY SUA

[5] *W.A Glaeser* (1992), Materials for tribology, Elsevier Science Phblishers B.V. Amsterdam, Olanda

[9]. *W.A. Glaeser*, Materials for tribology, Elsevier Science Phblishers B.V. Amsterdam, Olanda, 1992.

[10]. *F. Habashi* (Editor), Alloys - Preparation, Properties, Applications, ISBN 3-527-29591-7, WILEY-VCH Verlag GmbH, D-69469 Weinheim, Germany, 1998.

[11]. *K.C. Ludema*, Friction, Wear, Lubrication, A Textbook in tribology, CRC Press LLC, SUA, Chapter 7: Metallic antifriction materials, 1996, pp. 223-254

[12]. *M. Ramadan, A. S. Alghamdi, T. Subhani and K. S. Abdel Hali*, Fabrication and Characterization of Sn-Based Babbitt Alloy Nanocomposite Reinforced with Al2O3 Nanoparticles/Carbon Steel Bimetallic Material, *Materials* **2020**, *13*(12), 2759

[13]. *K.H. Matucha*, Structure and Properties of Nonferrous Alloys, ISBN: 3-527-26821-9, WILEY-VCH Verlag GmbH, D-69469 Weinheim, Germany, 1996.