EXPERIMENTS CONCERNING THE ELABORATION OF Sn BASED ANTIFRICTION ALLOYS USING RECYCLED MATERIALS IN THE CHARGE

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Due to the mechanical processing operations, more than 90% of the antifriction alloy cast on the gray iron or steel stand is removed under the form of chips. As the costs incurred by the elaboration of Sn based alloys are very high many attempts have been made in order to obtain these alloys with the addition of chips into the charge and with the elimination of Cd and As. (These two alloying elements are considered cancer generating). The present paper introduces a technology for the elaboration of Sn based antifriction alloys without Cd and As using recycled materials (chips) in the charge.

1. INTRODUCTION

Taking into account that in the literature the carcinogen nature of As and Cd has been widely acknowledged, considerable research work has been carried out lately with a view to obtaining antifriction Sn based alloys without Cd and As, but preserving similar mechanical and tribological characteristics that should make them suitable for the manufacturing of bearings.

The mechanical processing operations performed during the manufacturing of bearings remove more than 90% of the alloy cast on the steel or gray iron stand of the bearing. A large amount of chips will result. The costs incurred by the elaboration of Sn based alloys are therefore very high and many attempts have been made in order to obtain these alloys using chips in the charge but eliminating the harmful elements, *i.e.* Cd and As. The direct utilization of the chips in the elaboration process did not lead to the manufacturing of bearings possessing the same characteristics as those manufactured out of new alloys without chips.

The experiments carried out by the author under laboratory conditions and then at industrial level have shown that using an adequate elaboration technology for the master alloy with a Sn base, the addition of chips (but not of Cd or As)

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could lead to a material which is adequate for the manufacturing of antifriction bearings.

The characteristics of the alloys obtained are comparable to those of the standard alloys containing As and Cd, elaborated without any addition of chips.

2. THE ELABORATION TECHNOLOGY FOR ALLOY LgSnR$_1$ USING 50% RECYCLED MATERIALS IN THE CHARGE

a) The chemical composition that the LgSnR_1 alloy should have after the elaboration technology is the following: Sb 7.5–8,5, Cu 2.5–3.3, the rest is Sn. This chemical composition has generated a very good structure which led to mechanical properties close to those of the alloys elaborated from new materials (without chips). These properties are shown in Table 1.

b) The chemical composition of the molten alloy. The burnings occurring during elaboration are the following: Sb: ~10%; Cu ~10%; Sn ~10%.

The resulting chemical composition of the molten alloy will be: Sb 8–9.5 %; Cu ~4 %; the rest is Sn.

c) Materials used for elaboration:

- Sn 99,9 – STAS 3091/75
- Sb 99,9 or Sb 99,6 STAS 10262/75
- with ETP in keeping with SR ISO 431/1995
- chips with the chemical composition of $LgSnR_1$ alloy
- Sodium hydroxide for refining
- ground lime for slagging
- dry charcoal sized 2–5 cm
- Sulphur powder

d) The equipment used. Melting crucible made of Cr-alloyed cas-iron with a capacity of 40 kg (on a large industrial scale even Cr-Ni crucibles are used):

- graphite mixer,
- chip separator,
- moulds for the casting of the samples.

In order to obtain a good alligation and homogenization of the alloying elements, it is absolutely necessary to elaborate a master alloy out of the existing chips.

e) Preparing the chips for melting. The existing chips were first separated and sorted.

The chip sorter is equipped with an electromagnetic sorting device which allows for the elimination of ferrous impurities and a sieve for the separation of the fine powders.

As far as its design is concerned, it is made out of revolving bunker containing permanent magnets and an inclined vibrating sieve. The chips containing impurities descend from the bunker over a drum on a sieve. The rotating drum drives the metallic impurities and eliminates them. The rest of the material reaches to the vibrating sieve. The mesh does not allow the passing through of the fine particles.

The chips resulting from dry lathing operations may contain the following types of impurities:

– earth flax remains from the tightening surfaces,

– a layer of rust on the white metal generated by the drilling of the blanks,

– white metal powder (less than 1 mm).

f) The elaboration of the master alloy of chips. In order to avoid a heavy oxidation of the chips, ingots of Sn are melted (1/2 from the load) into the crucible. After the melting of these Sn ingots, chips are introduced in the furnace until it is filled up. To reduce the losses through oxidation, the temperature of the bath must not exceed 380–390 °C. The protection of the bath is permanently carried out by means of charcoal powder.

The treatment of the smelt. After the melting and heating of the smelt up to 500 °C, it will be mixed with a graphite mixer and will be treated in the following way:

– the charcoal is removed from the surface of the bath,

– the temperature is lowered to 450 °C, for the refining,

– a concentration of 0.05–0.07 % is sprayed on to the bath and it is lightly stirred for a few minutes,

– the foam generated on the surface is treated with ground lime, thickens and is removed from the bath,

– if a bluish layer remains, lime powder will be added and the thickened layer will be removed from the bath,

– if on the surface of the bath, a layer of lye is produced, this can be removed by means of an addition of sulphur powder (0.01% from the smelt), and by a continuous mixture at a temperature of 450 °C,

– the foam on the surface of the bath is removed and then it is covered with dry charcoal,

– the bath is overheated up to 480–520 °C, the charcoal is removed , and after the bath has settled down, samples for the chemical analysis are taken. If the analysis requires a modification, this is carried out and then the smelt is cast into ingots.

g) The modification of the chemical composition of the melt (alloying with Sb and Cu). For the Sb alloying to take place, the temperature of the alloy is decreased to 400–450 °C under a layer of charcoal.

When the temperature of the master alloy attains 400–450 °C, parts of Sb in the size of nuts are inserted deep into the smelt, while mixing.

After another increase of the temperature (which decreased once the Sb parts were inserted), pure Sn is added.

When the temperature amounts to 500 °C, pure Cu or SnCu30 is inserted into the smelt under the form of small parts.

The insertion of Cu triggers a decrease in temperature and this has to be again increased up to 500 °C, and maintained at this value. The bath is mixed to become homogeneous.

The temperature is raised to 480–520 °C, and then samples are taken for the chemical and metallographic analyses.

If necessary, a correction is made and then the smelt is cast onto the metallic stand of the bearing which has to be previously prepared for the casting.

Note. If the alloy is not cast onto the stand and is prepared to be sold it is cast in ingots. The beneficiary will have to resmelt the ingots and possibly to modify the chemical composition (due to the burnings of Sn, Sb and Cu which take place during elaboration). The technology used for this modification of the chemical composition is identical to the one previously described.

3. ANALYSES AND TESTS

In order to homologate the alloy, several charges were elaborated and cast and the following analyses were carried out for each charge:

1) the chemical composition
2) hardness – HB 250/10/60
3) HB hardness at 20 °C, 50 °C, 100 °C (Table 1)
4) mechanical characteristics R_m, $R_{p0.2}$, A
5) the microstructure

Table 1 shows the hardness of the alloy at 20 °C, 50 °C, 100 °C.

Table 1

Hardness of alloy LgSnR$_1$ at various temperatures

Temperature	HB hardness
20° C	250 / 10 / 60″ = 23.4 HB
	250 / 10 / 180 ″ = 21.5 HB
50° C	250 / 10 / 60 ″ = 17.7 HB
	250 / 10 / 180″ = 15.3 HB
100° C	250 / 10 / 60″ = 11.4 HB
	250 / 10 / 180″ = 9.7 HB

At temperatures of 50 °C, the temperature variations were of 2 °C at every minute and of 5 °C at every 3 minutes. The measurement was performed in this case from a temperature of 51°C for every one minute and from 52 °C for every 3 minutes. At the temperatures in the 100 °C range, the temperature variations were of 2/5 °C every one minute and of 8 °C every 3 minutes. The measurement was carried out starting from 101.5 °C for the measurement at every one minute and from 104 °C for the measurement at every 3 minutes.

Table 2 shows the average chemical composition, as well as the mechanical properties (average values) of alloy $LgSnR_1$ compared to those of alloy HMO2, which was obtained without any addition of chips, only out of new alloys.

Table 2

Chemical composition and mechanical characteristics of alloys: $LgSnR_1$ and HM02

Alloy	**Chemical composition**					**Mechanical properties**			
	Sn %	**Sb %**	**Cu %**	**Cd %**	**Ni %**	R_m **[N/mm^2]**	$R_{p0.2}$ **[N/mm^2]**	*A* **%**	**HB 250/10/60**
$LgSnR_1$	89	8	3	–	–	82.5	68.2	3…5	23
HM02	84.5	10.5	5	–	–	85	70	4	25

Microstructure. These alloys belong to the category of alloys that have a soft matrix and hard constituents.

Phases and constituents. The soft matrix (with a hardness of ~ 5 HB) is an eutectic structure consisting of a ternary solid solution Sn-Cu-Sb (small amounts of Cu and Sb are dissolved in the solid solution) and a chemical compound Cu_6Sn_5. The Sn-Sb-Cu alloy has a solidification temperature of + 230 ºC.

The hard phase is made of the following constituents:

- SnSb (30 HB) phase ß' – solid solution based on an intermetallic cubic compound;
- Cu_3Sn (100HB) phase ε has an acicular or lamellar interrupted form and may also occur under the form of Greek letters. It is an electronic compound with an electronic concentration of 7/4.
- other hard constituents: phase η′: Cu_6Sn_5; Cu_8Sn_3; Cu_2Sb. These constituents are germination centers.

The obtained microstructures are suitable. The SnSb crystals are well defined and evenly distributed in the matrix.

Figure 1 given below shows the microstructure of charge no. 8.

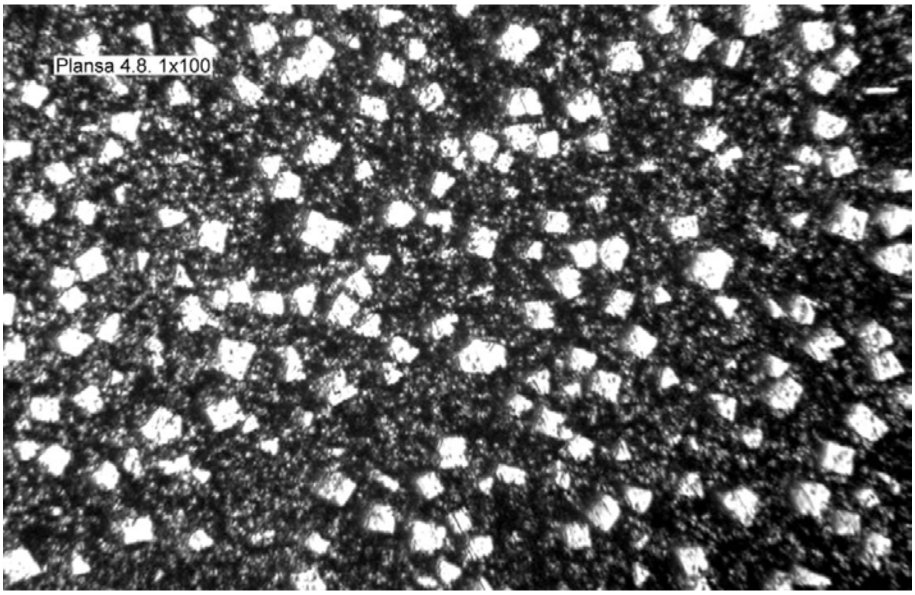

Fig. 1 – $LgSnR_1$ alloy: Sb 7.8%; Cu 2.7%; rest is Sn; attacked with Nital – 5 ml HNO_3 (67% concentration) and 100 ml ethyl alcohol; holding time: 30 seconds.

The microstructure of the alloys elaborated with an addition of 50 % chips has proved to be compatible with the microstructure of the alloys obtained without any addition of chips.

4. CONCLUSIONS

The alloys obtained via the application of the technology described in the present paper exhibit mechanical properties (R_m, R_{po}, A, HB) and microstructures that are comparable to those of the alloys obtained without any addition of chips. These properties observe the standards concerning Sn-base antifriction alloys. The application of this technology may bring about a decrease in the price of bearings.

In order to improve the mechanical and tribological properties of these alloys, the research work has been continued using vibrations during hardening. Following the application of the mechanical vibrations during solidification, alloys whose characteristics are similar to those with Cd and As have been obtained.

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