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PRODUCING BIMETALS BY DIRECT MELTING OF THE BRONZE MACHINING CHIPS INTO STEEL SUPPORTS

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ABSTRACT

The bimetals can satisfy some requests of the working conditions impossible to be obtained using one single metallic material. The bimetallic pieces are obtained by the different production methods by covering of a steel support with the non-ferrous alloys layers. The possibility of bimetals producing by direct melting of the bronze machining chips into steel support is considered in this work. In this way the superior valorisation of the metallic scraps for obtaining bimetallic steel-bronze parts was studied. The recycling of the metallic wastes as final products with added value is possible to be achieved. In this paper the flow sheet for the bimetal manufacturing through this method was showed. Also the parameters that influenced the quality of bimetal were analysed. The quality of the bimetal was analysed in term of contact zone quality. The interface zone of two alloys was investigated through the methods of metallographic and microscopic analyses.

KEYWORDS: bimetals, recycling, bronze chips, steel

1. Introduction

In many industrial applications, the working surfaces of the parts are simultaneously exposed to a very different kind of stresses. In these types of working regime, the bimetallic materials can be used. These materials are obtained using the depositing process of one material, as layers with different thicknesses, on top of another material considered as a base. These metallic materials, also named bimetallic can satisfy some requests of the working conditions impossible to be obtained using one single metallic material.

The covered steels with non-ferrous alloys layers are an example and the bimetallic pieces are obtained through the different production methods. The bimetals are obtained by metallic layers deposition on the surface of the support parts.

The joining of the metallic layer on the solid support is determined by diffusion and thermal processes [1]. The metal deposition most is made on one or both surfaces of the solid support.

The thickness of covering layers is 8 – 20% of the support alloy.

The first data about the bimetals is early mentioned. In the published papers, it is shown that 1858 is the year when the first patent (USA Patent) for the obtaining of bimetal is mentioned.

For Germany, the researches for the production of the cladded steel sheets begin in the seventh decade of the XIXth century and a patent was realized. The first special industrial application for bimetals occurred in 1930.

This happened in USA and referred to the utilization of some steel sheets with nickel cladded for the construction of the tank wagon for the chemical products transports.

The production of the great quantity of the carbon steel sheets cladded with stainless steel starts around 1938 [2].

One method of obtaining the bronze layer added on the steel support for the bimetal manufacturing is through by welding process. For this is necessary to remelt the bronze wastes and to mould them in the form of bars. The gas-shielded arc welding process with wolfram electrode can be used for welding bronze on the parent steel [3, 4].

During the obtaining bimetal of through this method, a lot of problems are associated: the loss of metal is greater; the costs of labour and energy or materials are increased as well as the problems of environment protection are higher.

The present paper presents the researches for bimetal manufacturing from waste products.

To create a bronze layer on the steel surface, bronze machining chips were used. In this case the chips waste of the bronze with aluminium complex alloyed with iron, nickel, manganese was used.

2. Experimentals research and materials

In the experimental work, steel samples as supports were used, Figure 1. In accordance with the complex work of this bimetal that was used as bearing parts (ability to carry heavy loads under friction conditions without excessive wear and resistance to corrosion), we used selected bronze chips in accordance with certain chemical compositions Table 1 [5, 6].

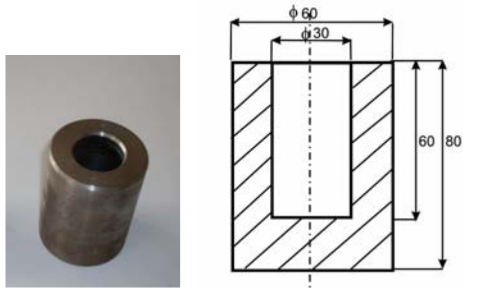


Fig. 1. *Experimental steel sample used as steel support into the experimental research*

Table 1. *Chemical composition of the bronze*

Elements, [wt%]	Al	Ni	Fe	Mn	Cu
Range expected	14-15	4-4.5	4-4.5	0.8-1.2	bal.
Chips	14.7	4.4	4.1	1.1	bal.

The fluxes with multiple actions were used: borax as neutral cover fluxes, glassy fluid cover flux, graphite as reducing flux containing carbonaceous materials and, copper-phosphorus metal mixed with bronze chips that are self-fluxing on copper-base metals [7]. A resistance furnace was used for heating the samples, Figure 2.

Fig. 2. *Furnace used for melting the bronze chips into the steel support*

The quality of bimetal is discussed in term of contact surface for both alloys (steel and bronze with nickel, iron and manganese). The structural aspects associated with the heating process were presented. An Olympus microscope Metallographic was used. Optical microscopy included standard methods for preparing samples.

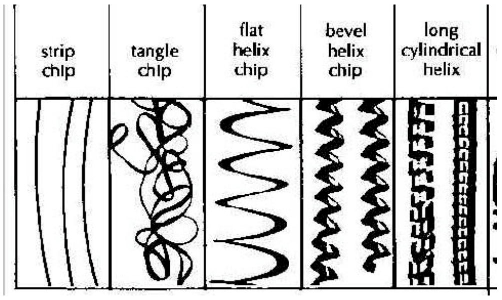
2. Results and discussions

Although the method proposed for bimetal manufacturing is cheap and simple, this involves some problems. The main problems are associated with the quality and the properties of the bronze layer and the bronze chips. Other are associated with processes that accompany the copper alloys melting and joining the steel support. The first condition for a quality process refers to the properties of the recycled material. The success of any melting system depends on the physical characteristics and nature of the feedstock, therefore, the integration of durable, efficient pre-treatment is crucial in achieving full processing efficiency and hence, a high metal recovery. This is particularly important when recycling the machining chips, which have a high surface area per unit volume. Even small residues of water/oil soluble fluid will have a significant impact on metal recovery. Such contaminants interfere with the bronze and may lessen the joint strength or cause failure. For this reason, the first step of the flow sheet is the pre-treatment.

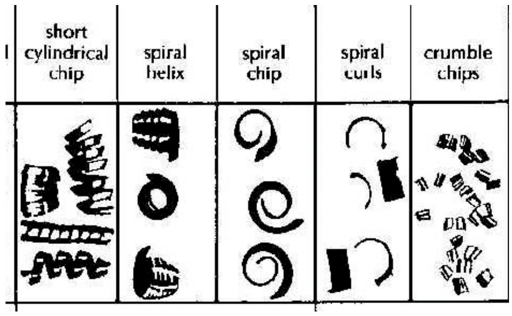
For good bronze melting into steel support are necessary small and uniform chips. The machining chips have various forms. The types of chips are categorised or subdivided into the following categories, Figure 3.

To obtain the uniform chip size, these are crushed. The cleaning can be considered to be a two-stage process. In the first process of the stage the centrifuge separation to minimize water and coolants is applied. Also the magnetic separation to eliminate ferrous parts is sometimes necessary. The second process of this cleaning stage is based on thermal processes. The goal is to remove the organic compounds from the surface of the chips by converting them into a gaseous state. This process requires a low temperature. Any water that is present within the chips will be vaporized. Then, at a higher temperature is removed the carbon-based deposit that remains on the surface of the chips.

The second condition for a quality process refers to the physical and chemical processes that are developed in accordance with thermal conditions that occur during at the melting of the copper alloys chips and during the heating steel support.



a.



b.

Fig. 3. *Chip forming classification: a - not desirable; b – good [8]*

Copper is considered a half noble metal but with a high solubility for oxygen in the liquid state. Generally an oxygen and hydrogen pick-up can lead to very negative effects on mechanical and physical properties of copper and copper alloys. These gases have a high solubility in liquid copper alloys that decreases sharply during solidification. This can lead to bubble formation, i.e. porosity in the solid material. Oxygen can also form cuprous oxide (Cu_2O) above its solubility level that immediately reacts with the moisture of the air forming water vapors. Dissolved hydrogen and oxygen (or Cu_2O) will react with water under extreme pressure in the lattice and will form cracks and lead to embrittlement [9].

Borax, as a neutral cover flux, is used to reduce metal loss by providing a flux cover. This melts at copper alloy melting temperatures to provide a fluid slag cover (borax melts at approximately 740^0C). The glassy fluid cover flux is used too. This flux agglomerates and absorbs nonmetallic impurities from the input material (oxides, machining lubricants, and so on). A reducing flux containing carbonaceous materials such as graphite is used. Its principal advantage lies in reducing oxygen absorption of the copper and reducing melt loss. Carbonaceous flux material should always be used with copper alloys to avoid gaseous reactions with sulfur or hydrogen from contained moisture. Use was made of the copper-phosphorus metal mixed with bronze chips that are considered self-fluxing on copper-base metals. Some of these fluxes are mixed with bronze chips and some covered the input materials after their preliminary heating.

The steel samples were also heated before the filling with bronze chips and fluxes. The amount of flux used was established in accordance with its effect on the porosity and mechanical properties of the bronze alloy. This is more than 5% of metal charge.

Fig. 4. *Preparation of the samples before insertion in the heating furnace*

The heating temperature ensures only the melting of the bronze chips and also for the bronze bounding on the surface of the steel. The heating temperature is very important for obtaining a good adhesion of the bronze layer on steel surface. This was established in accordance with the thermal process that is developed in the samples.

The thermal regime should ensure the melting of the bronze, the superheating of this melt for developing the diffusion zone at interface with the steel support. Certainly, this was correlated with the Cu-Al binary diagram and with the influence of other elements (iron, nickel and manganese) that are present in the aluminium bronze composition. After heating, the samples were maintained at optimum temperature and then were slowly cooled together with the furnace.

The experiments were carried out at different work temperatures between 1200 and 1300^0C. The experimental part shows that heating of the samples at 1200^0C cannot ensure a complete melting of the bronze chips, Figure 5.

Fig. 5. *Bronze chips incompletely melted often being heated at 1200^0C*

The choice of 1300^{0}C as optimum temperature is confirmed by the experimental samples, Figure6.

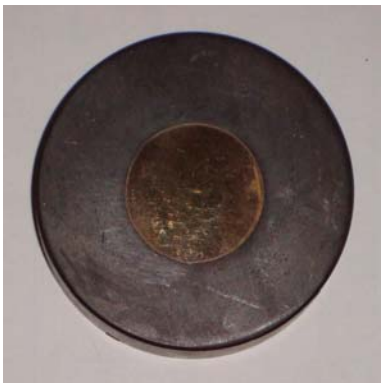


Fig. 6. *Good adherence of bronze on the steel surface for the bimetal sample obtained at 1300^{0}C, slowly cooled with the furnace (surface after exposure to metallographic attack)*

At the surface of the support steel, the aluminium bronze with nickel, manganese and iron was adhered to obtain the bimetal. The appearance of the joint zone shows that the process was conducted with optimum parameters. The surface layer had no defects such as oxide films, or porosity, Figures 7 and 8. The bonding takes place during heating and melting processes. In this way, with participation of diffusion processes good bimetals can be manufactured.

Fig. 7. *Aspect of bimetal at interface (100X without exposure to metallographic attack)*

The microstructural analysis shows that the interface layer formed by micro-melting and diffusion is very fine and uniform.

The transition area has a thickness of approximately 50μm and it resulted from the mass transfer processes developed between the two materials.

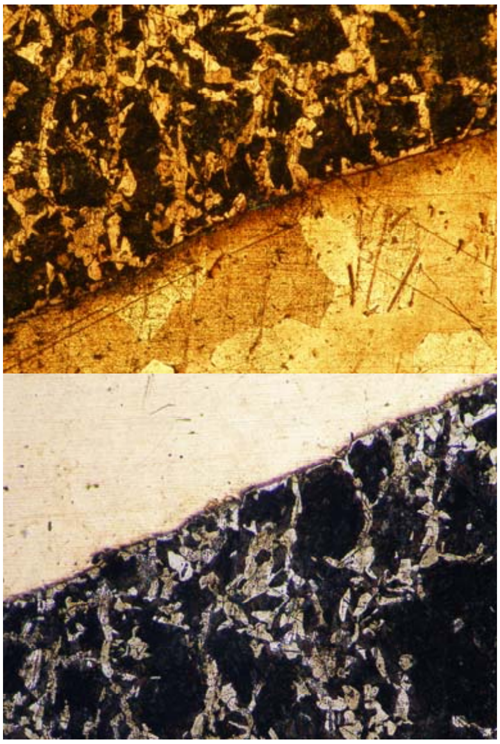


Fig. 8. *Microstructure of bronze and steel support after exposure to metallographic attack (100X)*

For comparison with the technology used for the production of similar bi-metals obtained by welding, it can be said that, in the case of the bi-metal obtained through the plating of bronze onto the steel support [4], the transition area is more extended, of approximately 150μm and it results from the diffusion processes caused by the high temperatures developed during welding and thermal treatment, respectively the concentration gradients between the two alloys (Figure 9).

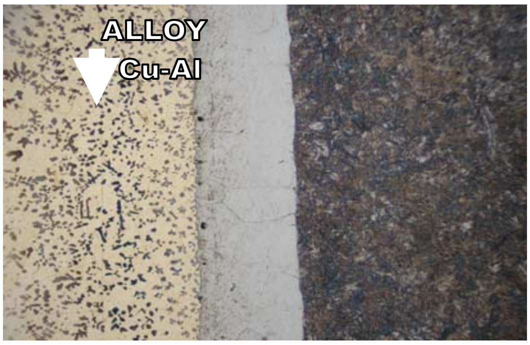


Fig. 9. *Microstructure of bimetal after exposure to metallographic attack (X200)*

The optimal performances regarding the behavior during exploitation of the bi-metals can be obtained only by knowing, and respectively, by controlling of the composition and microstructural transformations, both for the constitutive materials and the diffusion area developed at their interface.

4. Conclusions

The recycling of the chips usually presents many difficulties [10, 11]. Firstly, the metal chips can be classified in the category of hazardous waste because they have residues of water/oil soluble fluid with significant impact on metal recovery. The generation of pollutants is considerable. In the method proposed in this paper, some of these negative problems are suppressed. On the other hand, the metal losses at remelting are higher.

The direct melting of the bronze chips into steel supports for the bimetal manufacturing is possible. It is a cheap and simple solution to transform the machinery wastes as final products that can meet the requirements in industrial applications. The important factors that influenced the manufacturing process are the dimension of the chips and the cleaning. Also, heating and the melting parameters correlate in accordance with the physical and chemical properties of materials most. Especially, all of these have specific features in respect to the materials utilised, the manufacturing processes and the bimetal applications.

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