CHEMICAL AND STRUCTURAL CHANGES FOR BIMETALLIC MATERIALS OBTAINED BY THE WELDING PROCESS

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ABSTRACT

This paper presents the transformations which take place during the obtaining process of bimetallic materials. As a plating process was used the welding. The added material was a bronze with aluminum complex alloyed with iron, nickel. The based material was the steel. EDAX analyses and microstructures analyses were done in order to explain the metallurgical processes which take place during the facing by melting.

KEYWORDS: bimetal, plating by welding, steel, bronze with aluminium complex alloyed

1. Introduction

In many industrial applications, the working surfaces of the cast or plastic deformed bench-mark are simultaneously exposed to a very different kind of stresses. In these types of working regime, plated metallic 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. The plated 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. The bimetallic pieces were obtained by the welding process. The idea was to produce some steel machine parts covered with antifriction non-ferrous alloys layers. These are characterized by a high hardness necessary for special working conditions: a good wear resistance at a specific contact pressure of min. 200 daN/mm^2 and a working speed of 60 m/min, high corrosion and abrasion resistance, a minimum wear loss after the end of working time. As added materials bronzes with aluminium complex allied with iron, nickel and manganese were used. These materials posses a good tenacity combined with a suitable bursting resistance, low coefficient of friction, good behaviour during the wear tests, a high capacity of shock damping, and a good fatigue resistance (Table 1).

The structure of CuAlNi alloys. The Cu-Al alloys with aluminium content higher than 9.4 % solidify by forming the β phase which is transformed gradually, during a slow cooling, in a $\alpha + \gamma$ phase through a eutectoid reaction at ≈ 570 °C. The γ phase can be corroded preferentially due to the presence of high aluminium content. This presence deteriorates the material (Figure 1). The addition of nickel and iron in Cu-Al alloys leads with an increase of stability domain for α phase and a decreased formation of β phase. The addition ok Ni and Fe increase significantly the mechanical properties of CuAlNiFe alloys due to the formation of both α and β phases by the k intermetallics compounds. Thus, the CuAlNiFe alloys become quaternary copper based alloys. Accordingly the literature, casting alloys solidify by forming one single phase, β solid solution. This one is stable to the cooling process until $\approx$ 1000 °C [1-4]. Under this temperature, the α phase precipitates from β phase with Widmannstatten morphology, followed by a nucleation process of the globular k constituent. This constituent is identified as Fe3Al (named k_{II} for the elements content from table 1 and k_{I} at a Fe content $\geq 5\%$ when its morphology is dendritic).

Tabel 1. *Chemical composition of CuAlNiFe alloys, Wt %*

Element	Al	Ni	Fe	Mn	Cu
Limits of concentration	11,0-12,0	4,0-5,0	4,0-5,0	0,8-1,2	rest

At ≈ 850 °C, the iron solubility in the α phase decreases and it starts to precipitate a fine k constituent (Fe_3Al), named k_{IV}. At the end, at ≈ 850 °C, it appears a k phase rich in Ni, k_{III}, with a globular morphology. The morphology is formed by a eutectoid reaction when $\alpha + k_{III}$ is obtained (Figure 2).

The mechanical properties of bronzes with aluminium depend by the aluminium content and substantially vary with the secondary allegation elements contents. The iron refines the structure, increases the resistance and the hardness and decreases the fluidity of the alloy; every Fe percentage in a bronze with aluminium leads with an increase of the mechanical resistance of the alloys with 2.8 daN/mm^2. The nickel is the most efficient addition in the bronze with aluminium. The addition of nickel increases the mechanical characteristics, the antifriction and anticorrosion properties. The nickel addition also increases the compactness and the high temperature resistance. The manganese increases resistance, plasticity and the antifriction properties, but significantly decreases the fluidity. Comparing with iron, the manganese behaves as a stabilizer. It is dissolved in the solid solution and it doesn't provoke structural changes [5]. The bimetallic pieces are obtained using the welding process [6]. This process must provide a perfect adhesion of the plated layer on the based material. In the same time, the welding process parameters must create the most reasonable conditions in order to not affect the physical, chemical and mechanical properties of the compounds.

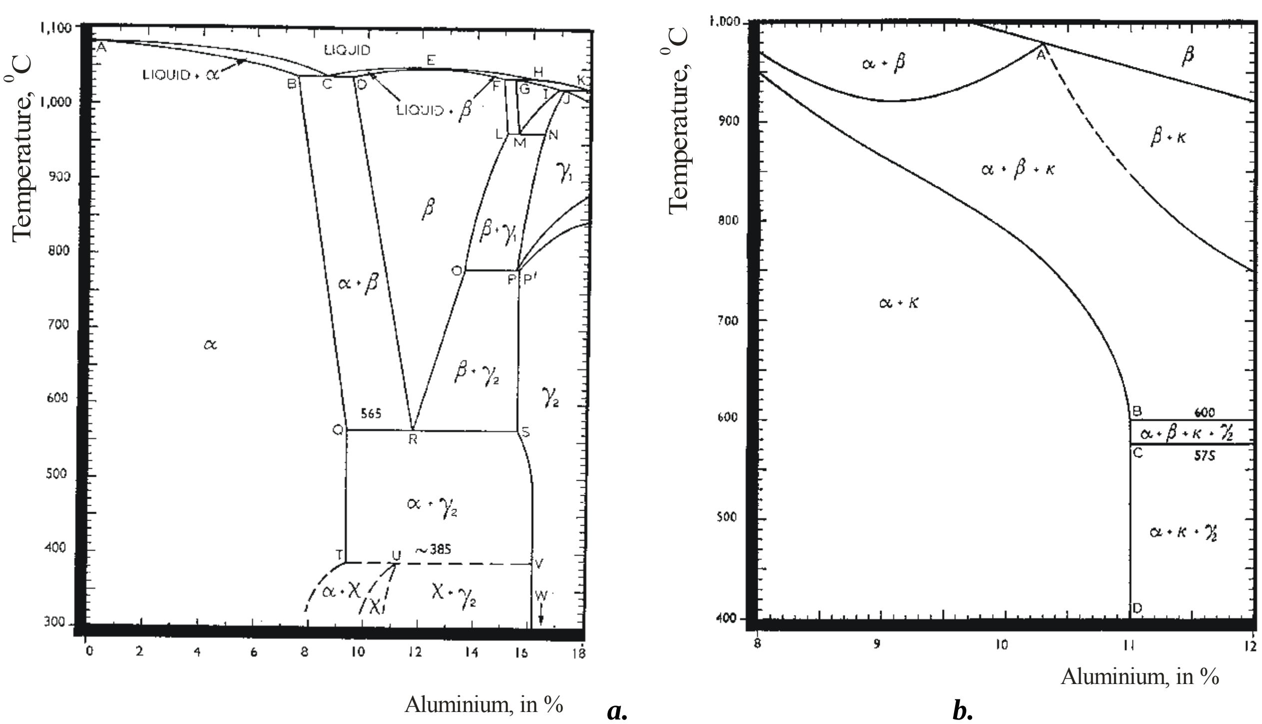

Fig.1. *The equilibrium diagram of Cu-Al system (a) and a cross section of CuAlFeNiMn diagram at 5% Fe and 5% Ni (b).*

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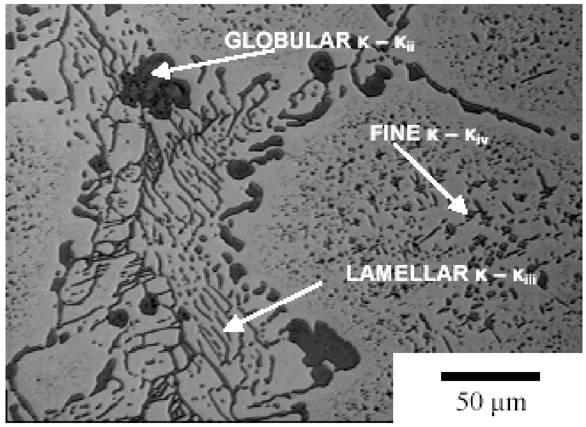

Fig.2. *The microstructure of CuAlFeNiMn casted-on alloy*

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The compounds participate to the mechanical stress of the plated pieces. The welding process provides a good junction of the layers specific to the interatomic junction at the grains boundaries of a polycrystalline material.The junction is favoured by the diffusion phenomenons which take place in the contact zones of the two materials. It is necessary to take place a reciprocally diffusion process between the added material and the based one. The mechanism and the characteristics of the junction is determinate by the metallic material nature, by the temperature, the damping properties of the solid based material with the welted added material, by the welding conditions, etc.

2. Experimental

The plating process of the steel was done with antifriction alloys using a welding process with an electric arc in a protected argon environment, type WIG. The deposited material was cast-on as wires with 4 mm diameters and 400 mm length. The optimized welding parameters were:
- preheating temperature of 150-200 ^oC;
- an alternative current or a direct current with an inverse polarization (DC^+);
- an welding current, I=120…150 mA;
- a protecting gas volume of 20…30 l/min.

Due to the big differences between the chemical compositions of the based and addition materials, the deposition process was done in many layers in order to reduce the effects of elements dissolution and diffusion phenomenon. The obtained thickness of the layers was enough to provide the chemical composition in order to obtain their required properties (figure 3).

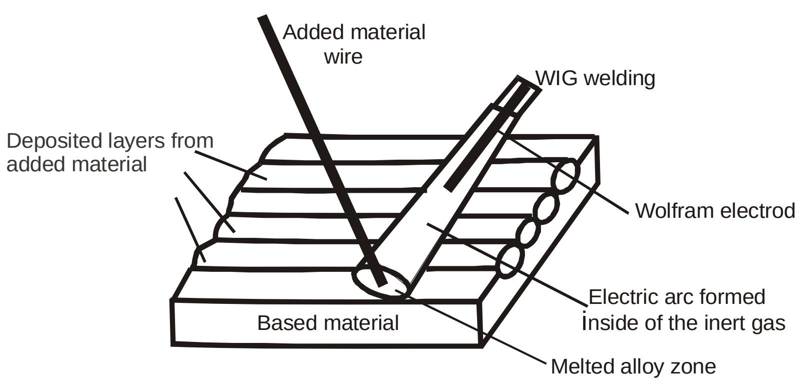


Fig. 3. *The multilayers deposition diagram of the antifriction alloy*

3. Results and discussions

On the border of the based material and the addition material it is formed a transition zone where take place structural and composition changes. This is due to the melting of non-ferrous alloy which behaves as a metallic bath. In this metallic bath take place the same processes as those specific for the non-ferrous alloys making: gases adsorption, elements loss by oxidation, etc (figure 4). The presence in the based material of some very strongly thermal influenced zones determinates diffusion and dissolution of the elements of both metallic materials. Figure 5 shows the microstructure of the obtained bimetallic material on the border of deposited non-ferrous alloy and the steel. It can be observed that the transition zone is very uniform, with a constant thickness about 0.010 mm, as consequences of a very well controlled deposition process. In the vicinity of the interfaces, the structure of the deposited material is dendriform with axes perpendicular oriented on the interface of the two materials (figure 6).

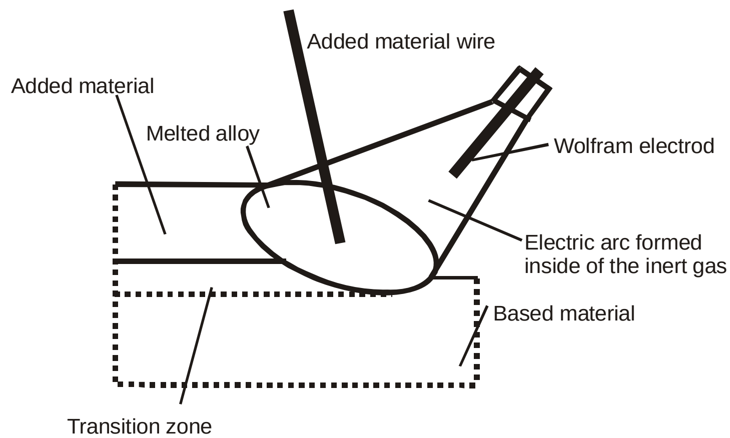


Fig. 4. *The processes which take place in the deposition zone*

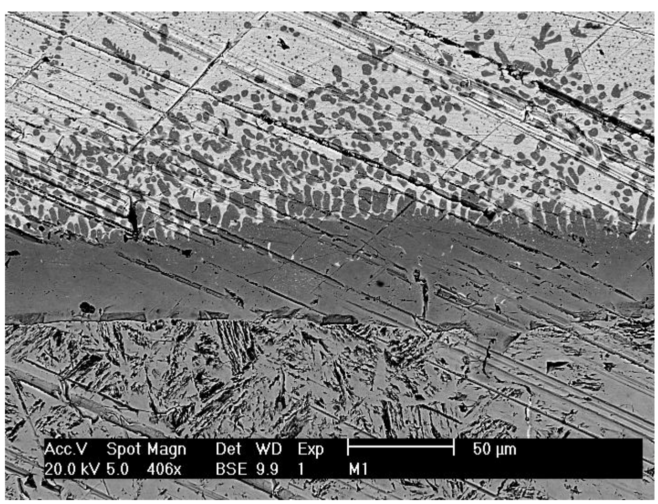


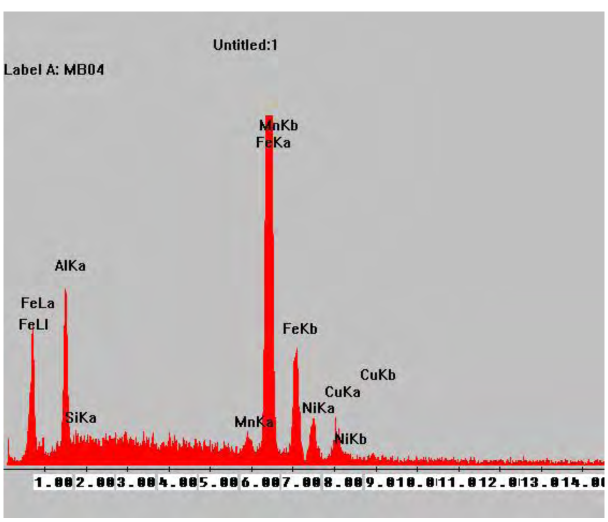
Fig. 5: *The transition zone; x 400, 20 kV, BSE (back scattering electrons).*

Fig. 6: *The dendriform structure of the deposited material in the vicinity of the transition zone.*

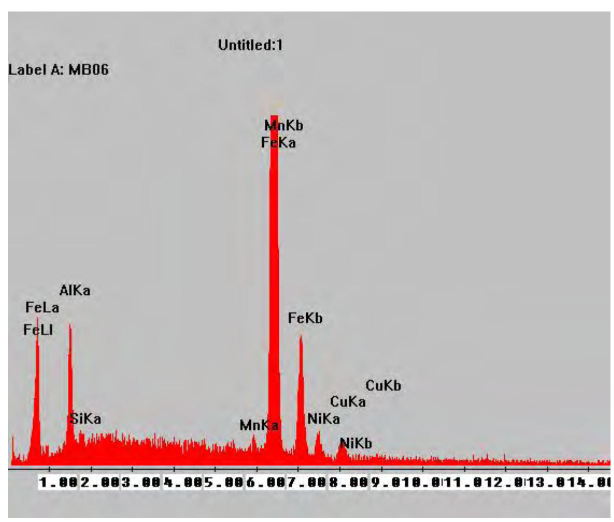
The chemical analyses made in different points of the transition zone show that the diffusion processes take place in two directions: from the steel to the non-ferrous alloy and reversed. Therefore, in the transition zone can be find chemical elements of the both materials (Table 2, figure 7).

Tabel 2. *The elements concentration in different points of the transition zone, Wt %*

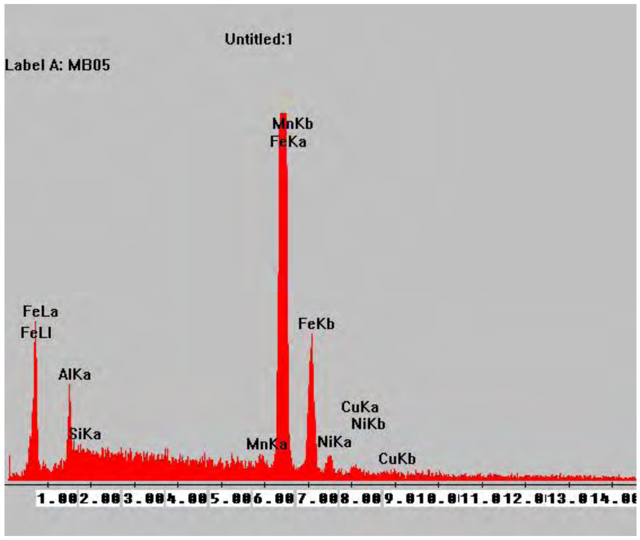
Element	Location in the transition zone		
	Point close by the non-ferrous alloy	Point in the centre	Point close by the steel
Al	8,09	6,04	3,35
Si	0,40	0,48	0,45
Mn	1,55	1,05	0,75
Fe	80,12	85,18	90,37
Ni	4,86	3,62	2,84
Cu	4,98	3,64	2,23



a. Point close by the non-ferrous alloy



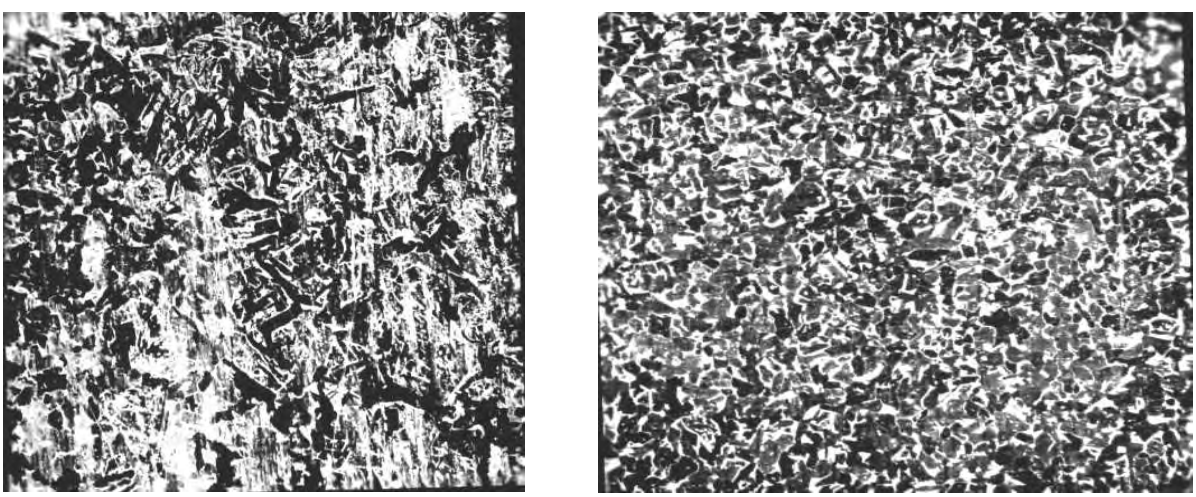
b. Point in the center



c. Point close by the steel

Fig. 7: *EDAX analyses in different points of the transition zone.*

The cross section analyses of the bimetallic material shows that the deposited layers surface has not defect as oxide films, others inclusions or porosities. The obtained bimetal material is a compact mass, without spiels, inclusions or cracks. In the based metallic material, at some depth from the deposition surface, it was noticed a thermal influenced zone where take place only the changes in the solid state. In this zone, the material was practically under uncontrolled thermal treatment. The effects of this treatment consist in a recristalisation and a presence of some grains with small dimensions, very close by the deposition zone. This caused an increase of the mechanical resistance of the bimetallic material (figure 8). Anyway, in order to reduce the effects of these thermal superheating some suitable thermal treatments are performed. As a consequence the required properties are obtained.



a. *b.*

Fig. 8. *Microstructure analyses on the based material:*
a – the steel microstructure used as based material, b – the superheating zone

4. Conclusions

The processes which take place when the steel is plated with a non-ferrous alloy using the welding are similar with the processes specific for a metallic bath formed through a metal melting in the welding zone with the contribution of both involved materials. The solidification mechanism of added material which caused the formation of a transition structure characterized by variable composition and properties can be different. If the welding process is well done, the transition zone of the melted added material and the superheating based material is formed.

This leads with an avoiding of unexpected variations in the chemical composition and properties from one material to the other one. The diffusion process, which takes place in both directions leads with formation of globular, or punctiform constituents. These constituents increase the hardness of material but do not affect its fragility.

There are not material defects and acicular constituents, which should affect the material quality.

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