IDENTIFICATION AND QUANTIFICATIONS OF CHEMICAL ELEMENTS AND MICROSCOPIC CHARACTERISATION OF THE COPPER BASE ALLOY AT DIFFERENT TEMPERATURE OF MOULDS

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Abstract: In this research paper, the structure identified by microscopic analysis for one copper base alloy at two different moulds are comparing between them because the solidified conditions was different. The samples were prepared by induction furnace using electrolytic copper and zirconium sponge and the ingots were cast into the steel moulds where solidifies its. Copper alloys are an knew group of casting Cu alloys, well-known as corrosion resistant materials, which are widely used as the devices for their antibacterial properties. Depending on the combination of alloying elements and other factors, like solidification temperature or micro alloying elements, the alloys with different mechanical and physic-chemical properties are obtained.

Keywords: *copper alloys, structure identification, optical microscopy imaging, chemical elements.*

1. Introduction

Devices copper alloys are a special group of industrial copper alloys which have antibacterial properties at normal room temperatures (approximately up to 25˚C).

These properties of the alloys are resistant to sudden temperature changes. Due to this, in the design of this type of alloys, their mechanical and thermal strains have to be critically considered without ignoring their environment aggressiveness during exploitation. In order to accomplish such set of requirements, copper alloys assigned for devices production need to have an appropriate microstructure. Together with chemical compositions and process parameters, microstructure is as important parameter that has a significant impact on the mechanical properties of cast parts. [1]

Copper alloys contain various contents of major and minor alloying elements. Cr-Zr has stable equilibrium phase diagram with a maximum solid solubility of ~0,12 at%Zr at 972°C and it reacts with copper and aluminium to form a thermodynamically stable phase. [2] One of the major difficulties of copper alloys with zirconium is that the last can lead particular intermetallic effect with deleterious effects on the physical and mechanical properties of the cast parts. Compounds are very hard with the result that machining cast parts with relatively high zirconium contents can be difficult, resulting in high casting finishing costs. Heat treatment processes do not change the size and distribution of this phase.

Are known that zirconium is desirable element in copper alloys which improves the temperature properties and thermal stability of such alloys. Now, all the efforts are being made in attempts to modify the adverse effect of intermetallic zirconium phases, e.g., decreasing their size and modifying them into a less harmful morphology. Besides the major alloying elements that have a huge impact on the solidification path of these alloys, there are also some minor elements that significantly change their solidification path. It is known that the addition of elements such as Al, Fe and Mo can modify the zirconium phase morphology into less harmful shapes. This means, that there is a possibility of controlling the cast components by optimizing Zr with usually Al additions. [3].

The typical copper devices are very complex regarding their chemical compositions and obtained structures. There are alloying elements, Al, Fe, Mo, which have a significant impact on the solidification path of these alloy Interactions among them create different phases and intermetallics, the shape and distribution of which in the as cast and heat treated alloys depend on the corresponding process parameters. At elevated temperature, thermally stable intermetallics should stop or reduce the movement of dislocations and increase the mechanical properties of alloys at elevated temperatures. The strengthening effect of such intermetallics depends on their stability at elevated temperatures. The more stable intermetallics achieved the better strengthening effect.[4]

2. Experimental procedure

2.1. Sample preparation

The structural matter of a material has a direct impact on the physical and mechanical properties of a cast. For this reason, the control of the manufacturing process and the attainment of the desired material properties require that the macro and microstructures present must be defined and described, both qualitatively and quantitatively (Fig.1). [1]

Casting was performed directly into the steel moulds. Alloy cast into the steel moulds (two) were prepared by induction furnace type into the graphite mould at a high temperature max. 1300°C.

The mass of the cast sample was generally 750g.

The shape of the chill-mould was circular with cone form without corrugate sides. The teeming was performed into different ways. The melt was teemed from above into moulds, down-hill casting, at the different temperature of moulds.

One problem with downhill casting is producing a good ingot surface. The quality of surface depends on how well the moulds have been prepared before the casting. In order to study the surface quality of the ingot it was proceed to heat one of mould before to be used. The second mould was used at the room temperature.

The stream of melt has a large area exposed to the air. The exposure greatly increases the risk of oxygen and nitrogen absorption by the melt. Those gases react chemically with alloying metals in the melt, in our case with Al and micro alloying elements, Fe and Mo in our case, which may occur in steel, and lead to the formation of oxides. The samples to study were cut horizontal from

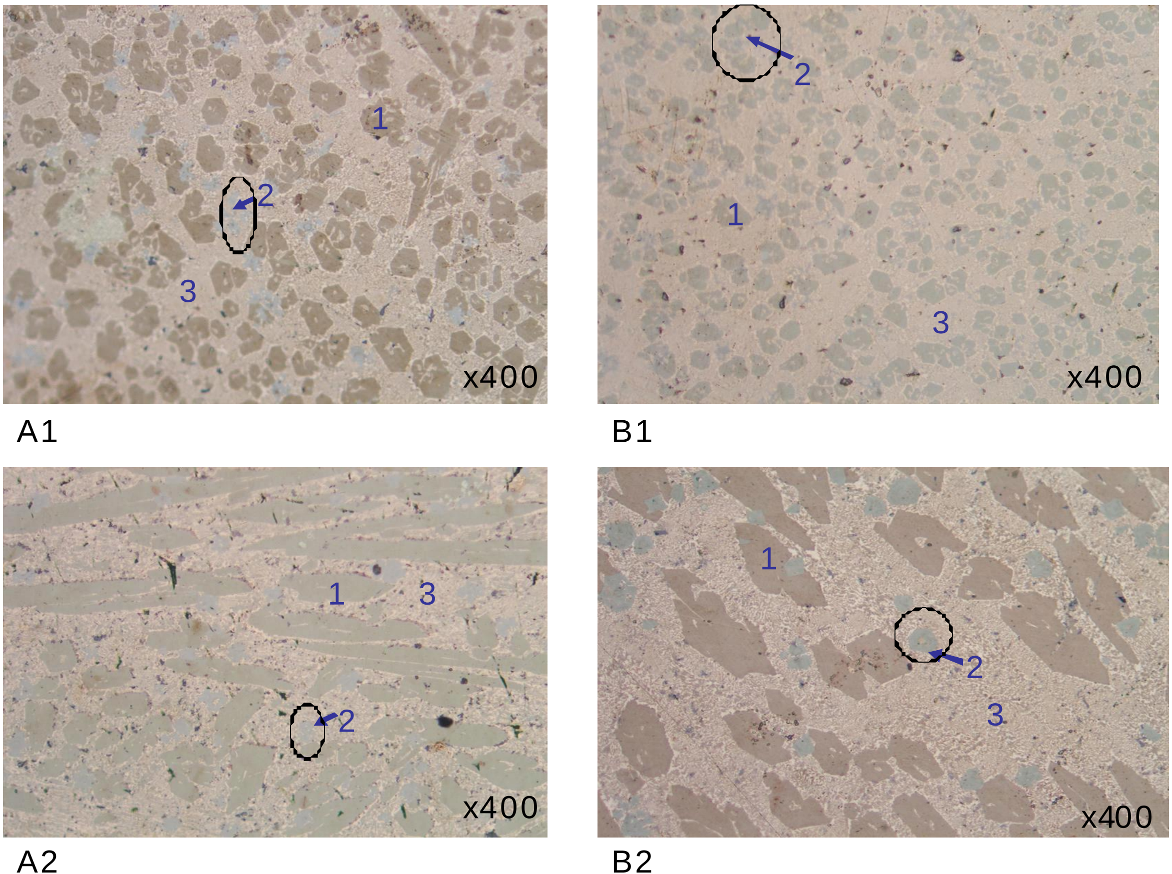

Fig. 1: Optical micrograph (x=400) of the joint prepared at 1300 °C and cast in two similar moulds of steel beeing at different temperature of mould. A-hot mould (100 °C). B-could mould (10 °C). A1: micrograph of the down part of the sample of the hot mould ; A2: micrograph of the middle part of the sample of the hot mould, B1: micrograph of the down part of the sample of the cold mould; B2: micrograph of the middle part of the sample of the cold mould.

different parts of shape and after that were prepared for analyses at the metallographic lab and vertical form different part of shape to analyse the internal character of crystals after solidification process.

Optical analysis was used for microstructure and phase identification. The measurements were performed with OLYMPUS BX 51M instrument. The elemental analyse was investigated with spectrometry of X ray fluorescence (FXR).

Table 1 presents a comparative view of the elemental composition of the tested copper alloy:

Chemical elements	Cold mould	Hot mould
Zr	14.76	15.29
Cu	78.46	77.91
Fe	0.53	0.31
Mo	0.070	0.081
Al	6.15	6.38

All the investigated alloys of the given elemental contents were prepared under laboratory conditions at Faculty of Metallurgy, Material Science and Environment, University Dunarea de Jos of Galati. Romania by the internal procedure, our own recipe for melting and preparation of copper alloy.

2.2. Sample characterization

The optical microscopy imaging is the first method used for investigating the solidification path of metals and alloys. The resolution of the optical instrument is generally very high, which makes this instrument useful for many research applications. A search of the available literature showed that optical microscopy imaging is a powerful tool that has been successfully used to determine characteristic of solid phase during solidification processes. [5]

To determinate quantitative and qualitative elemental analyses by FXR of the chemical composition of metallic samples which ware investigated for differenced temperature of moulds was used the portable spectrometer.

The main aim of the present work was to characterize the solidification path of copper alloy CuZrAlFeMo and especially the homogeneity and the assimilation of the chemical elements during the solidification process in two similar moulds but being at different temperature.

3. Results and discussion

Optical investigations

Optical micrograph imagines of samples casts by different heating and cooling rate of steel moulds, *i.e.*, presented in Fig. 1, relived that the solidification of the alloy is significant depending by the temperature of moulds.

The microstructure of the samples is shown in Fig. 1. (A1, A2-B1, B2). As shown in Fig. 1 at both samples casts in cold and hot mould the microstructure is clearly defined with three micro structural constituents: crystalline grains and mechanical mixture of phases. Two micro crystalline constituents: 1-black grains with polygonal form, 2-blau grains uniform distributed with round form. The third micro structural constituent is copper based matrix phases.

Solidification as encountered in common processes does not occur at equilibrium, since during solidification of most castings,

The major differences between the shapes and the sizes of micro constituents, and their arrangement/morphology in multiphase system are because both temperature and composition gradients exist across the casting between the moulds walls and alloy.

The four right-hand terms are the change in free energy because of temperature, composition, curvature, and pressure variation, respectively.

Table 1 shows obvious differences between the chemical elements as a result of the of the alloy cast at the different temperature of moulds.

Copper alloy of the hot mould A, contained high percentages of the alloying elements Zr, Al and less percentage of Fe as micro alloying element while copper alloy of the cold mould B contained low percentage of alloying elements Zr and Al but a high percentage of Fe.

The temperature interval of the solidification process was also shorter and it commenced at the cold mould.

Changes on chemical composition of alloy during the solidification process can be the result of different internal reactions.

Is known that the solid shell varies with the casting method and the shapes and sizes of the castings.

In our case the samples casts into steel moulds at of the different temperature if moulds have the columnar character of the internal crystals. The cross section area of the columnar crystal increases with the distances from the cooled surface of mould.

The growth rate of the solidification front decreases with the distance from the ingot surface.

The growth conditions and consequently also the structure morphologies are not constant.[6]

The dendrite arms and the crystal cross sections seem to grow in two or three different steps,

Eq (1) and (2).

The relationship:

$$\nu_{growth}\lambda^{2}_{den}=\text{const}, \qquad (1)$$

is valid in this case, but with different constants for each steps. At the constant eutectic temperature precipitation of the eutectic alloy occurs.

Ingot with long solidification times the number of new floating crystal decrease during the solidification process and the central zone of branched columnar crystals is extended over the whole section in the upper part of the ingot.[5]

Is known that that the necessary condition for solidification is undercooling:

$$dr/dt=\mu(T_L-T_{crystal})^n \qquad (2)$$

The temperature of the melt and the solid phase of an ingot as a function of time.

4. Conclusions

This paper presents the results of research on copper based alloy in the different temperature of moulds cast.

The structure can be characterised as a very fine surface zone that consists of a fine network of tin dendrite arms and not, as in ingots, of a great number of fine-grained crystals.

At the ingot from into the cooled mould we can observe the less quantity of micro alloying elements assimilate comparing with the chemical elements from the second ingot where the micro alloying elements are assimilated more.

In the same time, the dendrites from the cooling mould became tin comparing with the second ingot.

Due to the high temperature gradient the thin dendrite crystals grow inwards and form columnar crystals. In the cooled mould its are stopped by the formation of the equiaxed crystals that have grown freely in the melt.[1]

With the aim of improve the corrosion resistance of the antibacterial copper based alloys, a number of copper alloys can be prepared by changing the concentrations of alloy elements and micro alloying elements in order to increase the each possible phase or change of its shape in which the alloy element is dominant, since the phenomenon of change of the mean concentration in the actual case, due to redistribution of liquid enriched or depleted by the alloy elements, leads to a change of mean concentrations to values significantly higher or lower than the nominal value, and to the possibility of the occurrence of other phases.[4]

When a larger portion of micro alloying elements exists in the matrix phase the solidification occurs at different temperatures, which is good. However, a further increase in the content of micro alloying elements may lead to the formation of a new phase, the strengthening effect of which is poorer. This means, the micro allowing elements has to be added in a proper amount to the alloy, depending on the Copper content [2], [3] and [5].

The results presented in this paper are only an introduction to further ongoing research aimed at obtaining the required combination of the further antibacterial copper alloy with the goal of providing optimal characteristics for mechanical and corrosion resistance as well as defining a mathematical model that can predict the different cases on the micro and macro levels of segregation.

Performed thermal analysis and microscopic characterization of Cu-enriched phases can be determined using thermal analysis. The importance of the analysis of these phases is due to their strengthening effect that is usually enhanced and controlled by applying heat treatments that promote the precipitation of coherent or incoherent alloying or micro alloying elements that improve the properties of Copper based alloy.

Copper alloy with better properties than those achieved using conventional casting method can be produced with the rapid solidification methods.

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