Study on structure and properties of CuZn40Pb alloy

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Abstract. The paper shows aspects about the behavior of Cu-Zn-Pb alloys subjected to the temperatures variation and corrosion resistance in saline medium (sea water). The chemical composition was determined by spectral analysis on optical spectrometer, type Foundry Masters. The experiments are completed by a microstructure analysis made on scanning electronic microscope.

1. Introduction
The nonferrous alloys are used in the domain of manufacturing of cast parts. At the elaboration of nonferrous alloys can be use blocks of cast alloys, pure metals, pre-alloys, metallic waste, recycling materials, fondants and modifying admixtures. The calculus of load is made in function of the available materials, the burnt during elaboration and the final alloys which are achieved.

To obtain the superior characteristics of cast parts from nonferrous alloys, the limits of impurities admitted are provided in standards, being necessary their diminution. Due to his properties, the copper have a large utilization in industry: 50 % in electrotechnique parts and 30 ... 40 % for elaboration of alloys.

The brasses are copper alloys with zinc and contain at least 55 % copper. The alloyed brasses can contain and additions by aluminum, tin, manganese, iron, nickel, lead. The casting temperature for binary brasses is 1100 ... 1200 °C, in function of cast part and shape. If the load is composed by unpurified waste or metals, it is necessary to refining of metallic bath after the complete melting under a flux layer. The brasses with a high content of lead, can replace the bronzes with tin. At their elaboration is recommended initial the melting of copper, then simultaneous introduction of zinc and

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lead. Before casting is added 0.1 ... 0.2 % aluminum for fluidity and deoxidation, and the casting temperature is between 1000 ... 1080°C.

2. Results and discussions

2.1. Determination of chemical composition
The spectral analysis was made on Foundry Masters spectrometer, type 01J001 3, using copper base for analysis. The determinations were made on samples, obtained by cutting at optimal dimensions, using METACUT M250 machine, with abrasive disk and a cooling system. After 3 determinations, made on samples surface, it was obtained the average value for the alloying elements (table 1). The alloy is part of copper-tin alloys (brasses), cast in blocks, type CuZn40Pb.

| Table 1. Chemical composition for the studied alloy |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Cu             | Zn             | Pb             | Sn             | P              | Mn             | Fe             | Ni             | Si             |
| 58.5           | 38.8           | 1.88           | 0.186          | 0.003          | 0.0091         | 0.282          | 0.146          | 0.0063         |
| Mg             | Cr             | Al             | S              | As             | Be             | Ag             | Co             |
| 0.0014         | 0.0053         | 0.0147         | 0.002          | 0.0067         | 0.005          | 0.0207         | 0.015          |

| Table 2. Mechanical characteristics and utilization domains for the CuZn40Pb alloy [1] |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Type           | Cast mode      | Rm [N/mm²]   | As [%]        | HB [daN/mm²] | Utilization domain |
| CuZn40Pb       | Cast parts under pressure | 280 | 7  | 80 | fittings, elements subjected to usage, elements with good electrical and thermal conductivity |
|                | Cast parts in metallic matrix | 280 | 7  | 80 |

| Table 3. Physical properties[6] |
|-------------------------------|----------------|----------------|----------------|
| Properties                    | Units          | Value          |
| Density at 20°C               | [g/cm³]        | 8.4            |
| Specific heat                 | [cal/g·°C]     | 0.09           |
| Modulus of elasticity         | [kg/mm²]       | 10000          |
| Modulus of rigidity           | [kg/mm²]       | 3700           |

| Table 4. Manufacturing properties[6] |
|-------------------------------------|----------------|----------------|
| Properties                          | Units          | Value          |
| Melting interval                    | [°C]           | 895 – 900      |
| Melting temperature                 | [°C]           | 1000 – 1050    |
| Annealing temperature               | [°C]           | 450 – 650      |
| Hot processing interval             | [°C]           | 650 – 750      |
| Hot plasticity                      |               | Good           |
| Cold plasticity                     |               | Limited        |

2.2. Dilatometer analysis
The dilatometer analysis was made on Linseis L75H/1400 and is used samples with small dimensions. By dilatometer analysis is highlighted the structural transformations triggered at heating in linear regime, for temperatures domain between ambient up to 200°C.

| Table 5. Measured values for elongation by expansion at heating |
|---------------------------------------------------------------|
| Heating speed 2.5 [°C/min]                                    |
| T [°C]            | 17.7 | 36.2 | 55.8 | 71.3 | 87.8 | 104.3 | 119.3 | 137.6 | 156.5 | 172.4 | 186.8 | 200.0 |
| Al [mm]           | 0    | 2.7  | 7.0  | 11.2 | 16.0 | 20.7  | 24.7  | 29.5  | 34.3  | 38.5  | 42.2  | 45.6  |
| Heating speed 5 [°C/min]                                    |
| T [°C]            | 28.1 | 51.9 | 65.6 | 89.2 | 108.9 | 126.7 | 144.4 | 160.9 | 171.2 | 177.0 | 191.6 | 200.0 |
| Al [mm]           | 0    | 0.9  | 1.7  | 4.5  | 8.9   | 13.6  | 18.7  | 23.6  | 25.8  | 28.2  | 32.1  | 34.3  |
| Heating speed 7.5 [°C/min]                                 |
| T [°C]            | 28.2 | 53.3 | 74.7 | 96.5 | 115.3 | 131.7 | 148.1 | 164.4 | 178.9 | 183.4 | 190.9 | 200.0 |
| Al [mm]           | 0    | 0.10 | 1.95 | 2.92 | 6.35  | 9.75  | 13.75 | 18.20 | 22.44 | 24.85 | 26.15 | 29.0  |
| Heating speed 10 [°C/min]                                |
| T [°C]            | 32.9 | 59.9 | 81.1 | 99.5 | 116.2 | 129.9 | 146.2 | 159.2 | 169.3 | 182.3 | 193.8 | 200.0 |
| Al [mm]           | 0    | 2.19 | 1.42 | 2.78 | 3.80  | 6.09  | 9.24  | 12.04 | 14.41 | 17.61 | 20.63 | 22.36 |
2.3. Study on corrosion resistance

The electrochemical corrosion represent a ensemble of physical – chemical processes after which the alloys pass to metallic compounds form (oxides, hydroxides, salts), as a result of the formation of micropores in which the metal is subjected to anodic oxidation. In this time a compounds of the solution, named depolarizing, suffer a complementary reaction by reduction. Between the principal causes which determine the appearance of locally elements can be mentioned:

- Inpurifying with non-noble metals, oxides of metals;
- Chemical heterogeneity;
- Physical heterogeneity, due to mechanical treatment of irregular thermal treatment.

To appearance of this corrosion type it is necessary to exist an anode, a cathode, an electrolyte and a conductor. If one of these conditions not exists, the electrochemical corrosion is not produced.

To study the processes of electrochemical corrosion it is used the potentio-dynamic method (linear and cyclic) [12].

2.3.1. Characterization by linear polarization studies. Electrochemical corrosion tests were conducted using a three electrode electrochemical cell connected to a Volta Lab 21 (Radiometer, Copenhagen) potentiostat.

A saturated calomel electrode (SCE) was used as the reference electrode. The auxiliary electrode was a platinum wire [10,11]. The working electrode was realized in square shape and was assembled in teflon. Exposed area of the sample to the electrolyte was 1.0 cm².

The tests were conducted at room temperature (20°C). The solution used for the tests was orange juice.

The curves of linear polarization were recorded at a scanning speed of electrode potential by 3 mV/s, in a potential domain ± 545 mV, in a open potential circuit. The curves of cyclic polarization were recorded with 10 mV/s speed, in the potential domain between -1000…+2000 mV.

Figure 1. Dilatograms for the CuZn40Pb alloy, in function of heating speed.
The corrosion potential at corrosion current $E_0 \equiv E (I = 0)$, the Tafel branches ($b_a$ and $b_c$), the polarization resistance $R_p$, density of corrosion current $J_{cor}$ and corrosion speed $V_{cor}$, were evaluated with Volta Master 4 software.

The measurements were made at potential, in open circuit, using sea water. The sea water is considered the most aggressive natural agent of corrosion [9]. By its content in salt, gases and the fact it is in continuous moving, the sea water corroded all the metallic construction which are immersed or which are at surface. The principal form of corrosion is locally, type pitting.

The principal parameters of corrosion process ($E_0$ and $J_{cor}$) obtained by processing the curves of linear polarization for Cu-Zn alloy, in cast state are centralized in table 2.

![Table 6. The parameters of electrochemical process](image)

| Sample | Corrosive medium | $E_0$ (mV) | $b_a$ (mV) | $b_c$ (mV) | $R_p$ (kΩ/cm²) | $J_{cor}$ (µA/cm²) | $V_{cor}$ (mm/Y) |
|--------|------------------|------------|------------|------------|----------------|------------------|-----------------|
| Cu-Zn  | Sea water        | -961.1     | 528.1      | -306.1     | 1.77           | 0.0272           | 317.5           |

In order to check the passivation effect of the sea water to Cu-Zn alloy, is drawing the polarization curves for samples cu a polished surface [7, 8].

The copper forming compounds in which can be monovalent ($Cu^+$), divalent ($Cu^{2+}$) or rarely trivalent ($Cu^{3+}$). The divalent copper combination is colored, and for our case present an greenish color. The corrosion potential present negative value, relatively high, this fact highlighted the natural tendency of this alloy to spontaneous corrosion.

The corrosion current ($J_{cor}$) present a positive value by 25 µA/cm² and representative for the degree of material deterioration.

2.3.2. Characterization by cyclic polarization studies. The analysis of cyclic diagram presents the pitting character of corrosion, being by hysteresis type with return branch on external. The surface of hysteresis branch is a value of intensity of corrosion process with pitting character.

The pitting corrosion represents a dangerous behavior of materials at the interaction with external medium, due to the material quantity which pass in the electrolyte medium.

The curve of cyclic polarization obtained Cu-Zn alloy immersed in sea water present the form of pitting corrosion, process which is possible at a small potential, but the corrosion intensity is high.
The obtained layer is not adherent because can be removed by simply deleting with filter paper.

2.4. Structural analysis by electronic microscopy
It was made on a scanning electronic microscope, type VEGA II LSH, manufactured by TESCAN Cehia, coupled with a EDX detector, type QUANTAX QX2, manufactured by ROENTEC Germany.

Figure 5. SEM microstructures in cast state: a) 500x; b) 2000x.

Figure 6. SEM microstructures after corrosion in water: a) 500x; b) 2000x.

Figure 7. SEM microstructures after corrosion in sea water: a) 500x; b) 2000x.
3. Conclusions

The nonferrous alloys can be used in large domain of application for manufacturing the cast parts. The elaboration of nonferrous alloy can be used cast alloys in blocks, pure metals, pre-alloys, metallic waste, recycle material, fondants and modifying additions.

Brasses are copper-zinc alloys. These alloys have good strength and corrosion resistance, although their structure and properties are a function of zinc content. Alloys containing up to approximately 35% zinc are single phase alloys, consisting of a solid solution of zinc and alpha copper.

Brasses are used in applications such as blanking, coining, drawing, piercing, springs, fire extinguishers, radiator cores, lamp fixtures, ammunition, flexible hose, and the base for gold plate.

Brasses have excellent castability, and a good combination of strength and corrosion resistance.

The cast brasses are used in applications such as plumbing fixtures, fittings and low pressure valves, gears, bearings, decorative hardware and architectural trim.

We investigated the effects of natural seawater on the corrosion of a Cu-Zn alloy. In this study, the corrosion behavior of the alloy has been investigated using the open circuit potential measurements, Tafel curves and anodic potentiodynamic curves.

By comparing different samples of marine water indicates that salinity is the primary influence on corrosion behavior near the open circuit potential. At higher anodic potentials, the impact of mineral composition becomes significant.

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