STUDY OF ALUMINIUM BRONZE, MARK CuAl9Mn2

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Abstract: *This paper presents a study on changes in sample properties of aluminium bronze, under the influence of heat treatments. From the aluminium bronzes can be made bars, profiles, strips, bearings, gears, valves, coins, electrical conductors. After the preparation, melting and homogenization of the alloy in high-frequency induction furnace, the alloy was cast in a metal mold. Experimental tests were subjected to measurements of chemical composition, microstructure and hardness.*

Keywords: *bronzes, industrial applications, properties, microstructures, hardness.*

1. The characterization and the use of non-ferrous metal materials

Nonferrous metals and alloys are used in technique due to the physical, chemical and mechanical properties different from those of iron alloys - carbon.

Required to manufacture products metallurgical industries are needed new technologies and modern facilities [1].

Ferrous materials are either very heavy or very light, have high resistance to corrosion, electrical conductivity is very high or very low magnetic properties have special anti-friction qualities.

Ferrous metals production (easily accessible and low natural fragility) are copper, aluminium, nickel, magnesium, zinc, lead, tin, bismuth, cadmium, titanium, molybdenum and their alloys.

Ferrous metals due to low mechanical characteristics rarely used technique; they are used mainly in the form of alloys.

1.1. The characterization and the use of copper-based alloys

The most important copper alloys are brass, bronze and copper alloys - nickel – zinc [2].

Brasses are alloys of copper with zinc, the copper content of which is less than 55%.

Bronze are alloys of copper with tin (Cu + Sn), aluminium copper (Cu + Al) or copper with lead (Cu + Pb).

Tin bronzes containing up to 14%Sn, are highly resistant to corrosion, have good mechanical properties and exceptional anti-friction qualities (low friction). From tin bronzes with factory bars, bands, valves, bearings, art.

Aluminium bronze containing 5…10% aluminium and the remainder copper, and are bronzes with good mechanical and chemical properties.

From the aluminium bronzes are made bars, profiles, strips, bearings, gears, valves, coins, electrical conductors.

Leaded bronzes are copper-lead alloys with 10 to 40%Pb. It is used only for casting the camps or special parts.

Copper alloys - nickel - zinc are very numerous, the main constituents can come in different percentages. The best known is the alpaca that are used for cutlery, measuring instruments, surgical instruments, objects of art and so on, with good looks and corrosion properties.

They are highly resistant to corrosion bronze, high mechanical strength, anti-friction properties but weaker than tin bronzes.

Electrolytic copper wire is used for electrical and alloys of tin, zinc, nickel, aluminium, silicon, manganese, beryllium, phosphorus, lead, chromium[3].

The most common copper alloys are bronze (Cu-Sn, Cu-Al, Cu-Be, Cu-Pb, Cu-Si, Cu-Mn) and brass (Cu-Zn). Refined copper is delivered in the form of bars with different sections, plates, strips, plates, pipes, wires for use in mechanical engineering and electrical engineering, chemical, food, etc. It can process both forming and casting.

Deformable tin bronzes, 2 - 9%Sn, are intended, in annealed and skin-passed, turbine blades, fittings, screws, gears and other machine parts and mechanical resistance to corrosion in air, water, steam and gas, and the cast are machine parts for wear and corrosion resistant: bearings, bearings, valves, couplings, gears, worm wheels, blades, rotors, stators, turbine and pump bodies, bushings.

1.2. Aluminium bronzes (Cu-Al)

Are bronzes less expensive, very resistant to corrosion (9 times stronger than Cu-Sn), high mechanical strength, anti-friction properties but weaker than tin bronzes[2].

Aluminium bronzes are single-phase structure (α) up to 10% Al and biphasic $(\beta \Leftrightarrow \alpha + \gamma)$ more than 10% Al. The alloying elements iron, manganese and nickel finishing the structure and increases the resistance to corrosion and heat. Impurities harmful for these bronzes are bismuth, sulfur and zinc which reduces mechanical and technological properties [4].

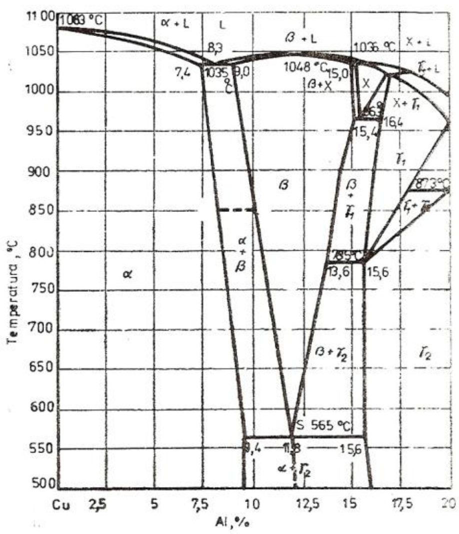


Figure 1: *Cu-Al equilibrium diagram.*

The mechanical characteristics of resistance increase and plasticity decrease by increasing the content of aluminium (Figure 2).

It is noted that these bronzes have superior strength properties of tin bronzes.

Aluminium bronzes have very good casting (components give greater compactness) and plasticity [5].

The deformable bronze by hot or cold rolled, forging, extrusion with 8 ... 11% Al are designed to bodies pressed: valve seats, bushings, slides, pistons rods and the foundry bonzes with 7.5 ... 11%Al are designed for the parts in aviation industry (valve seats, bushings guides), shipbuilding (propellers, rudders, fittings), the hydraulic power plants (superheated steam valves, boiler fittings, parts for steam turbines, housings, gears, snails, worm wheels, rods, shafts, guides).

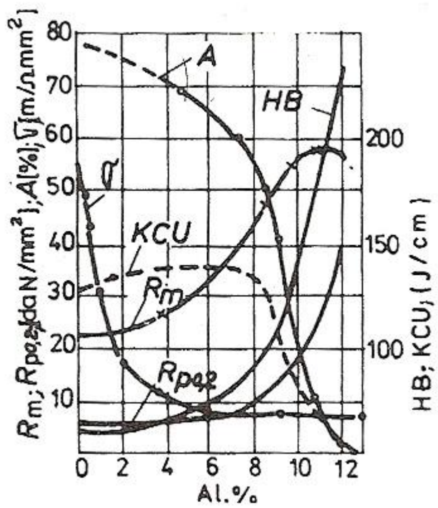


Figure 2: *Influence of aluminium on mechanical characteristics of aluminium bronzes.*

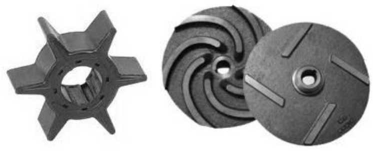


Figure 3: *Rotors for pumps.*

Figure 4*: Gear wheels.*

Figure 5: *Filter carcases, flow meters, sprinklers*.

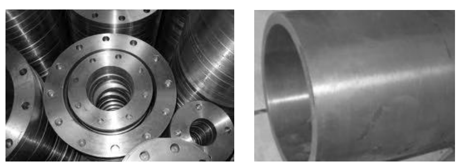


Figure 6: *Flanges and sliding bushings.*

Figure 7: *Pump bodies that work in corrosive medium.*

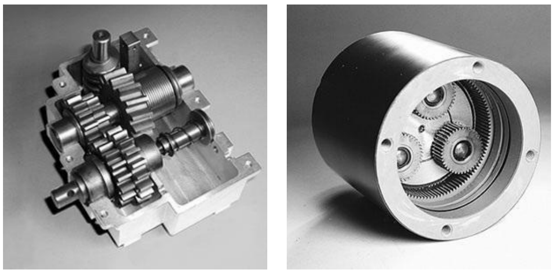


Figure 8: *Helical and planetary gear.*

1.3. Cu-Al-Mn ternary alloys

Metal alloys are systems produced by melting, evaporation, diffusion and sintering of two or more components including at least one metal. Currently alloys are obtained by melting and solidification.

While pure metals consist mainly of a single species of atoms, metal alloys are materials composed of two or more species of atoms belonging to the components of the alloy [5].

The alloys are generally characterized by their superior quality to those of the metal components. Thus, the melting temperature of the alloy is often less than that of the easily fusible component. Hardness and resistance alloys are preferred for modern techniques than pure metals.

Alloys Cu-Al-Mn has applications in medicine. The wires coated with the rosin can be used inside blood vessels. Also, these alloys can manufacture different sizes to use microtubules.

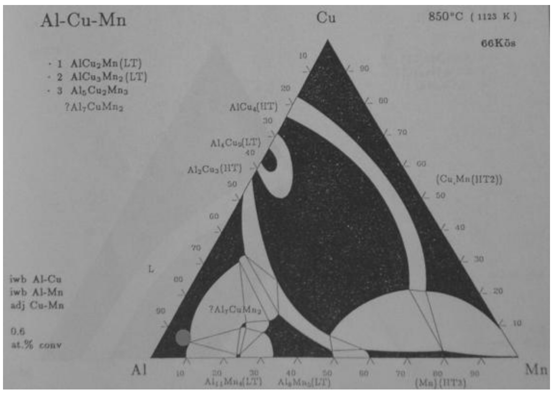


Figure 9: *Cu-Al-Mn ternary diagram at 850°C temperature [6].*

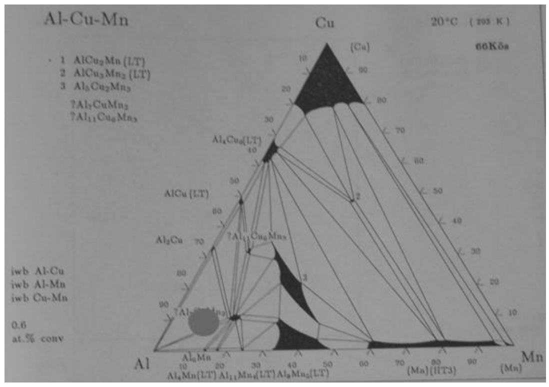


Figure 10: *Cu-Al-Mn ternary diagram at 20°C temperature [6].*

1.4. Heat treatment of non-ferrous alloys

1.4.1. Quenching of non-ferrous alloys

Non-ferrous alloys, depending on the nature and type of the structural changes that take place in the solid state may be heat-treated by hardening of the martensitic type and quenching for release for solution type.

1.4.1.1. Martensitic quenching of non-ferrous alloys

Apply to non-ferrous alloys which present eutectic transformation, such as aluminium bronze, titanium alloys.

Quenching martensitic type, apply the same purpose as ferrous alloys and Fe-C alloys, ie to increase hardness and change in physical and mechanical characteristics by obtaining a supersaturated solid solution in element dissolved out of balance like steel martensite and cast irons.

Quenching of martensite is typical of the bronzes, aluminium alloys with 10-14% Al, which has a eutectoid transformation temperature to 565°C, $(\beta \Leftrightarrow \alpha + \gamma)$, figure 1.

The eutectic is obtained at a concentration of 11.8% Al and has a structure similar to the equilibrium of the steels pearlite.

Quenching martensitic alloys Cu-Al involves heating at a temperature of 650-700°C, hold 1-2 hours to homogenize β phase ($AlCu_3$) and cooling rate greater than 1°C per minute.

After hardening in these alloys needle to obtain a structure composed of β phase in supersaturated Al, metastable, hexagonal network that has hard, present high specific volume and strong tension network.

Transformation-temperature-time diagram and graphic martensitic quenching of Cu-Al eutectic alloy (11.8% Al) is given in figure 10.

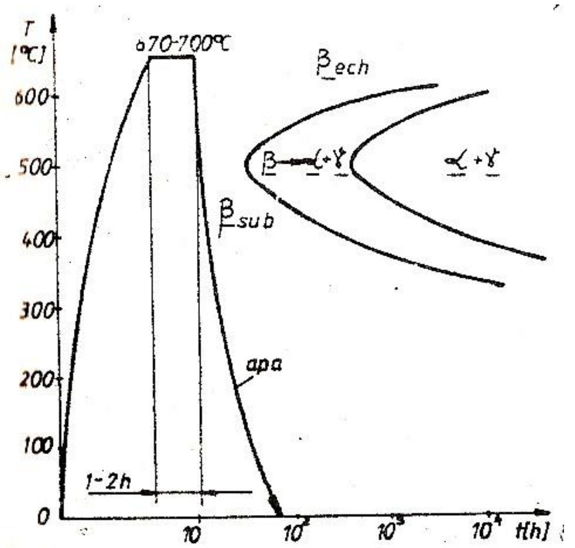


Figure 11: *TTT diagram chart quenching and Cu-Al eutectoid alloy with 11.8% Al.*

After quenching these alloys are very fragile, due to the presence $AlCu_3$ structure near the solid solution phase α (alloys hipoeutectoide) or compound γ (hipereutectoide). For this reason ferrous alloy tempered martensitic state is not used, it is subject to tempering operation as Fe-C alloys.

1.4.2. Tempering of non-ferrous alloys

Always martensitic quenching heat treatment is followed by tempering, to improve the mechanical strength properties.

Ferrous alloys present eutectic after hardening martensitic transformation returns above eutectic transformation temperature, the hardness decreases and decreases fragility.

The aluminium bronzes with 10-14% Al is tempering at temperatures just below 565°C while still achieving high tensile strength and resilience.

2. Experiments on aluminium bronze - mark CuAl9Mn2

2.1. Samples obtaining

Elaboration of alloys based on copper is made in electrical furnaces (especially induction) or oven flame.

Elaboration is the first step in the process of obtaining the alloy. The methods of preparation are different depending on the type of alloy and the same type of alloy, the properties achieved [6].

Specimens were obtained by casting in an induction furnace, using chemicals of high purity Cu, Zn, Al, Mn, Ni, and free of humidity.

Figure 12: *Dosage of alloying elements, in accordance with calculating the load elements.*

At the temperature of development, the interaction with the metal charge in the furnace atmosphere consists of the oxidation or the dissolution of the gas, of which the hydrogen is dangerous, because it is insoluble at room temperature, out of the network and form shrinkage or cracks.

Figure 13: *Melting of alloying elements.*

Figure 14: *Homogenization of alloy.*

Protection against oxidation of the metal bath is made with charcoal, borax ($Na_2B_4O_7$) or flux containing alkali metal halides.

Figure 15: *Metallic shell for casting alloy.*

Figure 16: *Shell preheating before casting alloy.*

After the preparation, melting and homogenization of the alloy in high-frequency induction furnaces, the alloy into a metallic mold.

Figure 17: *Casting the alloy.*

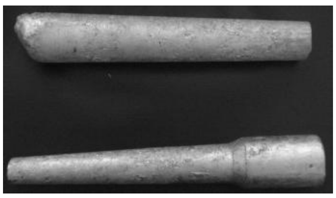


Figure 18: *Moulded specimens.*

2.2. Determination of chemical composition

Analysis of the chemical composition for the cast samples was performed on a spectrometer Foundry Masters, 01J0013 model, produced by WAS Worldwide Analytical Systems AG.

With software programs WASLAB and extensible calibration was obtained an analysis showing the amounts determined by the device.

Composition determined as of the analysis is presented in the following table:

Table 1

Chemical composition of alloy Cu-Al-Mn [%]					
Cu	Al	Mn	Ni	Si	Fe
87.3	10.1	1.96	0.087	0.043	0.4

The alloy studied is categorized as aluminum bronzes for deformation and it is CuAl9Mn2 type.

2.3. Modification of hardness properties through heat treatment

Quenching martensitic of the alloys Cu-Al involves heating at a temperature of 650-700°C, hold 1-2 hours to homogenize β phase ($AlCu_3$) and cooling rate greater than 1°C per minute.

Always martensitic quenching heat treatment is followed by tempering, to improve the mechanical strength properties.

Non-ferrous alloys present eutectic after hardening martensitic transformation returns above eutectic transformation temperature, the hardness decreases and decreases fragility.

The aluminium bronzes with 10-14% Al is back at temperatures just below 565°C while still achieving high tensile strength and resilience.

Changing the properties of the alloy after quenching and tempering can be highlighted by hardness measurements performed on Universal Hardness Testers Wilson Wolpert 751N.

Figure 19: *Wilson Wolpert universal hardness tester model 751N.*

Brinell method is one of the most used methods for determining the hardness of different materials, most commonly being used for heat treatment of metallic materials analysis and those with low to medium hardness.

Heat treatments parameters applied are the following:

Table 2

Heat treatment parameters	
Quenching	- heating 700°C - holding 2 ore - rapid cooling in water
Tempering	- heating 550°C - holding 1 ore - cooling in air

Brinell hardness test conditions:

- Indenter of 2.5 mm
- Weight of 62.5 kgf pressure.

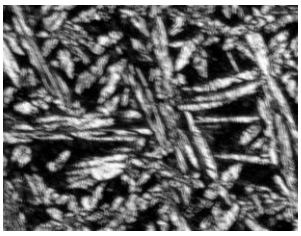
Experimental values of hardness are:

Table 3

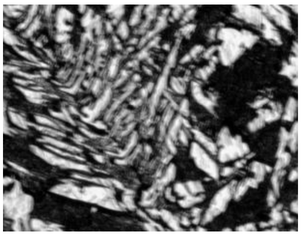
No.	Value	Average
After quenching heat treatment		
1	146,3	145,7
2	138,2	
3	152,7	
After tempering heat treatment		
1	147,6	141,36
2	141,6	
3	134,9	

2.3. Microstructure analysis by optic microscopy

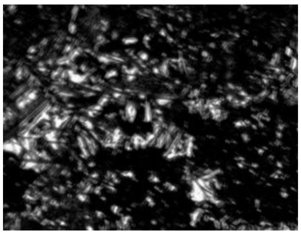
Analysis of the microstructure of the alloys studied was performed on an inverted microscope ZEISS metallographic - AxioObserver D1m model.



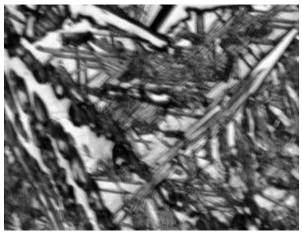
Cu-Al-Mn alloy, casting state, 100X.



Cu-Al-Mn alloy, casting state, 200X.



Cu-Al-Mn alloy, heat treatment state, 100X.



Cu-Al-Mn alloy, heat treatment state, 200X.

3. Conclusions

Metal alloys in the construction of facilities subject to both mechanical and the thermal, so that their inclusion in a system requires consideration of the function.

Physical and structural properties and good, can guarantee a lifetime parts used for various industrial applications.

An important objective of the research is the extension of the scope Cu-Al-Mn type alloys such as electrical components and assemblies, industrial robots, aerospace, solar panels.

Microscopic analysis of the results achieved in the alloy obtained by casting, such as Cu-Al-Mn, present needle structure.

Analyzing the experimental results it can be concluded that the studied alloy Cu-Al-Mn can be easily achieved by the classical method of casting using an induction furnace.

4. References

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