"HENRI COANDA"
AIR FORCE ACADEMY
ROMANIA

"GENERAL M.R. STEFANIK"
ARMED FORCES ACADEMY
SLOVAK REPUBLIC

INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2014
Brasov, 22-24 May 2014

PHASES ANALYSIS AND STRUCTURAL CHARACTERIZATION OF CuAlMnFe ALLOY

Dragoş Cristian ACHIŢEI*, Petrică VIZUREANU*, Mirabela Georgiana MINCIUNĂ*, Bogdan ISTRATE, Andrei Victor SANDU***

*Faculty of Materials Science and Engineering, Gheorghe Asachi Technical University, Iaşi, Romania,
** Faculty of Mechanical Engineering, Gheorghe Asachi Technical University, Iaşi, Romania,

Abstract: *The paper presents a study on alloy CuAlMnFe, analyzed in terms of phases and structural aspects and physical and mechanical properties, after some heat treatments like annealing, quenching and tempering.*

Keywords: *aluminum bronzes, micro-hardness, constituents*

1. INTRODUCTION

The properties of cast alloys are dependent on the chemical composition and structure.

The introduction of one or more alloying elements in the metal alloy can be obtained for various compositions, structures and properties that will be suitable for technical purposes.

Forming the non-ferrous alloys is influenced by development conditions and the configuration of the parts and on the casting and cooling thereof.

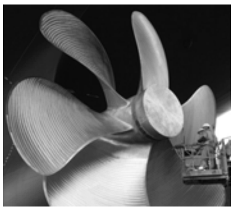
The most important copper alloys are brasses, bronzes and copper alloys - nickel - zinc.

Bronzes are characterized by good mechanical properties, superior castability and good corrosion resistance.

Alloying elements contained in a bronze may have influence on the properties:

- Aluminum - improves castability and plasticity.
- Silicon - increases the fluidity.
- Manganese - improves elasticity and electrical resistance.
- Lead - improves plasticity and anti-friction properties.
- Nickel - increases the mechanical strength and electrical resistivity.
- Beryllium and titanium - add further strength.

Table 1
Applications of aluminum bronzes


Valve case for railway industry [3]	Bearing pivoting for medical applications[3]
	
Clutch components for ship winch system [4]	Rough-cast wheel gearbox [4]
	
Fittings [7]	Spare parts [5]
	
Valve case for railway machines [3]	Six propeller blades used to propel the ship. It weighs 107 tons and is 9.1 meters in diameter [6].

Aluminum bronze are alloys of copper - aluminum containing up to 15 % Al , which may also contain other added materials (iron , silicon , lead , manganese , nickel) in order to improve certain physico - chemical properties [1,8] .

According to the Cu- Al equilibrium diagram (fig. 1), the structure of aluminum bronzes can be found:

- Phase α - solid solution of aluminum in copper substitution, with face-centered cubic lattice. The solid solubility limit is 7.4 % Al to 1037°C and is increased to 9.4 % at 570°C, remains approximately constant up to the normal temperature;
- β phase - intermediate solid solution based on electronic compound Cu_3Al, report $n_e/n_a = 3/2$;
- phase γ - is formed on the basis of a novel compound of formula $Cu_{32}Al_{19}$ electronic and electronic concentration and the changes in the ordering phenomena due to solid state at 780...870°C [1,9] .

β phase stable at high temperature undergoes eutectoid decomposition temperature of 570 ° C and 11.8 % Al : $\beta \overset{570°C}{\Leftrightarrow} \alpha + \gamma'$.

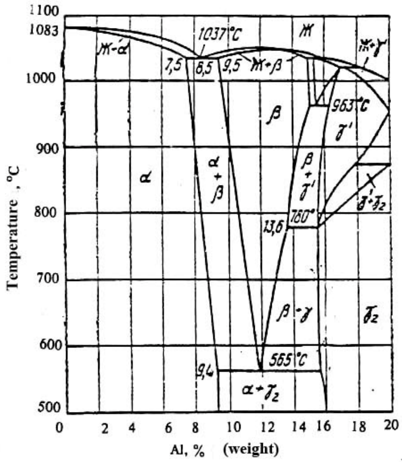


Fig.1. Cu-Al equilibrium diagram [2].

The structural constituents of the aluminum bronzes [1] according to the composition and the cooling rate are shown in table 2.

Table 2

Composition % weight		Equilibrium constituents after slow cooling – annealing	Equilibrium constituents after rapid cooling – quenching
Cu	Al		
100 … 92.5	0 ... 7.5	α	α
92.5 … 91	7.5 … 9	α	α + β
91 … 88.2	9 … 11.8	α + γ’	β → α + β
88.2 … 84	11 … 16	α + γ’	β → β + γ’

2. EXPERIMENTAL TESTS

a. **Chemical compositions determination**

Chemical composition determinate by spectral analysis, made on Foundry Masters optical spectrometer, is presented in table 3.

Table 3

Cu	Zn	Sn	Mn	Fe
88.8	0.0985	0.0053	1.97	0.741

Si	Cr	Al	As	Co
0.0637	0.0265	8.19	0.0097	0.015

Based on analysis bulletin, was establish that the studied alloy was from aluminum bronzes classes, type $CuAl_8Mn_2Fe_1$.

b. **Optimum heat treatment applied to studied aluminum bronze**

Heat treatments parameters recommended to studied bronze are the following:

- Annealing:

- heating 850…950°C
- cooling in air or once furnace.

- Quenching:

- heating 850…900°C
- maintaining 6…8 min/mm thickness sample
- rapid cooling in water or oil.

- Tempering:

- heating 380…420°C
- maintaining 2…3 min/mm thickness sample
- cooling in air

c. **Investigation using X-ray diffraction**

X-ray diffraction is a non -destructive analytical technique versatile, and with the help they can get information on the identification and quantification of various crystalline compounds known as "phase" compounds that are present in the material.

We analyzed and characterized, and structural roentgeno method based on X-ray diffraction crystallographic planes of the structure, the alloy CuAlMnFe.

Determination of structural constituents is by diffraction is the dependence of the diffracted radiation intensity and double diffraction angle.

Determination of the compositional phases was carried out by qualitative analysis by X - ray diffraction, X -ray diffraction carried out to Panalytical X'Pert PRO MPD.

Scope of analysis was between 2θ = 20-120°, step size being 0.0010, and the time step is 3 seconds / step.

It was used a proportional detector with a single channel, the analysis is performed as Gonio.

The analysis of copper alloys by X-ray diffractometry, the samples will be obtained from the system alloy, Cu-Al-Mn-Fe section having Ø15 mm and sample length 20 mm.

Figure 2 shows the diffraction pattern obtained for alloy CuAlMnFe - after annealing.

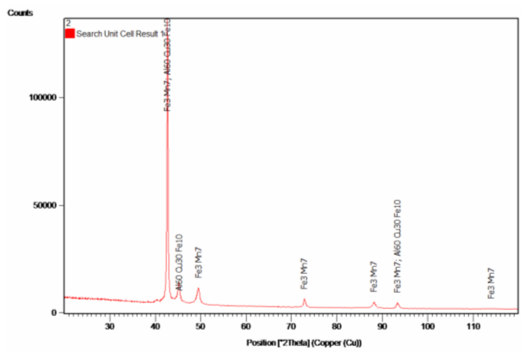


Fig.2. X-ray diffractogram (indexed) obtained for alloy CuAlMnFe - annealed

X-ray diffraction is the process by which the radiation, to wave lengths without change, is converted by interfering with the crystal lattice of a large number of "reflection" of the observable characteristic spatial directions.

Indexing diffractometry is the association of maximum - diffraction peak and a plan. Indexing diffractogram reveals the following: The test phases are present as majority: Fe_3Mn_7 with cubic crystal lattice, with the main peak at 2θ = 42.6430 and $Al_{60}Cu_{30}Fe_{10}$ angle with cubic crystal lattice, with the main peak at 2θ = 42.8920 angle.

Figure 3 shows the diffraction pattern obtained for new alloy CuAlMnFe - after quenching heat treatment.

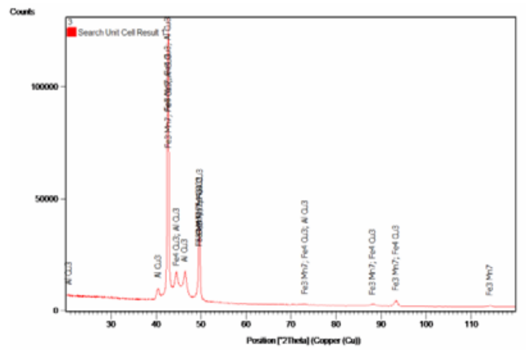


Fig.3. X-ray diffractogram (indexed) obtained on the sample CuAlMnFe - quenched condition.

Indexing X-ray diffraction pattern reveals the following:

The test phases are present as majority: Fe_3Mn_7 with cubic crystal lattice, with the main peak at 2θ angle = 42.54540 and Cu_3Fe_4 with cubic crystal lattice, with the main peak at 2θ = 42.1160 angle.

As a minor phase present $AlCu_3$ compound crystallized in the orthorhombic system, with the main maximum at the angle 2θ = 44.7910.

Figure 4 shows the diffraction pattern obtained for sample CuAlMnFe - after heat treatment tempered.

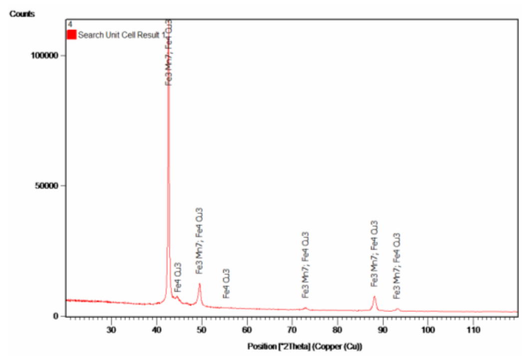


Fig.4. X-ray diffractogram (indexed) obtained for sample CuAlMnFe - tempered condition.

X-ray structural analysis is the method by which the direction and intensity of these reflections is measured and deducted order atoms.

The sample CuAlMnFe tempered condition is present as majority phases: Fe_3Mn_7 with cubic crystal lattice, with the main peak at 2θ = 42.6430 and Cu_3Fe_4 angle with cubic crystal lattice, with the main maximum at the angle 2θ = 42.59770.

d. **Dilatometric analysis**

The purpose of the experiments is the record length (Δl) that a sample undergoes when subjected to a certain temperature.

Dilatometer L75 is suitable for both the expansion and the contraction of the sample. Dilatometer analysis in this paper was performed using differential dilatometer L75H/1400 LINSEIS type (fig. 5).

Using large samples promotes good accuracy for determining elongation, instead using small samples ensures a good temperature control precision and repeatability of results.

To obtain accurate and repeatable experimental data is recommended that the dilatometer to work with relatively low speeds of approx. 5 to 10 °C/min.

The heating rate was required for the experiment at 10 °C/min.

Fig.5. Linseis L75H / 1400 dilatometer.

After applying heat treatment, the samples with specific size dilatometer tests were carried out dialatograme heating from ambient temperature to 900 °C.

The dilatograms, obtained for CuAlMnFe alloy, have the shape of the specific of alloy shown in figures 6, 7, 8.

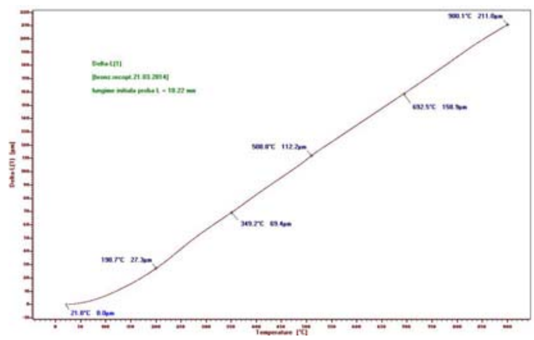


Fig.6. Dilatogram of alloy after annealing.

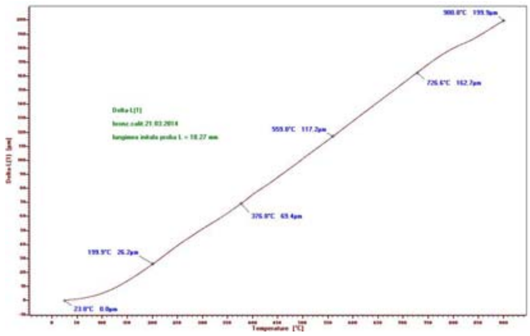


Fig.7. Dilatogram of alloy after quenching.

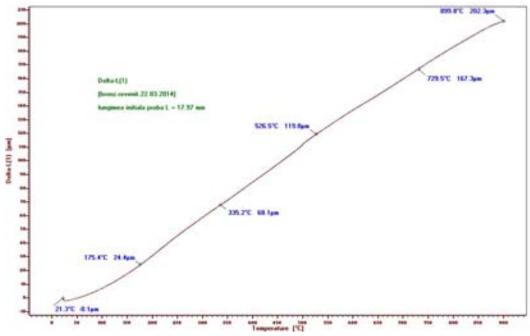


Fig.8. Dilatogram of alloy after tempering.

It was found that the samples were small oscillations of length, elongation is approximately 200µm, in any state of heat treatments that the samples are.

e. **Micro-hardness measurements**

To highlight the efficiency of heat treatments, applied to CuAlMnFe bronze, was made HV100 micro-hardness measurements on heat treated samples.

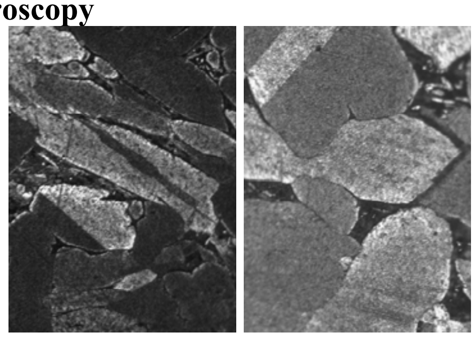
The measured values of micro-hardness are presented in table 4.

Table 4

Heat treatment	Measured micro-hardness in points / sample	Average value / sample
Annealing	181.40	175.84
	174.68	
	171.46	
Quenching	328.73	301.32
	304.83	
	270.41	
Tempering	217.02	203.39
	184.91	
	208.24	

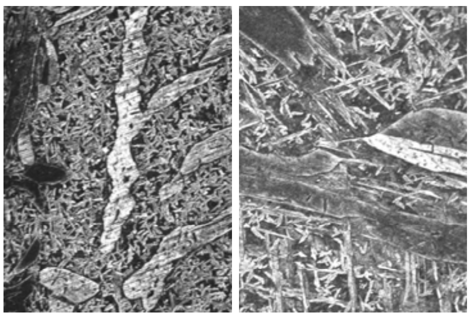
All the measurements of micro-hardness for studied aluminum bronze were in the specific values to the heat treatments applied. The quenching effect to hardness is visible, but the decrease of hardness after high tempering is specific to mechanical parts used in industry.

f. **Microscopic analysis by optic microscopy**



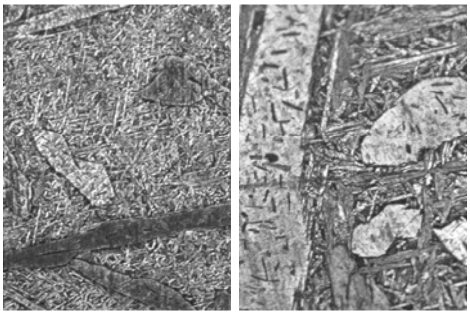
100X 200X

Fig.9. Alloy microstructure, annealing state, ammonium persulfate attack.



100X 200X

Fig.10. Alloy microstructure, quenching state, ammonium persulfate attack.



100X 200X

Fig.11. Alloy microstructure, tempering state, ammonium persulfate attack.

In annealing state, the studied bronze has a homogeneous structure composed by α solid solution, recrystallized in the form of polyhedral grains with macles and γ' phase, in smaller quantity and uniformly distributed.

After quenching and tempering heat treatments application, in the structure in addition to α Solid solution phase, appear and β phase, which improve the mechanical characteristics of alloy.

3. CONCLUSIONS

Phases composition of the unit cell structure and characteristics of each phase identified were determined by X-ray diffraction, and the main objective was to determine the phase composition, microstructure and of alloy composition CuAlMnFe after applying heat treatments annealing, quenching and tempering.

Physical and structural characteristics analyzed in the paper falls within the specific parameters of the alloy and can guarantee a good lifetime for industrial applications based on aluminum bronze.

4. REFERENCES

1. Gâdea Suzana, s.a., *Îndrumar de laborator pentru metalurgie fizică – structura materialelor metalice,* Editura Didactică şi Pedagogică, Bucureşti (1967).

2.http://pwatlas.mt.umist.ac.uk/internetmicroscope/index.html

3.http://www.piad.com/aluminum-bronze-alloys.html

4.http://www.copper.org/publications/newsletters/innovations/2002/08/aluminum1.html

5.http://www.indiamart.com/mamahamaya-engineering/products.html

6.http://images.businessweek.com/ss/06/05/supership/source/6.htm

7.http://www.sabtek.co.uk/aluminium.asp

8. Cimpoesu, N., s.a., *Behavior simulation of a cooper shape memory alloy under an external solicitation*, Journal of optoelectronics and advanced materials, ISSN 1772-1776, (2010).

9. Achitei, D.C.; Vizureanu, P.; Stanciu, S.; et al., *Studies concerning thermal conductivity for some copper base memory shape alloys,* Conference: 14th International Conference on Modern Technologies, Quality and Innovation - ModTech 2010, NEW FACE OF TMCR, PROCEEDINGS Book Series: Proceedings of the International Conference ModTech, pages: 15-18, (2010).