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Researches on the structure and properties of heat treated, nickel alloyed, molybdenum modified aluminum bronze

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The changes, after heat treatment, in the microstructure and hardness of copper-aluminum alloys, additionally alloyed with Ni and modified with Mo are investigated and described in the present study. The changes in the microstructure largely are determined by the presence of Ni in the composition of the alloy. The investigations were made for a case when the content of additional alloying element is fixed on 3%. Modification was made by addition of 0.1% Mo.

Key words: copper-aluminum alloys, modifiers, heat treatment, structure.

INTRODUCTION

The increase of aluminum content, in two-phase (duplex) Cu-Al alloys, from 8% up to10% leads to a progressive strengthening, due to the appearance of harder, body centered cubic beta-phase, which additionally makes the bronzes more suitable for hot working and casting. Ni alloyed, heat treated aluminum bronzes are ones with the highest strength among the nickel-bearing aluminum bronzes. They exhibit excellent yield and compressive strength, high hardness and adequate elongation. They are a good load-bearing material, suitable for heavy-duty machine details and such exposed of high impact. The additional increase of the strength is achieved through a heat treatment. The material exhibits excellent corrosion and heat resistance, good machinability and weldability. It is used for bushings and bearings of heavy duty, gears, and wear parts. It find application in the marine as pump parts, machine tool parts, aircraft parts, as well for military applications. The most often is used in the aircraft landing gear as bearing components [1, 2, 6, 8].

The primary fine-grain structure in aluminum bronzes are achieved by adding different refractory elements during the casting process. The changes in the microstructure (the magnitude and shape of the metal grains) of the alloys are provoked by modifying effect of these elements, and to large extent from the presence of Fe in the alloys. The optimum concentration of modifiers, according to the data cited in popular scientific literature, is between 0.05 to 0.5%.

EXPERIMENTAL EQUIPMENT, METHODS AND MATERIALS

Melting of the charge materials (electrolytic copper, aluminum, nickel and molybdenum) was carried out in a laboratory induction furnace MRA8-25 with graphite crucible. The casting temperature was 1130–1140 °C. The produced samples are cylindrical, with diameter 25 mm.

The effect of nickel alloying and molybdenum modifying was evaluated on the obtained alloys of a type CuAl9. Data for changes in the structure and hardness of the specimens as well for the effect of different heat treatments (Fig. 2–5) have been obtained, as these characteristics change in the cases of alloying (Fig. 1b–5b) and modifying with molybdenum (Fig. 1c–5c). The samples are prepared for examination by a standard technique [4] and micro-photographs of the alloys were made at a magnification 63x.

HEAT TREATMENT

The heat treatment of samples was conducted in a laboratory electric resistance furnace in several

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Table 1. Regimes of heat treatment on the investigated alloys

Regimes	Heat treatment	Temperature	Time	Cooling
1	Quenching	875 °C	60 min	In water
2	Ageing	300 °C	120 min	In furnace
3	Ageing	400 °C	120 min	In furnace
4	Ageing	500 °C	120 min	In furnace

stages. Initially, they were subjected to quenching, then to artificial aging regimes [7–9] (annealing temperatures) shown in Table 1:

INVESTIGATION OF THE STRUCTURE

Nickel-aluminum bronzes, generally, are two-phase duplex alloys containing aluminum and additionally nickel for increase of the strength. The different aluminum content of the cast alloys (Fig. 1a–1c) and alloying with 3% Ni (Fig. 1b–5b) and on the other hand alloying with 3% Ni and modifying by molybdenum (Fig. 1c–5c) resulted in markedly different microstructures. Hence, seemingly small variations in composition can lead to changes of the phases, developing in the stucture.

ESTIMATION OF THE HARDNESS

The hardness was determined to Brinell method (BS 1SO 6506). Measurement was made by a sphere with a diameter 2.5 mm, 187.5 kgf (1840N). Graphically, on Fig. 6 are presented measurements of the hardness for different regimes of heat treatment of investigated cuprum-aluminum alloys. The analysis of the results shows that the hardness tends to increasing with the increase of ageing temperature for specimens in cast, well as in quenched condition. This most likely is due to the partial dissolution of the phase, obtained in a time of the primary crystallization of the (α+γ) eutectoid, whose hardness and brittleness are higher.

RESULTS AND DISCUSSION

The subject of this paper was the evaluation of the effect of a small change in composition of aluminum bronzes on the microstructure, as well the evaluation the effect of alloying with Ni, modifying by Molybdenum and heat treatment on the hardness . Based on only three compositions and four regimes of heat treatment we make the next primary conclusions: Nickel alter and improve uniformity of the cast structure, raises hardness, and act as microstructure stabilizer. Nickel-aluminum bronzes are complex alloys in which small variations in composition can result in the development of markedly different microstructures, which can, in turn to result in wide variations in properties. Specifically:

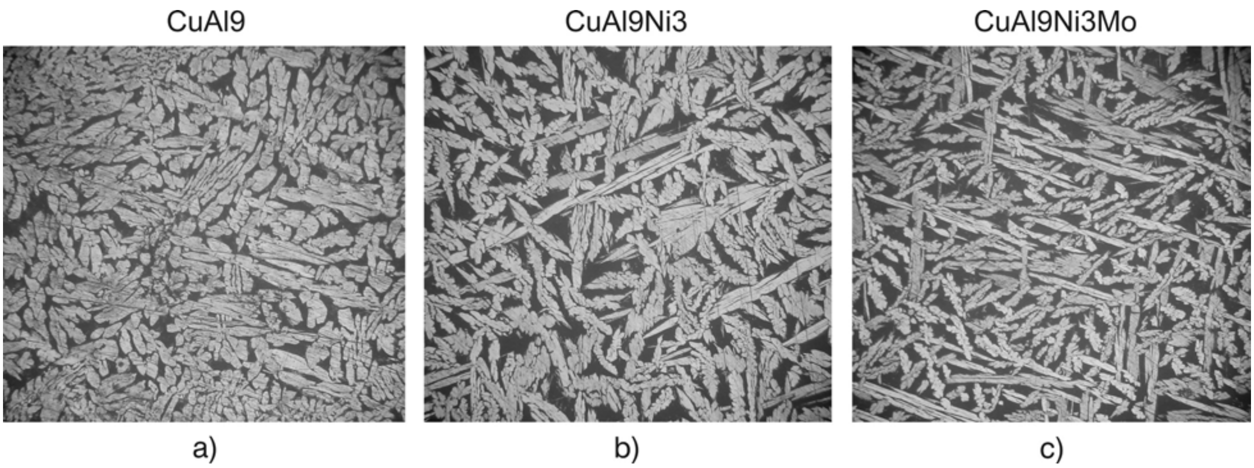

Fig. 1. Microstructures of investigated alloys in cast condition

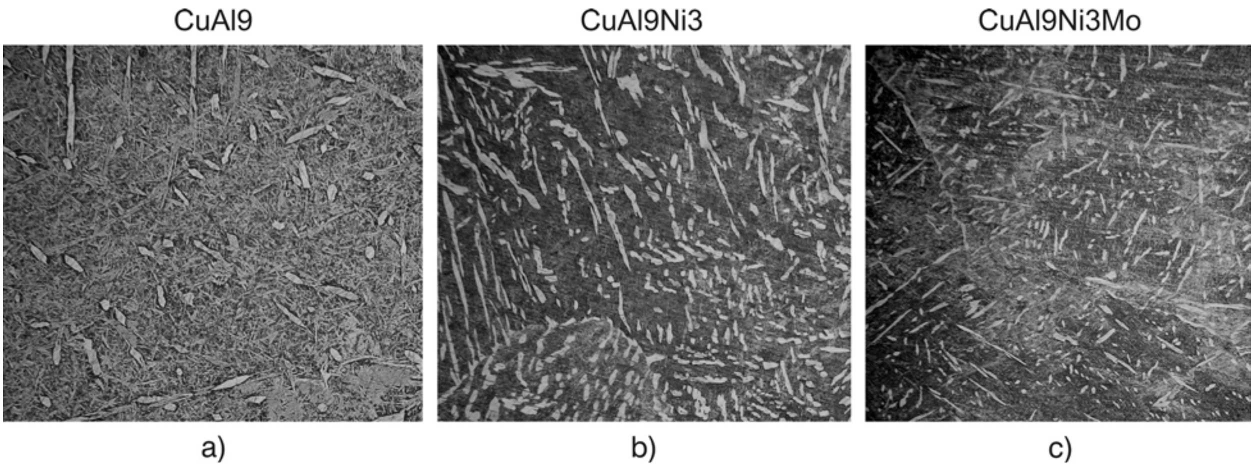

Fig. 2. Microstructures of investigated alloys in quenched condition

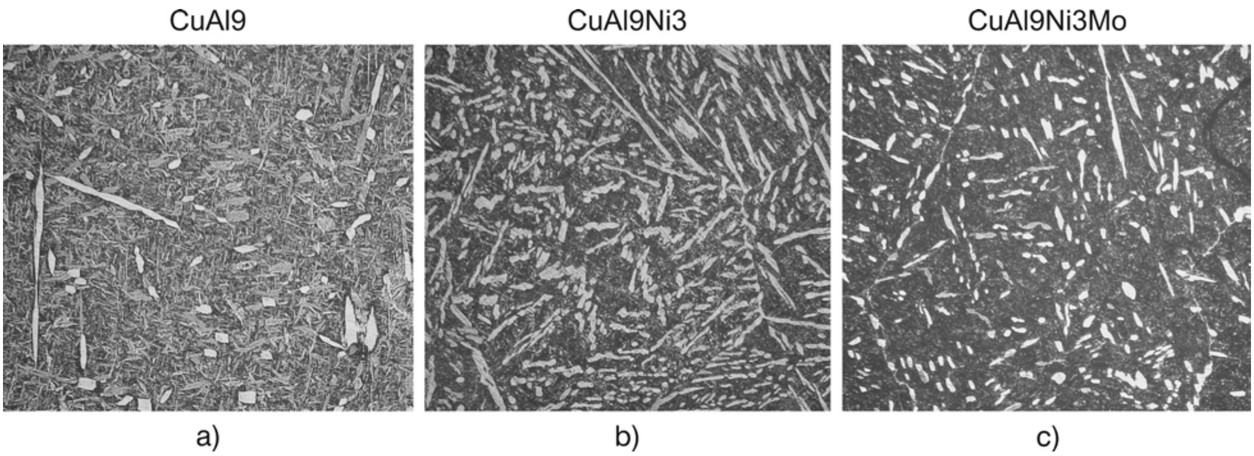

Fig. 3. Microstructures of investigated alloys after ageing at 300 °C for 2 hours

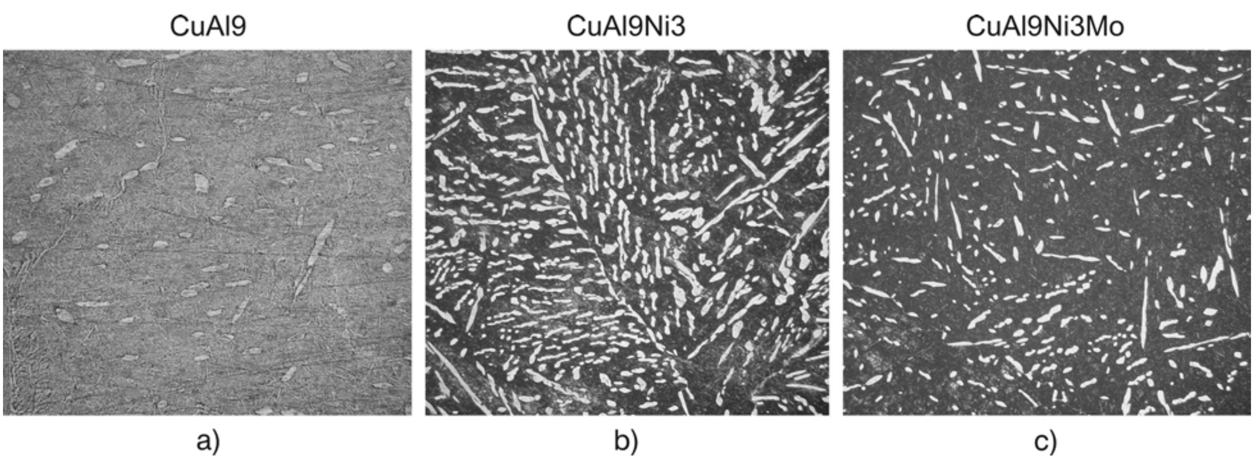

Fig. 4. Microstructures of investigated alloys after ageing at 400 °C for 2 hours

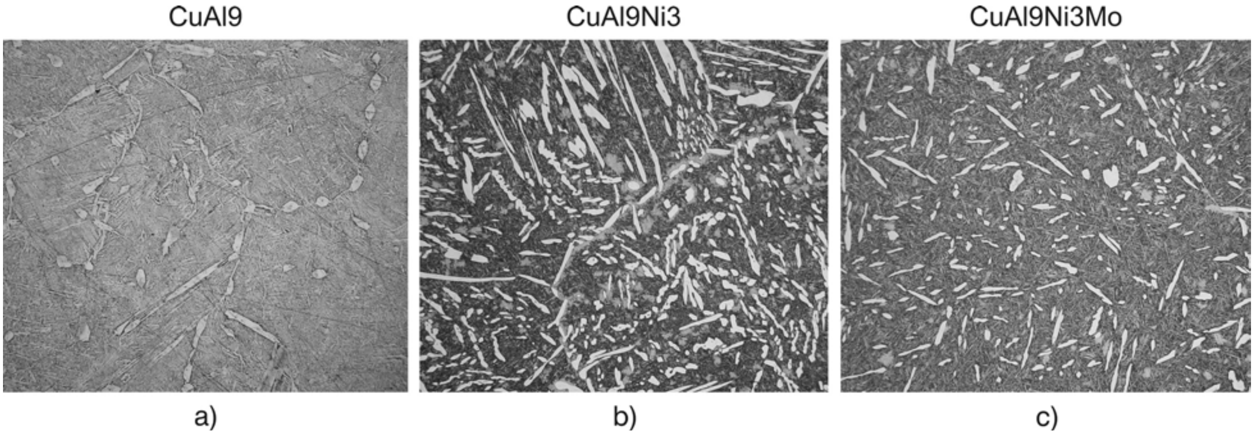

Fig. 5. Microstructures of investigated alloys after ageing at 500 °C for 2 hours

• The analysis of the structures shows, that for the basic CuAl9 alloy (Fig. 1a–5a) after the different heat treatments the structure becomes finer and with a relative decrease in the amount of the eutectoid component.

• Adding of nickel in aluminum bronze (Fig. 1b–5b) leads to a change in the form of eutectoid crystals - they elongate and acquire form similar to Widmanstatten structure plus intercepts of martensite or bainite between releases of the second phase (Fig. 2b–5b). This can be confirmed with certainty at higher microscopic magnification and by measuring the micro-hardness of the different structural elements. (These studies will be the subject of our next work).

• The modification of a nickel-aluminum bronze with molybdenum leads to keeping the acicular nature of the structure and visible refinement of the eutectoid component (Fig. 1c–5c).

• In regard to the hardness, adding of nickel in the aluminum bronze leads to an overall increase of the hardness (Fig. 6) compared with the base alloy. The explanation is that nickel hampers the eutectoid decomposition. The β-phase is kept, and the struc-

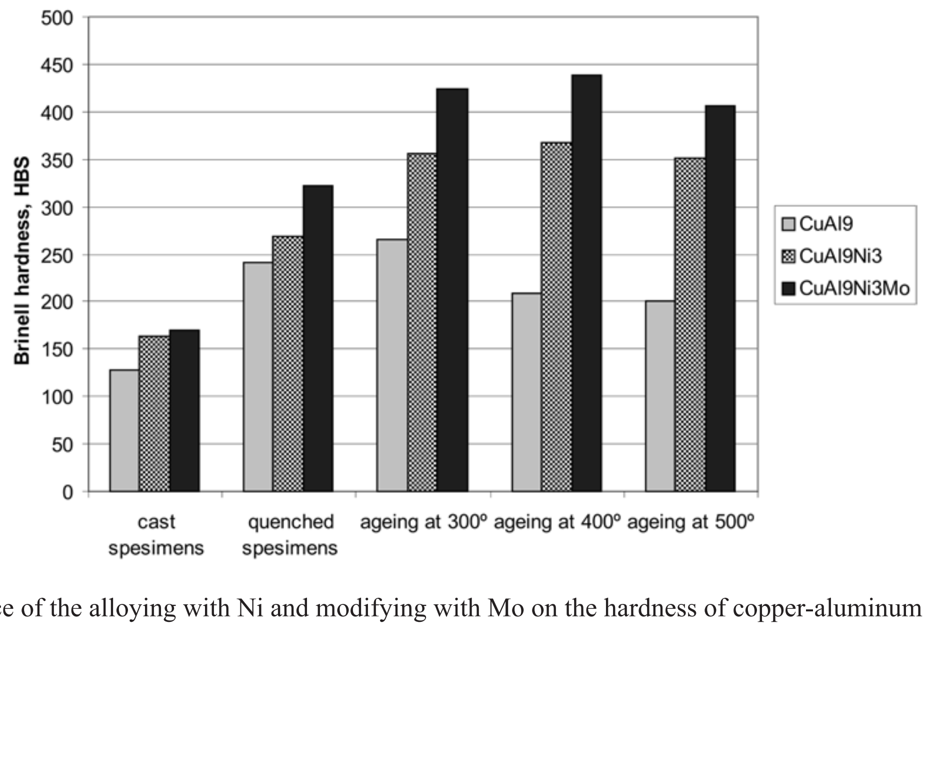

Fig. 6. Influence of the alloying with Ni and modifying with Mo on the hardness of copper-aluminum alloy

ture became fine-grained. Modification of the alloy with molybdenum causes refinement of the structure, a base for further increase of the hardness. The tendency of hardness increasing with the increasing of ageing temperature to 400 °C is kept.

• At high temperature aging – 500 °C, and holding time 2 hours, the measured hardness values marked fall. This fact shows that the optimal mode of heat treatment after quenching of alloys of this type should not exceed 400 °C.

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ИЗСЛЕДВАНЕ НА СТРУКТУРАТА И СВОЙСТВАТА СЛЕД ТЕРМИЧНО ОБРАБОТВАНЕ НА МЕДНО-АЛУМИНИЕВИ СПЛАВИ, ДОПЪЛНИТЕЛНО ЛЕГИРАНИ С Ni И МОДИФИЦИРАНИ С Mo

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(Резюме)

Настоящото проучване установява промените в микроструктурата и твърдостта, настъпили в резултат на термично обработване на медно-алуминиеви сплави, допълнително легирани с 3% Ni и модифицирани с 0.1% Mo. Закаляването на легираните с никел алуминиеви бронзи води до общо повишаване на твърдостта в сравнение с базовата сплав, а допълнителното модифициране с молибден предизвиква издребняване на структурата и също води до повишаване на стойностите ѝ. В резултат на приложените различни режими на отвръщане, в изследваните структури са констатирани промени по отношение на едрината и разпределението на отделената втора фаза, а стойностите на твърдостта значително се повишават.