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Presented paper No. *2577711019* ***Entitled***

The Effects of Aging Treatment Parameters on Microstructure and Hardness of Aluminium Bronze Alloy

In ICMH 2012 -May 30-31 st ,2012
Hotel Abbasi, Isfahan, Iran.

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nternational Confrance on
Materials Heat Treatment
CMH 2012

Isfahan, Iran, May 30-31
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Abstract :

In the present study, the effects of aging treatment parameters on microstructure and hardness of aluminium bronze C95500 was investigated. Different parameters in aging treatment were aging temperature, aging time and quenching environment. Microstructure and hardness were examined by optical microscopy, scanning electron microscopy (SEM) and Vickers hardness tester respectively. Different phases were detected. The experimental results demonstrated that after quenching, all β phase transforms to martensite phase β′ and after aging, α and κ phase were precipitated from matrix (β′), moreover, the dispersed κ phase are the dominant factor that improves the hardness of alloy after a solution at 1000 °C for 1 h followed by quenching at saltwater and aging at 300 °C for 2 h. With regard to quenching environment, saltwater leads to highest hardness both in as-quenched and aged samples.

Keywords : nickel-aluminum bronze, aging heat treatment, precipitation, hardness

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The Effects of Aging Treatment Parameters on Microstructure and Hardness of Aluminium Bronze Alloy

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1- Abstract

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2- INTRODUCTION

Nickel-aluminum bronze is a series of copper-based alloy with additions of aluminum, nickel and iron. Combined with high strength, it shows good resistance to corrosion and wear, which makes it one of the most versatile engineering materials and has replaced the binary aluminum bronze in many applications [1-4]. It is widely used as engineering parts, such as various worm-gears, gears, bearings, dies, valves and propellers [5]. These alloys contain 8–14% Al and approximately about 1–5% Mn, Ni and Fe, and the casting process is not carried out much easily because they require much bigger gating systems in comparison with the others [6].

The mechanical properties of these bronzes depending on their chemical compositions can be improved significantly with heat treatments. For example, the value of tensile strength subjected to the heat treatment approaches over 700 MPa. On the other hand, it is not possible to take a reasonable result from the heat treatment processes in Al-bronzes consisting of nearly 8–9.5% Al when the value of other elements is less than 2% [6]. In general, the properties such as hardness, toughness and elasticity of any Al-bronzes are much higher than that of Sn-bronzes. Meanwhile, any duplex (a + ß) Al-bronze is much more apt to form Al-oxide than all α-Al-bronze. But their fatigue limits with respect to manganese and copper bronzes are much higher [7]. Some researchers have investigated the seawater corrosion of nickel-aluminum bronze. They conclude that nickel-aluminum bronze is susceptible to dealloying corrosion in the cast condition due to the presence of phase, which is anodic with respect to the *a* matrix [8]. During casting of large components the cooling rates encountered are often of the order of 10^{-3} Ks^{-1}; accordingly the bcc-phase formed during solidification transforms to the fcc primary-phase with a Widmanstatten morphology beginning at about 1030◦C [9] .Heat treatments, in the forms of quenching, normalizing and aging, improve the tensile strength and hardness, with a corresponding fall in elongation. Annealing raises the elongation but reduces the tensile strength and hardness of the experimental materials [1].

Because of the complex nature and small volume fraction of many phases present in nickel aluminum bronze, and the non-equilibrium cooling conditions usually encountered, identification and analysis of the phases and the mechanisms by which they are produced have proved difficult to determine. The amount and distribution of the phases in nickel aluminum bronze and their chemical composition has a significant effect on the properties of this material [3].

The purpose of this study is to investigate the effect of aging heat treatment parameters on the microstructure and hardness of nickel-aluminum bronze.

3- EXPERIMENTAL

The nominal chemical composition of the experimental material is given in table 1.

Tabl1. Chemical composition of experimental material.

Element	Al	Ni	Fe	Mn	Cu
Wt. %	9.5	4.6	4.1	1.1	balance

Heat treatment cycle is given in fig. 1. Solid solution treatments subjected to all specimens and followed by quenching in different environment include compressed air, oil, water and 10%-salt water solution.

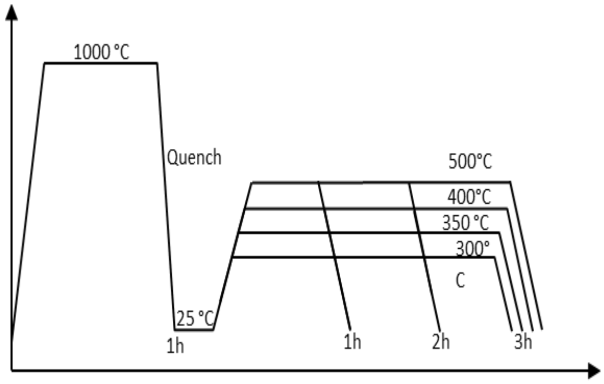

Fig.1. Heat treatment process applied to specimens.

Different parameters in aging heat treatment were aging temperature and time. The specimens were polished and etched with the solution of 5g $FeCl_3$ + 5mL HCl + 100mL H_2O. Microstructure of the experimental material was analyzed by optical microscopy and scanning electron microscopy with energy dispersive spectroscopy and hardness was measured by Vickers tester with a load of 30kg.

4- Result and Discussion

Microstructure of as-cast specimen is given in fig. 2. It can be expected that α-Cu, α+ß, Cu_3Al, Cu+$NiAl_2$ (ß), Al+$FeNiAl_9$ and Cu_3NiAl_6 phases to be formed base on the phase diagram of Al-Cu-Ni, Al-Fe-Ni and Al-Cu in [10]. Since the practical cooling speed is higher than that under equilibrium condition, the alloy is composed of α, β', γ_2, and κ phases. After aging α phase grows at the ß grain boundaries and along crystallographic panes to form a Widmanstatten structure. Various forms of the κ-phase are evident in cast aluminum bronze. These were identified as follows: κ_I a rosette form of composition 6%Al, 8%Ni, 69%Fe, 13%Cu. κ_{II} and κ_{III} a globular or lamellar form of composition 18-20%Al, 23-34%Ni, 26-43%Fe, 13-20%Cu. κ_{IV} a fine precipitate within the α grains, thought to be iron-rich [3].

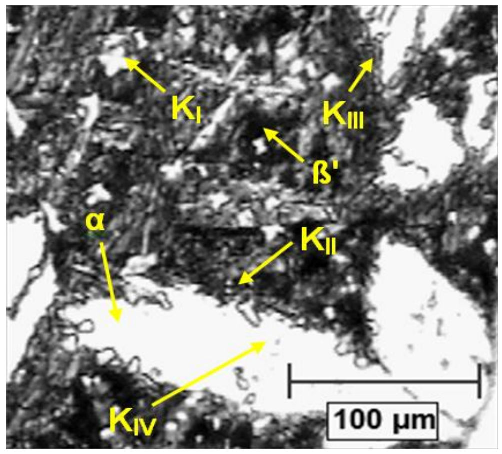

Fig.2. Microstructure of as-cast specimen

Duma [11] investigated the structure and analysis of the κ phases and identified their morphologies. Fig. 3 shows Chemical analysis of precipitated phases of the specimen which subjected to solution treatment at 900 °C for 1 h followed by quenching in 10%saltwater solution studied by EDS. The microstructure of specimens which were subjected to the solution treatment at 900°C for 2 h and the aging at 350, 400 and 500°C for 2 hour showed in fig. 4. Microstructure of quenched samples still consist of α, ß' and κ phases.

Martensite transformation occurred on ß phase during quenching and the volume fraction of ß' increased due to the dissolution of α and κ phases. After aging the samples in different temperature, fine κ phase was precipitated from the as-quench microstructure of ß' phase. However, κ phases precipitated during aging was finer than that precipitated during casting. On the other hand, α phase growth with diffusion mechanism as the aging temperature increased.

Since hardness of α phase (174 HV) is lower than ß' phase (370-290 HV), the hardness of specimens that aged in higher temperature which consist of more volume fraction of α phase decreased. Furthermore increasing in aging temperature caused more κ phase precipitate. Since κ phase is very hard

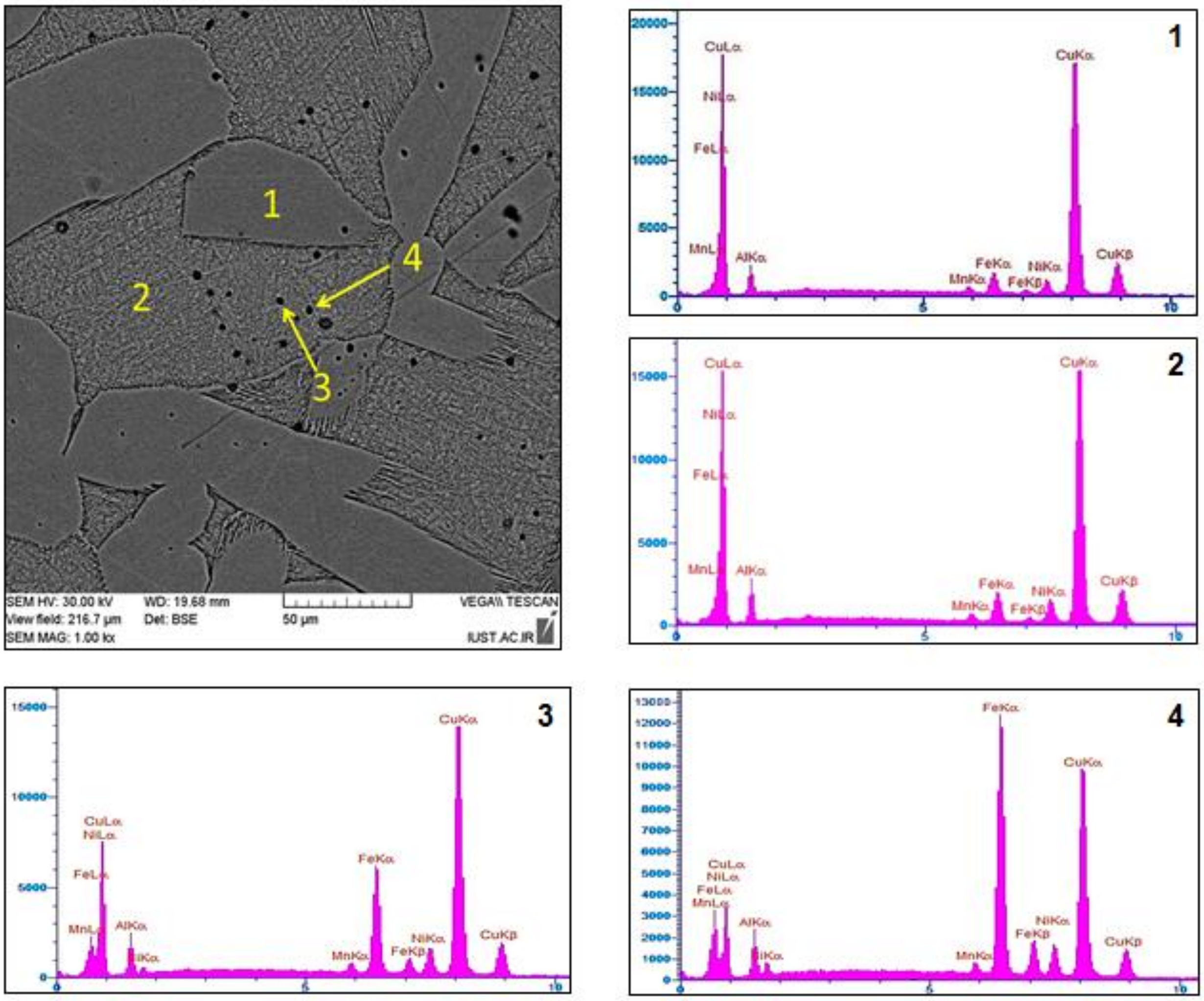

Fig.3. SEM image and EDS analysis of precipitated phases of the specimen which subjected to solution treatment at 900 °C for 1 h followed by quenching in 10%saltwater.

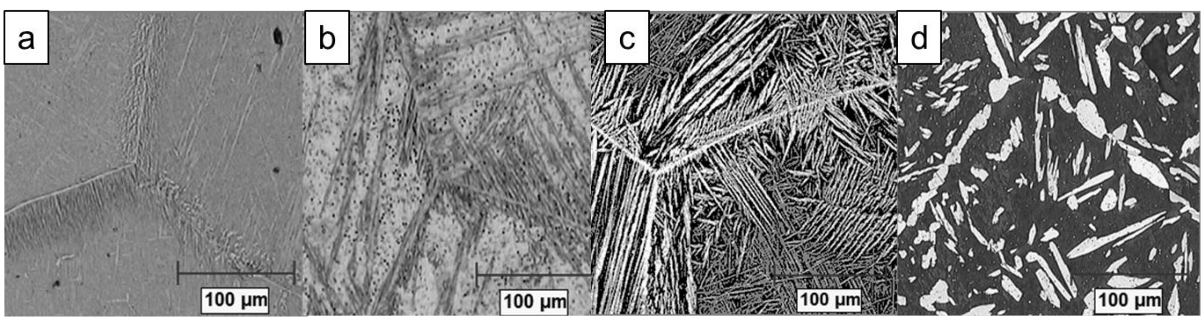

Fig.4. Microstructure of heat treated specimens, a) as-quenched specimen solution treated at 900 °C for 2h, aged specimens for 2h at b) 350°C, c) 400°C, d) 500°C.

fine phase with hardness more than 700 HV [3], there is a competition between decreasing in hardness by precipitating and growth of α phase and increasing in hardness by precipitating fine and appropriate distributed κ phase.

Fig 5 shows that there is an optimum point in hardness vs. aging temperature curve. As showed in fig 5 in elevated temperature the effect of aging temperature on hardness dominate the

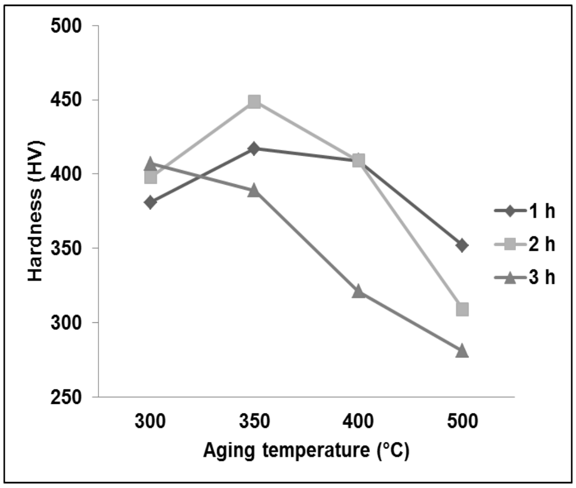

Fig.5. Effect of aging parameter on hardness of Nickel-aluminum bronze alloy

aging time, but below 350 °C aging time has more effect on hardness.
The effect of quenching environment on hardness of samples is given in fig. 6. Quenching environment has great effect on hardness of both as-quenched and aged samples. Increasing in cooling severity of quenching environment caused formation of finer grains and phases in microstructure which has effect on next process as aging heat treatment.

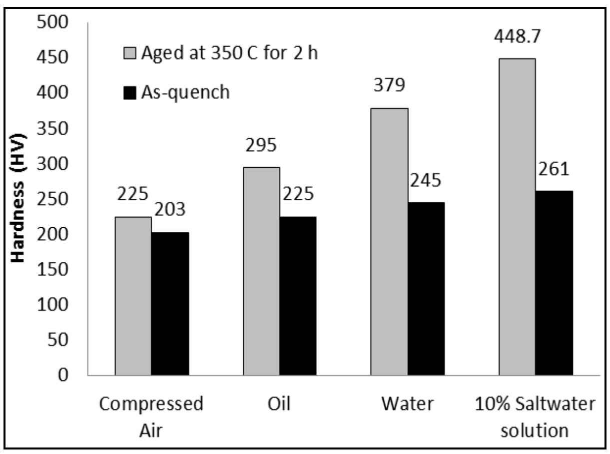

Fig.6. Effect of quench environment on samples hardness

5- CONCLUSIONS

Quenching causes all ß phase transformed into ß' phase, however aging heat treatment causes the transformation of ß' martensite into α and fine κ phases. Heat treatment lead to the precipitation of a further κ phase which differs in chemical composition and morphology to those present in as-cast structures. Quenching environment has great effect on hardness of both as-quench and aged samples. Hardness of the nickel aluminum bronze C95500 can be improved remarkably by solution at 1000°C for 1h followed by aging at 350°C for 2h.

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