Influence of Strengthening Phases on the Microstructure and Mechanical Properties of CuAl9Fe4 Alloy

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Abstract. In this article, the influence of strengthening phases on the microstructure and mechanical properties of CuAl9Fe4 alloy were investigated. The samples were heat treated with different processes to improve the mechanical properties of this alloy. The best mechanical properties (hardness and abrasion resistance values due to the mass reduction after abrasion) of this alloy were obtained with an optimal heat-treatment process (heating up and holding at 850^0C in 2h, cooling down in water, re-heating and holding at 350^oC in 2h then cooling down in water), thereby, the hardness of this alloy was 93 HRB and the mass reduction after abrasion experiment was 0.12391g. According to this heat-treatment process, the fine microstructure was obtained, the inter-metallic phase and Fe (δ) were appear, therefore, reduces the grain size and increases the wear resistance of this alloy.

Introduction

Alloyed aluminium bronze (with a composition of about 5 ~ 12% aluminum in mass) usually has one of the following phase components[1]:

- The alloys have an aluminum in a mass content of less than 9.4%, only the α phase exists.
- Two phases α + β'
- Three phases $\alpha + \beta' + \gamma_2$ with the content of aluminum higher than 9.4% in alloys.
- Or $\alpha + \gamma_2$ phase with the content of aluminium high and slow cooling

After casting, by the heat treatment process the alloys were changed the mechanical properties of the alloy due to the change in grain size and structure phase.

When heat treatment, depending on the element alloying, Cu-Al alloys occur in a variety of transformations, in which the martensite of transformation gives the alloy a special characteristic (durability, anti-wear properties, shape memory ...).

In Cu-Al alloys, the martensite transformation was occured by quenching from a temperature above the critical temperature with many of the same characteristics as the martensite process that occurs when quenching alloy carbon steel. The properties of this alloy can be controlled by the temperature tempering after the quenching process or interrupt quenching instead of the normal quenching process [1-3].

When the speed of cooling was decreased, the α phase increases with the grains size. The β' phase has the same needle shape as martensite in steel. Although under the OM, the grains are shaped like needles, in fact, they are the cross-section of these grains and it has a planar shape. This β – martensite phase is a kind of non-stable form of α in β. Because the β phase does not exist at room temperature, all phases are called β at room temperature as β '. This β' phase is very hard, brittle and has great tensile strength. If the alloy has a large β ' phase, it will lead to easy corrosion alloys, so that aluminum brass alloys usually only have about 9 percent aluminum. The plate shape phases are in the eutectoid, the result of the transformation of the β phase to $\alpha + \gamma_2$ at temperatures below 565^0C. Alloyed aluminum brass eutectoid has very good resistance mechanical [4-7].

The indirect micro prove obtained during the research and experiment have concluded that the formation of iron-rich clusters in Cu-Al-Fe alloys occurs prior to the transformation of martensite. Figure 1b, dark-field photographs show the contrast of iron-rich phases in the martensite matrix and also show that these phases have the same orientation as the beam of electrons. Clusters of cube form and if they are all formed in the cube shape-cubic orientation in relation to the β phase, all variants will be parallel (Figure 1)[8].

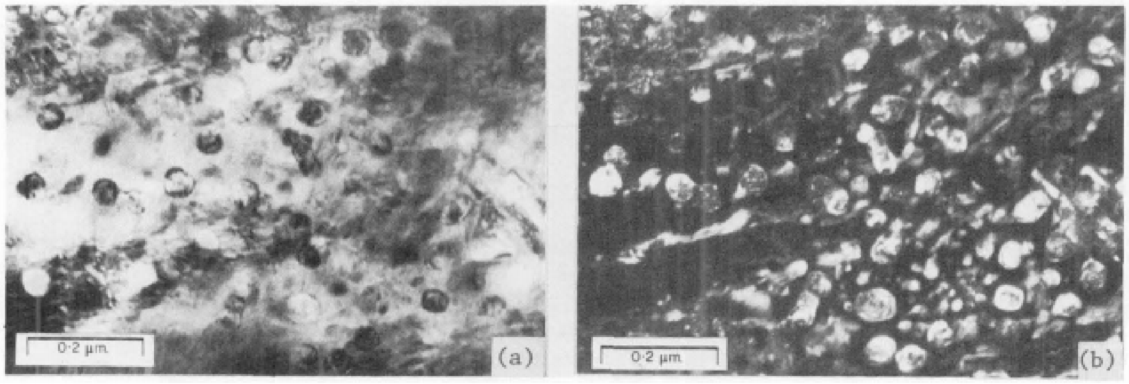


Fig 1: a) Microstructure β'-martensite Bright field image[8]
b) Microstructure β'-martensite Dark field image[8]

In contrast, if these phases non-orientation such as or if it inside forms the martensite plates, the magnetic diversity in the orientation is that only one part of all the amount of phase is seen in the photograph taken under a dark field in the above image .

Aluminum bronzes complex α-β are most of the these have the microstructure containing more than one phase. When quenching and tempering, these alloys will be very beneficial. The Aluminum-aluminum alloys, iron and without iron, are heat-treated by processes similar such as steel heat treatment processes and the chart isothermal conversion as in carbon steel. These alloys are kept at high temperature to dissolve all phases into the β phase after quenching have rigid martensite β alloys at room temperature, then increase a small phase-clustered α phase in the structure, forming martensite β-termpering.

It is these intermolecular phases that will affect the microstructure and the mechanics of the aluminum alloy system. This paper presents the effect of durable phase (mainly Fe phase) on the microstructure and mechanical properties of the aluminum alloy.

Experiment

Table 1: chemical composition of the sample

Elements	Al	Fe	Mn	Ni	Sn	Zn	Pb	Si	Cu
(%)	9,2	3,9	0,1	0,145	0,278	0,961	0,217	0,208	Bal.

After casting, the samples were cut and heat treated according to the process: Raise the temperature to 850^0C to keep the heat for two hours and then fast cooling down in water; The samples were termped at 350^0C for two hours.

The microstructures of the specimens were examined by Optical Microscopy (OM) (Axiovert 25[a]), Scanning Electron Microscope (Jeol – JSM 7600F) and Transmission Electron Microscopy (TEM). The specimens's hardness was determined on the ATKF1000 device,; Analysis of the mass defect on Tribo Technic

Result and Discusions

After casting

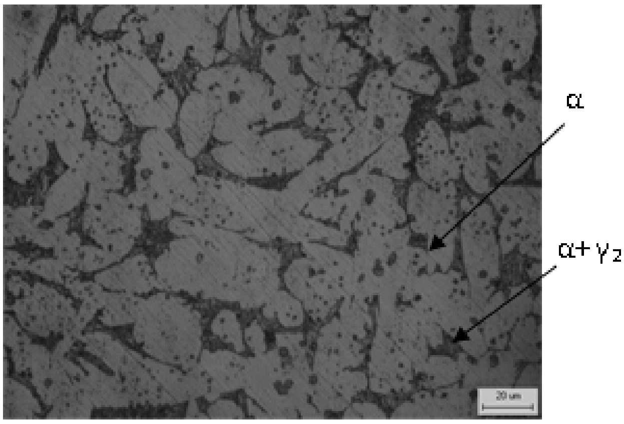


Fig 2: Microstructure of sample after casting

The microstructure of the specimens consists the two phases: the light α phase (branch phase), the dark phase (α + γ_2), the hard and brittle phase, and the rich iron Fe(δ) phase - alloy on the basis of electronic compound Fe_3Al.

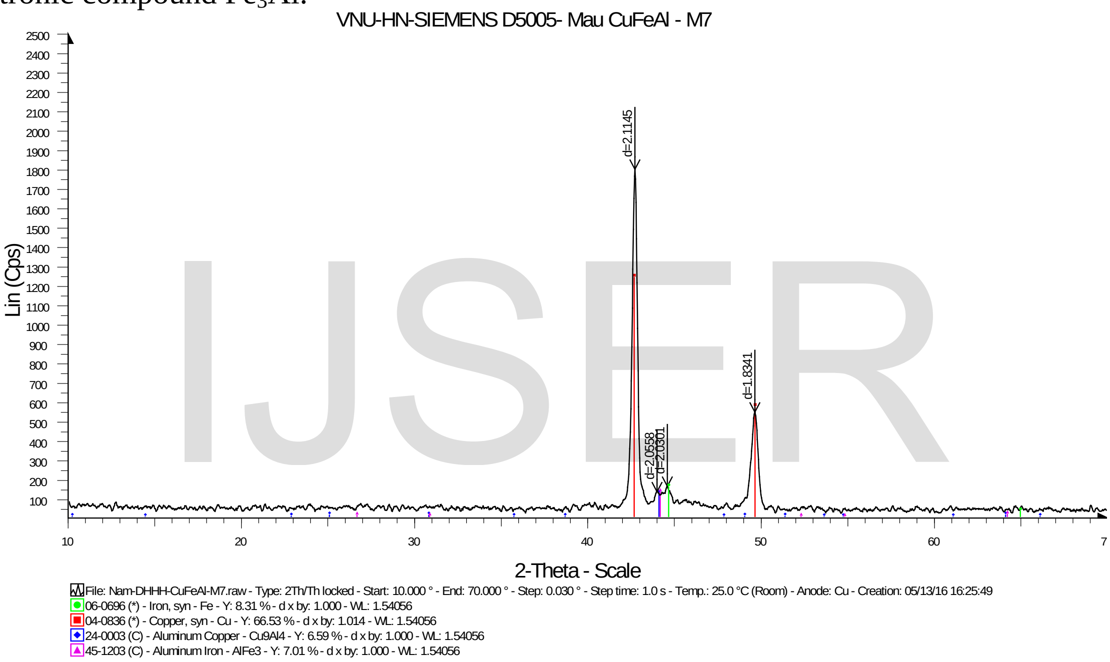


Fig 3 : Xray of sample after casting

At the casting, the microstructures consist of solid solution is the main light; In addition, there are mixed phases Cu and Al (Cu_9Al_4-γ_2), the phase rich Fe in iron Fe(δ)

After quenching

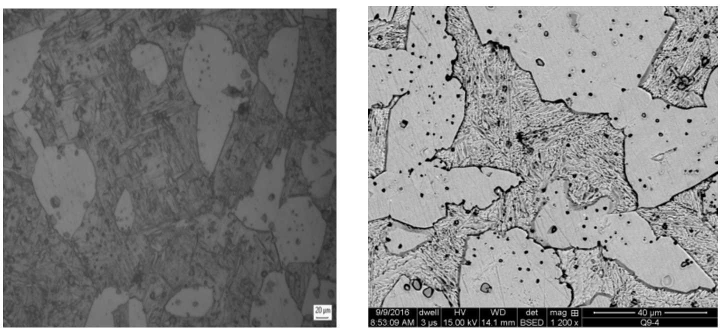


Fig 4 : Microstructure of sample after quenching

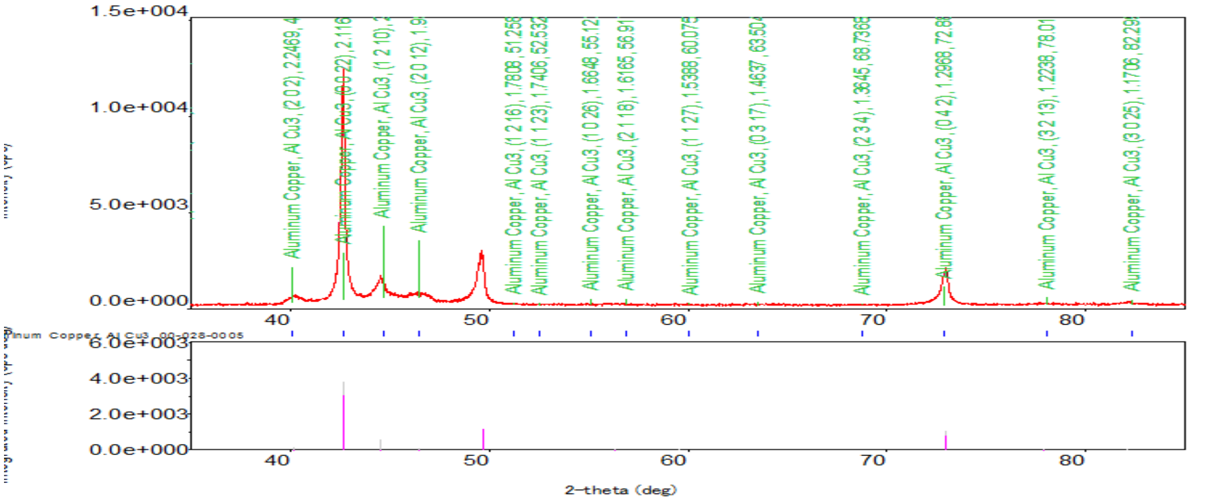


Fig 5 : Xray of sample after quenching

When heated and retained at 850^{0}C, the α + (α + γ_2) casting is converted to the two-phase (α + β) region. The phase Fe_3Al rich iron remains unchanged. The implement rapid cooling of water in β-phase turns into β-martensite (β → β'). The final was consists of the light α phase, the dark phase with the β-martensite phase, and the small phase alloys rich iron in Fe_3Al

After quenching (Figure 3.4b) shows the clear appearance of the β' phase; In addition, the rich phases do not solubility into the ground.

After tempering

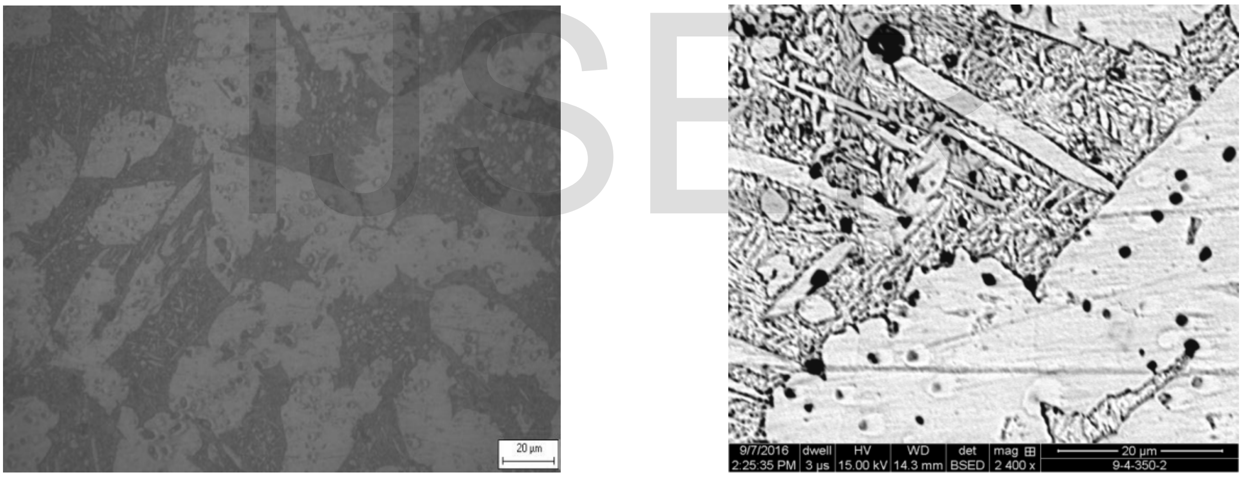


Fig 6 : Microstructure of sample after tempering

As the tempering at 350^{0}C phase martensite (Cu_3Al) convert into β' phase; At the same time, In the ground was formed an α phase (rich copper solution) and γ_2 phase, which is the interwoven pair of matted martensite sheets that becomes sharp and regularly distributed on the substrate. Amount of α is increased but small and regular distribute more than casting microstructure, to here, it can be confirmed that black spots are not caused by the dirt of surface of the sample or by oxidation, due to the phase Fe_3Al which are dispersed throughout the microstructure, created.

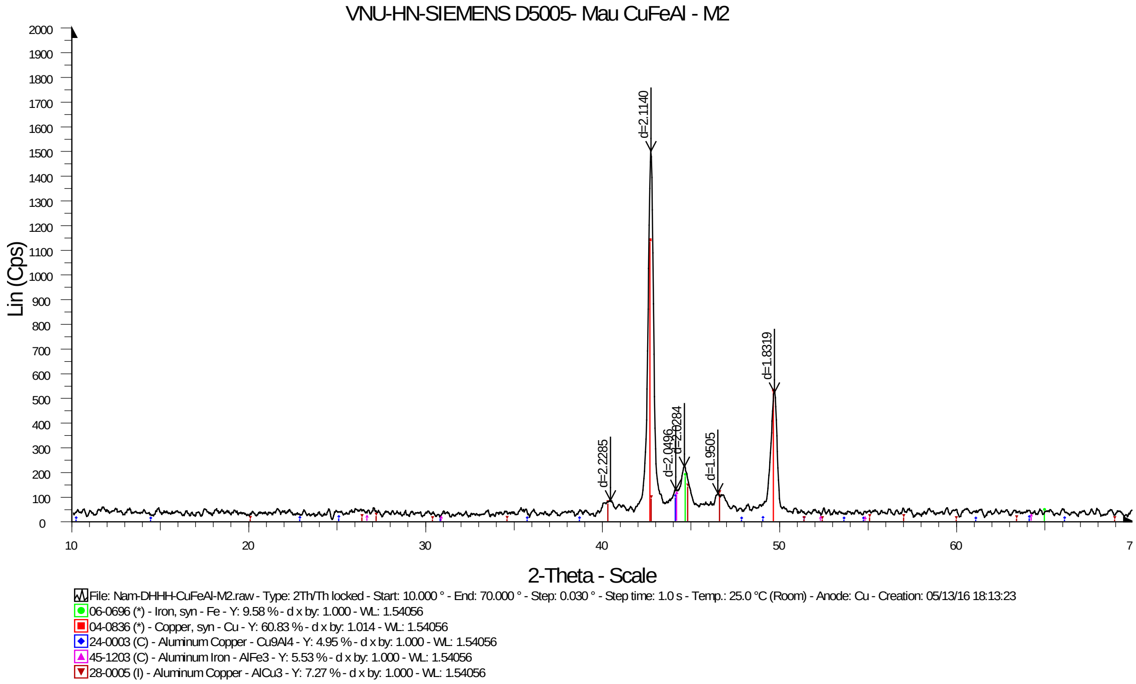
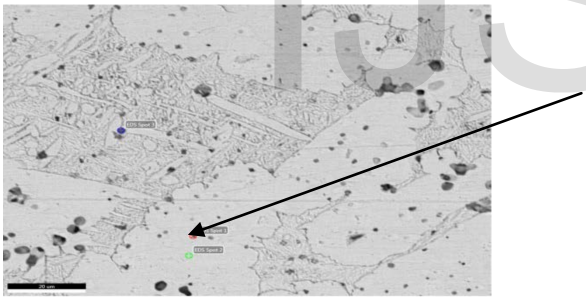


Fig 7 : Xray of sample after tempering

When the tempering in two hours: β martensite (Cu_3Al) phase convert into β' phase,at the same time in the ground appears α phase (rich copper solution) and small size phases was segregation. The optical image is not visible.



Elements	% mass	% atoms
Cu	82.72	77.85
Al	3.19	7.06
Fe	14.10	15.09

Fig 8 : EDS of sample after tempering

Fig 8 shows that in CuAl9Fe4 alloys after tempering at 350°C, the black spots predicted is intermetalic phase segregated rich iron phase throughout the main process, also CuAl9Fe4Ni2 alloy beside intermetalic phase Fe(δ), (Fe3Al) phase, there is also small phase Ni contain showed on Fig 8) proved that everything shows on the result microstructure and diffractometer X-ray complete suitable.

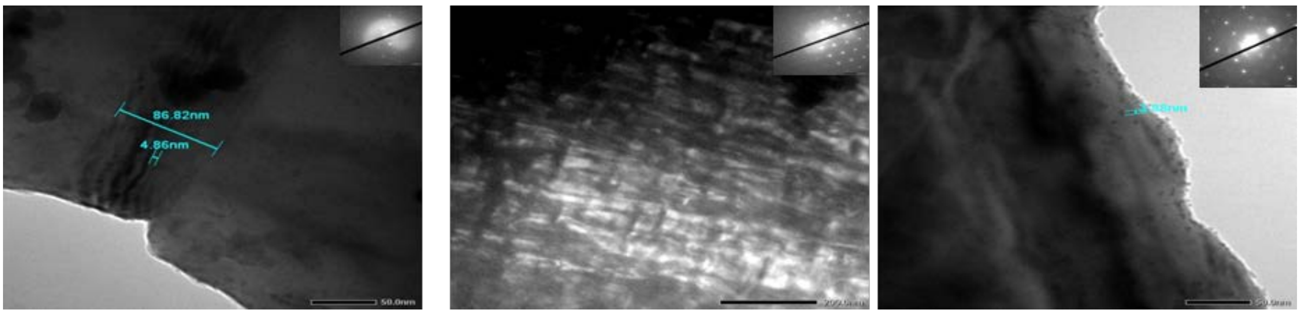


Fig 9: Microstructure of sample by TEM

Through the TEM results of CuAl9Fe4 alloy (Figure 9) by analysis micro-diffraction,we can conclude that small phases show around α phase, grain boundaries and β phase is intermetalic phase Fe(δ), (Fe_3Al) with similar about structure and parameters lattice

Hardness and Mass reduction

Table 2: Results of hardness and mass reduction

Samples	Hardness (HRB)	Mass reduction (g)
CuAl9Fe4	93	0.1239

From the result of the hardness show that when the tempering at 350^0C had a durable phase, observed α phase have small size and tiny γ_2 phase so ability to burable for alloys

Conclusion

Thus the Cu-Al alloys added iron, if the heat treatment is a suitable, it will be produces an excellent improvement in abrasion resistance.

Determined durable of phase contributes to improve the mechanical properties of alloys as well as intermetallic phase and phase γ_2.

When quenching at 850^0C and tempering at 350^0C for two hours, this alloys will be high hardned value (93HRB) and low mass weight (0.1239g). Through research that, the part made from brass aluminum alloy with abrasion-resistant applications, high pressure environment. In fact complete can be improve ability to more resistance and one of the main solutions is a heat treatment.

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