The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2020

Volume 11, Pages 154-158

IConTES 2020: International Conference on Technology, Engineering and Science

Secondary Aging Effects in Copper - Chromium Alloy

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Abstract: Copper Chromium alloys are been widely used in electrical contacts and electrical resistance electrodes for their durability during the welding process. In the welding process, the Cu-Cr alloy exposed high currents and high stamping pressure, the Cu-Cr alloys preferred in spot welding because of high electrical conductivity and high strength. In this study, it is aimed to increase mechanical strength more to restrain the plastic deformation of Cu-Cr alloys during welding. At least 1 % Cr containing spot welding tips of Cu-Cr alloys were treated for aging and secondary aging conditions. Secondary aging heat treatment processes are applied mostly to Aluminum alloys. In this study, the Cu-Cr alloy samples were aged at 650 ^{o}C for 4 hours. Secondary aging treatment was done at 400 ^{o}C for 2,4, and 6 hours. The maximum hardness value of Cu-Cr alloys was secondarily aged at 400 ^{o}C for 6 hours which was 10 % higher than the sample aged at 650 ^{o}C for 4 hours.

Keywords: Copper-Chromium Alloys, Aging, Microhardness, Optical Microscopy

Introduction

Copper element, in most areas of our lives, is an element that confronts us. That the reason for the properties of these elements as the wide use of the area. In the prehistoric periods and humanity's first uses of metals comes at the beginning. Copper by humans for the first time 10000 years ago began to be used. Found in archeological excavations, pendant, ornament goods, containers of objects, such as BC.8700 years it is estimated that is used. Of this stuff pure copper produced from ore is known to be. Alloy with excavations in Anatolia called a copper-tin alloy with the use of the bronze BC.7000 years started this period of the Bronze Age has been named. Around Thailand in ancient times was more of the alloying technique findings yielded in the direction. Bronze Age BC Technology transition and ended at 1200 iron experienced (Association, 2018; Davis, 2001; Lipowsky, 2007; Schlesinger Mark E., 2011).

Date uses copper as an element from before in terms of places today, still, it hasn't transfer off the rare materials engineering is one of them. Copper can be used alone as such, different according to the intended use alloying elements with copper are very different properties can carry. Used alloying elements according to very general nine different alloy classification it is possible to speak from the group of (Davis, 2001; Lipowsky, 2007). These are;

Copper, at least 99.3% Cu contains
High Copper alloys 5% maximum of alloying elements
Copper-zinc alloys (the brasses) 40 % Zn contains
Copper-Tin Alloys (Phosphor Bronzes) 10 % Sn maximum of 2% P
Copper-Aluminum alloys (Al Bronzes) contains 10 %, Al
Copper-Silicon alloys (Si Bronzes) contains 9-11 % Si

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Copper-Nickel Alloys contains 30 % Ni
Copper-Zinc-Nickel Alloys (Nickel Silver) Up to 27 % Zn, 18% Ni,
Special alloys, Special alloys, these alloys are specifically named where the purpose of use stands out, such as machinability.

Copper and featured in copper alloys properties required in the use of these materials the features according to their use constraints. These features tell sortable;

Electric conductivity
Thermal conductivity
Corrosion resistance
Color
Processing ease

Cu-Cr alloys that we consider here are preferred alloys in cases where mechanical strength is desired to be high without compromising electrical conductivity as much as possible. Places where these alloys are preferred; in the spot welding machines, impact-resistant conjunction with the use of electrical conductivity as high end, especially in the petrochemical industry with spark, shine contains different fields to be used in the construction of the undesirable tools (Association, 2018; Davis, 2001; Ellis, Kim, & Verhoeven, 1995; Gao, Huttunen-Saarivirta, Tiainen, & Hemmila, 2003; Kim, Berge, & Verhoeven, 1995; Raghavan et al., 2017; Sun, Sakai, & Suzuki, 2001; Wang et al., 2009) the measure of electrical conductivity is measured according to the conductivity of annealed pure copper for all materials. The internationally recognized conductivity unit is recognized as 100% IACS (International Annealed Copper Standard) for annealed pure copper (Association, 2018; Davis, 2001). The electrical conductivity of the Cu - 1% Cr alloy discussed here was measured as 85% IACS.

Copper-Chromium Alloy

Chromium containing copper alloys in UNS standards are shown as UNS 18200, which refers to Cr alloys containing 0.6-1.2% Cr by weight. Cu-Cr alloys are preferred because of their high strength, corrosion resistance, and electrical conductivity. Cu-Cr alloys are higher than pure copper (221-455 MPa), which can be applied to precipitation hardening, i.e. their strength by aging, and can rise to fractions (234-593 MPa) as a result of aging heat treatment (Davis, 2001). The hardening mechanism of Cu-Cr alloys is by precipitation of chromium from a solid solution. These high-strength alloys retain their strength at high temperatures. The corrosion resistance of Cu-Cr alloys is better than that of pure copper because chromium protective oxide improves the chemical properties of the film. Cu-Cr alloy has excellent cold formability and good hot workability (Davis, 2001; Durashevich, Cvetkovski, & Jovanovich, 2002; Krishna, Rao, Jha, Pant, & George, 2015).

Cu-Cr alloys with the use of resistance welding electrodes, seam welding discs, gears, key, electric, electrode holding jaws, cable connectors, current-carrying arms, and rods, circuit breaker parts, arc and bridge components, patterns in electron tubes, spot welding tips, copper electrical and thermal conductors that require more strength, and the key in the ignition, is used. Cu-Cr it is important to use alloys; resistance welding electrodes, seam welding drives key electric gears, the electrode holding jaws, cable connectors, current-carrying arms and rods, circuit breaker parts, arc and bridge components of dot patterns in electron tubes source lugs, more resistance than copper requires conductors of electricity and heat, switch it is used in the ignition.

The Aging Heat Treatment of the Copper-Chromium Alloy

In Cu-Cr alloys that can be hardened by precipitation, the temperature drop decreases the solid solution of chromium in copper. Slow-cooled Cu-Cr structure is a mixture of two-phase chromium and Alpha copper. Superior mechanical properties are supplied by the rapid cooling of Cu-Cr alloys from the annealing temperature, so Copper is saturated with chromium solid solution. The microstructure of the quick-cooled Cu-Cr alloy resembles unalloyed copper. Rapid cooling prevents chromium from accumulating during solid dissolving, so casting construction consists of a single Alpha copper phase structure. The first material that begins to solidify is pure copper, which follows a eutectic mixture of Alpha copper and chromium. Alpha copper and chromium eutectic material, the plate-like structure is formed in interdendritic zones. Alpha copper consists of twin grains in the solid solution. In general, Chromium is cooled quickly to remain in the alpha copper solid solution. Aging distributes chromium precipitates along with the matrix (Chakrabarti & Laughlin, 1984).

Aging heat treatment;

Solid the solution
Quenching to obtain an over-saturated solution
Aging to form second phase particles to obtain the desired properties

Materials and Method

The copper and chromium elements were obtained from Alfa-Aeser of high purity 99.99 %. The melting and casting were done in Leybold-Heraus vacuum induction melting furnace under an argon atmosphere. The ingots were homogenized at 1000 °C for 72 hours. The samples were solutionized at 950 °C for 4 hours and quenched in water at room temperature. Aging heat treatment was done at 650 °C for 4 hours and quenched in water. Secondary aging heat treatment was realized at 400 ° C for 2, 4, and 6 hours.

After completing the heat treatment procedure the samples were polished and etched with 5 g $FeCI_3$ (ferric chloride), 50 ml HCI, and 100 ml H_20.

The microhardness testing was done by Futuretech make FV-800 instrument with 100 g load for 10 seconds.

Results and Discussion

The microhardness testing results revealed that the secondary aging heat treatment improves the hardness. The hardness increases with aging time. The maximum value of hardness obtained in samples aged 650 °C for 4 hours and secondarily aged at 400 °C for 6 hours giving 75 H_v. This hardness value is 12% higher than the samples only aged at 650 °C for 4 hours. The trend in hardness differentiation was given in Figure 1.

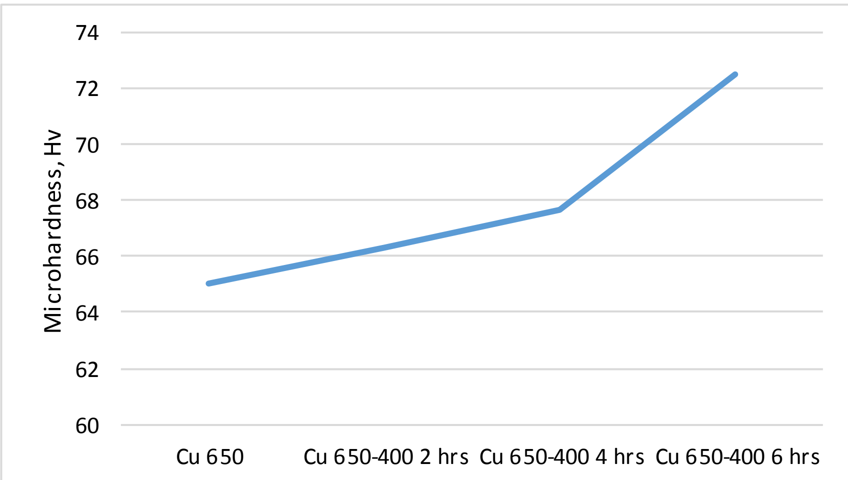

Figure 1. Microhardness change versus aging heat treatment

The microstructures of aged and secondarily aged samples were given in Figure 2. The microstructures revealed that the grains were coarsening by increasing time in secondarily aged samples. The factors causing the hardness increase are the second phase particles that have precipitated. During aging, with the effect of temperature, alloying elements first begin to gather under edge dislocations. The GP regions, which are clusters of atoms, cause a certain amount of distortion as they create internal stress in the lattice, and at the same time cause the structure to harden even a little. As the aging continues, these clusters begin to form β precipitates compatible with the α matrix phase. These precipitates play a role in increasing hardness. As the aging continues, the sediments grow further and reach a critical height, it is seen from the trend of the graph in Fig.1 that the time and temperature limit required for excessive aging is not reached in the study. Since the experiment was not continued any longer, it was not clear at this stage whether the highest hardness zone was reached. At higher magnifications, the grain coarsening and fine precipitates were seen. As the aging time increases the fine precipitates dispersed very fine all over the matrix. The precipitates in the grain borders were also getting smaller and dispersed through the matrix which confirms an increase of the hardness. This situation may be useful for the production of materials with higher strengths in tool manufacturing. Especially, it may be a more suitable solution in the production of spot welding tips, non-sparking tools such as keys and hammers used in petrochemical plants.

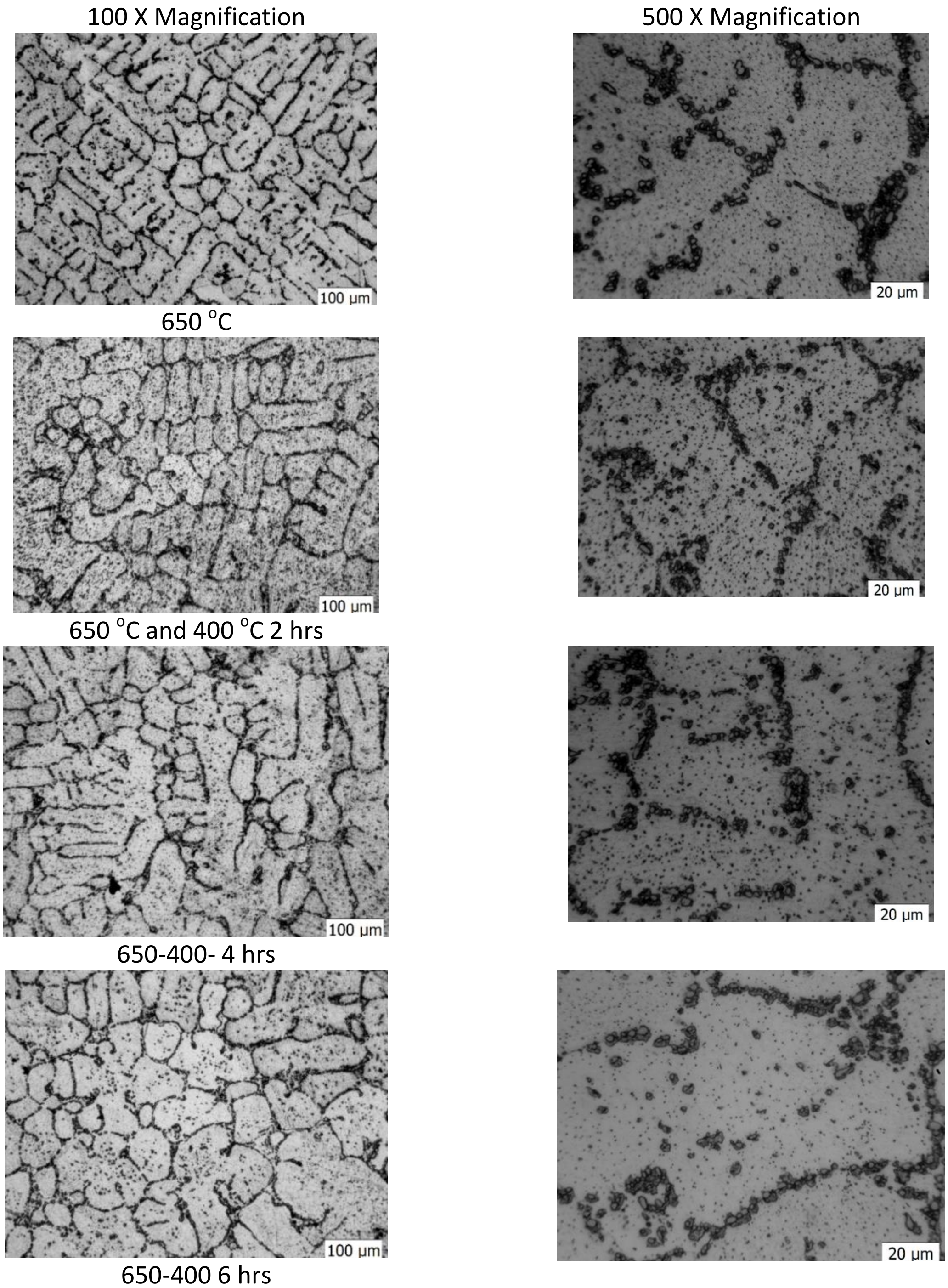

Figure 2. Microstructures of the aged and secondarily aged samples (left 100X, right 500X magnification)

Conclusion

The secondary aging heat treatment would be an emerging method for increasing the strength of age hardenable alloys. This may also increase the service life of age-hardened parts. The increase in hardness in this study obtained more than 10% which is higher than ordinary aged ones. However the hardness is increasing, the precipitates grow from very fine and coherent agglomerates into coherent spherical particles in the course of aging. With a further increase in time, the precipitates almost dissolve in the matrix so it is thought that they lose coherency with the matrix. The overall conclusion the aging time increases the hardness, and the Cu-Cr alloys can be in service more according to single-stage aging.

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