INFLUENCE OF HEAT TREATMENT AND DEFORMATION ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES Cu-Ni-Sn ALLOY

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1. INTRODUCTION

Present, on electronic engineering, mechanical engineering, need about products are created from copper alloy require high strength, high elastic, well electrical conduction, and anti-corrosion. Furthermore, these products are used with a special purpose to create weapons. In the military industry, the copper alloys with the high strength, high elasticity, and corrosion resistance are also important productions in the material of all kinds of shells, detonators of bombs, mines, bullets, unexploded ordnance, and no electric spark. Many details in the electrical equipment of aircraft, missiles, radar are also made from copper alloys with high strength, stability, corrosion resistance in tropical conditions or marine environment, to be able to Long-term preservation and combat readiness. In the maritime field, copper alloys are widely used. Details such as a shaft, electrical systems on board are made from copper alloys. With the high strength and must withstand corrosion in long-term seawater conditions. Some details also require elasticity. The mechanisms’ copper alloy need high strength and elastic, well electrical conduction in the electric transport equipment are usually created by copper alloy about 2% beryllium. However, deficiency of this alloy is refractory; berilli is poisonous and noble. So the study new copper alloys have equally behavior to copper-beryllium alloy is demand necessary.

In the world, there have been some studies on other systems to replace beryllium alloys such as Cu - Ni - Sn system, Cu - Ni - Zn system with curvature Ni, Sn, Zn smaller than 10 - 15%. These alloys in terms of strength, elasticity and electrical conductivity through heat treatment can be nearly as close as beryllium, but they are lower melting temperature, non-toxic, available materials and cheaper prices [1-3]. So that requirement, the authors of this article carry out a study copper-nickel-tin alloy. This alloy about strength, elastic and electric conduction adopt heat treatment, and strain can adequate numerically copper-beryllium, but facile melting, non-poisonous and the material find out the essay and cheaper.

Figure 1: Strength and electrical conductivity for copper alloys

Copper and nickel dissolve unlimited, Ni and Sn almost don’t dissolve at the room temperature. On the ternary alloy phase diagrams, the stable metal phases are created among copper and tin, or nickel and tin: Ni3Sn; Ni5Sn3; Ni5Sn4. These are also the metastable phase for the alloy. When the study for this alloy, people usually take about the binary phase diagrams with the axis is tin, the axis is copper and nickel compound with the fixed content. (Figure 1). On the profile of ternary alloy phase diagrams, at the temperature profile, the studied alloy lasts at the solid solution. This article shows the initial research results about alloy Cu-7Ni-7Sn.
RESULTS AND DISCUSSION

The special cause makes for copper-nickel-tin alloy obtain high strength is right heat treatment, in this alloy take place spinodal decomposition. Spinodal transformation is a rather characteristic transformation of Cu-Ni-Sn alloy system. Therefore, this system is called the spinodal. Because, there is spinodal transformation, this alloy system can adjust the properties such as strength, elasticity, ductility, to apply the high mechanical and mechanical requirements of manufacturing. Cu-Ni-Sn alloy system is used to replace beryllium more and more. The Cu-Ni-Sn copper system is a testament to the significance of spinodal transformation in practice [2,4,5].

Most of the alloys by copper are strengthened by the increase in solid solutions, cold machining, increased phase savings, or by a combination of these durable mechanisms. Particularly, the Cu-Ni-Sn three-alloy alloy, high durability is achieved by the heat treatment process called spinodal transformation processing. Spinodal structures are composed of a fine, homogeneous mixture of two phases that form by the growth of composition waves in a solid solution during suitable heat treatment is called spinodal structure. The phases of the spinodal product differ in composition from each other and the parent phase but have the same crystal structure as the parent phase. The fineness of spinodal structures is characterized by the distance between regions of identical composition, which is of the order of 50 to 1000 Å [3,6-9].

Figure 2: The cross-section diagram of Copper-nickel-tin alloy

Figure 3: Spinodal diagram

Spinodal transformation is a mechanism in which a solid solution of two or more constituents can be divided into different basic phases of chemical and mechanical properties. This transformation mechanism differs from the classical phase transition in that the separation phase due to spinodal differentiation is much harder to detect, occurring simultaneously and uniformly throughout the material, not only in separate phase transition positions [10-12]. Spinodal transformation is of interest for two main reasons. First, it is one of several phase transitions in a solid form based on reasonable theory. Since there is no thermodynamic barrier to the reaction of the spinodal region, the transformation is determined by diffusion only. Thus, the transformation is considered completely a problem of diffusion; many characteristics of transformation are described by solving the approximate generalized diffuse problem [9,13,14]. Secondly, nucleation theory related to thermal fluctuations and diffusion problems related to germ growth is difficult to explain because of non-realistic properties when linearizing diffusion functions. In practical terms, spinodal transforms make sense to create a small microstructure that is finely dispersed and increases the physical properties of materials.

Figure 5: Tension Specimen

The sample is quenched at 750 temperature (water cooling to create an unstable solid solution) After quenching the depth of sample is 14mm, is hot-rolled down 2.5mm depth, continual cold-rolled at 40%, then tempering at 350°C in the 1h and 2h order solid solution decomposition. Before and after treatment state, samples are tested photomicrograph on the Axiosvert 100A microscope, hardness test on the Mitutoyo with the HV hardness numerals and steady load 1KG and tested strength.

2. RESULTS AND DISCUSSION

The study alloy show: After casting, the microstructure of alloy have fish-bone form, the component is uniform, the grain size is bigger about 200μm. The average hardness value 92.6HB.
After quenching the microscopy of the alloy is uniform, the grain size is less than after casting about 150μm. The hardness value is increase about 113HB. Possible, the microstructure uniform and minor ascended strength for alloy because on the photomicrograph have an only solid solution. After strain microstructure and behavior of alloy change positive.

The thick's sample is 1.6mm, the area of the cross-section is 10x 1.6=16mm²; the tensile strength is 893.7MPa. After tempering, the average hardness value is 370HB. Above after casting and quenching, show after tempering the sample have strength limit (on the diagram that limits concurrent is the elastic limit) and hardness increases. This fact approved to have a transition in the structure increasing strength and hardness for alloy but the product of transition doesn’t detect when a show by the optical microscope. On the optical microscope, after quenching and tempering, microstructured on many different. Possible, the component grows strength have very small dimension, and the possible is a spinodal structural cluster so that confirms this fact must do with the testings with the modern machine that is carried out a draw at 2h with the sample.

The thick's sample is 1.58mm, the area of the cross-section is 10x 1.58=15.8mm²; the tensile strength is 949.4MPa. This value is equal to an elastic limit of the sample. After tempering, the average hardness value is 367HB. After tempering the hardness value is constant but the elastic limit value increases indicate have changed about strain and ductility. Furthermore, in the microscopic microstructure have twining.

**Table 2: Hardness value (HB) after casting and quenching**

|     | N1  | N2  | N3  | Medium |
|-----|-----|-----|-----|--------|
| Casting | 92.9 | 95.0 | 89.8 | 92.6 |
| Quenching | 119.0 | 108.0 | 112.0 | 113.0 |

After quenching the microscopy of the alloy is uniform, the grain size is less than after casting about 150μm. The hardness value is increase about 113HB. Possible, the microstructure uniform and minor ascended strength for alloy because on the photomicrograph have an only solid solution. After strain microstructure and behavior of alloy change positive.

**Figure 8: Strength diagram and photomicrograph x500**

On the microstructure have a sliding surface, don’t see a dimple. The average grain size is 60-70μm. On the microscopy of grain have twinning. The mechanism is that the sample is strained 40%, the thick's sample is 1.48mm, the area of the cross section is 10x 1.48=14.8mm². The tensile strength is 953.7MPa, the elastic limit is 694.4MPa. After strain, the average hardness value is 309HB. This fact indicated transition microstructure, minor grain, more resistance to sliding, the sample is cold-hardened, harden, reinforcing above after quenching. The mechanism of modification is more robust when assembling quenching, strain, and tempering.

**Figure 9: Strength diagram and microscopy after tempering 1h x500**

The thick's sample is 1.6mm, the area of the cross-section is 10x 1.6=16mm²; the tensile strength is 893.7MPa. After tempering, the average hardness value is 370HB. Above after casting and quenching, show after tempering the sample have strength limit (on the diagram that limits concurrent is the elastic limit) and hardness increases. This fact approved to have a transition in the structure increasing strength and hardness for alloy but the product of transition doesn’t detect when a show by the optical microscope. On the optical microscope, after quenching and tempering, microstructured on many different. Possible, the component grows strength have very small dimension, and the possible is a spinodal structural cluster so that confirms this fact must do with the testings with the modern machine that is carried out a draw at 2h with the sample.

**Figure 10: Strength curve after tempering 2h**

The thick's sample is 1.58mm, the area of the cross-section is 10x 1.58=15.8mm²; the tensile strength is 949.4MPa. This value is equal to an elastic limit of the sample. After tempering, the average hardness value is 367HB. After tempering the hardness value is constant but the elastic limit value increases indicate have changed about strain and ductility. Furthermore, in the microscopic microstructure have twining.

**Figure 11: Microstructure of sample after deformation and strength:**

Sample microstructure analysis on FESEM equipment found that after deformation and senescence, particles with extremely fine size appeared from 10nm to 100nm; In addition, there are also atoms that can be surmised that it is the structure of spinodal decomposition when performing microhardness measurements, it was found that the hardness of the material increased significantly; Carry out the test to see the elongation of the material (8% elongation). It is these claims that the process of elongation and elongation of the material is based on small particle size and spinodal decomposition

3. CONCLUSIONS

After strain and tempering, the elastic limit and hardness value is increased. This fact approved to have a transition in the microstructure of increasing hardness for the alloy. The transition is conjectured spinodal decomposition. After curing the elastic limit of the material is very higher. This fact is very well for element behavior on the high elastic limit condition. The results can compare with some sample

**Table 3: Mechanical properties of Cu-7Ni-7Sn**

| Sample     | Strength (MPa) | Elastic limit (MPa) |
|------------|----------------|---------------------|
| Cu-7Ni-7Sn | 949.4          | 949.4               |
| High strength low alloy steel (A565 grad 1) | 695            | 552                 |
| Durya (2024) | 470            | 325                 |

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