Impact of CuZn33 Alloy Annealing Temperature on Plasticity and Grain Size

Shicheng Li
Fishery Machinery and Instrument Research Institute, Chinese Academy of Fishery Sciences, Shanghai 200092, China
*Corresponding author e-mail: li-sc@qq.com

Abstract. In order to study the relationship between the plastic performance and the grain size of heat treated material, the stress-strain curves of the samples were obtained. In order to analyse the relationship between the plastic performance and the grain size of heat treated material, the grains photo were obtained by a polarizing microscope. The relevant standards were applied to measure the grain size of materials heat treated under different temperatures, the relationship between the annealing temperature and the grain size were obtained.

1. Introduction
The copper alloy has very good ductility, high strength, good workability and corrosion resistance, and therefore it is more commonly being used for IC connectors and small electronic components [1]. In this paper, we used the designation CuZn33 copper alloy material, when the material cold-formed at room temperature, the first diagonal direction and the sliding surface octahedral decent, that is, the atomic arrangement of the crystal orientation and the densest crystal plane. The brass material have 12 slip system, has a very good plasticity, can deformed relatively easily at room temperature [2, 3]. Brass alloy iron content is generally less than 1%, its only a small amount of non-equilibrium crystallization (α + β) organization exists in the form of two-phase structure among α-phase component, it has a very high strength and toughness, in warm forming of the process of plasticity excellent cold forming can also be, hence the components of this material production has good mechanical properties and process performance [4-6].

2. Annealing Process
The purpose of heat treatment is generally to regaining its original properties, increasing ductility, shrinking hardness and strength, or change the microstructure within the material to obtain a better grain size and improve the plasticity of the material [7]. During the study, the annealing process is divided into three steps. Firstly, heating the work piece to a specific temperature, secondly, keep the temperature within a certain period of time, which is insulation, thirdly, cooled down slowly. When the material is heat-treated to ensure that the part has a substantially uniform thickness, so that the effect of the heat treatment to avoid uneven. During the heat treatment, three different brass alloy process occurrence: recovery, recrystallization and grain growth.
According to the heat treatment temperature of the material grain size corresponding to the diagram, the experimental program of the selected heat treatment is shown in Figure 1, heat treatment is conducted a total of 3 times, respectively, the maximum temperature for 450 °C, 500 °C, 550 °C, the specific process for the: the crucible material is placed in a tank-contained heat treating furnace is heated to a maximum temperature, and incubated 0.5 hours, removed from the furnace and air-cooled down to room temperature.

![Figure 1. Heat treatment solutions](image1)

The experiment uses two different diameters of the material, the sample numbers in Table 1, where the odd group with a diameter of 3mm, the array group with a diameter of 2mm, each having 5 samples, three of the sample use as compressed samples wherein the two materials used to measure the grain size.

### 3. Experimental results

In order to measure the plastic performance change after heat treatment of the CuZn33, the stress-strain curve required to obtained after heat treatment of samples, therefore need to measure the relevant data material, the sample were expand the compression test experiment on 50KN universal testing machine (Figure 2).

![Figure 2. Compression Tests](image2)
Figure 3. Engineering stress-strain curves (All)
In the compression test, in Table 1, each set of three samples out of compression tests, the loading rate of compression tests 0.01 mm / s, to obtain a deformation of the material over the test load curve, the experiment failed after removing the sample, the average value as the data of the group of samples. In order to make the results showing more simple and clear, and therefore all of the engineering stress-strain curve in one page, as shown in Figure 3. They are regularly spaced, horizontal two heat Treatment of the same figure, the same as the corresponding four pictorial vertical specimen geometry. During the compression test, the universal testing machine is also measured the modulus of elasticity of the sample data, statistical data, the results shown in Table 2.

| Group | Heat Treat | Diameter | Length |
|-------|------------|----------|--------|
| 1     | No heat treatment | 3mm | 7.5mm |
| 2     | No heat treatment | 2mm | 5mm |
| 3     | 450° thermal insulation | 3mm | 7.5mm |
| 4     | 450° thermal insulation | 2mm | 5mm |
| 5     | 500° thermal insulation | 3mm | 7.5mm |
| 6     | 500° thermal insulation | 2mm | 5mm |
| 7     | 550° thermal insulation | 3mm | 7.5mm |
| 8     | 550° thermal insulation | 2mm | 5mm |

| Group | Elastic modulus | Fmax | Strain | Stress | Initial diameter | Initial area |
|-------|----------------|------|--------|--------|------------------|--------------|
| Units | Gpa            | N    | —      | Mpa    | mm               | mm²          |
| 1     | 2.33           | 3769.82 | —      | —      | 3                | 7.068        |
| 2     | 10.16          | 2974.16 | 0-0.325 | 175-350 | 2                | 3.142        |
| 3     | 11.13          | 12119.3 | 0-0.45 | 125-950 | 3                | 7.068        |
| 4     | 18.36          | 2651.64 | 0-0.325 | 150-320 | 2                | 3.142        |
| 5     | 11.15          | 9432.97 | 0-0.45 | 120-800 | 3                | 7.068        |
| 6     | 11.34          | 3384.42 | 0-0.325 | 125-400 | 2                | 3.142        |
| 7     | 11.57          | 7942.61 | 0-0.31 | 100-350 | 3                | 7.068        |
| 8     | 10.50          | 3301.48 | 0-0.325 | 110-370 | 2                | 3.142        |

In the normal calculation, we need to use the real deformation of the material stress and strain, the usual experimental data is given in the name stress-strain approach, therefore, and in this case, we need to convert the nominal value of the stress and strain stress to real strain values. Therefore, the experiments measured engineering stress-strain curve is converted to real engineering stress-strain curve, as shown in Figure 4 and Figure 5.
Figure 4. True stress-strain curve (diameter 2mm)

Figure 5. True stress-strain curve (diameter 2mm)

Figure 3 is an engineering stress-strain curve of the sample at different diameter 3mm solution heat treatment, the first set of samples during the compression test, because of poor parallelism of the face on the sample, when the discontinuity in the experiment, and therefore only for short out the curve because it is not heat treated sample, so it does not affect the analysis of the experiment, it can be seen from the figure, a half-hour thermal insulation at 550 °C heat treatment had the minimum true stress specimen.

The blank was cut into the sample after the heat treatment to conduct metallographic observation after grinding and polishing, and then with hydrochloric acid and ferric chloride etching solution for etching arranged. The Phase photo were shot by polarizing microscope, shown in Figure 6.
Figure 6. Phase photo of the sample
(A-without heat treatment; B- 450° heat treatment, C- 500° heat treatment, 550° heat treatment)

As can be seen from Figure 6, when the blank without heat treatment, it has very small grains, the grain size in the heat treatment condition of the first group, the second group, the third group sequence is increased, in order to quantify the grain size, we need measure the grain size, according to the relevant standards, i.e., grain size, according to the standard method can be used to calculate the intercept grain size, which would be in the grain image, random draw three consecutive segments, to ensure that at least 50 across the three segments grain, and then calculate the total line segment passing through the realm of cut points n, the end of the end is not always cut-off point of measurement does not count when computing segment, the end just when exposed to grain boundaries, counted as 0.5 cut-off point, the measurement realm tangent line, counted as a cut-off point, the measurement line and the confluence of three grain boundaries coincide count 1.5 cut-off point. The average grain intercept s calculated using the following formula;

\[ s = \frac{l}{m \times n} \]

\( M \) is the microscope magnification, the total cross-sectional point on the line segment, the length of the segment. According to the above standards, the group 1-3 and the grain size of the sample without heat treatment were 40\( \mu \)m, 35\( \mu \)m, 30\( \mu \)m, 25\( \mu \)m.

4. Conclusion
According to experimental results it can be concluded the following conclusions:

1. In 450℃ - 550℃ annealing range, with the annealing temperature increase, the Elastic modulus the material does not change significantly, but the stress reduced at the same strain conditions, indicating that the plastic changed to better.

2. Analysing from the experiment results, it was found that, in the 450℃ to 550℃ annealing range, with annealing temperature increased, the material crystal grains become smaller, it can also be concluded that in a certain range, the smaller grains size, the better plasticity.

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