Abstract

Copper alloys are extensively used in the engineering applications because of its superior features. These properties are high thermal conductivity, high electrical conductivity, excellent ductility and toughness, excellent corrosion resistance. In this study corson type of Cu alloys has been investigated. The main purpose of this study is to examine and improve mechanical properties of CuNiSi alloy. For achieving this aim, predetermined CuNiSi compositions were prepared, melt and cast into permanent molds, solutionized for appropriate temperatures, cold worked and heat treated at different temperatures. Furthermore, microstructural analyses such as grain size determination, hardness measurement were carried out through the study. Thus, it was aimed to reach the best mechanical properties with optimum heat treatment and other thermomechanical methods.

1. Introduction

With the improvement of the technology electrical conduction has become one of the utmost important research areas. It is mostly because latest technological devices and equipments especially the ones developed in the last quarter of the 19th century and so on are basically depends on the electrical energy. As mentioned above this reason has led the researchers on this area of science. Specifically, as will be dealt in this work copper and its alloys are being constantly researched. Not just for their higher conductivity value but also for their mechanical properties, these Cu and its alloys are becoming one step ahead. Moreover, Copper-base alloys are extensively involved in electronic fields, to exemplify these field are framework of IC and connectors for their high electrical conductivity. High portion of these alloys are usually consists of precipitation-strengthened types and are dilutely alloyed with elements of very low solubility to sustain high conductivities. Cu–Ni–Si type alloys are included in these precipitation-hardenable copper-base alloys group. The precipitates responsible for the strengthening effect have been identified as $\delta$-Ni$_2$Si[1].

Besides these, in this study grain size determination and grain growth control was given priority to. By grain size control, producing smaller grain size microstructure, mechanical properties can be altered significantly. Research results show that the strength values of Cu–Ni–Si alloys can reach higher numbers with only a modest decline of electrical conductivity after appropriate aging, so Cu–Ni–Si alloys are mostly preferred for such usages. These alloys are quenched from high temperature and then exposed to different heat treatments, which induces the precipitation of a second phase ($\delta$-Ni$_2$Si) in the copper matrix and this improves the strength [2].

2. Experimental Procedure

In this study, suitable composition of CuNiSi alloys was determined which is Cu-(1.9)%Ni-(0,6)%Si. First of all, these alloys were obtained in bar form. Then they were melt and cast as 9 mm thickness slabs into permanent molds as can be seen in figure 1 and 2. Before casting, mold was preheated to prevent any shrinkages and surface deteriorations.

Figure 1: 7 mm thickness permanent mold and preheating operation.

Figure 2: Melting and casting of CuNiSi alloy.
After obtaining desired thickness cast slabs, they were solutionized at different temperatures at around 900-950°C for different durations. After solutionizing treatment the specimens were water quenched for improving the strength of the alloy. As the next step these water quenched specimens has been cold rolled and 9 mm to 3mm section reduction (%67 deformation) was obtained. Then they were aged at temperatures around 700-800°C for recrystallization.

Following the recrystallization step specimens were prepared for microstructural analysis. They were grinded, polished and etched with suitable etchant for observing grains in the microstructure. Afterwards, Their optical microscope pictures were taken and grain size measurements were done with software.

3. Results and Discussion

After abovementioned experimental procedures were carried out, following microstructures were obtained. As can be seen from the microstructures and the grain sizes different heat treatments leads to different results.

![Figure 3](image3.png)

**Figure 3**: Solutionized at 920°C for 90min, water quenched & aged at 750°C for 60min. Average grain size:35.96

![Figure 4](image4.png)

**Figure 4**: Solutionized at 920°C for 90min, water quenched & aged at 750°C for 90min. Average grain size: 23.91

![Figure 5](image5.png)

**Figure 5**: Solutionized at 920°C for 90min, water quenched & aged at 750°C for 150min. Average grain size: 36.86

![Figure 6](image6.png)

**Figure 6**: Solutionized at 950°C for 100min, water quenched & aged at 750°C for 120min. Average grain size: 32.59
Figure 7: Solutionized at 920°C for 120min, water quenched & aged at 730°C for 5min. Average grain size: 65.25

Figure 8: Solutionized at 920°C for 120min, water quenched & aged at 730°C for 60min. Average grain size: 32.65

Figure 9: Solutionized at 920°C for 120min, water quenched & aged at 730°C for 90min. Average grain size: 28.75

Figure 10: Solutionized at 920°C for 120min, water quenched & aged at 730°C for 120min. Average grain size: 26.75

Table 1: Average grain size versus experiments table for specimens annealed at 750°C.

Table 2: Average grain size versus experiments table for specimens annealed at 730°C.
In the first 4 microstructures it can be seen that grain size were determined as smallest 23.91microns at 920°C 90’ solutionized 750°C 90’ annealed sample, largest 36.96microns at 920°C 90’ solutionized 750°C 90’annealed sample. In the second 4 microstructure grain sizes can be examined as smallest 26.75microns at 920°C 120’ solutionized 730°C 120’ annealed sample, largest 65.25microns at 920°C 120’ solutionized 730°C 5’annealed sample. These results show that optimum heat treatment time and temperature lies at solutionizing 920°C for 90’ and annealing 730°C for 90 to 120’.

If tables 1 and 2 are examined carefully, it is observed for the first procedure when the annealing time gets higher, grain size start to increase after sometime i.e 90’. However, this is not the case for the table 2 procedure completely. In the second table after 90’ of annealing grain size still decreases, nonetheless this behavior is not generalized since it is unknown how grain size will change after 120’. In the first table it is obvious after 90’ grain size increases, this is the result of continuous recrystallization effect.

Table 3 gives the hardness results of different heat treatment procedures.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>920°C 90min</th>
<th>950°C 100min</th>
<th>920°C 90min</th>
<th>920°C 90min</th>
</tr>
</thead>
<tbody>
<tr>
<td>750°C 150min</td>
<td>6.46HB</td>
<td>72.1HB</td>
<td>68.8HB</td>
<td>60.9HB</td>
</tr>
<tr>
<td>750°C 120min</td>
<td>5.68</td>
<td>77.3</td>
<td>67.3</td>
<td>62.2</td>
</tr>
<tr>
<td>90°C 90’</td>
<td>63.7</td>
<td>77.7</td>
<td>67.6</td>
<td>63</td>
</tr>
<tr>
<td>120°C 90’</td>
<td>66.1</td>
<td>78.5</td>
<td>69.9</td>
<td>64.7</td>
</tr>
<tr>
<td>150°C 90’</td>
<td>65.4</td>
<td>79.8</td>
<td>74.7</td>
<td>61.1</td>
</tr>
<tr>
<td>Average</td>
<td>65.56</td>
<td>77.08</td>
<td>69.66</td>
<td>62.38</td>
</tr>
</tbody>
</table>

All values measured in Brinell scale

Table 3: Hardness data for different heat treatment procedures.

With structural features of the alloy. By structural features, precipitates as δ-Ni2Si and crystallographic orientations were implied. In these alloys main strengthening effect come from precipitates that are forming during production processes. However, it may be deducted that these δ precipitates were not formed as intended to give desired high strength values in these heat treatment. To reach higher hardness values subsequent 300-500°C relatively long time aging is needed to induce this δ-Ni2Si second phase.

4. Conclusion

Thermomechanical treatment of Cu-(1.9)%Ni-(0.6)%Si corson alloy were carried out. The alloy has been cast into desired shape and several heat treatments applied. Basically these heat treatments were solutionizing at 920-950°C, after quenching annealing at 730-750°C. By these thermomechanical procedures optimum heat treatment time and temperatures were tried to determine. Thus this time and temperature was determined as optimum heat treatment time and temperature lies at solutionizing 920°C for 90’ and annealing 730°C for 90 to 120’.

5. References

[5] Xiang-Peng Xiao, Bai-Qing Xiong, Qiang-Song Wang, Guo-Liang Xie, Li-Jun Peng, Guo-Xing Huang, Microstructure and properties of Cu-Ni-Si-Zr alloy after thermomechanical treatments, Rare Met,(2013) 32(2):144-149.