Influence of Solution Treatment on Cold Drawing of CuNi2Si Rods

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Abstract. The influence of different microstructures resulting from the solution heat treatment of previously pressed rods of the CuNi2Si alloy on the process of cold drawing is reported. The best workability was obtained with rods having a uniform microstructure and without precipitates. On the other side, a non-uniform microstructure with the coarse grain boundary Ni_2Si precipitated particles results in a periodical appearance of arrow-like macrocracks. This material not suitable for cold drawing was a straight consequence of an inadequate solution treatment. By accommodating solution treatment parameters, all these defects were successfully eliminated and satisfactory quality of rods was obtained.

Introduction

CuNi2Si rods represent only a portion of the extensive production program of Copper and Brass Mill, Sevojno. This paper describes one of the many activities which objective is to improve technological process, especially the process of heat treatment, in order to accomplish the better quality of CuNi2Si rods and to reduce the waste of the material during the routine industrial production.

CuNi2Si alloy possesses a favorable combination of properties such as high tensile strength, electrical conductivity, resistance to stress-corrosion, durability and excellent workability. This alloy is extensively used for different technical purposes.

The purpose of this paper was to investigate the effect of solution treatment through different microstructures on the process of cold drawing of CuNi2Si alloy rods.

Experimental

CuNi2Si alloy was continuously cast (the nominal chemical composition is given in Table 1). The first operation in production of CuNi2Si rods was pressing, i.e. extrusion through die. At pressing temperature at 890°C nickel silicides (Ni_2Si) were completely dissolved in Cu matrix and alloy may be regarded as an α-solid solution. Pressed rods were cooled down in the air. During air-cooling some Ni_2Si particles were precipitated leading to the strengthening of the alloy and its high brittleness. Since the following plastic deformation (cold drawing) of these rods was impossible to perform, the next operation was solution treatment. Solution treatment of the pressed rod above solution temperature for Ni_2Si, which in this case was 800°C, should bring Ni_2Si into the α-solid solution. After solutionizing precipitation of Ni_2Si was inhibited by water-quenching and the supersaturated α-solid solution was retained at the room temperature. The supersaturated solid solution was ductile and the process of drawing may be performed without any difficulty. CuNi2Si rod treated in such a way may be cold drawn almost as pure copper.

Table 1. *The Nominal chemical composition of CuNi2Si alloy*

Standard	DIN 17666	Chemical composition (wt.%)			
		Ni	Si	impurities	Cu
Alloy	**CuNi2Si**	1,6 - 2,5	0,5 - 0,8	max. 0,5	remainder

However, during drawing some quenched rods vibrated and some waves could be seen on their surface. The cross-cut section of these rods (defined as VBR rods in further text) clearly revealed the appearance of hidden defects. Characteristic ring-shaped defects have been found: a relatively thick part near the surface was separated by a ring-shaped hollow from the central part of the rod. On the other side, longitudinal section revealed a periodical appearance of macrocraks in the form of an arrow point. All these defects are shown in Fig. 1.

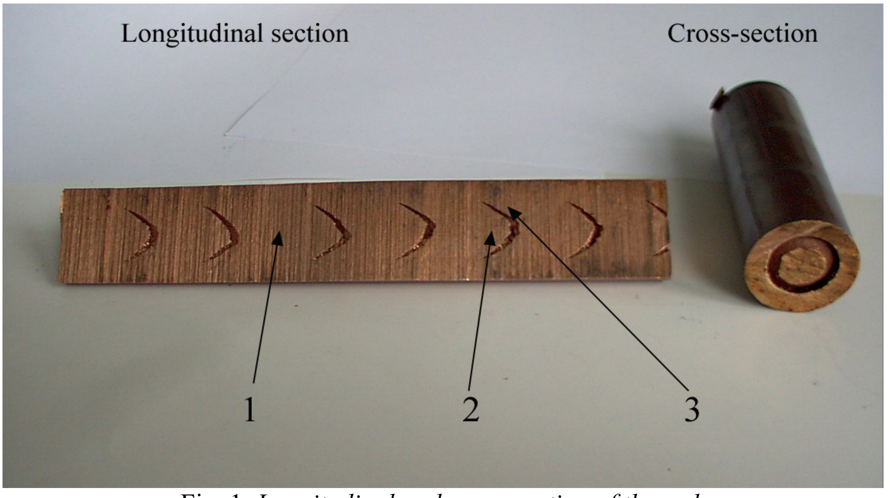

Fig. 1. *Longitudinal and cross-section of the rod.*

For microstructural investigation specimens were cut from both the cross-section and the longitudinal section of the defect rod. Also, some specimens were taken from the water-quenched rods, and the pressed rods cooled in the air. Metallographic preparation of specimens consisted of grinding and pre-polishing. The final polishing was performed with the diluted ammonium hydroxide in distilled water. A 10% mixture of ammonium persulphate was used for etching which was followed by rinsing in tartaric acid [1]. A light microscope "Leitz" was used for microstructural investigation.

Results

I pressed rod. Figs. 2 and 3 show micrographs of specimens taken from rods pressed at 890ºC and air-cooled.

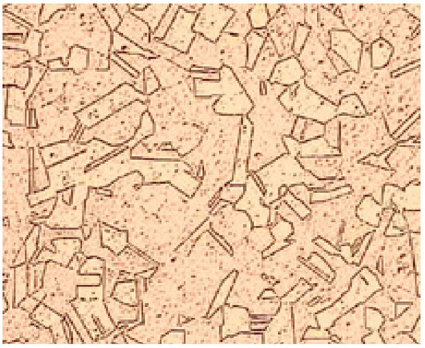

Fig. 2. *Pressed and air-cooled rod. (100x)*

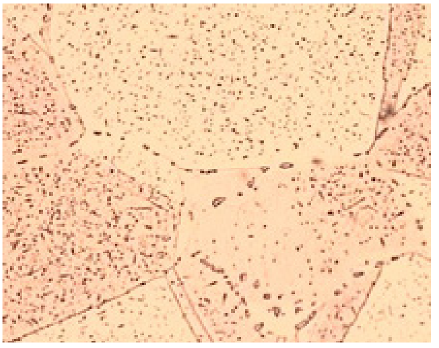

Fig. 3. *Pressed and air-cooled rod. (1000x)*

The microstructure is uniform throughout the cross-section. Coarser Ni_2Si particles are precipitated at grain boundaries, whereas smaller particles may be seen inside the grains.

II quenched rod. Figs. 4 and 5 show microstructure of the rods water-quenched after solution treatment at 800ºC. The structure is uniform throughout the cross-section. There are no precipitated Ni_2Si particles at the grain boundaries. Rods with this structure were drawn without any problems.

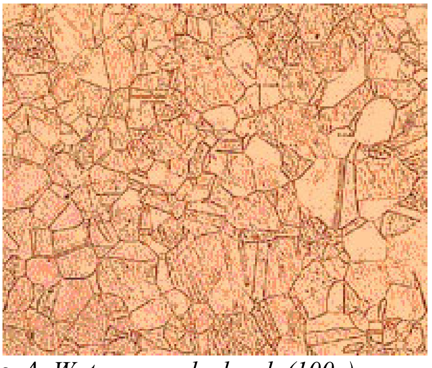

Fig. 4. *Water-quenched rod. (100x)*

Fig. 5. *Water-quenched rod (1000x)*

III Cross-section of drawn VBR rod. Fig. 6 shows the microstructure of the cross-section of the VBR rod, i.e. the segment taken between the edge and the center (see Fig. 1).

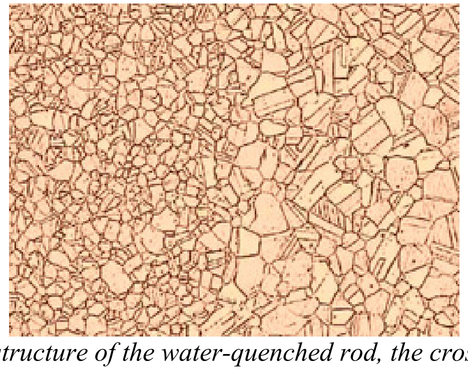

Fig. 6. *Microstructure of the water-quenched rod, the cross-section; the segment between the edge and the center of the cross-section. (100x)*

Microstructure of the cross-section is not uniform. Grains towards the center of the rod are small and round in shape with Ni_2Si particles precipitated at the grain boundaries, whereas the region near the surface of the rod consists of larger polygonal grains without precipitates.

IV Drawn VBR rod – specimens with hidden defects. Specimens were taken from three locations of the longitudinal section – denoted as positions 1, 2 and 3 in Fig. 1. Microstructure of position 1 corresponds to the area between two arrow-like macrocracks (Fig. 7.). Under higher magnification (1000x) globular particles may be seen at grain boundaries (Fig. 8). Coarse globular and plate-like Ni_2Si particles precipitated at grain boundaries are characteristic for positions 2 and 3 in Fig. 1 (Figs. 9 and 10). Even at low magnification (100x) microcracks formed at grain boundaries may be clearly seen in the vicinity of position 2 and 3 (Figs. 11 and 12). Higher magnification illustrates that microcracks are originated in the area where coarse or plate-like particles were precipitated (Figs. 13 and 14).

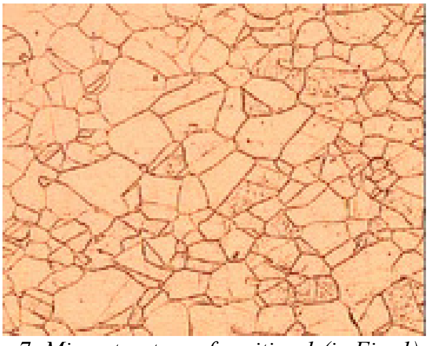

Fig. 7. *Microstructure of position 1 (in Fig. 1). (100x)*

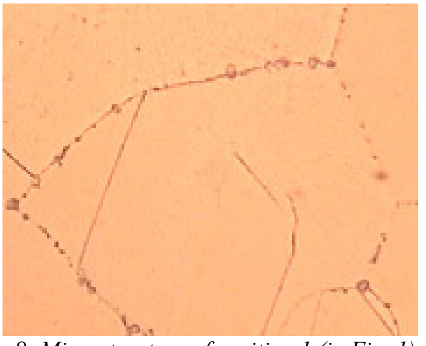

Fig. 8. *Microstructure of position 1 (in Fig. 1). (1000x)*

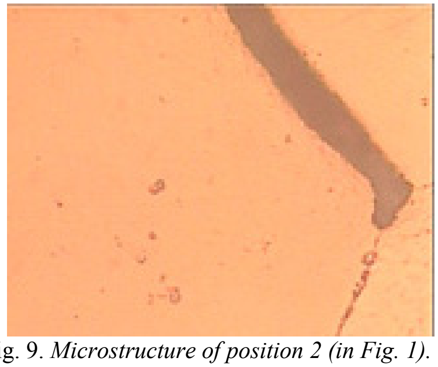

Fig. 9. *Microstructure of position 2 (in Fig. 1). (1000x)*

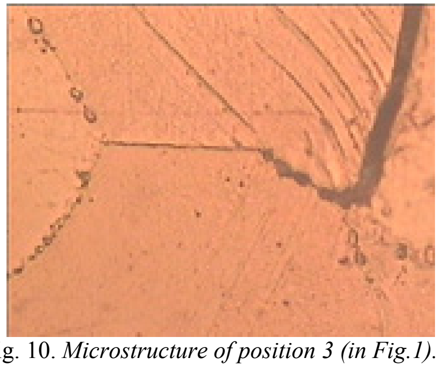

Fig. 10. *Microstructure of position 3 (in Fig.1). (1000x)*

Fig. 11. *Microstructure of position 2 (in Fig. 1). (100x)*

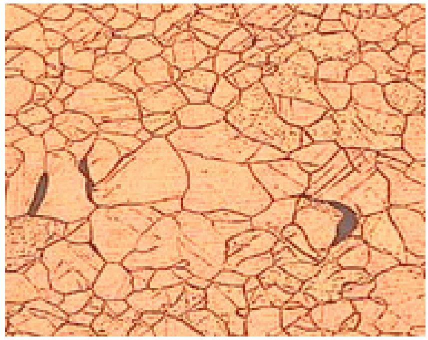

Fig. 12. *Microstructure of position 3 (in Fig. 1). (500x)*

Fig. 13. *Microstructure of position 3 (in Fig. 1). (500x)*

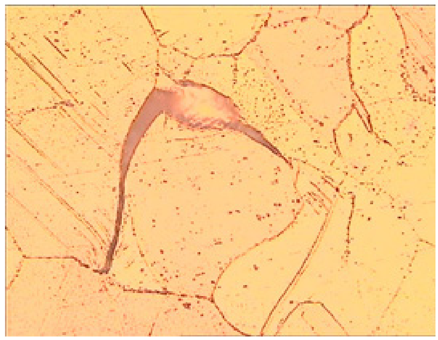

Fig. 14. *Microstructure of position 3 (in Fig. 1). (500x)*

Discussion

Due to a relatively great number of rods (mass of rods vs. capacity of the furnace was inadequate) subjected to solution treatment at 800^0C, the time necessary to transform the microstructure into the uniform α-solid solution was short, resulting in a non-uniform microstructure after quenching. Actually, the temperature of the outer parts of rods reached 800^0C, the temperature that will bring Ni_2Si into α-solid solution. Central parts of rods, however, were heated at temperature lower than 800^0C and Ni_2Si remained at grain boundaries as nondissolved globular and plate-like particles. In the following process of cold drawing these rods were observed to vibrate since the outer part of rods could be easily deformed passing through die, whereas the central parts were brittle due to grain boundary Ni_2Si particles. Interfaces between ductile Cu matrix and brittle Ni_2Si particles were regions for initiations of microcracks. The overall result is that these rods in longitudinal direction show hidden defects in the form of periodical appearance of arrow point-like macrocracks.

To eliminate this problem, the smaller number of rods was inserted into the furnace and annealed at 800^0C for the same time as in the previous case. After quenching the microstructure was uniform (similar to microstructure in Fig. 4) and no difficulties were experienced during drawing in the further practice.

Summary

The effect of different microstructures, as a result of solution heat treatment, on the cold drawing has been described in this paper. Due to inadequate solution treatment at 800^0C the microstructure of rods after water-quenching was not uniform and a mixture of globular and plate-like Ni_2Si particles remained nondissolved at grain boundaries. In the process of the following cold drawing these rods were vibrating and hidden defects in the form of periodical appearance of arrow point-like macrocracks were revealed in the longitudinal section of these rods. These macrocracks were the consequence of microcracking occurring at interfaces between grain boundary brittle Ni_2Si particles and ductile Cu matrix. With the lower mass of rods subjected to solution treatment the problem of cracking was eliminated with the unchanged time of annealing.

References

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