Effects of thermal treatments on mechanical properties of Cu-24.2%Mn alloy

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In this work, some physical and mechanical properties of Cu-24.2%Mn (wt %) alloy have been investigated by X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and compression deformation test. Austenite phase has been obtained in the samples by applying slowly cooling and rapidly cooling processes according to the SEM analysis. It has been observed that the grain size obtained by the rapidly cooling is smaller than the grain size obtained by the slowly cooling. Therefore, it has been concluded that the cooling process differences change the grain size of the alloy. Compression stress has been applied to the alloy in order to research the deformation effect on the austenite phase. Slip lines and martensite structure were observed on the surface of the alloys after the deformation. In the present work, shows that, in the slowly cooling and deformation provide not in effects of diriving forces on martensitic transformation, but the rapidly cooling and deformed sample was observed γ_1' (2H) martensite.

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1. Introduction

Solid-state reactions of the alloys provide some useful information to be used in the industry. Solidification is one of the most important phenomena during materials processing, therefore, research on solidification phenomenon. In the past four decades, important advances have been made in our fundamental understanding of solidification microstructures [1] The influence of the heat treatment solid-state reactions depending on homogenization periods, diffusion-strengthening effect, grain size and cooling rates on the phase structure of alloys. Grain boundaries are therefore important properties of the microstructures. They can be manipulated to control the mechanical properties. Coarse grains in particular are undesirable since they increase the mechanical strength, ductility and especially the strain recovery of the shape-memory alloys [2, 3, 4].

Moreover, the deformation behavior of metals and alloys is governed by the motion of dislocations and by deformation twinning, and, on a larger scale, by the formation of deformation inhomogeneities, especially shear bands [5, 6, 7, 8, 9]. But, it is difficult to maintain the desired chemical compositions and to control the grain size of Cu-based shape memory alloys (SMAs) by the conventional casting method. In general, the composition change will shift the transformation temperature and coarse grains give rise to weaken the mechanical properties of alloys [10]. The purpose of this work is to study, the effects of cooling rate on the thermal and mechanical behaviour of Cu-Mn (%Wt) alloy was investigated by SEM, XRD, and compression test. Firstly, the microstructure of the alloy was defined by SEM. Afterwards, compression tests were applied on samples exposed to various cooling rates. The effect of cooling rate on the mechanical behaviour of the Cu-Mn alloy was discussed. Changes in phase structure of the alloy were also examined by means of XRD technique.

2. Experimental Procedure

The composition of the alloy used in the present study was Cu-24.2%Mn (wt%) which was prepared by vacuum induction melting under an argon atmosphere from pure (99.9%) alloying elements. After this alloying, product alloy was used in the form of cylindrical bars with 1cm diameter, 10 cm length. In order to observe the effect of thermal treatments on deformation, two heat treatments were used, Table 1. Samples cut from the alloy were heated in evacuated quartz tubes in an Ar atmosphere and immediately quenched into iced-water rapidly cooling or in furnace cooled slowly cooling for homogenization. First group of samples were homogenized at 800 °C for 2 h and furnace cooled to 25 °C at a rate of approximately 2 °C/min and then air cooled, the second group of samples were homogenized at 800 °C for 2 h and then quenched

into ice water. Subsequently, homogenized samples were plastically deformed 30% on an Instron 8510-type compression test machine with a 0.2 mm/min crosshead speed at room temperature. Compression samples were prepared in the shape of rectangular pieces with dimensions of 4x4x8 mm. Bulk samples used in the SEM observations were mechanically polished and etched into a solution composed of 2.5 g $FeCl_3.6H_2O$ and 48 ml methanol in 10 ml HCl for 8-10 minutes. SEM observations were made using a JEOL 5600 scanning microscope, operated at 20 kV. Powder samples for X-ray examinations were prepared by filing the alloy. X-ray diffraction patterns of the powder samples were taken by a Bruker D8 Advance diffractrometer. For these examinations the monochromatic copper K_α radiation with wavelength of 1.5418 Å was used, a step size of 0.02°.

Table 1. Heat treatments and plastic deformation.

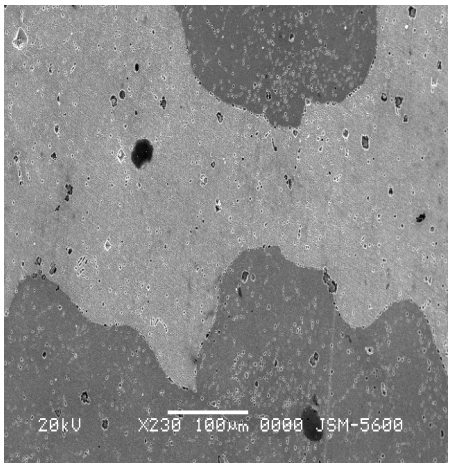
Samples	**Nature of heat treatments and plastic deformation**
A	Homogenized at 800 °C for 2 h and cooled to 25 °C furnace.
B	Homogenized at 800 °C for 2 h and quenched into ice water.
C	Homogenized at 800 °C for 2 h and cooled to 25 °C furnace then compressed by 30% deformation at room temperature.
D	Homogenized at 800 °C for 2 h quenched into ice water and then compressed by 30% deformation at room temperature.

3. Results and discussion

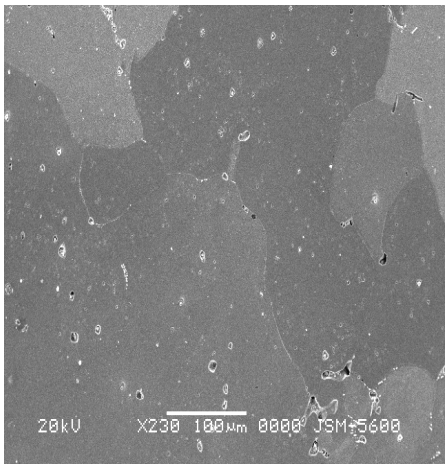
3.1. Effects of heat treatment on the Microstructure

The mechanical properties of the alloy were determined for two differently-heat treated materials (samples A and B). In order to investigate the influence of thermal treatments on the grain size responsible for the mechanical and transformation properties of the alloy, SEM observations of the samples were made before the compression tests. Fig. 1(a) and (b) shows SEM micrographs of sample A and B. According to the SEM analysis, austenite phase has been obtained in the samples which have been applied slowly and rapidly cooling process and tone difference of gray in the figures originates from the difference of the grain orientations. The microstructure of metals and many solid materials consists of many grains. A grain is a portion of the material within which the arrangaments of the atoms is identical. However, the orientation of the atom arrangement, or crystal structure, is different for each adjoining grain [2].

As seen from obvious morphological, grain size obtained by the rapid cooling is smaller than the grain size obtained by the slow cooling (Fig.1). Except for cooling rates so slowly that extremely small amounts of retained austenite result because of insufficient quenching, the amount of retained austenite decreases with increase in cooling rate. The main reason for this is that when cooled more slowly, frozen vacancies in specimens have enough time to migrate and disappear during cooling. Increase the number of grains and hence increase the amount of grain boundary. Any dislocation moves only a short distance before encountering a grain a boundary and the strength of the metal is increased [2, 3].



(a)



(b)

Fig. 1. SEM images of Cu-Mn alloy which was applied various cooling rate, (a) sample A and (b) sample B.

3.2. Effects of deformation on the Microstructure

Compression stress has been applied to the alloy in order to search the deformation effect on the austenite phase. Fig. 2 shows SEM micrographs of microstructures in samples C and D. In the specimen with a 30% stress the microstructure drastically changes, and a slip lines between grains obviously occurs (Fig. 2.). Slip lines and some martensitic variants have been observed in the compression strain of 30% sample D as shown in (Fig. 2(b)). The γ_1' martensite plates appeared as coarse variants (Fig. 2(b)). Three types of martensites, α' (3R), β'_1 (18R) and γ'_1 (2H), form depending on the amount of aluminum and manganese present in the Cu-based alloys [11]. The surface energy and transformation strain energy are needed for the martensitic transformations. However, the driving force necessary for the nucleation of the γ_1' martensite is expected to be higher than that of the β_1' martensite [12, 13]. But, our study shows that provide not in thermal effects of driving forces on martensitic transformations for Cu-24.2%Mn alloy [3].

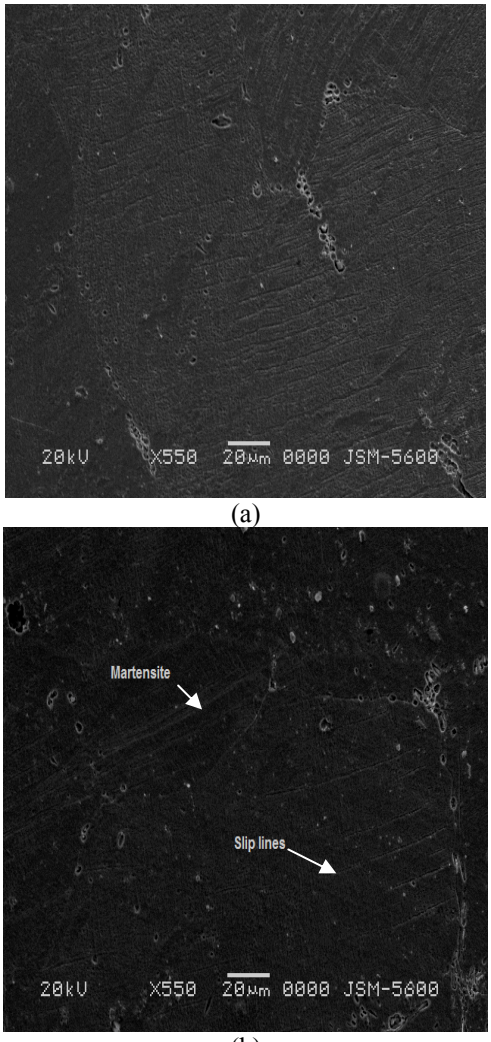


Fig. 2. SEM images of Cu-Mn alloy which was applied of samples and after deformation of 30% (a) slowly-cooled and (b) rapidly-cooled sample.

3.3. XRD Observations

In order to determine the crystal structure of the Cu-Mn alloy in the austenite state, X-ray diffraction sample was taken powder samples of the alloy. The phases of X-ray diffraction pattern of Cu-Mn alloy is determined by comparing between calculated peak positions with unit cell parameters of the phases and observed peak positions. By using this method, the different phases and the precipitates formed were identified by the X-ray diffraction analysis. Related peak positions of the phases were noted in the diffractogram the samples are shown in Figs. 3 and 4 on which diffraction peaks have been indexed.

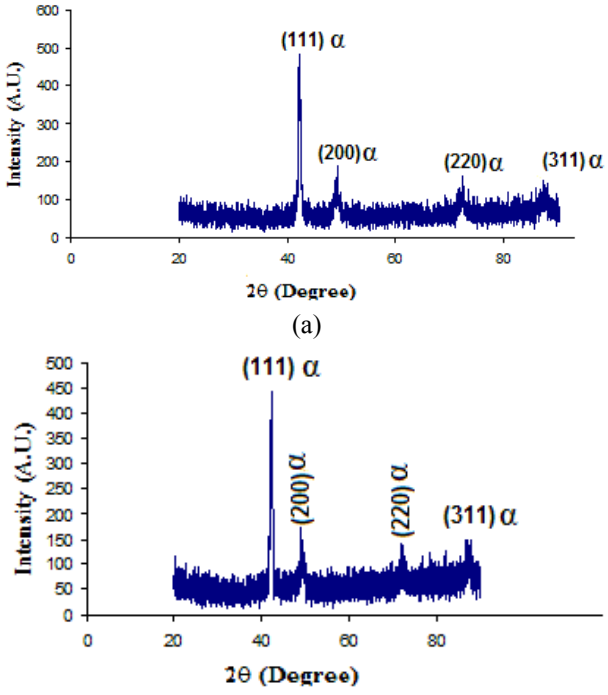


Fig. 3. X-ray powder diffractogram taken from sample A (a) slowly-cooled and (b) rapidly-cooled sample.

XRD observations show that the samples A and B have a structure of α-phase fcc Cu (a_o=3.6993 Å). The α-phase is the cubic f.c.c. copper-rich solid solution [14]. This situation means that this kind of two differently-heat treated does not change the crystal phases of this alloy. Phase transformations obtained by the plastic deformation have similar to results with the phase transformations obtained by the thermal methods.

But, Fig. 4(b) γ_1'(2H) martensite was observed for the rapidly cooling and deformed sample. SEM micrographs were observed of the some martensitic variants in sample B (Fig.2(b)). In addition, the intensities of X-ray peaks intensity decrease as cooling rate increases. This result indicates that density of crystal defects increases in the alloy with rapidly cooling [15].

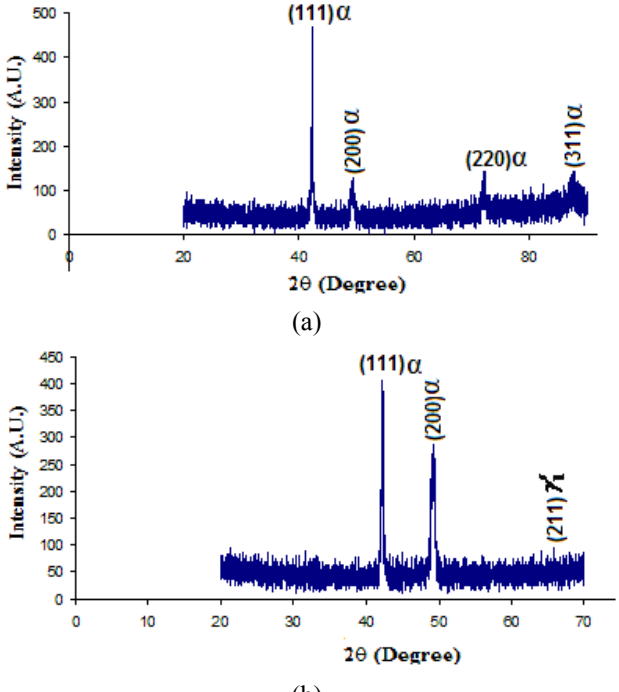


Fig. 4. X-ray powder diffractogram taken from sample B (a) slowly-cooled and (b) rapidly-cooled sample.

4. Conclusions

Finally, the cooling process differences changed the grain size of the alloy. Moreover, phase transformations obtained by the deformation method have similar results with the phase transformations obtained by the thermal method. But, slip lines and some martensitic variants have been observed in the Cu-24.2%Mn alloy after deformation of 30%. Thus, Cu-24.2%Mn alloy wasn't showed martensite phase transformation with thermal effect, because surface energy and transformation strain energy are needed for the martensitic transformations and they provided by thermal effect only for this alloy.

References

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