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PHASE TRANSFORMATIONS IN Cu-Zn-Al SHAPE MEMORY ALLOY

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ABSTRACT

The effects of speed of heating on transformations in selected Cu-Zn-Al alloy were studied.Using differential thermal analysis and X-ray measurements it was stated the sequence of transformations which takes place in quenched alloy as follows: $\beta_1' \rightarrow \beta_1 \rightarrow \alpha + \gamma_2 \rightarrow \beta$. It was observed that the transformations start temperature were virtually unaffected whereas the temperature range of the transformations progressively shifts upward with rate of heating increases.The $\beta_1 \rightarrow \alpha + \gamma_2$ transformation is connected with two thermal effects, i.e. endothermic $\beta_1 \rightarrow \gamma_2$ transformation and exothermic precipitation process of the α phase.

INTRODUCTION

Beta copper-base alloys have the unusual ability to recover an original shape after undergoing what would appear to be because of the magnitude of the strain involved, permanent deformation. These so-called "shape memory efects" are a direct results of thermoelastic martensitic transformation [1].In Cu-Zn-Al alloys, apart martensitic transformation, there are several phase transformations, depending on their chemical composition and rate of cooling or heating of the alloy [2] . These copetitive transformations like eutectoidal decomposition or ordering processes in the β phase and in the eutectoid could be the reason for a complicated of phase transformations sequence, especially in nonisothermal conditions.

The present paper provides some additional information on the Cu -14.4 wt.% Zn -8.4 wt.% Al, as part of a precise determination of phase transformations which take place during linear cooling and heating of this alloy.

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MEASURING METHODS

An alloy of the composition Cu -14.4 wt.% Zn -8.4 wt.% Al was melted in an induction furnace. After casting and rolling of the material, rods about 5 mm in diameter were obtained.This material was machinned into discs 3.0 mm thick which were solution treated 20 minutes at 700°C in helium protective atmosphere and quenched in ice-water. DTA curves were obtained during heating of the samples in the temperature range from 25 to 600°C by using a TA 1 type Mettler Thermoanalyser. The sequence and characteristic temperatures of the transformations were determined also by the X - ray studies and compared with DTA results.

RESULTS AND DISCUSSION

A. Post-quench phase transformations

Several phase transformations which take place during heating of the martensite of Cu-Zn-Al alloy were found by using DTA analysis. These transformations are connected with thermal effects which are marked on Figure 1 a as effects from P_1 to P_5.

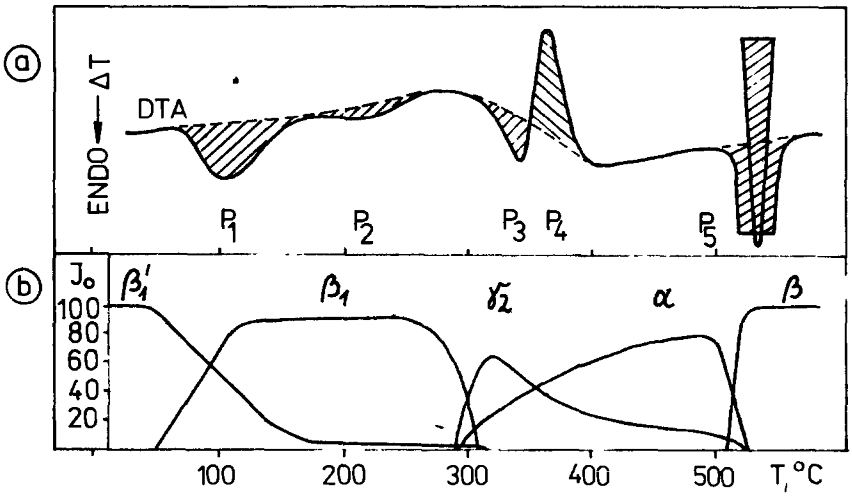

Fig.1a. DTA curve for Cu-Zn-Al alloy /heating rate 2°C/min /
1b. Relative X-ray peaks intensity of respective phases as a function of temperature

In order to analyse what transformations represent the registred thermal effects, the high-temperature X-ray analysis was applied /Fig.1b/. On the basis of X-ray results one can conclude that the following transformations occur:

1. In the temperature interval 80 - 300°C the martensite transforms into ordered β_1 matrix phase /$\beta_1' \rightarrow \beta_1$/. This transformation takes place in two steps which represent two endothermic effects P_1 and P_2. Nearly the whole quantity of martensite transforms into β_1 phase in the temperature interval 80-160°C. The second thermal effect - P_2, is connected with further transformation of the remaining martensite.
2. The next transformation which was indicated as P_3 and P_4 peaks on Figure 1 was connected with the transformation of β_1 phase into eutectoid mixture of $\alpha + \gamma_2$ phases /$\beta_1 \rightarrow \alpha + \gamma_2$/. In this case one can also determine two steps of the transformation. The first step /P_3 peak/ is connected with the endothermic transformation of β_1 phase into γ_2 phase. The second one is exo - thermal /P_4 peak/ and it is connected with the precipitation process of the α phase.
3. At the temperature of 520°C the α and γ_2 phases transform into the high-temperature β phase / $\alpha + \gamma_2 \rightarrow \beta$ /.

B. Effect of heating rate change

In order to determine the influence of the heating rate the samples were heated at different rates from 2 to 25°C/min. It was found that the sequence of phase transformations didn't change with the increasing of the heating rate. Some of the characteristic temperatures change only /Fig.2/. As we can see from Figure 2 the beginning of the reverse martensitic transformation /P_1 peak/ the $\beta_1 \rightarrow \gamma_2$ transformation /P_3 peak/ and $\alpha + \gamma_2 \rightarrow \beta$ transformation /P_5 peak/ begin at constant temperature. With the increase of heating rates the increase of the temperature of precipitation of α phase occurs /P_4 peak/. These results indicate that the precipitation of α phase is dominated by their reaction during DTA scans. In contrast the other transformations are dominated by their thermodynamic equilibrium [3].

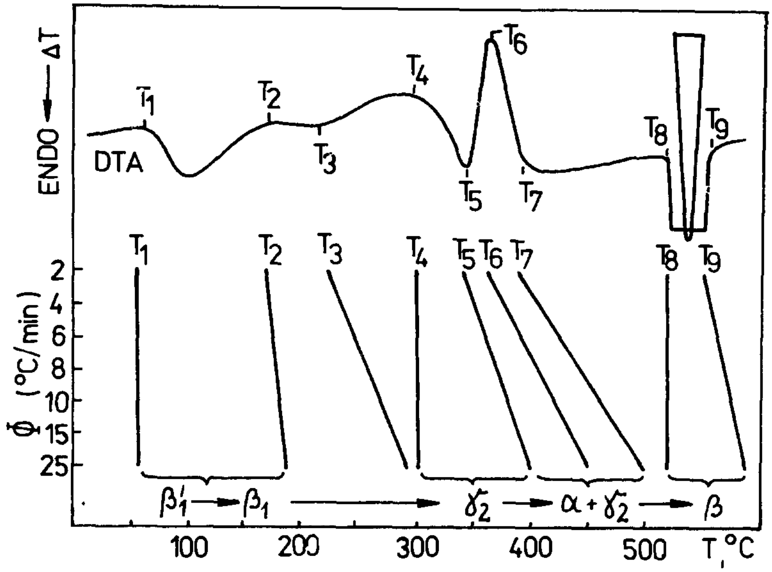

Fig.2. Influence of the heating rate on the temperature intervals succeding phase transformations

CONCLUSIONS

During linear heating of the martensite of the Cu-Zn-Al alloy containing 14.4 wt.% Zn and 8.4 wt.% Al the following phase transformations sequence was ascertained: $\beta_1' \longrightarrow \beta_1 \longrightarrow \alpha + \gamma_2 \longrightarrow \beta$. The $\beta_1 \longrightarrow \alpha + \gamma_2$ transformation is connected with two thermal effects i.e. endothermic $\beta_1 \longrightarrow \gamma_2$ transformation and exothermic precipitation process of the α phase. The precipitation of the α phase is dominated by their reaction during DTA scans. The reverse martensitic and eutectoid transformations are dominated by their thermodynamic equilibrium. The change of the heating rate didn't influence the sequence of phase transformation.

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