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KINETIC OF MARTENSITE TRANSFORMATION IN A Cu-13wt. %Al-4 wt.%Ni SHAPE MEMORY ALLOY

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ABSTARCT

In this paper we present some results was obtained on the Cu-13wt. %Al-4 wt. %Ni shape memory alloy. This alloy was elaborated by a classic melting method starting at pure metals. A DSC analysis was made for quenched sample cut from 4 mm diameter hot extruded wires. The results confirm thermoelastic transformation and provide for further application the critical temperatures for martensitic transformation.

KEYWORDS: Cu-13wt. %Al-4 wt. %Ni shape memory alloy, differential scanning calorimetry, JMA model

1. Introduction

Shape memory alloys (SMA) constitute an important alloy system due they capacity to use both as sensor and actuators. At the present, polycrystalline Cu-Al-Ni SMA have been developed as an alternative to the classically used Cu-Zn-Al and Ni-Ti alloys [1].

The main interest of these alloys is their possible use at temperatures near 200 ^{0}C in advantage over Ti-Ni alloys whose maximum working temperature is around 100^{0}C.

On the other hand polycrystalline Cu-Al-Ni SMA obtained under classic technology benefit by a low price.

Shape memory effect is related to the thermoelastic martensitic transformation. It is implicit in the concept of the thermoelastic transformation that there is reversible behavior involved in the martensite-austenite transformations [2].

Therefore, reversible transformation occurs on heating an alloy, martensitic transformation advances with the transformation of the martensite plates and the earlier formed plates vanish later during the reverse transition on heating.

After an alloy which exhibits thermoelastic martensitic transition is deformed at a temperature below M_f where the transition completes, even if the deformation stress are removed, it remains at the deformed shape but recovers the original shape on heating over the austenite phase finish temperature-A_f and gains the deformed shape on re-cooling below M_f.

2. Experimental procedure

The polycrystalline Cu-13wt. %Al-4 wt. %Ni alloy used was elaborated by a classic melting in a tilting induction furnace from DJ University of Galati. The samples were extracted from hot extruded wires 4 mm diameter and 145 mm length. The samples were quenched comprised heat treatment using a vertical furnace (air environment) holding at 850^{0}C during 30 minutes for annealing and immediately in ice water quenched. For DSC measurement was used a small piece weighting less the 0.100 g. The differential calorimetric experiment were performed by means of SETARAM 92 instrument in air at a heating and cooling rate of 10^{0}C/min between -50 ^{0}C and 250 ^{0}C. The cooling treatment was acted by using liquid nitrogen. The sample weigh was 0.07 grams. Prior to the DSC experiment the sample were submitted to a chemical etched 1:1 HNO_3 in water for 13 minutes in order to remove the layer deformed by cutting operation as well as the oxide. Endothermic and exothermic peaks on DSC profiles were taken from two consecutive thermal cycles.

Nucleation and growth process in studied Cu-13wt. %Al-4 wt. %Ni alloy follow the Jhonson-Mehl-Avrami (JMA) model:

$$Y = 1 - e^{-kt^n}$$

where Y is fraction transformed, k is a time independent but temperature dependent rate constant, and *n* is referred to the as the mechanism constant.

The above equation can be rearranged into a linear equation:

$ln\ (1-Y)=-kt^n$ or $ln\ [-ln\ (1-Y)]=ln\ k+n\ lnt.$

From fraction transformed versus time data, the values of *Y* and *t* can be inserted into this function, to generate a straight line

3. Results and discussions

Figure 1 show the results for two thermal cycles DSC. Fist of all the base line was established and then the peaks value. After subtracted peak values four curves was obtained (Fig.2.)

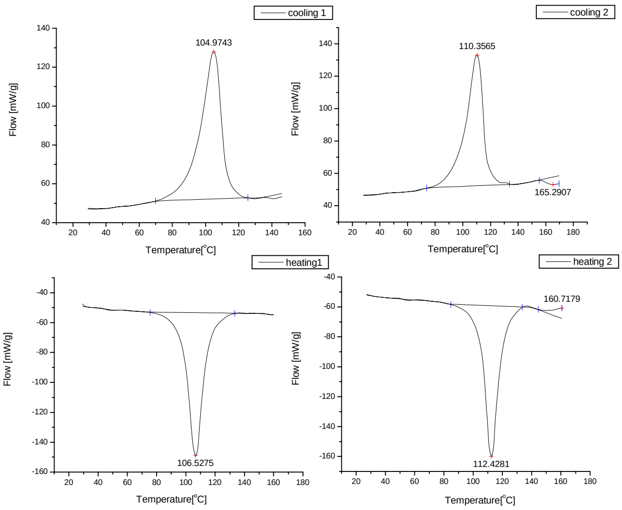

Fig.1. *DSC temperature peaks. Two thermal cycles between -50 ^{0}C and 250 ^{0}C*

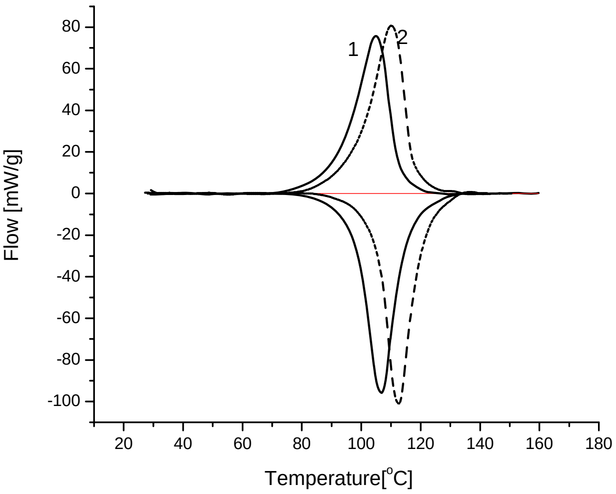

Fig.2. *DSC subtracted curves.*

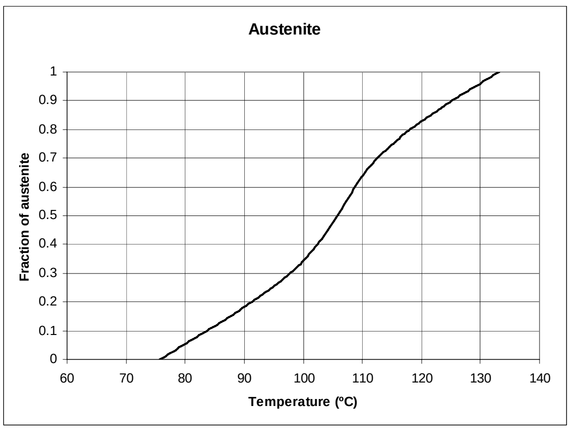

Fig.3. *Kinetic curve for inverse transformation on heating Cu-13wt. %Al-4 wt. %Ni sample.*

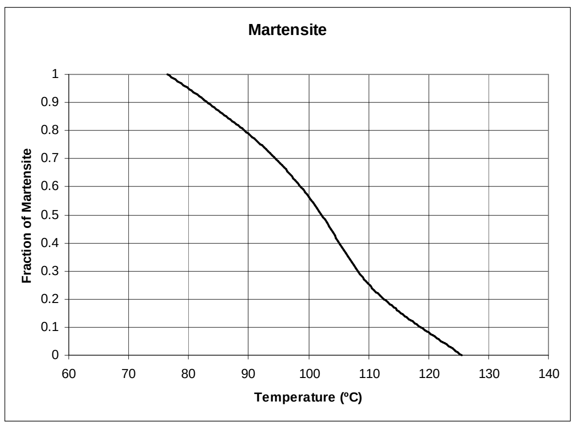

Fig.4. *Kinetic curve for direct transformation on cooling Cu-13wt. %Al-4 wt. %Ni sample.*

These curves allow carrying out a more detailed analysis of the thermoelastic transformation process (fig.3, fig.4).

Following JMA model the so obtained transformation temperatures M_s, M_f, A_s, A_f, is shown in table 1. The start transformation temperatures was considered for 1% transformed phase and the finish temperature for 99% transformed phase.

For Cu-13wt. %Al-4 wt. %Ni we obtain: M_s at 124.9 ^{0}C, M_f at 77.43 ^{0}C, A_s at 76.3 ^{0}Cand A_f 132.1 ^{0}C. Kinetic of transformation martensite to austenite on heating is shown in figure 5. Illustration of a transformation of fraction transformed plot to JMA plot for Cu-13wt. %Al-4 wt. %Ni alloy is presented in figure 6.

Table1.

Fraction of austenite [%]	**Temperature of transformation [^{0}C]**	**Fraction of martensite [%]**	**Temperature of transformation [^{0}C]**
0.1	75.6	0.1	125.5
1.0	76.3	1.0	124.9
5.0	79.6	5.0	122.3
10.0	83.7	10.0	118.7
50.0	105.5	50.0	102.4
90.0	125.2	90.0	83.3
95.0	128.8	95.0	80.05
99.0	132.1	99.0	77.4
99.9	132.8	99.9	76.7822

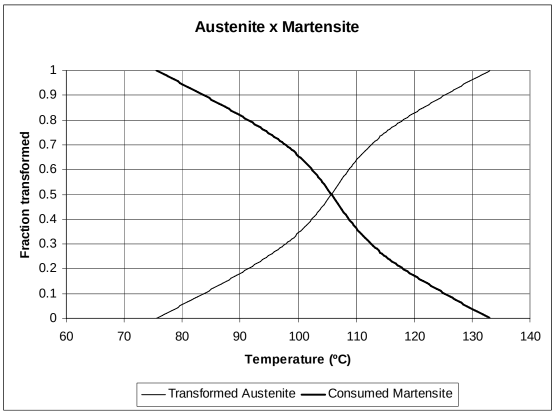

Fig.5. *Kinetic curves Martensite -Austenite Transformation on heating for Cu-13wt. %Al-4 wt. %Ni alloy.*

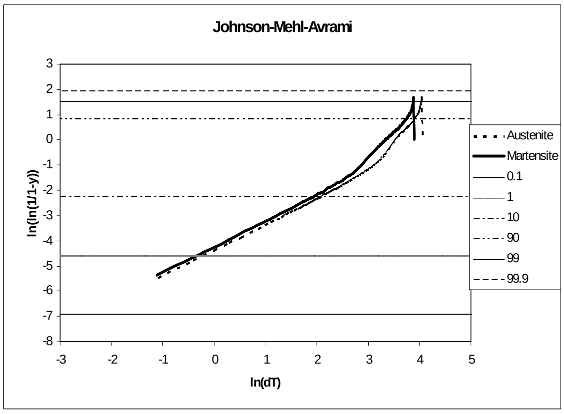

Fig.6. *JMA plot for Cu-13wt. %Al-4 wt. %Ni sample.*

4. Conclusions

a) Cu-13wt. %Al-4 wt. %Ni obtained by classic casting method is a thermoelastic alloy. The direct and inverse martensitic transformation is present. This alloy is reliable SMA alloy.
b) The samples in ice water quenched at the end of annealing treatment have the increasing transformation temperatures with thermal cycling because defects in the lattice are induced additional stress.
c) The kinetic curves for studied alloy are the normal plot for a SMA alloy.
d) The specific martensitic transformation for Cu-13wt. %Al-4 wt. %Ni alloy was precisely determined with JMA model.

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