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TWO - WAY SHAPE MEMORY EFFECT IN A Cu-13wt. %Al-4 wt.%Ni SHAPE MEMORY ALLOY BY THE THERMO -MECHANICAL CYCLING METHOD

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ABSTARCT

A Cu - 13 % wt Al 4% wt Ni polycrystalline shape memory alloy has studied with a thermo mechanical cycling method. The two – way shape memory effect (TWSME) was obtained bending the alloy around a cylinder mold and by using a constrained heating – cooling technique. This alloy elaborated by a classic melting method was extruded in wires with 4 mm diameter and was hot rolled in sheets with thickness.

KEYWORDS: Cu-13wt. %Al-4 wt. %Ni shape memory alloy, Two way shape memory effect, Cu based shape memory alloy, Thermal cycling, Martensite transformation

1. Introduction

Shape memory alloys (SMA) obtained under classic technology benefit by a low price engineering applications like sensors and actuators. Cu Al Ni SMAs can be used for higher working temperatures required (200^{0}C) excellent conductivity. Also those alloys are more resistant to degradation of functional properties due undesired aging effects than Cu Zn Al SMAs [1]. In Cu Al Ni SMAs with DO3 parent phase order thermoelastic transformation can be generate the two way shape memory effect (TWSME) not only shape memory effect (SME) like in reversible non thermoelastic martensite

TWSME is none an intrinsic property of shape memory alloys, it can be obtained only by training methods.

In parent phase is induced an internal tension by several methods:

- Thermo mechanical training under load heating;
- Excess deformation;
- Constrained aging treatment.

After training for obtain two-way shape memory effect, the material can alternate between two distinct shapes as it undergoes a thermal cycle. The origin of this particular property of SMA`s is still not completely understood but it has been proposed few different explanations:

- The effect of internal stress fields due to the complex dislocations introduced during training that produce selected martensitic variants;
- The presents of stress induced martensite inhibits the nucleation of self accommodating martensite plates.

The second mechanism has been reported to be the most plausible for TWSME [3].

In Cu-Al-Ni Alloys the types of martensite phases formed β'_1 (18R) or γ' (2H) can also play a role in have been considered that TWSME is. It is clear that TWSME corresponds to the preferential creation of certain variants of martensite that are energetically more stabile. Although there have been reports on the induction of TWSME by banding alloy samples around cylindrical shaped structures but only in Cu-Al-Zn alloys. The Cu-Ni alloy with 13% Al weight is a hard deformable SMA are less to the stabilization process then Cu Zn Al, and only few results exists on this training method for this alloys and that more for single crystals.

2. Experimental

The elaboration of Cu 13 Al 4 Ni alloy was made in the tilting induction furnace using pure metals copper nickel and aluminum plates. The cast ingot after remelting was turned in cylindrical shapes and was extruded from 35mm to 4 mm diameter in two steps. The specimens after extrusion were solubilised at 850 ^{0}C for 30 minutes and immediately in ace water quenched. The transformation temperatures measured by DSC (Differential Scanning Calorimetry) and calculated for 1 % austenite and martensite start and 99% austenite and martensite finish were M_s= 70 ^{0}C, M_f=109 ^{0}C, A_s=102 ^{0}C, and A_f=159 ^{0}C. Finally the hot extruded wires were hot rolled in fourteen successive passes into strips with 0.32 mm x 8 mm x 140 mm.

***Fig. 1.** Trained TWSME strip specimen*

The specimens obtained after hot rolled were in martensite state. The transformation temperatures after measured by DSC calculated for 1 % austenite and martensite start and 99% austenite and martensite finish were M_s= 44 ^{0}C, M_f=91 ^{0}C, A_s=60 ^{0}C, and A_f=109 ^{0}C.

In the first step the strip shaped specimens were bent around a cylinder mould of 50 mm diameter in R at room temperature in a circular arc shape. The second step consists in an unconstrained immersing in boiled water at 100^{0}C when the strips recovered the straight shape.

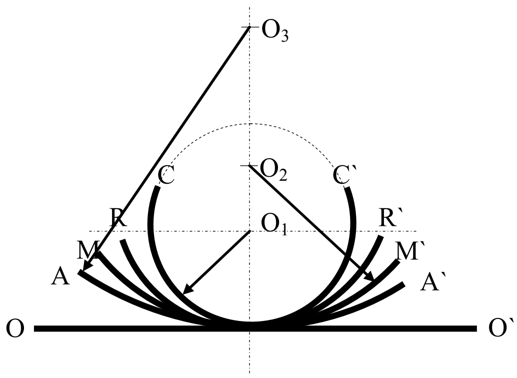

***Fig. 2.** Measurements TWSME scheme*

The qualitative TWSME was assessed by cycling the samples between the temperature below M_f and above A_f. This routine was repeated for 50 cycles in the same bending direction. A good SME was obtained after 20 cycles.

Measurements were carried out in the manner indicates in figure 2, in which the distance OO`, AA`, MM`, RR` and CC` were measured at both ends of the sample. The curve MM` represents the cold states while curve AA` represents the hot state shape after training treatment. OO` represents the original shape of the sample, RR` remanent shape after eliminated constrain in cold state an CC` the deformation of imposed shape during the treatment.

TWSME was assessed using the following equation:

$$strength\ of\ TWSME = \frac{AA` - MM`}{CC`} \cdot 100\,[\%] \quad [5]$$

Times between two consecutive cycles are 10 to 15 seconds.

For DSC measurement was used small pieces weighting less than 0.100g. The calorimetric experiments were performed by means of SETARAM 92 instrument in air at a heating and cooling rate of 15^{0}C/min, between -50^{0}C and 250^{0}C. The cooling treatments were acted by using liquid nitrogen. Endothermic and exothermic peaks on DSC profiles were taken from two sets of experiments:

- one thermal cycle were performed for hot rolled strip
- one thermal cycle were performed for sample trained.

3. Results and discussions

In table 1 is shown the variation of strength of two way memory effect in Cu13Al4Ni alloy as a result of varying the number of training cycles in the cold water constrained bend and unconstrained heating bend at 100^{0}C.

Table 1

Number of cycles	10	20	30	40	50
TWSME [%]	28.95	34	76.3	76.3	76.3

The strength of TWSME are about 28.95% after 10 training cycles and 76.3 after 30 training cycles indicating that TWSME increases continuously at least up to 30 cycles and it is maintained until 50 training cycles (fig.3.)

The transformation temperatures were obtained by DSC and calculated for 1 % austenite and martensite start and 99% austenite and martensite finish. In figure 4 is shown the subtracted DSC peaks for hot rolled samples and trained for TWSME samples.

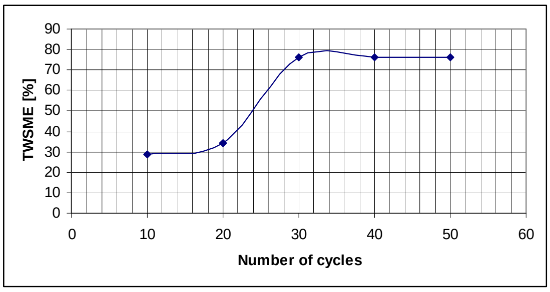

Fig.3. *TWSME variation with number of cycles.*

When the critical points for hot rolled specimens were: M_s= 70 ^{0}C, M_f=109 ^{0}C, A_s =102 ^{0}C, and A_f=159 ^{0}C and for trained specimens were M_s= 44 ^{0}C, M_f=91 ^{0}C, A_s=60 ^{0}C, and A_f=109 ^{0}C.

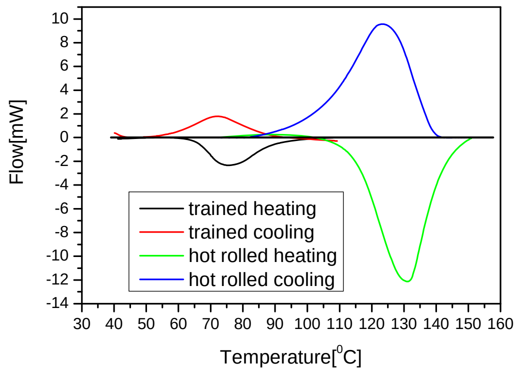

Fig. 4. *Subtracted DSC curves*

Thermo mechanical cycling, by which one forward and reverse transformation is completed it is known that produces a large number of dislocations, especially in parent phases of shape memory alloys. In this system alloy M_s temperature decreases markedly with increasing number of thermo mechanical cycle in the same time with A_f temperature.

That means equilibrium temperature between parent and martensite is decreasing. It is considered that the density of dislocations accumulated by thermo mechanical cycling also depends on transformation mode. The amount of dislocations produced by repetition of parent phase to 18R transformations is larger than to 2H transformations.

In figure 5 is shown the comparative transformation temperature between specimens after hot rolled and trained strip shaped.

After training process for obtain TWSME all the critical points decreases.

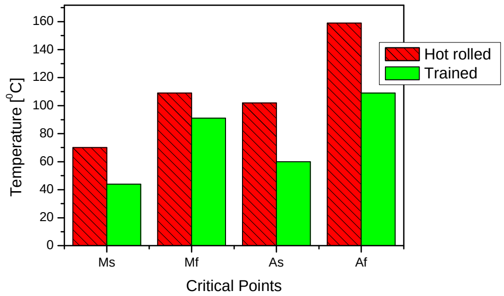

Fig.5. *Critical martensitic transformation points in hot rolled state and trained state.*

4. Conclusions

The two way shape memory effect in Cu13Al4Ni alloy was induced by a training method with cycles of constrained cooling and unconstrained heating.

The thermomechanical cycling treatment was achieved with constraining in ace water and unconstrained training at 100^{0}C in as- quenched state. After hot rolling, samples are in the martensite state without quenching treatment.

The mechanical straitening of the alloy was performed by bending around a cylinder mould.

The strength of TWSME tends to increase with increasing number of thermomechanical cycles until almost 30 cycles and tense to maintain for 20 cycles more.

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