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CHARACTERISTIC EVALUATION OF SHAPE MEMORY EFFECT OF COPPER-MANGANESE-ALUMINUM (CUMNAL) ALLOY

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Abstract:
Nowadays, shape memory alloys based on copper are attracting a lot of attention. Due to their low cost, excellent mechanical stability, ease of fabrication through induction melting, and widespread availability, much research on shape-memory alloys has focused on Ni-based alloys across all classes. Adding manganese to copper-based shape memory alloys improves their performance, which in turn allows them to withstand higher working temperatures [8]. Therefore, this study aims to create a CuMn13Al 7 very high temperature SMA by enhancing the manganese content by meticulous research. We use XRD, DSC, and the Pseudo Elastic effect to analyze the test samples' structures. The two primary design parameters for the SMA application—the shape memory ratio and recoverable strains—are investigated. The form memory effect is introduced in this article. With its newly-developed shape memory alloy, actuators can withstand a great deal of heat and cold.
Keywords: XRD, DSC, Shape Memory, CuMnAl Alloy.

1. Introduction

Shape memory alloys, characterized by the addition of the anthropomorphic properties for memory and training ability. A property of shape memory alloys is that they can be plastically deformed at one temperature and then fully recovered when subjected to a higher temperature, a phenomenon known as the shape memory effect. These alloys create a displacement or force that is proportional to the temperature as they return to their original shape. It is common to see a mix of the two effects. Activators allow metals to undergo a wide range of thermal transformations, including shape, position, pull, compression, expansion, bending, and twisting. Products with shape memory have many advantages, such as a huge range of possible shapes and configurations, a small temperature change that causes a large movement, resistance and long-term durability, ease of application (no tools are needed), and simple use(just heat it up).

Boon is these properties that make the Shape memory alloys help in solving a variety of problems. Shape memory alloys' practical qualities are associated with a (mostly) reversible (non) thermoelastic martensitic transformation, which usually occurs within a temperature range of -100 ° C to + 200 ° C. Present shape memory alloys are thought to have a high attenuation capacity, which is a crucial functional characteristic. Thus, a great deal of effort has gone into studying the relationship between the composition and, in particular, thermomechanical treatments, in order to optimize and quantify these damping qualities. Metal alloys known as shape memory alloys (SMAs) are able to recover from apparently permanent deformations by going through solid-to-solid phase transformations induced by temperature and stress variations stresses.

Production process and Experimentation:

The casting obtained from the selected composition was made by induction melting of the total mass of 10 kg (Cu - 80 %, Mn - 13 %, Al – 7 %) and through the sand-casting process. The ingot measures 250*85*45 mm. The CuMnAl memory alloy prepared was subjected to further homogenization process by heating the material above the recrystallization temperature to 850º C. It is then cooled in the oven to ensure uniform properties. The alloy block was cut into required specimens by EDM wire cut to remove the porous outer layers and to get 1*1*0.5 mm for DSC test. All test samples weigh less than 15mg as per the ASTM standards. Other tests for SEM, EDAX and XRD analysis do not require specific standards. DMA specimens are used for ASTM standards with length, width and thickness of 45*5*2 mm, as well as for non-DSC tests.

Results and Discussion:

XRD Analysis:

The Fig.1 shows the XRD model of the $CuMn_{13}Al_7$ alloy. Peak corresponding to the Cu plane (111) at position 2Ɵ is 42.53º. These XRD results are consistent with copper [27]. A peak corresponding to the Mn plane (220) is at 49.57°. The peak corresponding to (311) plane of Al at 72.70º and (222) plane of Al at 88.02º is based on the analysis of the microstructure. Wire Arc Additive Manufactured $CuMn_{13}Al_7$ High-Manganese Aluminium Bronze [26], which is in close agreement with the XRD pattern obtained by the researcher for the developed $CuMn_{13}Al_7$ alloy.

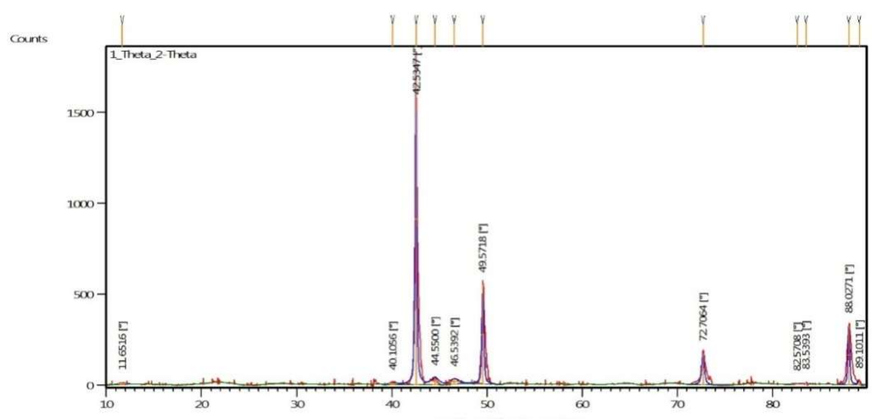


Fig 1: The XRD Pattern of the CuMn13Al7 alloy

DSC Analysis:

Differential scanning calorimetric analysis was then carried out to evaluate the thermal characteristics and to figure out the transition temperature of the shape memory alloy. A pace of 10º C/min was maintained for both heating and cooling. Both samples are carefully examined for DSC testing. You can see the flawless temperature hysteresis pattern that the tested sample generated in picture 1. After cooling, the first forward thermo elastic martensitic

transformation happened at around 40º C, and the first reverse thermo elastic transformation happened at approximately 380º C.
and can be used for high temperature applications in the aeronautical structures.

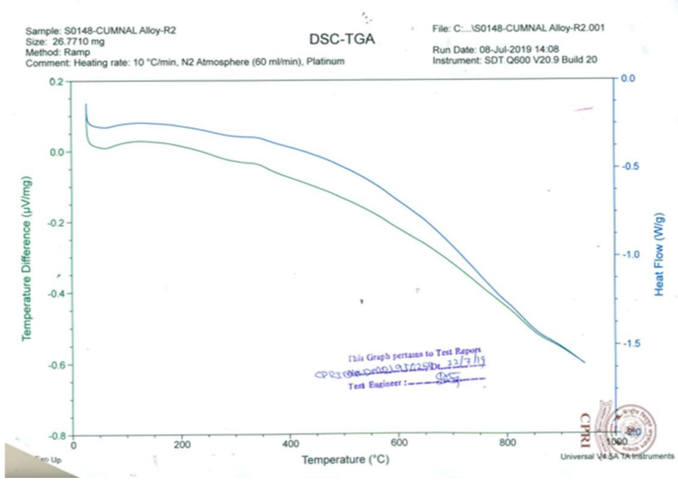
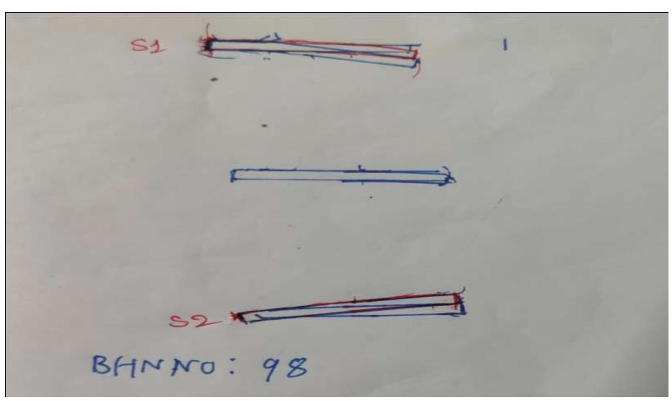


Fig 2: The DSC Plot

Shape Memory Effect:

Two samples of rectangular cross section of 10*4*2 mm of length, width and thickness have been taken. The two samples were bent at 5º and 10º respectively. The samples were subjected to heating around 410ºC in a muffle furnace which is above the transition temperature. The two samples have almost recovered the shape at an angle of 5º in each case have been observed and which shows that the shape memory effect exists for the chosen alloy with a limited value. The less shape memory effect is perhaps related to the increase in manganese content makes the alloy harder as found by Brinell hardness test. The maximum hardness obtained is 98 BHN.

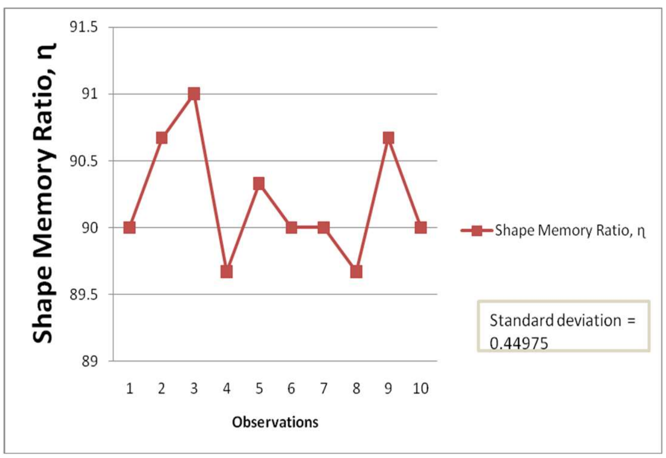


The sample with 5º repeated for the SME testing and the following observations are drawn regarding the shape memory ratio using the following formula (8).

S. No.	Initial Angle	Recovered Angle, ϴ	Shape Memory Ratio, ƞ
1	3	0.30	90
2	3	0.28	90.67
3	3	0.27	91
4	3	0.31	89.67
5	3	0.29	90.33
6	3	0.30	90
7	3	0.30	90
8	3	0.31	89.67
9	3	0.28	90.67
10	3	0.3	90

Table 1: The shape memory ratio of the samples

It was observed that the average of all the samples show an average of 90.2 as the shape memory ratio and with standard deviation of 0.4795. It is clear that the shape memory ratio is almost same for the all the observed samples. There is no much loss in the shape memory ratio of all the samples which signifies that the repeatability is high and the material can produce the SME over a large number of cycles.



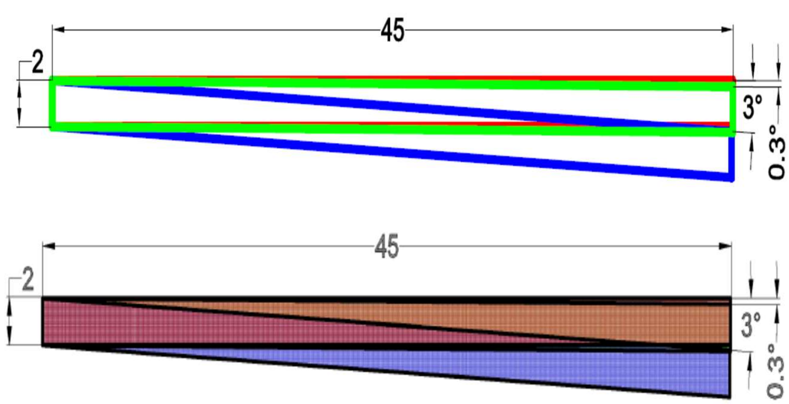


Fig 2: The photograph of SME reproduced in AutoCAD

The shape memory ratio ƞ = (1 - ϴ/3) X 100% = (1 – 0.3/3) X 100% = 90%

Conclusions

- XRD peak Pattern shown the composition has all the peaks of Cu similar to the JCPDS No. 040836 data and Mn and Al also have shown strong peaks showing all the elements of CuMnAl SMA is significant.
- The DSC study revealed that the composition has a perfect hysterisis curve which has a reverse thermo elastic deformation at 410ºC is achieved is almost same that of Cu–11.91Al–2.48Mn–0.1Zr (wt. %) developed by J. Chena, Z. Li a,b,∗, Y.Y. Zhaoc [8]**.** It is evident that there is improvement in the content of manganese helps the SMA to recover at high transformation temperatures and the alloy can be used for very high temperature applications.
- The shape memory is limited for this CuMnAl Shape Memory Ratio shown for individual measurements has an almost similar value which indicates that there is no loss in shape memory with increased number of cycles and as the inclusion of Mn exhibits a good resistance to irreversible martensite transformation [8]. This indicates that the Shape memory effect can sustain over the large number of cycles, so that this alloy can have good repeatability.

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