MECHANICAL CHARACTERIZATION OF CU BASED SMART MATERIAL WITH MN AND SI

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Abstract
The Cu-Al-Ni shape memory alloy billets were prepared using powder metallurgy technique by varying composition of major alloying elements such as copper and aluminium, and minor alloying elements manganese, and silicon. The sintered billets of 20 mm in diameter were machined to 18 mm in size in a lathe. The machinability of the sintered powder compacts were good. The tensile strength of the Cu-Al-Ni alloy sample without any minor alloying elements was 308.36 MPa. The hardness assessment carried out on the specimens revealed a maximum hardness value of 64 in rockwell hardness 'B' scale for the alloy Cu-Al-Ni with 'Mn' and 'Si' in it. The optical micrographs revealed the presence of fine grains and intermetallic compounds.

INTRODUCTION

A shape memory alloy keeps the original shape in memory after deformation and regain it's original shape when it is heated. A shape memory material has unique characteristics of relationship between stress, strain and temperature and is based on crystallographic reversible thermoplastic martensitic transformation. The phase transformation taking place at low temperature is martensite and the transformation taking place at higher temperature is known as austenite as in steel. The martensitic transformation temperatures can be "adjusted" between -200°C and 200°C. The shape memory properties are based on properties of the high temperature binary Cu-Al phase known as β, having a body centre cubic structure. Among various shape memory alloys, the costs of copper based shape memory alloys are less and have commercial significance. Cu-Al-Ni shape memory alloys are the only suitable alloys for high transformation temperatures requirement. Li et al fabricated Cu–Al–Ni–Mn shape memory alloy by adopting mechanical alloying and vacuum hot pressing followed by hot extrusion. The samples were examined with scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis. Presence of intermetallic compounds and their distribution was revealed in the above examinations. Morin and Trivero studied the thermo mechanical fatigue behavior of Cu–Al–Ni shape memory alloy. They studie d the effect of fatigue cycles and applied stress on shape and transformation temperature of SMA.

The shape memory recovery of the hot-extruded sample solution-treated at 850 oC for 10 min and quenched in water was 100% as it was immersed in boiling water bath for 40 s after deformed to 4.0%. The shape memory recovery of the sample remains 100% as it was subjected to cyclic loading conditions for 100 times. Cortes et al prepared multilayer shape memory alloy thin films with different Cu–Al–Ni composition. This multilayer's were thermally treated to produce alloys by solid solution diffusion and characterized for the martensite phase. Aydogdu et al investigated the role of long-term ageing on martensite characteristics and stabilization in two Cu–Al–Ni alloys. Each sample was heat-treated for long time and the heat-treatment time was selected in such a manner that the difference in time between each sample was very long. The XRD performed on the samples revealed variation in'd' spacing among the selected pairs of selected diffraction planes in the martensite formed Segui et al presented the changes in the martensitic transformation of a two different composition Cu-Al-Ni-Ti alloy by hot-rolling at two different temperatures 600 and 800 oC.

Mechanical properties of the alloy and internal friction were significantly improved by thermal treatments. Dagdelen et al revealed the martensitic transformation behavior, morphology and transition temperatures in copper-based shape memory alloys were strongly influenced by heat treatments. The effects of various quenching methods such as up-quenching and stepquenching in a water bath at 100 ◦C and in an oil bath at 200◦ C was studied on two way shape memory Cu–Al–Ni alloys. The changes in entropy and enthalpy at the martensitic transition were determined by means of differential scanning calorimeter (DSC) measurements. The SMA's are used in automotive, aerospace, robotics and in biomedical industries.

Experimental work

Powder metallurgy is the process of blending fine powdered materials, pressing them into a desired shape known as compacting, and then heating the compressed material in a controlled atmosphere to bond the material which is sintering. The powder metallurgy process generally consists of four basic steps: powder manufacture, powder blending, compacting, and sintering. Compacting is generally performed at room temperature but in few cases it is carried out at higher temperatures. Cu-Al-Ni-Mn-Si metal powders are purchased from MEPCO metal powder company, Madurai. The average particle size of powders is in the range of 27-44 microns. The cold compactions of powders for various compositions were done by using cylindrical die with bored hole to produce billets of dimension of 20 mm diameter and 30 mm height. The experiments are conducted by varying the composition of the alloying elements as shown in Table 1. The process parameters are set at two levels and the values are shown

S.NO 1- Cu-14Al-4Ni 620 MPa 850 °C

S.NO 2 -Cu-12Al-5Ni-2Mn 560 MPa 900 °C

S.NO 3- Cu-14Al-4Ni-2Mn-0.5Si 560 MPa 950 °C

The sintering process for the powder preforms were carried out in the temperature range of 850-900^{o}C for 2 hours followed by furnace cooling. The optical microscopic examination of the samples was carried out by polishing the samples using different grades of silicon carbide abrasive sheets. Finally, the samples were polished with Alumina compound to obtain mirror finish. The polished surfaces are etched with a chemical etchant containing 5 g Fecl3, 15 ml ethanol and 10 ml HCl. The mechanical properties of the Cu–Al–Ni cylindrical pieces were evaluated by conducting tensile test and hardness assessment on the specimens. The tensile test specimens were of 2 mm in diameter and 15 mm in gauge length. The tensiletest is conducted using a specially designed fixture as shown in Figure 1 (a) to hold the specimen and in turn the fixture is held in a tensile testing machine of 200 ton capacity as shown in Figure 1 (b). The load range of the machine is very high, therefore, a load cell having 7000 N capacity is used. The shape memory properties were evaluated by carrying out bend test on thin strips of rectangular section specimens with the dimensions of 30 mm × 3mm × 0.5 mm. The shape recovery ratio (SRR) due to one-way SME was estimated using following expression:

Results and Discussion

Tensile strength

The tensile test results of the various samples are shown in Table 3. A maximum tensile strength of 308.36 MPa was observed for the sample 1 as given in Table 2. The maximum tensile strength obtained for this sample is attributed to lesser amounts of intermetallic compounds formed in the alloy. For the sample 2 the tensile strength was 288.76 MPa. This tensile strength value is better than the tensile strength value obtained for the sample 3. As the alloy content increases, the tensile strength decreases because of more amounts of intermetallic compounds formed in the alloy. The tensile strength of the alloy containing Cu-Al-Ni-Mn-Si exhibited a minimum tensile strength of 271.67 MPa.

Conclusions

• The shape memory alloys Cu-Al-Ni with the addition of 'Mn' and 'Si' were produced by varying the process parameters such as composition, compacting pressure and sintering temperature. • These alloys possessed good machinability, moderate ductility and strength. • A maximum tensile strength of 308.36 MPa was exhibited by a Cu-Al-Ni alloy without 'Mn' and 'Si' addition. The sample failed in a ductile manner. • Brittle fracture was prevalent in the shape memory alloys added with 'Mn' and 'Si' in Cu-Al-Ni alloys. • The hardness of the samples was not so high. A maximum hardness of 64 in Rockwell hardness B scale was obtained.

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