ICAM2009
11th International Conference
on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

Thermoelasticity - Superelasticity and Shape Memory Mechanism in Copper Based Shape Memory Alloys

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Abstract – The shape memory alloys are termed as smart or functional materials and exhibit two peculiar properties: shape memory effect (SME) and superelasticity (SE). SME and SE are linked to a diffusionless solid state phase transformation process known as martensitic transformation (MT) in crystallographic manner, and lattices of materials exhibit two different configurations of the crystals: austenite and martensite. If the shape memory alloys are cooled to any critical temperature, martensitic transformation (MT) occurs and the material changes its internal crystalline structure with transformation. Shape memory materials can be plastically deformed when stress is applied and then are able to recover their original shape just by thermal means, on heating over the reverse transition temperature after removing the strain. These alloys cycle between the deformed and original shapes on cooling and heating; this property is termed thermoelasticity. The shape memory alloys have another property, superelasticity (SE) or pseudoelasticity (PE).

If the sample is stressed at a temperature over a temperature in austenitic matrix condition, a similar result is reached and this behaviour is called superelasticity or pseudoelasticity, whose mechanism is shematically illustrated in Figure 1. The superelastic SMA has the unique capability to regain the original shape from a deformed state when the mechanical load that causes the deformation is withdrawn [1].
When a shape memory alloy undergoes a martensitic phase transformation, it transforms from the parent phase to one or more of the different variants of the martensitic phase. In the absence of applied stresses, the variants of the martensitic phase usually arrange themselves in a self-accommodating manner through twinning, resulting in no observable macroscopic shape change [1, 2]. By applying mechanical loading the martensitic variants are forced to reorient (detwin) into a single variant leading to large macroscopic inelastic strains. The multiple martensite variants begin to convert to single variant, the preferred variant determined by alignment of the habit planes with the axis of loading [1, 2, 3].
In the present contribution, two copper based ternary shape memory alloys were selected for investigation: Cu-26.1%Zn-4%Al and Cu-11%Al-, 6% Mn. Powder specimens for X-ray examination were prepared by filling the alloys. Specimens for TEM examination were also prepared from 3mm diameter discs and thinned down mechanically to 0.3mm thickness. All of the specimens obtained from these alloys were heated in evacuated quartz tubes in the β-phase field (15 minutes at 830°C for CuZnAl and 20 minutes at 700°C for CuAlMn) for homogenization and quenched in iced-brine. These specimens were also given different post-quench heat treatments and aged at room temperature. TEM and X-ray diffraction studies carried out on these specimens. An x-ray diffraction profile taken from the quenched CuAlMn alloy sample is shown in Figure 2. X-ray powder diffractograms and electron diffraction patterns reveal that both alloys exhibit superlattice reflections in quenched case.

Key Words: Shape memory effect, thermoelasticity, superelasticity, martensitic transformation.

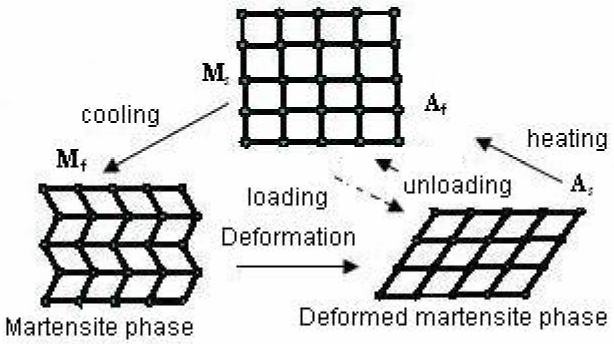

Figure 1 : Schematic illustration of the mechanism of the shape memory effect and superelasticity, solid lines represent the shape-memory path and dotted lines represent the superelasticity path

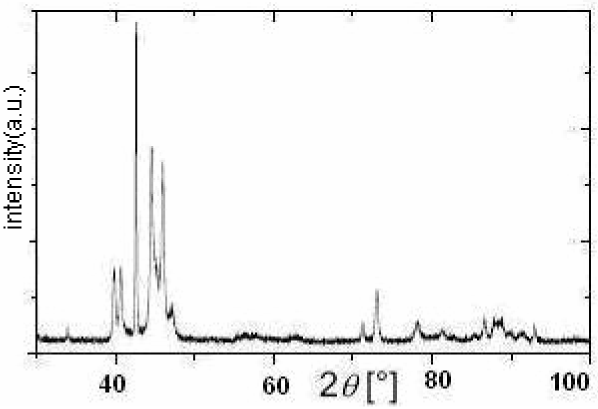

Figure 2: An x -ray powder diffractogram taken from CuAlMn alloy sample

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