ABSTRACT

Functionally graded material (FGM) is new generations of composite materials where the properties are changed linearly according to the change in composition. This research presents the design, fabrication and characterization of multi NiTi shape memory alloys incorporated into single functionally graded materials. This design assumed to improve the general properties of NiTi shape memory alloys, especially the transformation temperature range. These materials are designed to have gradual microstructural or compositional variations within the body in one piece or single material. The powder metallurgy approach has been used extensively in preparing of NiTi alloys as well as the two models of functionally graded materials. The effect of layers composition, sintering time and temperatures was studied on the; microhardness, porosity percentage, transformation temperature, microstructure as well as the developmental phases. Corrosion rate and characteristics as well as the toxicity of sintered materials are investigated also.

The fabrication phase of research starts with the design and development of functionally graded NiTi materials consists of axisymmetric seven layers. Four different compositions and thickness were considered. The composition of layers is (atomic percent) as follow: 50 Ti- 50 Ni, 49.3 Ti- 50.7 Ni, 48.5 Ti- 51.5 Ni and 47.8 Ti-52.2 Ni.

Two designs of functionally graded system were proposed and compared with the composition of each layer. Two functionally graded materials models were proposed and tested with the ANSYS -14. Both of the models were accepted from the mechanical design point of view. However, FGM_2 shows a logical deformation and linear stresses than FGM_1 model.

All layers as well as the functionally graded samples are compacted with (300 MPa) and sintered at (950 $^{\circ}$C) for (7 hours) under controlled atmosphere (argon). XRD tests show that the sintered samples consist of two phases; Martensite and Austenite at room temperatures (A-NiTi, M-NiTi and Ni_3Ti). DSC test illustrated that each of functionally graded materials, sample having lower and higher (A_f) and (M_f) respectively than each of the layer. SMA-FGMs show a superior and developed transformation temperature range rather than single alloy design. The microhardness test display hardness decreased when increased Nickel contents for layers and decreased to the core of functionally graded samples.

Corrosion test results show that the current of corrosion ($I_{corr.}$) for SMA-FGM samples are less than that obtained at each layer (i.e.19.02, 15.32 $\mu A/cm^2$ for $SMA\text{-}FGM_1$ $SMA\text{-}FGM_2$) respectively, and Nickel ions percentage in Ringer solution after corrosion test show $SMA\text{-}FGM_1$ $SMA\text{-}FGM_2$ samples less than each layer.

The thermal properties include thermal conductivity, thermal diffusivity and specific heat are also investigated for prepared SMA-FGMs and the thermal conductivity is 5.33, 4.14 W/km for $SMA\text{-}FGM_1$ $SMA\text{-}FGM_2$ respectively.

Ultrasonic test as nondestructive inspection was used to calculate mechanical properties such as young modulus, shear modulus and poison's ratio. In this study, modulus of elasticity and other mechanical properties have been determined by destructive compression tests.

The second design of functionally graded materials shows a superior shape memory effect (SME) and shape recovery (SR) properties (i.e. 8.747, 10.270 for $SMA\text{-}FGM_1$ $SMA\text{-}FGM_2$ respectively, and SR is 1.735, 2.977 for $SMA\text{-}FGM_1$ $SMA\text{-}FGM_2$) respectively.