Development of a new constrained recovery application of FeMnSi-base shape memory alloys

V Paleu[1], G Gurău[2], R I Comăneci[1], V Sampath[3], C Gurău[2] and L G Bujoreanu[1]
[1] 'Gheorghe Asachi' Technical University of Iaşi, Blvd. Dimitrie Mangeron 67, 700050, Iaşi, Romania
[2] 'Dunărea de Jos' University of Galati, Str. Domnească 111, 800201, Galaţi, Romania
[3] Indian Institute of Technology Madras, Chennai-600 036, India

Abstract: A new application of Fe-Mn-Si based shape memory alloys (SMAs) was developed under the form of truncated cone-shaped module, for self-adaptive axial preload control in angular contact bearings. The modules were processed by high-speed high-pressure torsion (HS-HPT), from circular crowns cut from axially drilled ingots of Fe-28Mn-6Si-9Cr (mass%) SMA. The specimens were mechanically tested in the hot rolled state, prior to HS-HPT processing, demonstrating free-recovery shape memory effect (SME) and high values for ultimate tensile stress and strain as well as low cycle fatigue life. The HS-HPT modules were subjected to static loading–unloading compression, without/with lubrication at specimen-tool interface, both individually and in different coupling modes. Dry compression cycles revealed reproducible stress plateaus both during loading and unloading stages, being associated with hardness gradient, along cone generator, caused by HSHPT processing. Constrained recovery tests, performed using compressed modules, emphasized the continuous generation of stress during heating, by one way SME, at a rate of ~9.3 kPa/%. Dynamic compression tests demonstrated the capability of modules to develop closed stress–strain loops after 50 000 cycles, without visible signs of fatigue. HS-HPT caused the fragmentation of crystalline grains, while compression cycles enabled the formation of ε hexagonal close-packed stress-induced martensite (ε), which is characterized by a high density of stacking faults. Using an experimental setup, specifically designed and manufactured for this purpose, both feasibility and functionality tests were performed using HS-HPT modules. The feasibility tests proved the existence of a general tendency of both axial force and friction torque to increase in time, favoured by the increase of initial preloading force and the augmentation of rotation speed. Functionality tests, performed on two pairs of HS-HPT modules fastened in base-to-base coupling mode, demonstrated the capacity of modules to accommodate high preloads while maintaining both axial force and friction torque at constant values in time. These preliminary results suggest that, for the time being, the modules can operate only as single use applications, more effective during the running-in period. This bevahior recommends HS-HPT modules as a new application of Fe-Mn-Si SMAs, with the potential to be used for the development of new temperature-responsive compression displacement systems.

Keywords: shape memory alloy, high-speed high-pressure torsion, martensitic transformation, functional testing, constrained recovery, thermomechanical training, self-adjustable axial preloading