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A comparative study of Ni–Ti and Ni–Ti–Cu shape memory alloy processed by plasma melting and injection molding

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ABSTRACT

Shape memory alloys (SMA) are smart materials that present potential applications in such diverse areas as aeronautics, automotive, electronics, biomedicine and others. This work aimed at comparing some physical and functional properties of a Ni–Ti–Cu and equiatomic Ni–Ti SMA. Therefore, Ni–50Ti and Ni–50Ti–5Cu (at.%) were manufactured using plasma melting followed by injection in metallic mold, named Plasma Skull Push–Pull (PSPP) process. Afterwards, samples of both Ni–Ti based SMA were annealed at 1113 K during 2400 s and water quenched. The obtained specimens were analyzed by optical microscopy, microhardness, differential scanning calorimetry, electrical resistance as a function of temperature, and force generation tests. The results showed that Ni–Ti alloy presented higher levels of hardness and lower generated recover forces during heating when compared to the Ni–Ti–Cu SMA. Moreover, the Ni–Ti alloy holds hysteresis larger than the Ni–Ti–Cu SMA as a result of the presence of the R-phase transformation. There was also a better stability under thermal cycling of NiTiCu SMA compared with the equiatomic NiTi.

1. Introduction

Among the several materials already designed and produced, there is a relatively new class denominated smart materials, such as the shape memory alloys (SMA). SMA exhibit the capacity to recover an original shape that existed before the introduction of a plastic deformation, through a reversible martensitic transformation, when submitted to a heating up to a critical temperature. Therefore, these materials are considered thermo-mechanical actuators. However, the shape memory effect (SME) is a peculiar phenomenon presented by some alloys that exhibit reversible martensitic phase transformations [1]. These special alloys present, through SME, recoverable deformations that can reach up to 5% in uniaxial tension accompanied by a thermal hysteresis [2]. Alternatively, considerable forces can be generated if these reversible deformations are restricted in some direction during the activation of the SME. This capacity of generating forces as a function of temperature allows these SMA have a great potential application in couplings and others similar devices [3,4]. This ability has also motivated the development of composites with SMA wires embedded in polymer matrix mainly targeting attenuation of mechanical vibrations and controllable shape change of the composite structure [5–7]. As demonstrated recently by da Silva et al. [8], in applications involving mechanical vibrations, high damping capacity of SMA compared with conventional metallic alloys can also be harnessed to improve the performance of any mechanical system.

In general, three large families of SMA are available commercially: Ni–Ti, Cu–Zn–Al and Cu–Al–Ni [1]. Due to its excellent corrosion resistance and better shape memory properties, Ni–Ti based alloys are more frequently found in commercial applications, mainly as thermo-mechanical actuators in several sectors of the engineering in general, but as well as in the medical and dental fields [1,9].

The Ni–Ti binary equiatomic alloy is widely used in commercial devices. In this SMA the martensitic transformation can be preceded by an intermediate transformation, called pre-martensitic. This intermediate phase, designated R-phase, presents a rhombohedral structure. Furthermore, this alloy presents a relatively larger thermal hysteresis compared to copper based alloys [1]. However, to meet the needs of a given project, a third element can be added to Ni–Ti binary alloys in order to modify their phase transformation temperatures, but never interfering in the ductility of the martensitic phase and the great performance of SME verified in binary alloys. Copper is one of the elements that can be added to Ni–Ti binary alloys. In Ni–Ti–Cu alloys the intermediate R-phase does not occur and the thermal hysteresis is much smaller than those in the Ni–Ti binary alloys [1,10].

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