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Damping behavior of a NiTi Shape Memory Alloy

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Abstract – Shape Memory Alloys (SMA) are smart materials that have attracted increasing attention due to their superior damping properties when compared to classical structural materials. These functional materials exhibit high damping capacity during phase transformation and in the low temperature martensitic state [1]. In this work a Ni-45.3Ti (% wt) SMA was produced using the plasma skull push-pull process to study its phase transformations and damping capacity in a single cantilever mode. Plate specimens were manufactured to accomplish the dynamic mechanical analysis. The studied NiTi presented the characteristic damping peak on phase transformation and increase of storage modulus after conversion of low temperature phase to high temperature phase.

The Shape Memory Effect (SME) phenomenon occurs as a result of a diffusionless phase transformation induced in the material. Among SMA, the NiTi alloys have been used to develop applications in some engineering fields as aerospace, biomedical, automotive and oil exploration, mainly as thermomechanical sensors and actuators. In this context, a better damping capacity of SMA is interesting because it can lead to a better vibration control and improvement of the life time of mechanical systems incorporating these advanced alloys. Moreover, these materials also present an increase in their storage modulus, which indicates an improvement of stiffness degree during phase transformation. The martensitic phase of SMA is related to low stiffness and higher damping capacity in comparison with the high temperature of the parent phase (austenite), which presents high values of stiffness. The best damping capacity of martensite is closely related to the movement of twin interfaces and dislocations induced through processing of the material [2].

In this work, a Ni-45.3Ti (% wt) SMA bar was produced by the Plasma Skull Push Pull (PSPP) process, which was cutted off and hot-rolled to achieve a plate specimen with dimensions around 17 mm x 5 mm x 0.4 mm. The dynamic mechanical analysis was performed using commercial equipment from TA Instruments (DMA Q800) that was used to measure damping capacity of the designed specimens in single cantilever mode. The specimen was annealed at 450 ºC for 15 min followed by water quench at room temperature to achieve martensitic structure.

As can be observed in Fig. 1, the SMA presents a peak of damping capacity during its phase transformation and increase of storage modulus, which indicates improvement of material's stiffness. The specimen shows higher damping capacity in low temperatures (martensitic region), when compared to the austenite state (high temperatures). The change that storage modulus undergo during the phase transformation process has the same reasons of damping capacity, associated to inner movement of material structure, increasing while temperature increases, which demonstrates inferior stiffness in martensitic phase whether compared with the parent phase as reported in literature [3]. Thus, through DMA test it's possible to determinate the start and finish of phase transformation temperatures under dynamic regime, besides to delimit the high damping capacity in different temperature regions presented by NiTi SMA.

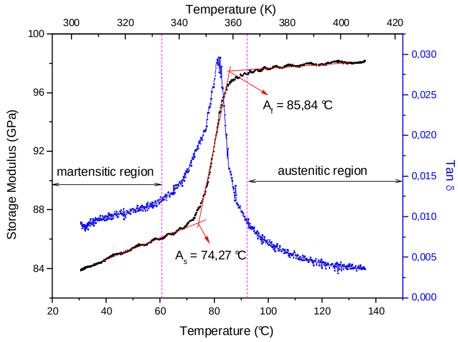

Figure 1: Damping capacity and storage modulus as a function of temperature for NiTi SMA specimen.

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