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A comparative study of dynamic properties between NiTi SMA and classical structural materials

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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, commercial aluminium and stainless steel were submitted to dynamic mechanical analysis (DMA) in a single cantilever mode. Plate specimens were manufactured to accomplish the DMA tests. The studied NiTi presented a damping capacity peak during phase transformation, being much higher than damping of conventional materials. SMA also showed an increase of storage modulus after conversion of low temperature phase to high temperature phase (Fig. 1b) while an almost linear decrease is observed for the conventional materials studied.

NiTi SMAs have been used to develop applications in some engineering fields as aerospace, biomedical, automotive and oil exploration, mainly as thermomechanical sensors and actuators. The damping capacity is an important property of materials because it can lead to a better vibration control and improvement of the life time of mechanical systems. According to literature, SMA exhibits highest damping capacity for all hidamets which makes them attractive for specific applications [2]. Moreover, these materials also present an increase in their storage modulus after heating, which indicates an improvement of stiffness degree during phase transformation. The best damping capacity of martensite in SMA is closely related to the movement of twin interfaces and dislocations induced through processing of the material [3].

A NiTi SMA, aluminum and stainless steel specimens with dimensions around 17 mm x 5 mm x 0.4 mm were used in this comparative study. The dynamic mechanical analysis was performed using commercial equipment from TA Instruments (DMA Q800) that was used to measure the variation of damping capacity and storage modulus of the specimens in single cantilever mode with the temperature increase. The SMA specimen was annealed at 450 ºC for 15 min followed by water quench at room temperature to achieve martensitic structure.

As can be observed from Fig. 1(a), the damping capacity of NiTi SMA is much higher than classical materials at median (80 ºC) and room temperature. During heating, there is a perceptive increasing of damping capacity in the classic materials, being it smooth for stainless steel. At high temperatures, NiTi SMA presents a reduction of damping capacity due to its parent phase (austenite) to absorb less mechanical energy, while the aluminum demonstrate a higher damping capacity. Thus, the aluminium presents more mechanical energy absorption than SMA and stainless steel at high temperatures (above 100 ºC). It is verified that the stainless steel presents a larger storage modulus than another materials, which result in a higher stiffness too. Both, stainless steel and aluminium, present decrease of storage modulus when temperature increases. The NiTi SMA presents completely opposite behavior, because it demonstrates an increase of modulus during phase transformation. So, at high temperatures (austenitic state) the NiTi SMA specimen holds higher storage modulus and, consequently, higher stiffness than at low temperatures (martensitic state). In Fig.1(c), it can be seen that the classic structural materials presented a decrease of about 5 % in storage modulus for the temperature range studied, while in SMA the modulus is increased in 16% due to phase transformation.

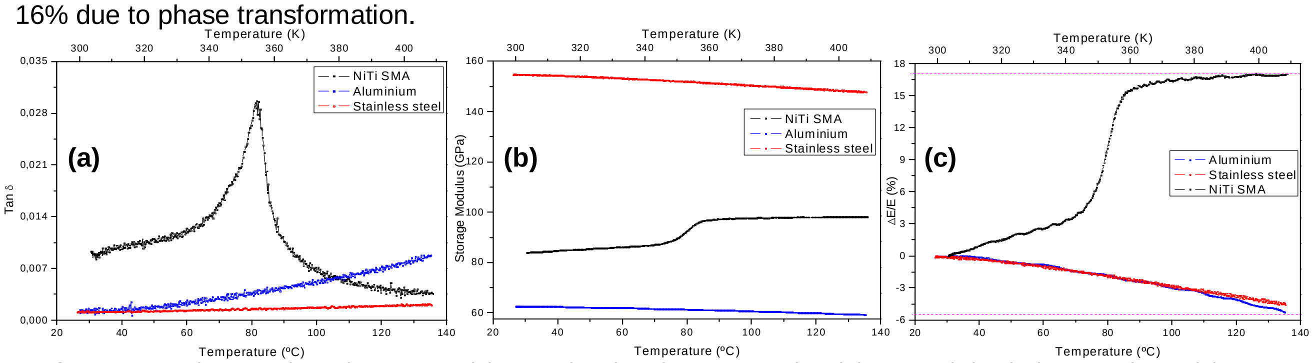

Figure 1: Damping capacity and storage modulus as a function of temperature for NiTi SMA and classical structural materials.

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