APPLICATION OF SHAPE MEMORY ALLOYS FOR JOINING PROCESSES

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Abstract

The shape memory effect (SME) can be interestingly used to perform joining processes of various components. Hence, the first industrial application of Ni-Ti alloys, were on joining sleeves for the hydraulic circuit of the F-14 fighters planes from the US Navy. Since then, it has been often referenced in literature, the possibility of using the SME in the joining process of various components with rivets. Although conceptually interesting, the fact is that there are no indications of industrial use of this type of joining process. In 2013 a patent in the aeronautic domain was issued [1], this launches new interesting perspectives for this type of joining processes, combining the action of the SME, the hardening on both materials, and finally the thermal hysteresis transformation.

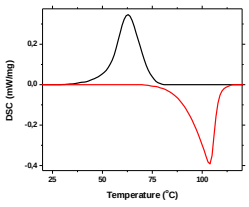
In this work the effectiveness of using NiTi for joining purposes is tested by means of mechanical and thermo-mechanical characterization.

Experimental

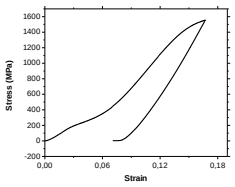
DSC Thermal analysis NiTi (Ti rich) as-received → Compression test 16% deformation → Free recovery analysis using dilatometer → Thermo-mechanical testing (13% compressive deformation followed by heating and cooling of the sample)

Experiments & Results

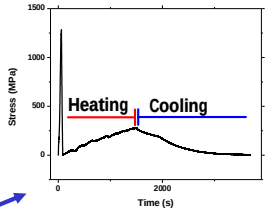
DSC testing



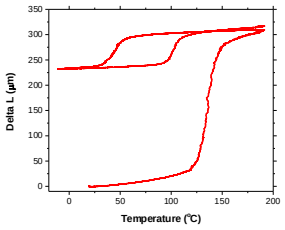
Compressive deformation

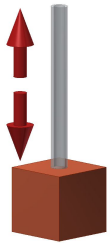


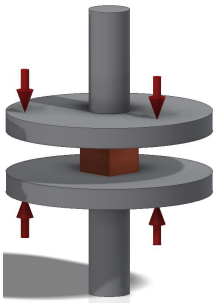
Thermo-mechanical testing



Free recovery analysis (Dilatometry)







Prototype

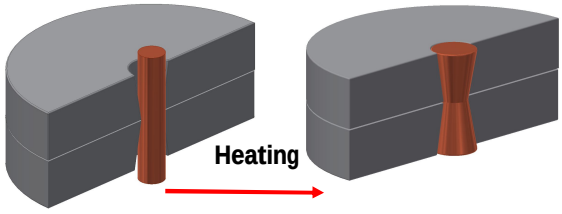


Diagram showing the joining process

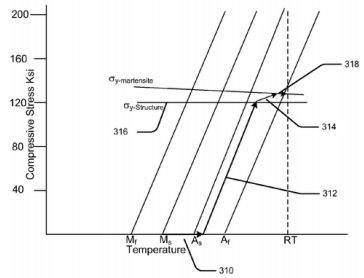


Diagram retrieved from [1]: shows the evolution of the compressive stress with temperature

Ti-rich NiTi alloy was studied. By differential scanning calorimetry (DSC) analysis we've reached the widest thermal hysteresis (Ms->As) of 21,5ºC, with the corresponding temperature transformation of 67,2ºC and 88,7ºC. Compression tests reached a maximum value residual strain of 8% for a uniaxial request and the corresponding free recovery value was of 4,5%, meaning that this recovery is due to the shape memory effect (SME), and the remaining 3,5% plastic deformation is not recoverable. With the thermo-mechanical test we can evaluate the possible stress level during the SME, for the corresponding sample. A stress value of 275 MPa was measured, which means that we can use NiTi as a joining process, for materials that have a yield strength below 275 MPa, thereby promoting the plastic deformation of the material to be joined and hardening the interface of both materials, as we can see in the last diagram [1].

A prototype is proposed, in which two plates are pre-drilled giving a final conical finish, prior to the NiTi rivet insertion, pre-stretched to reduce the diameter and finally inserted and heated above austenite transformation temperature, hence the joining of the two plates.

Conclusions

The use of shape memory alloys (SMA) as a joining device is possible using the shape memory effect, further tests are required to ensure a wider thermal hysteresis, and a greater compressive stress employed by the rivet. Using SMA takes the advantage of the stress induced transformation, as a dampening effect on the stress levels throughout the structure, ensuring a longer lifespan of the rivet.

References

[1]B. L. Kirkwood, "SELF EXPANDING FASTENER," US 20130097847A1, 2013.

[2]A. dos S. Paula, "TRATAMENTOS TERMOMECÂNICOS DE LIGAS DO SISTEMA Ni-Ti," Universidade Nova de Lisboa, 2006.

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