ICCES Online ICCES, vol.1, no.1, pp.21-21, 2019

Numerical and Experimental Investigation of Heterogeneous Transformation Behaviour in Shape Memory Alloys

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Abstract: Shape memory alloys (SMAs) are a unique collection of materials which can return to their initial configuration after being largely deformed. Near-equiatomic NiTi is the most widely used SMA due to its excellent shape memory properties and fabricability. One exceptional property of this alloy is superelasticity, which refers to the ability of the alloy to accommodate relatively large deformation typically up to 8% of tensile strain and return to the original undeformed shape upon unloading. As a result of this outstanding feature, superelastic NiTi have been increasingly used in different areas of engineering, such as in biomedical engineering and in structural engineering. In this study, we investigated the creation of nonuniform stress-induced martensitic transformation field in NiTi structures with geometrical nonuniformity through experimentation and finite element analysis (FEA). Geometrically graded superelastic NiTi structures with series and parallel design configurations with respect to the loading axis have been created. The heterogeneous transformation evolution within these structures were presented by thermal images recorded by a high-resolution infrared camera during tensile loading. The following figure illustrates the experimental setup and the evolution of martensitic transformation within a tapered NiTi plate (with series design configuration) during loading up to 7% nominal strain. It is seen that the transformation propagation is along the loading direction in this sample. Also, it was found that this type of NiTi structure exhibits stress gradient over stress-induced transformation, which improves the controllability of the shape memory component in actuating mechanisms. The transformation propagation in geometrically graded NiTi structures with parallel design configuration was found to be in an oblique or a perpendicular direction with respect to the loading direction. In this study, the transformation propagation and the deformation behaviour of the two types of geometrically graded NiTi structures were predicted by FEA. The FEA results were in good agreement with experimental data.

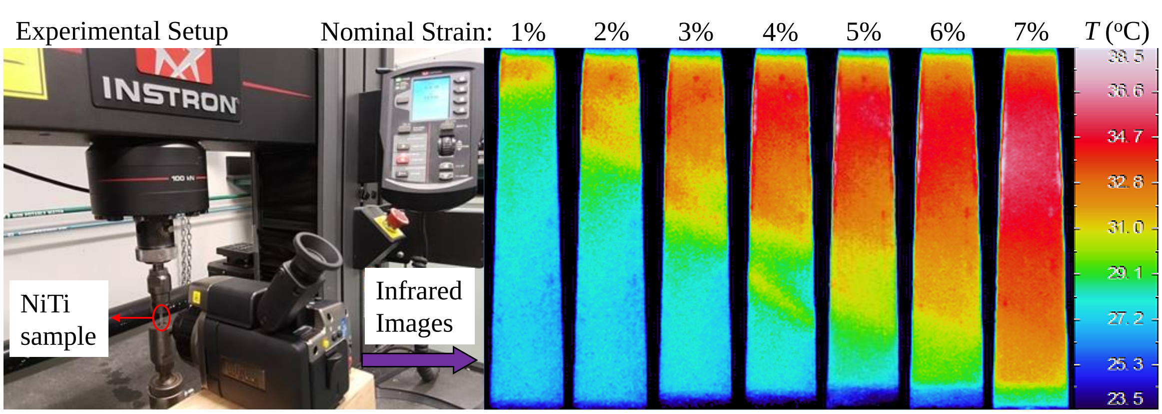

Figure 1: The experimental setup and the thermal images of a geometrically graded NiTi sample with series design configuration under tensile loading.

DOI: 10.32604/icces.2019.05559 www.techscience.com/icces