Combined observation between Digital Images Correlation and X-ray diffraction for a 1D in-situ tensile loading test perform on Ni-Ti Shape Memory alloy

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Résumé

Shape memory alloys (SMA), because of their pseudo-elastic behaviors and/or shape memory properties, have increasing industrial applications in domains such as robotic, medicine and aerospace. Equiatomic Ni-Ti, probably the most widely used SMA, has been intensively studied by many authors concerning the mechanism of pseudo-elastic behavior and associated phase transformations. The modeling of its behavior under complex thermal and multi-axial loading conditions remains challenging because:
- Associated phase transformations are out-of equilibrium phenomena, as evidenced by the hysteretic character of the transitions, requiring adequate modeling;

- Ni-Ti alloy is also well-known to develop a possible R-phase, intermediate between Austenite and Martensite associated with a specific free transformation strain;

- Phase transformation under applied stress induces a localization instability so that the spatial distribution of phases is highly heterogeneous. It is thus of great interest to determine locally the presence of the different phases as a function of the local experienced strain. This information is accessible from a combined X-Ray Diffraction (XRD) and Digital Image Correlation (DIC), provided XRD is performed {in situ} and if the analyzed points can be repositioned on the DIC strain map.

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One particular difficulty for the XRD analysis is that, due to martensitic variants selection, crystallographic texture is induced making Rietveld method quantification of phases very delicate. To circumvent this difficulty a Proper Orthogonal Decomposition (POD) (aka Principal Component Analysis (PCA)) technique is proposed to identify the principal modes, over which the spectra are decomposed. These modes are further interpreted as combinations of Austenite, Martensite and R phase. So that a robust determination of the cristallography can be achieved.
This tool is used to map the different phases during a uniaxial loading test performed on a strip of Ni-Ti SMA. Combined DIC and XRD observations allow the coexistence between Austenite, R-phase, Martensite at transformation plateau to be confirmed. Our results indicate that Martensite saturates in the localization bands, Austenite is dominant in the non-transformed areas, and R-phase concentrates at the interface between these two regions.

Mots-Clés: Digital Images Correlation (DIC), X, Ray Diffraction(XRD), Shape memory alloy, Proper orthogonal truncation (POD), Principal components analysis (PCA)