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Influence of anisotropy on strain localization phenomenon in tension of superelastic NiTi thin walled tubes

Tubes of Nickel-Titanium Shape Memory Alloy (NiTi SMA) are employed to produce 60% of self-expanding cardiovascular stents. Such small-scale devices require tubes with small thickness, which in turn implies a material with highly textured microstructure. Previous works demonstrate that this texture causes significant anisotropy, affecting various thermomechanical key properties. This knowledge is of critical value for the modeling of thermomechanical behavior and design of superelastic devices. As well as thermomechanical properties, the localization phenomenon observed in tensile tests is affected by the anisotropy in a NiTi tube and also needs investigation.

The present work aims to address the effect of anisotropy on localization phenomenon through a series of tensile tests performed at three temperatures above Af. Tensile dogbone samples were cut in five orientations from a flattened NiTi thin walled tube (0.165 mm of thickness). The orientations were 0° (drawing direction), 22.5°, 45°, 67.5 and 90° (transverse direction). Using Digital Image Correlation (DIC) technique, strain rate fields were calculated over a zone of interest in the gauge area of the samples, measuring 10 x 2 mm². Localization characteristics (in particular the angle of the localization bands with respect to the tension direction) were determined from these fields.

Localization phenomena were observed for the samples cut at 0°, 22.5°, 67.5° and 90° at the three test temperatures. The samples cut at 45°, however, did not present strain localization at any of the three temperatures; the strain rate fields were very uniform both during loading and unloading. The localization morphologies of the samples cut at 0°, 22.5°, 67.5° and 90° were similar. All showed clear bands inclined from the longitudinal direction of the sample. The paths taken by the bands were essentially the same during loading and unloading, but bands were much more stable during unloading. The influence of the anisotropy on the localization phenomenon was analyzed regarding the band inclination angles from the sample axial direction. The inclination angles were measured for all strain range using the strain rate fields. The inclination angles measured in the samples oriented at 0° and 90° were similar and around 60°. In comparison, the inclination angles measured for the samples 22.5° and 67.5° were smaller, between 50° and 55°. The anisotropic state of the material was analyzed using Hill's

quadratic anisotropic yield function. With the obtained Hill's anisotropic parameters the inclination of the bands were calculated for each tensile orientation. When confronted with experimental measurements, good qualitative results were obtained from this analysis, allowing to evaluate the relation between the angles of localization bands with samples' orientation.