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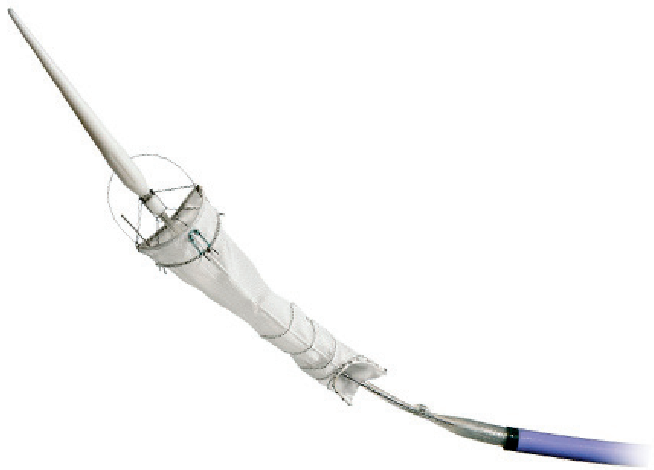
IN APPLICATION

Strain Measurements of Ring Stent Wire using Micro Stereo-DIC

Vascutek Ltd. a Terumo Company, UK
The University of Strathclyde, UK

Introduction

Nitonol is a shape memory material which is able to elastically recover large deformations. This, together with its bio-compatible characteristics, lends itself to use in small scale biomedical devices. Although the general mechanical properties of the material are known, little detailed information is available on the functional behaviour of small scale wire as used for implantable devices. This information was required by Vascutek Ltd, who utilize the superelastic Nitinol wire in their Anaconda endo vascular stent graft. This device is introduced to the artery in a compacted shape and then self-expands at the implant site to follow the contours of the artery walls.



In service, small diameter stent wire (<0.5 mm diameter) is loaded to and unloaded from large bending deformations during compaction and deployment, and therefore a test method was devised which simulated this process (Ref. 1). One of the primary aims of the testing was to provide experimental strain results for validation of Finite Element Analysis (FEA) material models, which in turn could be used for strain-based total life fatigue assessment of the Nitinol ring stent components.

Experimental Setup

Given that the aim was to obtain strain results during bend testing of sub millimetre wires, there were no traditional contacting sensors available to make the desired measurements. Therefore a microscope based 3D DIC system was chosen as a suitable solution, allowing the measurement of full field shape and strain.

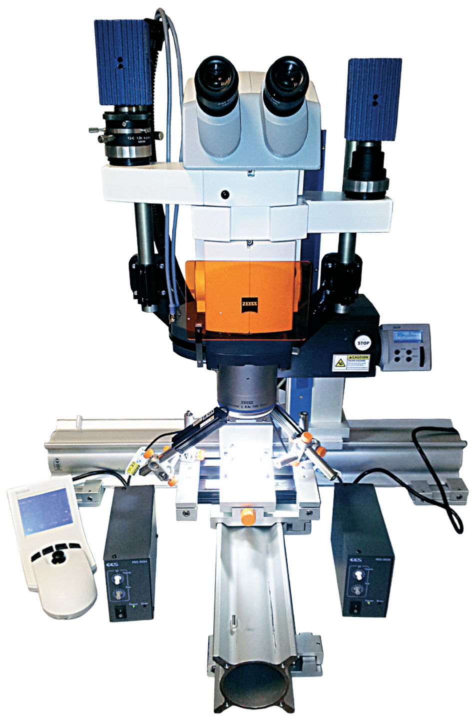


Figure 1: *Microscopic experimental setup*

The exact specimen type chosen for testing was 0.45 mm diameter Nitinol wire (Fort Wayne Metals NiTi#1, ‘Vascutek specification’). This had equivalent mechanical properties specification to thin stent wire whilst having sufficient thickness to allow strains across the wire width to be measured within the 2.5 mm x 2.5 mm DIC microscopic Field of View (FoV).
The wires had no natural pattern upon which the DIC system could correlate, and therefore a speckle pattern was applied using a fine airbrush system.

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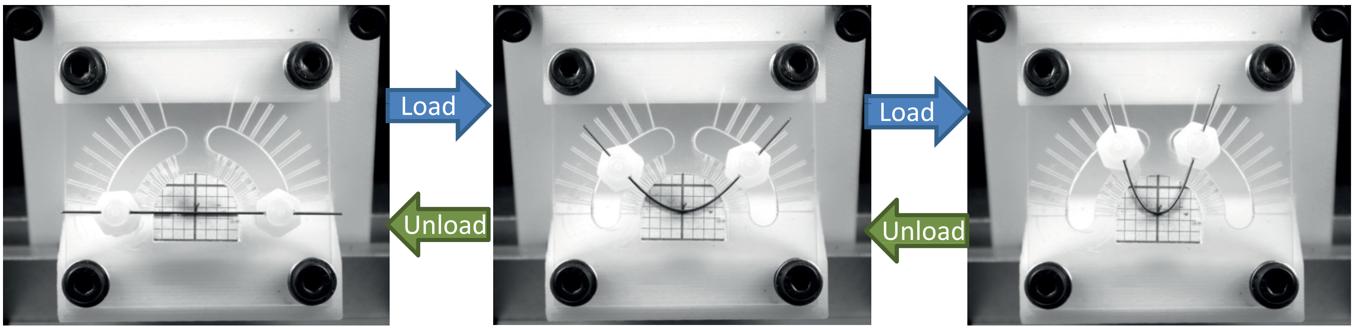

Test rigs were designed and manufactured ensuring that the bend ‘apex’ (the region of maximum curvature) would remain within the FoV during bending to large deformations. Two rigs were produced; a ‘free bend’ test rig allowing an unconstrained bend apex, and a ‘three point bend’ test rig to allow bending of the wire by a central indenter pin.

Results

The DIC system was calibrated to account for the complex optical distortions through the microscope system and to map the cameras to the physical volume prior to testing. Baseline precision and experimental accuracy were assessed by considering the noise in results from consecutive images with no wire movement and by considering scatter in results from repeat tests, giving confidence that the measured results were real. Each wire specimen was incrementally loaded and unloaded from an initial straight position. The images were then processed using the StrainMaster system to calculate the surface shapes, deformation vector results, and strain maps.

Using these results, strain parameters that could be used for FEA validation were obtained:

- plots of the ‘E_{xx}’ strain and the surface height for the bend apex cross-section
- neutral axis position
- measurement of the wire shape in the bend apex region

The tests showed that Microscopic 3D DIC could be successfully applied to measure surface strains of thin superelastic Nitinol wire in bending, allowing investigation of material behaviour and providing results that can be used for FEA material model validation. These DIC results can be used for calibration and validation of a robust material model of the ring stent wire.

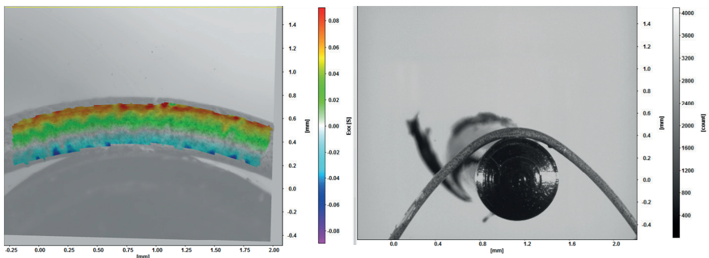

***Figure 2**: strain map on the surface of the specimen illustrating the compressive and tensile sides of the wire, with eccentric neutral axis position.*

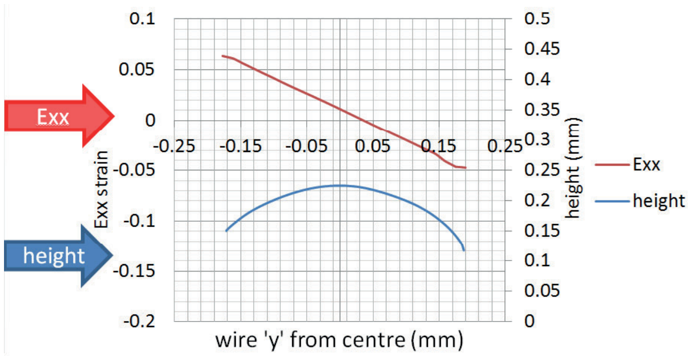

Figure 3: Mapping of strain against surface position (ie. Strain at distance ‘y’ from the wire centre axis)

Ref (1) ‘Strain Characterization of Superelastic Wire in Bending Using Digital Image Correlation’ R Brodie (presented at SMST 2013)

03/14

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