On the characterization of thermomechanical properties of curved NiTi shape memory wires intended for cochlear implant electrode arrays

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Objective

A cochlear implant (CI) is an auditory neuro-prosthesis used to restore hearing in deaf and profoundly deaf patients. It features an electrode array (EA) which needs to be inserted into the inner ear (cochlea) to enable electrical stimulation of the auditory nerve (Fig. 1). Spatial proximity of the EA and the nerve fibers is considered beneficial. This requires a shape change of the initially straight EA to enclose the inner wall of the spiral-shaped inner ear after implantation. Thin wires made of Nitinol—a shape memory alloy (SMA)—are investigated regarding their applicability as embedded actuators to implement a shape change (Fig. 2).

Material and Methods

Nitinol wires (∅100 µm) have been trained to a spiral shape which was derived from cross-sectional images of a human specimen as an exemplary adaption to a specific cochlea geometry (Fig. 4). Ten different variations (MV) of thermo-mechanical processing were applied by the supplier (G.RAU GmbH & Co. KG) to tailor the shape memory effect to the application specific requirements. In order to determine the resulting transformation temperatures (A_S, A_F) a bend and free recovery (BFR, Fig. 3) test suitable for curved wires was developed and utilized.

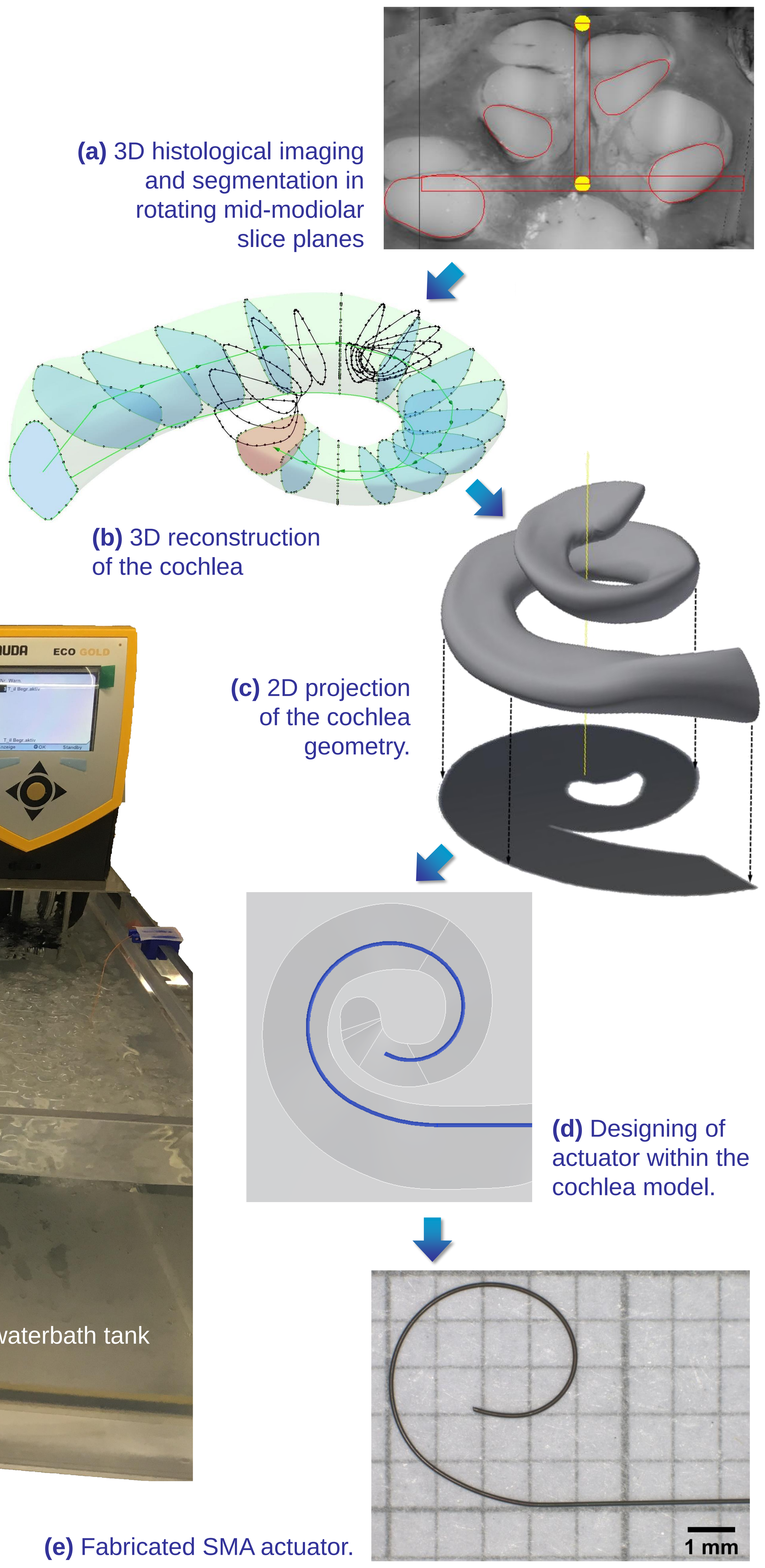

Fig. 4: Design process workflow of shape memory actuators tailored to the shape of a human cochlea specimen.

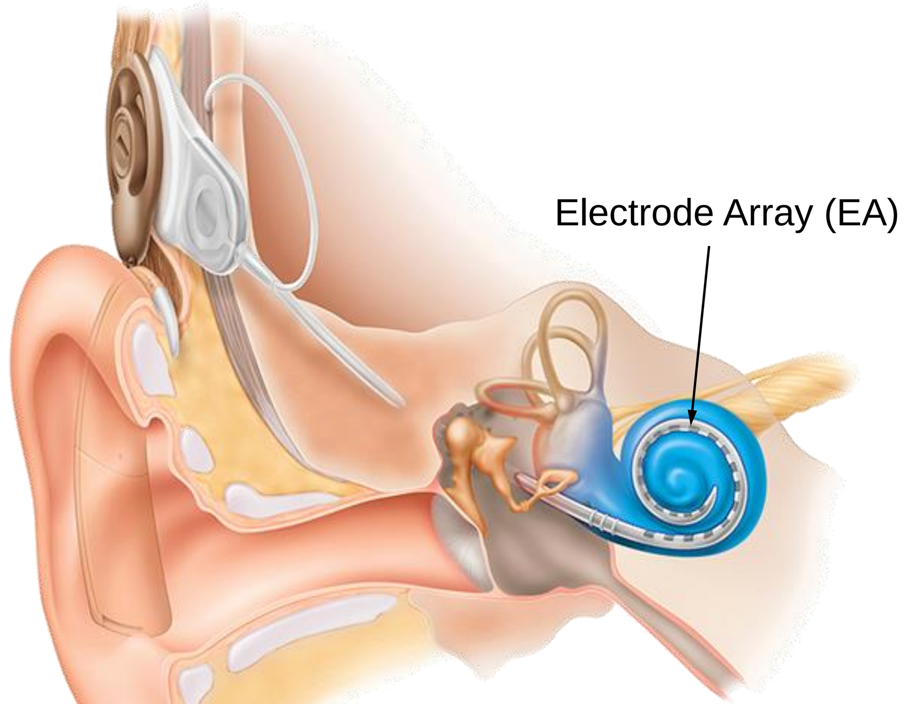

Fig. 1: Components of a CI displaying the electrode array
[Cochlear Ltd.]

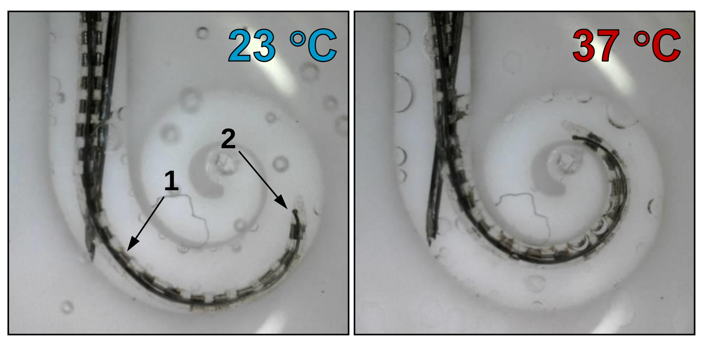

Fig. 2: Cochlear implant prototype displaying the EA (2) with an integrated nitinol wire (1).

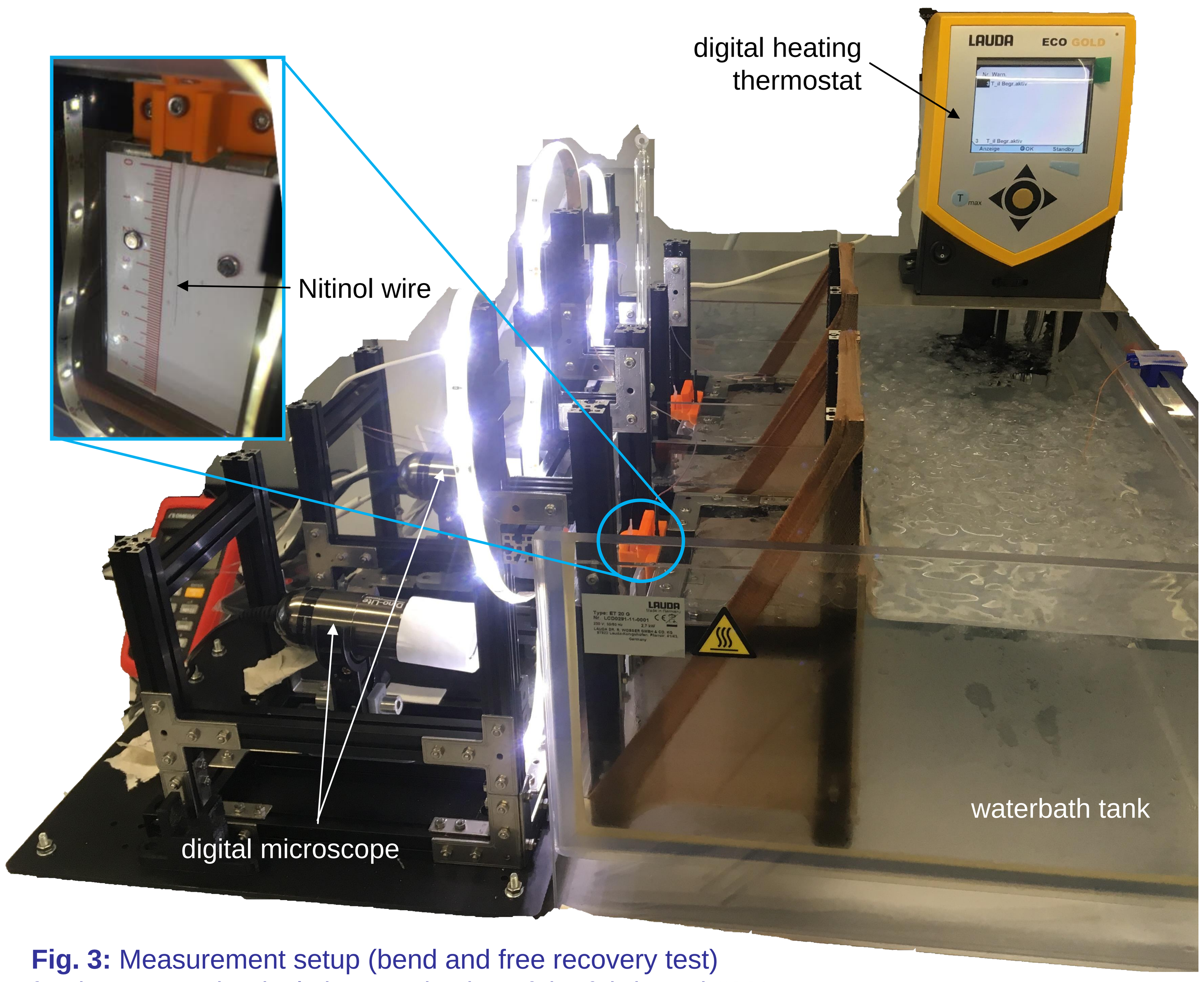

Fig. 3: Measurement setup (bend and free recovery test) for thermo-mechanical characterization of the fabricated SMA actuators.

Results

It is possible to design and fabricate spiral-shaped SMA wires which fit to a specific cochlea shape (Fig. 5). The developed BFR test setup allows for measuring the thermomechanical properties of these actuators in an application oriented manner. This provides slightly higher but more clinically relevant measures for A_S and A_F compared to differential scanning calorimetry (Fig. 6).

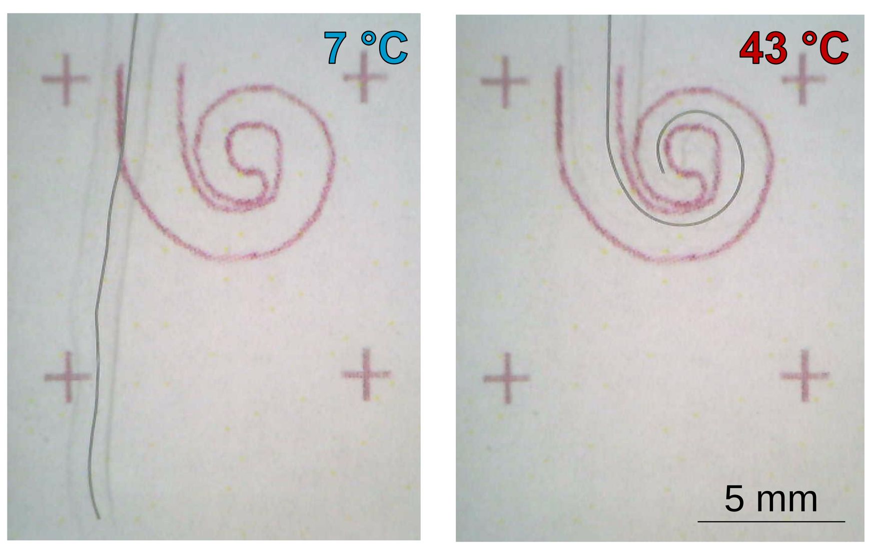

Fig. 5: Nitinol wire showing the shape memory effect. In the example the wire reached its final shape at an austenite finish temperature (A_F) of 43°C.

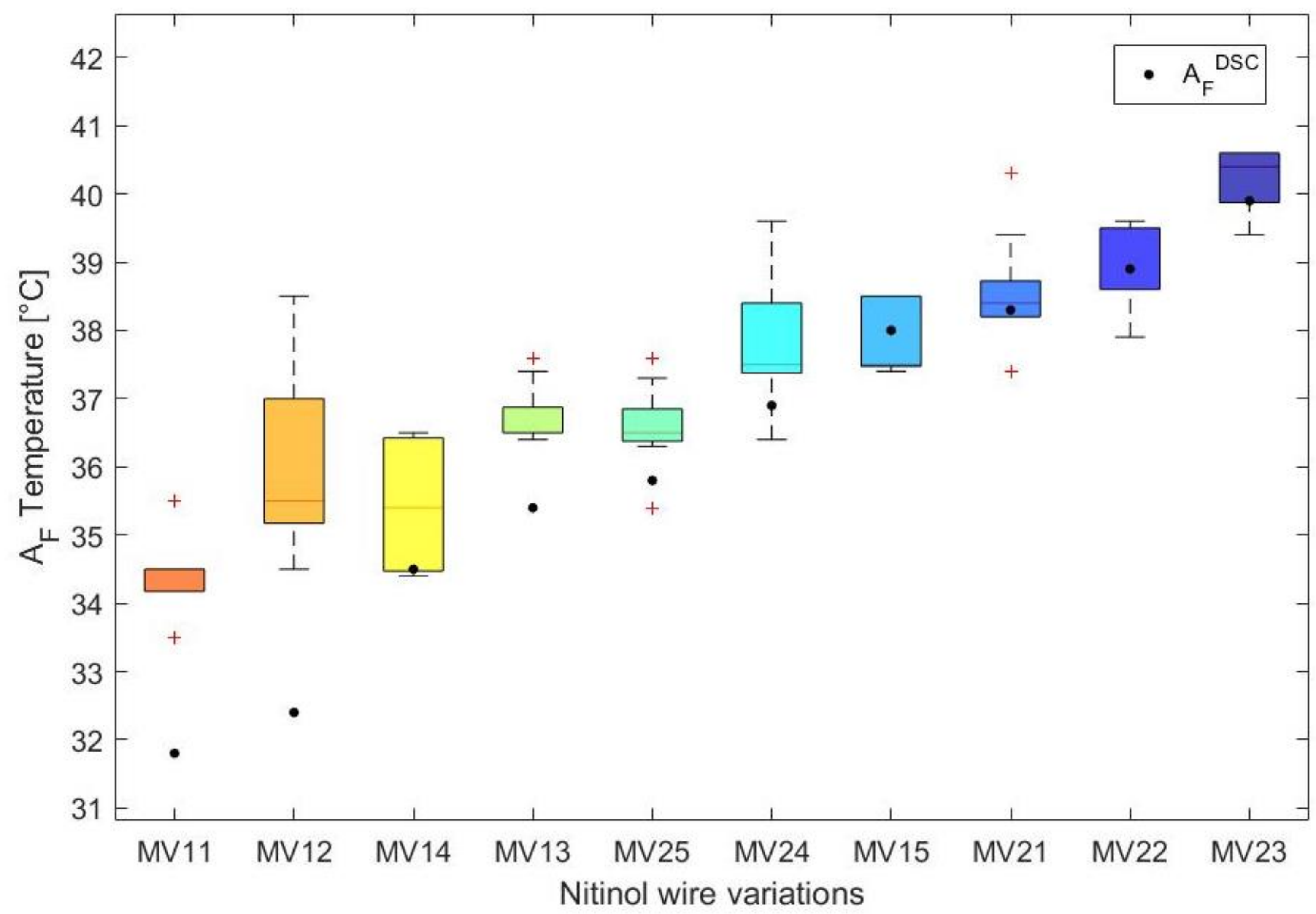

Fig. 6: Results showing the active A_F temperature of the nitinol wires in ten different variations (MV).

Outlook

A complete design, manufacturing and validation process for thin spiral shape memory wires could be established. The next step is to integrate these wires into an EA and perform BFR measurements again as it is known that external forces due to stiffness of the EA alter the transformation temperatures.

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