MODIFIED Ni-Ti WIRE FOR MEDICAL MESH APPLICATION

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Introduction

Shape Memory Alloys (SMA) are certain metallic materials which after deformation, regain their original shape. This phenomenon is connected with reversible thermoelastic martensitic transformation. Shape memory effect can be induced by external stress, temperature and/or magnetic field [1]. Ni-Ti alloys (Nitinol) are the most widely used shape memory alloys in medicine, due to their exceptional mechanical properties, high corrosion resistance and biocompatibility. Implants made of Ni-Ti wires are commonly used in cardiac surgery e.g.: blood vessels stents, amplatzer septal occluders, clots removal devices, embolic protection devices [2]. In most cases, after expansion, implant keeps the programmed shape and stays at fixation place. However, there are cases when healed/supported tissue or organ changes its' shape in time eg.: during cardiac muscle contractions [3]. Thus, stent or implant should follows these changes. Moreover, its properties should comply with requirements of cyclic repeatable deformation with no fatigue effect. For this purpose, another unique feature of SMA can be exploited – superelasticity.

The present work provides a brief overview of preliminary evaluation and verification of commercially available Ni-Ti wire properties for use in braiding cardiac implants designed for work in cyclic deformation conditions connected with contracting myocardium.

Materials and Methods

Commercially available Ni-Ti wire with 0,5 mm in diameter was used (BHH Mikrohuta sp. z o.o., Valbruna Group, Dąbrowa Górnicza, Poland). First, the temperature range of the reversible martensitic transformation was determined using a DSC differential scanning calorimeter (Metler Toledo DSC 1). Then the presence of superelasticity effect was verified under uniaxial tension test (Zwick-Roell 1445 RetroLine). Test speed was 1 mm/s. Uniaxial tension test was cyclically repeated on the same sample and deformation was increased by 0,5% each time respectively. The test was aborted when first signs of elastic deformation of inducted martensite appeared.

Results and Discussion

FIG. 1 shows the thermograms measured for the tested wire. In order to confirm the repeatability of the reversibility of the martensitic transformation, two thermal cycles were measured. Comparison of thermograms indicates the repeatability of the martensitic transformation occurrence. It appears in the temperature range from -8°C to 20°C. The temperature of the end of reverse martensitic temperature is about 17 degrees lower than that one of the human body. This difference meets the requirements for the safe use of the wire for a medical implant.

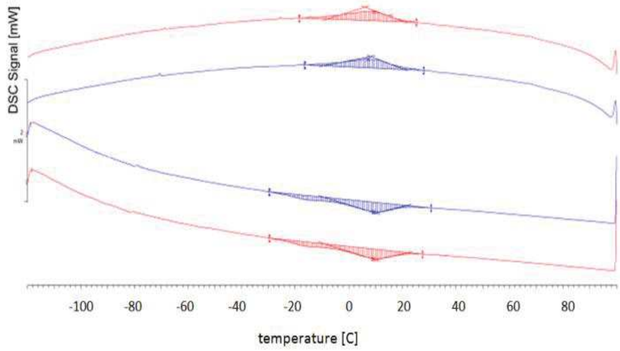

FIG. 1. DSC cooling/heating curves measured for studied wire.

Such conditions guarantee the occurrence of the superelastic phenomenon. Its presence was confirmed in the cyclic tensile test (FIG. 2). The nature of the measured curves indicates that the alloy is in its parent phase under zero stress, as confirmed by the DSC curves. The introduction of external tensile stress - induced martensite. Consequently, a change of shape was observed. After its unloading, the wire returned to its original size, undergoing a reverse martensitic transformation. In the first deformation cycle, up to 0.5%, the martensite-inducing critical stress was 570 MPa, while in the last one, its value decreased to 509 MPa. The stress-inducing reverse martensitic transformation was about 51 MPa.

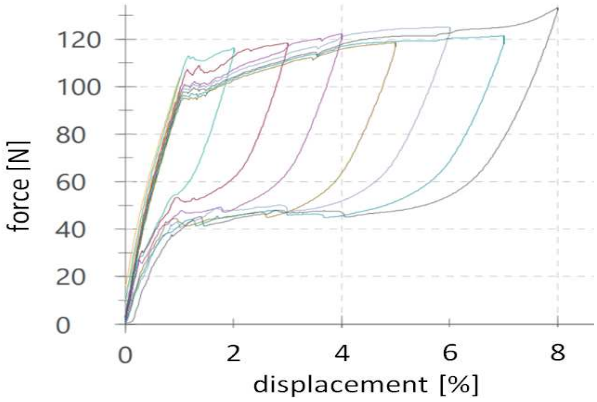

FIG. 2. Cyclic stress-strain curves measured for Ni-Ti wire.

Conclusions

The obtained results, both from thermal analysis and mechanical testing, proved that tested Ni-Ti wire reveals the repeatable martensitic transformation in the temperature range from -8°C to 20°C and the occurrence of superelasticity up to 8%. Such characteristics are desired for further development of tailored braided cardiac implant designed for working in cyclic repeatable deformation conditions.

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