3D-printed auxetic structures for bio-medical application

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INTRODUCTION: The SPIRITS Interreg project (Smart Printed Interactive Robots for Interventional Therapy and Surgery) aims at developing innovative robotics by 3D-printing for interventional radiology and image guided surgery. In this context, the development of a pneumatic actuator is required to propel a biopsy needle also on different surgical tools. Beside the technical functionality and medical requirement of the OR environment, the component has to be optimised for undisturbed interaction with the used imaging technology. Based on a preceding project by INSA Strasbourg, the development of a metal-based, auxetic actuator is investigated for optimized translation performance

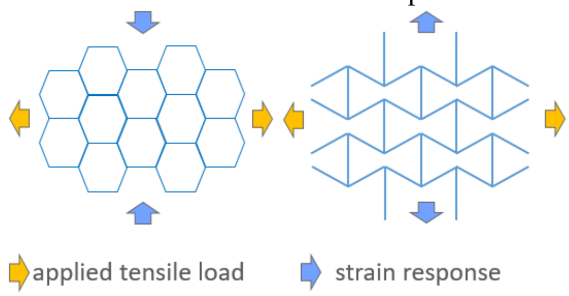

Fig. 1: Visualization of auxetic behavior (left) compared to standard material (right).

METHODS: SolidWorks™ (Dassault Systèmes, France) was used for the design and Magics™ (Materialise, Leuven, Belgium) for processing, slicing and support generation. The Selective Laser Melting (SLM) system (DMG Mori, former Realizer, Germany) is used as manufacturing process operating the machine models SLM-100 and SLM-125. The used materials are Ti grade 2 and a NiTi shape memory alloy. Process parameters for Ti were slightly modified standard parameters, NiTi parameters were based on. Mechanical testing was done using a hydropulser LFV-5-PA/EDC120 from Walter & Bai, W+B testing equipment.

RESULTS: It was possible to print auxetic structures down to a planned strut size of 300 µm. that had an elastic range of almost 10% and showed no critical failure in tensile tests up to 33% forced elongation. Furthermore, the mechanical properties of the structure (i.e. the spring constant) could be maintained almost constant (± 5%) despite the plastic deformation during the tensile test (compare Fig. 2).

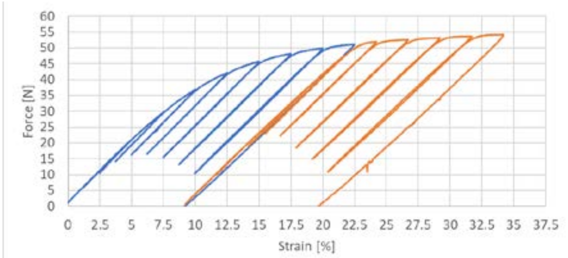

Fig. 2: Two consecutive tensile test of an auxetic structure, showing constant stiffness.

In stress-controlled cyclic loading tests at approximately 66% of their elastic limit, the samples failed after 40-50 k loading cycles. The critical failures were always preceded by defects in single elements.

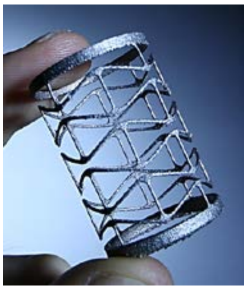

Fig. 3: 3D-printed auxetic Ti structure

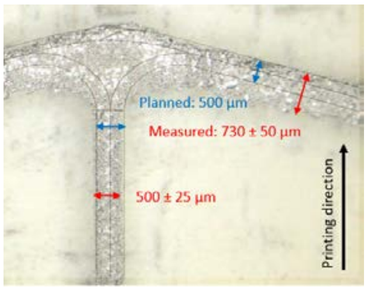

Fig. 4: Sintering of powder on down-facing surfaces

The construction of a functional actuator was not yet possible, due to the still relative stiff structures obtained. One reason for this is the thicker than planned structure, due to sintering of surrounding powder onto the printed structure (Fig. 4).

DISCUSSION & CONCLUSIONS: These initial mechanical results are quite promising, but further optimisation of the manufacturing process (e.g. energy input) is a necessity until thinner and still functional structures are obtained.