Three-dimensional deformation behavior of a single hinged SMA integrated fiber rubber composite

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Abstract: Decades of enhancement in textile technologies have improved the variability of design. Integrating smart materials such as Shape Memory Alloys (SMA) further enhances their applicability in a few key industrial sectors such as in bio-medical, aircraft and automotive industries. The unique properties of the SMAs are also being widely screened in soft robotics by integrating it into elastomeric composite structures to obtain actuation mechanisms. However, the achieved mechanisms are particularly limited to two-dimensional deformations due to multiple factors and one being the design constraint. This limitation can be subjugated with the help of advanced textile technologies in fabric knitting and weaving techniques by achieving multi-oriented directional fibers, which are further developed into SMA integrated fiber rubber composites. This paper discusses the use of knitting technology [1] and tailored fiber placement (TFP) to develop a hinged semi-finished composite with two variants of fiber orientation of 45° and 60°, respectively. The hinged portion divides the glass fabric into three segments and is obtained by reducing the fiber density in the middle segment of the textile. The two fiber angle variants are irrespective of each other, and the oriented fiber space is assigned to only one segment of the textile resulting in bend-twist coupling of the composite upon deformation. The deformation is achieved by activating a pre-stretched SMA wire, which is stitched onto the textile using TFP methodology. The complex deformations are measured using computer vision by tracking points on the edges of the composite. The results are further evaluated by comparing them to the simulation results obtained from a meso-macro scale model. Simulations for the SMA wire are performed using Woodworth-Kaliske SMA user-defined model implemented in ANSYS software [2]. This user-defined model has the advantage of defining pre-stretch for the SMA wire, which simplifies modelling of the one-way shape memory effect for wires that must undergo stretching before being inserted into the composite. The obtained results act as the basis for multi-joint structures capable of undergoing complex three-dimensional deformations.

Keywords: *hinged structure, interactive fibre rubber composites, shape memory alloys, tailored fibre placement.*

Figure 1 Example of an *integrated fibre rubber composite structure* subjected to bend-twist coupling

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