INTERACTIVE FIBERBASED MATERIAL APPROACHES FOR SMART TEXTILE STRUCTURES

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EXTENDED ABSTRACT

Key Words: Textile Actuator, Fiber Elastomer Composite, Multicomponent Filament Yarn, Melt Spinning

1. INTRODUCTION

Textile elastomeric composite materials are increasingly used in various technical fields, e. g. automotive and medical engineering. Potential applications include their use in systems for precise gripping and transportation processes, such as hand prostheses, automated lids, seals, shapeable membranes, and adaptive flaps for rotor blades of wind turbines as well as trim tabs for ground- and watercraft to effectively reduce flow separation.

In the context of the Research Training Group 2430 "Interactive Fiber Rubber Composites (I-FEV)", smart actuator structures are developed, which are able to react adaptively to their environment and, for example, carry out gripping processes. Actuation is to be performed by textile components to avoid product defects that occur in the case of non-textile functional elements. Also, high efficiency can be ensured as the actuator is inserted into the reinforcement structure in a structure compatible manner. Furthermore, long-term stability can be significantly increased, and automated manufacturing processes, reproducible properties as well as cost-effective production can be achieved. In addition, conventional mechanism technologies, which are heavy and complex, required for the powertrain can be overcome, thus enabling structures with low material use, whereby human-machine interaction can be considerably improved [1]. This results in the necessity for extensive research in the field of conductive fibers with adaptive properties and their interconnection to sensor and actuator networks. In addition, the integration of these fibers into a suitable elastomer material and the design of appropriate geometries are to be investigated.

2. MATERIALS AND METHODS

The research project targets the design, construction, and processing of novel textile actuator and sensor networks, which have short reaction times as well as large deformation paths and are capable of transmitting high forces. Presently, it is impossible to generate an actuator uniting all these requirements. The solution approach presented here involves the combination of different actuator strategies, for example based on Shape Memory Alloys (SMA) and Dielectric Elastomer Actuators (DEA).

SMA are metal alloys that switch from one crystal structure (martensite) to another (austenite) when treated with high temperature. This crystal change enables the SMA to perform a macroscopic deformation releasing high forces.

A DEA is composed of three layers and acts as a capacitor (see Figure 1). If an electric voltage is applied, the electrodes move towards each other, whereas the dielectric elastomer is compressed in height and its cross-sectional area is stretched, i. e. macroscopic movement can be seen. DEA are high dynamical and exhibit short response times.

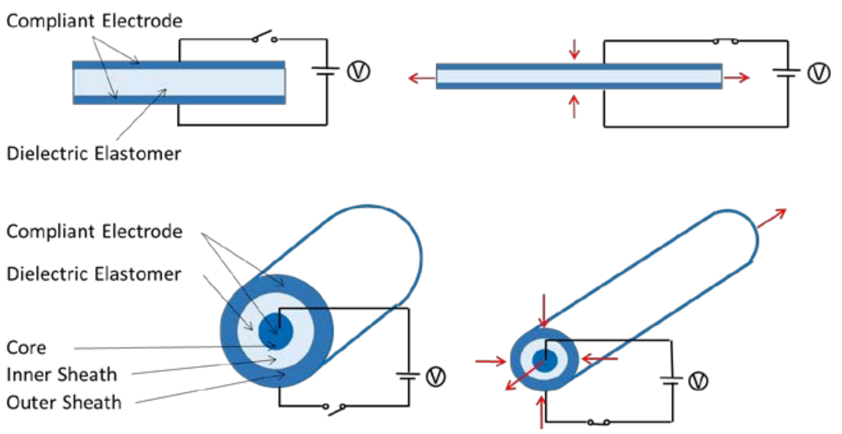

Figure 1. Working principle of a planar DEA and a DEA in filament form

In combination with SMA, functionalized filament actuators in the form of multicomponent filament yarns made of DEA are investigated to enable high switching frequencies (in the range of 5 Hz). The potential and limitations of the desired fibrous actuators are listed in Table 1. The aim is to arrange textile-based and textile-processable actuator components (SMA and DEA) in multilayer reinforcement structures with gradient properties, enabling the generated I-FEV to respond to external influences within short reaction times and realize complex deformation patterns.

Table 1. Potential and limitations of fibrous actuators made of SMA and DEA

	Excitation	Distortion	Force per actuator	Deformation of the component (per segment)	Frequency in the component
SMA	$\Delta T = f(I) =$ 10...15K	1...8 %	50...150 N [2]	0…20° [3] 0…>90° [1]	< 0,1 Hz ca. 1 Hz [1]
DEA	10...100 MV/m [4],[5]	30...60% [4],[5]	0,1...1 N [1,2]	0...10° [1]	> 5 Hz [1]

[1] ... Estimation of the effects to be achieved through function-specific designed structures
[2] ... Execution as actuatoric multifilament yarn with 1000 treated filaments

3. RESULTS AND DISCUSSION

The structural integration of SMA into the textile reinforcement of I-FEV enables the transmission of high forces (minimum 10N) and degrees of deformation (> 90°). An example motion sequence can be seen in Figure 2.

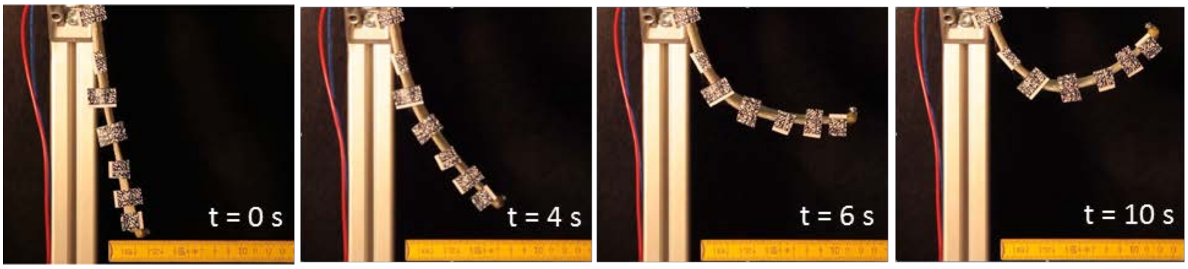

Figure 2. Movement of a SMA at different time intervals [3]

DEA are not available in fiber form yet, although in the past, they have already been used in electrical engineering in flat form and are currently employed for the manufacturing of soft robotics [6,7]. For novel fibrous DEA, a tri-component yarn consisting of an inner and an outer electrode as well as an elastic actuator layer will be developed. Figure 1 illustrates the structure and mode of action of flat and fibrous actuators.

In order to realize the presented structures, it is of decisive importance that all used materials have an appropriate Young's modulus to enable large deformations. The actuator yarns are manufactured based on melt spinning and coating technologies. Hence, blends made of thermoplastics and carbon nanotubes are employed, silvering is used to manufacture the electrodes, and thermoplastics with a low Young’s modulus, such as TPU, are utilized for the inner actuator sheath.

The combination of various actuator mechanisms results in a completely new class of materials for adaptive elastomers. Due to their high intrinsic deformation capacity, I-FEV have become a promising approach to generate controllably deformable components with specifically adjustable properties.

4. ACKNOWLEDGEMENTS

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