SUBPROJECT 1: Development of innovative textile configurations for actuation performance enhancement of linear and bulky actuating fibers for use in I-FRC

CH. CHERIF in cooperation with S. WIEßNER;
external advisor: E. JAGER (Linköping University/ SE)

Motivation

Due to their proximity to natural muscles and their ability to be processed into textiles and integrated into the reinforcement structure of intelligent fiber-rubber composites, fiber-shaped electroactive polymer (EAP) actuators are particularly promising. Furthermore, in numerous cases the mechanisms of actuation and sensing are nearly identical, allowing fibrous or textile actuator structures to also function as structurally compatible sensors, thereby enabling the real-time detection of strain, deformation, and degradation.

State of the art and previous research

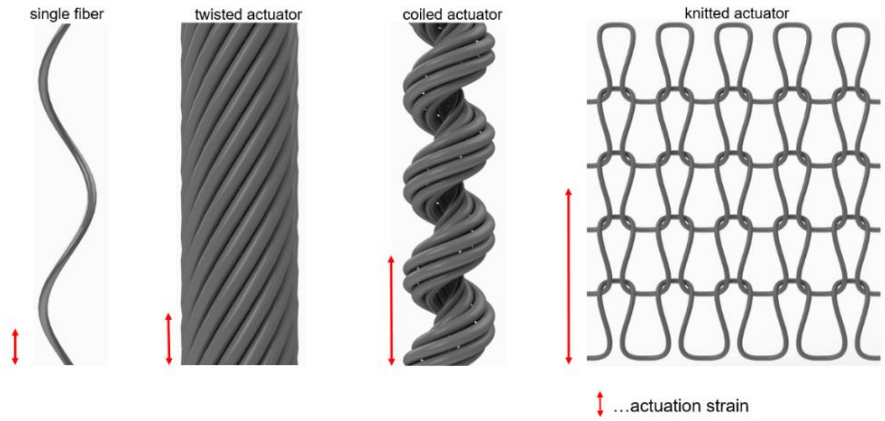
Within the first cohort, straight dielectric elastomer actuator (DEA) fibers were developed [1]. In the second cohort, fiber-based actuators using the ionic EAP actuator principle were investigated and developed [2]. The actuation of these conducting polymer (CP) actuators is achieved at low activation voltages of <1.5 V leading to repeatable linear actuation strain of approximately 1.8% (max. 2.5%) and actuation stresses of ca. 1 MPa for a single fiber. Since the actuation of CP actuators is a bulk actuation, textile processing like knitting or twisting and coiling of CP actuator fibers can amplify the actuation strain of a single fiber by several orders [3, 4] reaching actuation strains of >10 % (max 33%) and 5 MPa actuation stress. This renders the linear actuator textiles based on the in the second cohort developed linear actuating fibers highly promising for use in intelligent fiber-elastomer composites in a further developed, textile configuration. Another promising actuator class based on textile structure integration are so-called twisted coiled polymer actuators (TCPAs), driven by heat are gaining high mechanical actuation properties [5].

Scientific questions and project objectives

The objective of SP 1 is to develop fiber-based textile actuators with a particular focus on the relationship between the structure or morphology of the textile and the actuation performance, with the aim of enhancing the mechanical actuation properties for use in I-FRC.

In particular, the mechanical properties of the previously developed CP fibers or suitable fibers for usage as TCPAs like polyamide 6 are tailored (including adjusted spinning methods and the use of additives or fillers) for subsequent textile processing using various tailored and specifically adapted textile technologies, such as braiding, coiling or knitting.

In conjunction with SP 3, a suitable rubber formulation is investigated with the objective of creating a composite of the developed textile actuators, sensor networks and rubber matrix, which could serve as a performant interactive fiber-elastomer composite soft robot demonstrator. A control system is developed in cooperation with SP 9. A model of the actuator and soft robot is investigated in cooperation with SP 2, 5 and 10.



Schematic representation of potential textile structures to determine the relation between fiber- and textile structure and actuator performance, targeting an actuator performance enhancement for use in I-FRC.

References

[1] Grellmann, H.; Bruns, M.; Lohse, F.M.; Kruppke, I.; Nocke, A.; Cherif, C.: Development of an Elastic, Electrically Conductive Coating for TPU Filaments. Materials, 2021, 14: 7158, https://doi.org/10.3390/ma14237158.

[2] Bruns, M; Mehraeen, S; Martinez, J.G.; Mersch, J.; Kruppke, I.; Jager, E.W.H.; Cherif, C.: A straightforward Approach of Wet-Spinning PEDOT: PSS Fibers for Use in all Conducting Polymer-Based Textile Actuators. Advanced Intelligent Systems, 2024, *under review.*

[3] Maziz, A.; Concas, A.; Khaldi, A.; Staland, J.; Persson, N.-K.; Jager, E.W.H.: Knitting and weaving artificial muscles. Science Advances, 2017, 3: e1600327, https://doi.org/10.1126/sciadv.1600327.

[4] Hu, H. et al.: Artificial Muscles Based on Coiled Conductive Polymer Yarns. Advanced Functional Materials, 2024, 2401685, https://doi.org/10.1002/adfm.202401685.

[5] Mersch, J.; Witham, N.S.; Solzbacher, F.; Gerlach, G.: Continuous textile manufacturing method for twisted coiled polymer artificial muscles. Textile Research Journal, 2023, 93(19-20): 4623-4638, https://doi.org/10.1177/00405175231181095.