Generative AI-supported 3D Textile Knitting-Technologies for highly adaptive and functional integration and preforming for lightweight, smart, biomedical and protective applications

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Abstract

The research group Generative 3D Technologies for Functional Integration and Preforming develops advanced textile technologies for the manufacture of complex, lightweight and multifunctional structures. The research combines textile structure development, machine technology, preform engineering, functional integration and composite processing within an integrated process chain. A key technological platform is AI-supported and algorithm-based knitting technology, including flat, multi-layer and three-dimensional knitting approaches for the near-net-shape production of geometrically complex high-performance textile structures. Adapted machine concepts, yarn-handling systems and algorithm-based, locally controlled textile architectures further enable the precise placement of reinforcing and functional yarns for lightweight and ballistic applications.
For lightweight applications, the research focuses on textile preforms for thermoset and thermoplastic fiber-reinforced composites, addressing their structural adaptability, drapability, fiber orientation and three-dimensional permeability, the latter enabling controlled resin infusion and infiltration during subsequent composite processing. Near-net-shape and contour-adapted textile structures provide opportunities to reduce enormously or avoid completely material waste and secondary processing while enabling complex three-dimensional composite components.

Functional integration, including in-situ bonding technologies such as Knit+, constitutes a further central research field. Sensors, conductive yarns, actuators and functional pathways can be incorporated directly during textile manufacturing, enabling applications ranging from real-time structural health monitoring and adaptive composite structures to smart, wearable and protective textiles - including near-net-shape structures engineered with high cover factors for enhanced protective performance and durability.
Resource-efficient manufacturing concepts and the processing of recycled fiber materials additionally contribute to more sustainable textile and composite production. By linking textile design, machine and process development, preforming, functional integration and composite manufacturing, the research group establishes a continuous pathway from textile concepts to application-oriented demonstrators. This interdisciplinary approach enables the transfer of generative 3D textile technologies into next-generation lightweight and multifunctional textile systems.

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Keywords: Knitting technology, 3D textile preforming, Functional integration, Fiber, reinforced composites, Smart textiles