Data-Driven Computational Modelling and Engineering of Textiles: From Structures to Composite, Medical and Protective Applications

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Abstract

This poster presents selected examples of computational textile engineering for composite, medical, and protective applications. Multilayer woven fabrics offer a high degree of design flexibility, enabling their structural architecture and properties to be tailored to specific application requirements. To exploit this potential for composites, their mechanical behaviour is investigated using multiscale computational modelling approaches with defined length scales for reduced computational effort. Comprehensive data sets describe the relationship between textile architecture and mechanical performance. These are integrated into an AI-supported data-driven framework to design suitable fabric structures for specific functional requirements. In another approach, a model of an SMA wire integrated into a textile structure is presented, which is used to represent the deformation pattern of an adaptive thermoplastic composite structure. These models enable efficient virtual development and selection of tailored textile architectures, reducing the need for extensive experimental trial-and-error and supporting the development of application-specific textile solutions for use in automotive, marine or aircraft applications, among others.

A mesoscale finite element model is developed and validated to enable the simulation-based design of woven structures for sternum closure after thoracic surgery. The model captures the bimodal structural behaviour of woven tapes designed to absorb high forces and strains. By systematically varying yarn and fabric parameters, structure-property relationships between the textile architecture and its mechanical response are derived. A design tool supports the targeted development of woven sternum closure structures with application-specific mechanical performance.

Simulation-based dimensioning of knitted ballistic textiles is used to gain a deeper understanding of the complex deformation mechanisms in multilayer knitted structures during impact. An efficient hybrid finite element model combines high spatial resolution in the impact region with reduced resolution in the surrounding areas, enabling computationally efficient simulations. Based on the simulation results, different reinforcement concepts are systematically designed and evaluated to achieve gap-free textile structures with high cover factor and minimal deformation under ballistic impact. The approach provides a powerful basis for the targeted simulation-driven development of high-performance protective textiles.

Keywords: Finite, element simulation, data driven modelling, composite, medical textile, protective textile

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