Sustainable Technologies for Thermoplastic Composites Using Natural and Recycled High Performance Fibers

Lukas Möller*†[1], Christian Herrmann*‡[1], Anwar Abdkader[1], and Cherif Chokri[1]

[1]Institute of Textile Machinery and High Performance Material Technology – Germany

Abstract

The growing demand for lightweight, resource-efficient materials has increased the need for sustainable composite manufacturing solutions. Due to their recyclability and efficient processing capabilities, thermoplastic composites offer significant potential. Using alternative reinforcement materials can further reduce their environmental impact. Natural fibers (NF) and recycled carbon fibers (rCF) as well as aramid fibers (AF) are promising reinforcement materials, but their application requires the understanding of their structural and processing characteristics.
This contribution aims to highlight the potential of NF and rCF as sustainable reinforcement materials for thermoplastic composites based on two approaches. The first approach investigates a bionic concept for load-path-oriented stiffening of a hemp fiber-reinforced shell structure using rib structures made from rCF hybrid yarns. The load-bearing base structure is a lightweight shell structure made from hemp fiber (HF) tapes, while locally applied ribs made from high-performance hybrid yarns provide additional stiffness where required by the mechanical load. To achieve this, yarn structures based on different material concepts were developed through the defined micro hybridization of HF, rCF, and polypropylene (PP).

The second approach focuses on the development of novel lightweight structures based on shell structures with structurally integrated, joining-free connection elements and load-path-oriented fiber alignment. Based on carding, drawing, tape manufacturing, and spinning technologies, the Institute of Textile Machinery and High Performance Material Technology (ITM) developed a process chain for manufacturing textile structures from recycled carbon and thermoplastic staple fibers. The resulting textile structures exhibit flowability that enables the formation of complex 3D structures, such as connecting elements with load-path-oriented fiber alignment, from 2D preforms in a single thermoforming step.
Together, the two approaches demonstrate the potential of natural and recycled carbon fibers to contribute to more sustainable thermoplastic composite solutions. While the first approach combines natural fiber-based lightweight structures with locally reinforced rCF hybrid yarn ribs, the second addresses the processing of rCF-based textile structures into complex 3D geometries. The investigations provide valuable insights into the structural and processing characteristics of natural fibers and rCF, thereby contributing to the development of resource-efficient thermoplastic composites with tailored structural and processing properties.

*Speaker
†Corresponding author: lukas.moeller1@tu-dresden.de
‡Corresponding author: christian.herrmann1@tu-dresden.de

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