Adaptive FRP Plus-Energy Shading Modules with Self-Regulating, Energy-Self-Sufficient Properties

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Abstract

In contrast to rigid body mechanisms, adaptive shading systems composed of fiber-reinforced polymers, whose deformation is based on local flexibility, do not necessitate the use of joints that are prone to failure due to friction and require extensive maintenance. Furthermore, these systems enable continuous adaptation to complex double-curved façade geometries, thereby ensuring optimal performance under varied conditions. Previous material approaches for technical implementation have been based on glass-fiber-reinforced plastic and elastomeric layers. However, because they are made from fossil-based materials, their potential in terms of sustainability is limited.
The "BioSunShade" project focuses on a fundamentally new material approach for adaptive fiber-reinforced polymers. Instead of continuous filaments, the project uses hybrid yarns made from cottonised flax and thermoplastic staple fibers. The material selection is based, on the one hand, on the goal of reducing CO emissions and a focus on recyclability. On the other hand, it is based on the hypothesis that, when bent or flexed, staple fibers slide off the matrix at the macroscopic level due to creep. This could allow the mechanical properties of the component to be tailored under cyclic loading

For the "BioSunShade" hinges, 3D fabrics are being produced, resulting in a quasi-unidirectional, undulation-free textile structure in the consolidated component. To achieve this, the hybrid yarn is used as the weft in the fabric, and a thermoplastic warp yarn is used that melts during consolidation. Areas adjacent to the joint are resistant to delamination due to the interlock weave between the layers. Actuation is achieved using shape-memory alloys to save space and energy, especially compared to pneumatic actuation.

The "BioSunShade" shading module is functionalized with photovoltaics. The result is an

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energy-self-sufficient shading system. Unlike conventional static photovoltaic modules, which require additional surface area, this technology utilizes previously unused façade surfaces to generate energy. Furthermore, a significant increase in energy yield is achieved through solar tracking.
The technical implementation of the flax-fiber-reinforced shading element occurs on three levels: (1) development of the semi-finished product (yarn and textile); (2) investigation of the functional response of the shape memory alloy and design of the local joint; and (3) architectural application as an adaptive, solar-tracking façade element with PV integration. Material properties, design guidelines, and process and energy balances are incorporated into a "design tool". This allows the results to be transferred to other industries, such as automotive or aircraft manufacturing.

Keywords: flax, fiber, reinforced polymer, compliant mechanism, photovoltaic, building envelope