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Advances in Fibre-reinforced Composite and Sandwich Structures

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Composite materials have become essential across various industries, including aerospace, automotive, construction, sports equipment, and electronics. These materials excel in strength-to-weight ratio, resistance to fatigue and corrosion, and low thermal expansion. The flexibility to customize composites by altering the type, size, and orientation of the reinforcement, along with the matrix material used, enhances their utility [1]. However, challenges such as high manufacturing costs, complexities in repair, vulnerability to delamination and other forms of damage, and difficulties in characterization and modelling present significant barriers [2]. However, it should be emphasized that numerical modelling has advanced significantly, particularly in simulating the complex behaviours of composite materials under various conditions. Nanocomposites aim to improve strength, stiffness, thermal and electrical conductivity, thereby expanding their application range [3]. Simultaneously, the push for sustainability has led to the development of eco-friendly composites that utilize renewable or recycled materials to minimize environmental impact. Bioinspired composites, inspired by natural materials like spider silk, seashells, and bone, aim to replicate their unique properties. Multifunctional composites, which incorporate materials such as shape memory alloys, piezoelectric elements, and carbon nanotubes, allow the creation of smart systems with capabilities for self-monitoring, adaptive responses, and energy harvesting [4]. Composite sandwich structures are widely used in industries like aerospace, automotive, marine, and construction due to their excellent strength-to-weight ratio, stiffness, and durability [5]. Innovations in materials, such as fibre-reinforced polymers and metal matrix composites for the face sheets, along with cutting-edge core materials like foams, honeycombs, and lattice designs, are being explored. To further enhance these structures, advanced core materials, including 3D-printed lattice configurations and bioinspired designs, are being developed to increase impact resistance, energy absorption, and overall structural integrity [6]. Understanding how sandwich structures behave under dynamic conditions such as impacts, blasts, and vibrations is essential.

As the current tendencies, composite and sandwich structure research is anticipated to move towards more integrated, multifunctional, and sustainable solutions that answer to the industry needs. Multi-material and hybrid structures aim to integrate different materials, such as composites with metals, ceramics, and polymers, to provide unique features [7]. Embedding sensors, utilizing data analytics, and applying machine learning algorithms are proposed techniques for structural health monitoring (SHM) [8]. Developing advanced coatings, surface treatments, and materials designed to withstand UV exposure, moisture, and chemical agents, will assist in increasing the durability [9]. Exploring additive manufacturing (3D printing), automated layup methods (including automated fibre placement and tape laying), and novel curing techniques is expected to boost production efficiency and reduce costs [10]. In the numerical point of view, creating multi-scale models that accurately represent the complex behaviours of composites, is expected to provide new design and predictive possibilities [11]. Incorporating functional materials in sandwich structures provide adaptive, self-healing, or sensing capabilities to composite structures [12]. Improvement in eco-friendly manufacturing processes, the development of biobased resins, and the creation of recyclable composite and sandwich structures, alongside improving methods for material recovery and reuse, is also expected soon [13].

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