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Advanced Multifunctional Composite Cellular Structures: Innovations and Impact in Aerospace Engineering

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Abstract. In recent years, the aerospace industry has increasingly adopted composite materials and honeycomb structures to address the need for lightweight, high-performance, and energy-efficient designs. These advancements have led to the replacement of traditional metallic components with fiber-reinforced polymers, ceramic matrix composites, and advanced honeycomb cores in critical structural parts such as wings, fuselage skins, and rotor blades. Honeycomb sandwich panel structures, due to their superior specific stiffness and energy absorption capabilities, are widely used in both civilian and military aircraft. This paper investigates the mechanical performance, design applications, and manufacturing techniques of these structures. Special attention is given to the integration of gradient-density honeycomb cores, radar-absorbing materials, and morphing wing technologies that enhance aerodynamic efficiency and stealth capabilities. The study also addresses prevalent challenges such as impact resistance, lightning strike vulnerability, flutter phenomena, and water ingress, which can compromise structural integrity. Furthermore, the paper explores recent innovations in additive manufacturing and bioinspired designs that support the development of complex geometries and adaptive structures. This article is prepared as a comprehensive review, aiming to synthesize and critically evaluate recent advances in composite materials and multifunctional cellular structures in aerospace engineering.

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