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Bio-inspired composites

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Abstract

The exoskeletons of many crustaceans are similar to fibre reinforced composites because they are made up of layers of aligned chitin filaments layered together. The helicoidal lay-up of crustacean laminates is a unique property. Each layer is rotated at a tiny angle from the one below it, similar to the steps of a spiral staircase — an uncommon structure that is rarely used in structural composites. To see if carbon fibre reinforced epoxy with helicoidal lay-ups offered any benefit, they were constructed and tested. Helicoidal laminates outperformed cross-ply and quasi-isotropic laminates in terms of peak load by up to 50% under transverse stresses. Further testing involving various composite material systems reveal and validate reasons for the enhanced performance. Ideas for helicoidal laminates that can repair after injury will be given based on these findings.

The rising demand for lightweight materials with the best strength-toughness balance is driving research towards the development of new materials with outstanding performance. Composites are frequently the best choice for structural applications because they offer an excellent balance of mechanical qualities and low weight. Composite materials' low toughness, on the other hand, is frequently a drawback. Many researchers attempted to circumvent this constraint by replicating natural principles, resulting in a new class of tougher composites known as biomimetic composites.

Natural hierarchical materials are an excellent source of design inspiration for emerging smart materials. Bone is a viable choice among these materials, with a good combination of mechanical qualities and a lightweight structure that can support a wide range of animal bodies. Bone, in particular, is attractive for research studies because to its amazing hardness.

We provide instructions for developing novel materials based on the bone structure. The goal is to apply important microstructural aspects of bone tissue in de novo composite materials to imitate the fundamental toughening mechanisms happening in bone microstructure. Various case studies on the realisation of new bone-inspired materials using various manufacturing techniques, such as composite lamination and additive manufacturing, are presented in this chapter. A thorough analysis of the novel materials reveals how the bone-like pattern influences the crack course and overall fracture behaviour of the composites, resulting in improved mechanical performance. Furthermore, it is feasible to observe some parallels between the failure modes and the bone tissue by observing the failure modes.

Microscopic examinations revealed that the toughening mechanisms had been executed correctly in the new materials and had a good impact on the overall mechanical performance.

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