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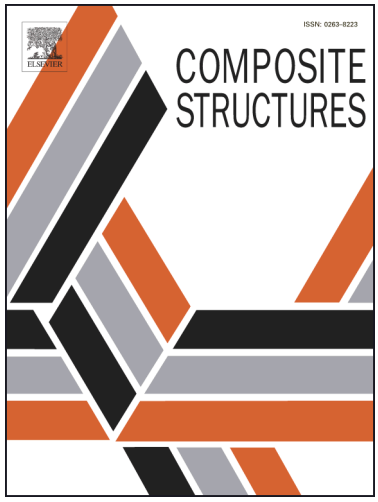

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Impact Energy Absorption of Bio-inspired Tubular Sections with Structural Hierarchy

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Abstract

Structural hierarchy in nature can be mimicked in order to develop novel composites and structures with desirable properties. In this study, hierarchy is introduced at multiple length scales into tubular sections that can be utilised as energy absorbing systems in various industries. The proposed hierarchical tubular section is inspired by the micro- to nano-architecture of biological materials, such as tendon and muscle, which can be mimicked by packing smaller tubes into a tube of a higher hierarchical level. The process can be repeated for creating tubular sections of higher orders of structural hierarchy, regardless of size or choice of materials. Numerical experiment has revealed that the impact energy absorption capability can be improved significantly when hierarchy is introduced and greater enhancement is achieved for higher-order hierarchical sections. A parametric study has been undertaken, and with the use of dimensionless parameters, the robustness and the generality of the phenomenon are demonstrated.

Keywords: Structural hierarchy; Bio-inspired; Tubular section; Impact; Energy absorption

Declaration of Interest: None

1. Introduction

Structural hierarchy exists in natural materials [1,2], such as tissues of bone, tendon, muscle, bamboo and wood. Enhanced mechanical properties, in terms of strength and toughness, have been found in hierarchical biological materials. It is believed that the exceptional properties have been developed as a functional adaptation and optimisation process of the structure at each hierarchical level through natural selection, as the primary function of those materials is to provide support (e.g. strength and stiffness) and protection (e.g. toughness and chemical barrier) of the bodies of animals or plants. There are studies about the structures of nacre over several length scales in relation to its excellent strength, modulus and toughness for protecting the soft organisms enclosed in the shell [3,4], and the seven hierarchical levels of bone at micro- and nano-levels that contribute to the mechanical and functional properties [5,6]. Hence, nature's structural hierarchies are fruitful learning resources for the development of new technologies.

High-performance materials and structures have been developed for solving various complex problems in the world. Biomimetics or bio-inspiration is a promising approach as natural materials have evolved over geological time leading to their present forms by actively responding to biophysical stimuli in their external environment [2]. There have been studies about the biological hierarchical structures at different length scales and the knowledge

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