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Editorial

Editorial for Special Issue: Performance Enhancement of Advanced Composites and Bio-Based Composites through a Hybrid Approach: Opportunities and Challenges

Hom Nath Dhakal

Advanced Polymers and Composites (APC) Research Group, School of Mechanical and Design Engineering, University of Portsmouth, Portsmouth PO1 3DJ, UK; hom.dhakal@port.ac.uk

The hybridisation of two or more fibres is a technique in which the benefits of each reinforcing material can be combined to achieve a composite that demonstrates better and improved properties for various advanced engineering applications. In this Special Issue, a hybrid approach comprising two or more types of reinforcement (fibres) in a single matrix is covered. In recent years, there have been many attempts to achieve higher-performance composite materials through the hybridisation technique. Many studies suggest the positive effects of hybridisation on various properties. However, understanding the hybrid compatibility (interfacial layer characteristics and adhesion to matrix) of two reinforcements is important and needs to be fully understood to realise the full potential of the hybridisation technique.

Therefore, this Special Issue invited authors to submit recent studies that display cutting-edge research on composite and hybrid composite materials, their manufacturing, characterisation, and failure mechanisms. The main aim of this Special Issue was to attract original papers that deal with the science and mechanisms of hybrid systems relevant to the structural, semi-structural, and non-structural service performance of composite materials for industrial applications. Importantly, innovative studies on both experimental and numerical investigations are also encouraged.

The papers included in this Special Issue therefore illustrate and highlight an in-depth analysis of hybrid composites and how the hybrid approach can achieve performance improvement via the synergic benefits of hybridising constituents. Similarly, the challenges and critical issues of hybridisation are critically discussed.

Moving forward, Kafetzi et al. investigated the properties of colloidal organic–inorganic hybrid perovskites (Hyb-Per) on optical and thermal stability over time, correlating the different ratios of perovskite to copolymer. They used various characterisation techniques, including ultraviolet-visible (UV-Vis) and fluorescence spectroscopy. Similarly, dynamic light scattering and transmission electron microscopy were used to determine the size and morphology of the particles. They also reported the high temporal stability of the optical properties of thin hybrid films under certain conditions. It is important to use correct characterisation techniques to appreciate the size and morphological distribution of nanoparticles in polymeric hybrid systems. The reported investigation provides important information when synthesised. Properties of a new class of polymer/perovskite hybrid nanoparticles were developed for improved thermal stability in addition to the optical properties that have potential use in the development of photovoltaic devices.

The work carried out by Islam et al. covered the fatigue behaviour of flax-fibre-reinforced epoxy bio-based composites and their carbon fibre hybridised inter-ply and intra-ply hybrid composites. The study aimed to attain more tailored properties by flax/epoxy composites through hybridisation, benefiting from the synergic effects of both reinforcements. Bio-based composites reinforced with natural plant fibres (flax, hemp, kenaf, jute, among others) have gained significant interest in recent years. This interest is driven by

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their attractive properties, such as light weight, renewability, higher specific properties, and lower cost compared with their conventional (carbon, glass, and aramid) reinforcements. There is a significant body of knowledge available concerning their mechanical and thermal properties. However, fatigue behaviours of these bio-based composites have not been well investigated. In this respect, this work covered the important area of the possible application of natural plant-reinforced bio-based composites for non-structural and structural applications. In this regard, the fatigue behaviour of inter-ply flax/carbon hybrid composites was compared with intra-ply flax carbon hybrid systems. The results showed a significant increase in fatigue behaviour with carbon fibre hybridised samples compared with flax/epoxy composites without hybridisation. The key achievement of this work was that with a suitable hybrid ratio and optimised fibre stacking sequence, flax/epoxy hybridised composites provided comparable mechanical properties to synthetic fibre reinforced composites, as an increase in already-high natural plant fibre contents provided an increased bio-based content.

Furthermore, the study carried out by Barouni and Rekatsinas reported the importance of monitoring the structural health of natural fibre composites. They used a non-destructive technique (Lamb waves) to characterise the stress propagation in different types of unidirectional flax-fibre-reinforced linear low-density polyethene (LLPDE), flax/vinyl ester and glass vinyl ester composites. They also used flax/glass hybrid composites for damage investigation. The report highlighted that the semi-analytical time domain spectral finite-element numerical method effectively measured damage propagation in the flax and flax/glass hybrid composites.

The contribution of Jiang et al. on the flexural properties of sustainable sandwich composites fabricated from recycled carbon fibres, flax/PP skins, and recycled polyethene terephthalate (PET) core is significant. The fabrication process used was high-pressure compression moulding. They reported that the developed sandwich bio-based composites are suitable as a lightweight component for truck side panels. This work clearly showed that flax/recycled-carbon-fibre-based hybrid composites could be excellent candidates for lightweight, low-cost, and environmentally friendly engineering structures. The findings also highlighted that these composites help meet the European Union's end-of-life vehicle directive mandates. Using thermoplastic-based bio-based composites further provides high-impact toughness as well as recyclability features. Utilising sustainable natural plant fibres, such as flax with recycled carbon fibre using a thermoplastic matrix, can certainly be suitable for semi-structural engineering applications. The hybrid approach used in this study can further lead to using natural fibre/carbon hybridised composites for structural applications. This is very difficult with natural plant fibres alone due to their low mechanical properties.

In addition, Kannivel et al. investigated the influence of low-velocity impact on the residual flexural behaviour of glass/epoxy laminates hybridised with glass fillers. They employed various impact velocities and residual flexural performances, such as that of flexure after impact (FAI). Damage behaviour was evaluated using acoustic emission (AE) monitoring. It was reported that substantial improvements in the impact toughness and post-impact residual flexural properties were achieved. This was attributed to the addition of glass fillers as a hybrid constituent. The presence of nano-fillers often contributes to an improved energy dissipation, which helps to arrest the delamination crack growth, reducing the damaged area after the impact tests. Composite materials are exposed to damage under various loading scenarios in their service conditions. Understanding their damage behaviours using non-destructive damage-evaluation techniques becomes crucial with various impact loadings. These phenomena explain lightweight composite structures in the automotive, aerospace, and defence industries, among other application areas. The findings of this work suggest that hybridising nanoparticles into matrix materials has great potential for improving impact toughness and interlaminar properties.

Hybrid effects of various loading situations on composite materials are important to investigate. Therefore, Rajput et al. studied the effect of carbon- and glass-fibre-reinforced inter- and intra-ply hybrid composites. The resin transfer moulding was used to fabricate the composite laminates. The researchers reported both positive and negative hybrid effects. The stacking sequence and how the hybrid composites were fabricated influenced their final performances. It is important that hybrid strategies influence the final properties of composite structures. Optimised hybridisation strategies are important to exploit a balance between the cost and the performance of composites for structural and lightweight applications.

Additionally, Nguyen et al. reported the effect of submicron glass fibre incorporation on the mechanical properties of short carbon-fibre-reinforced vinyl-ester (VE)-based composites using varying fibre lengths of 1, 3, and 25 mm. This study examined the effect of fibre length on the key mechanical properties. From the results obtained, it was evident that static properties, such as impact, bending, and tensile strength, were significantly influenced by the fibre length. Hybridising submicron glass fibres into the carbon/VE systems provided remarkably enhanced performances, especially on the fatigue life of the composites.

Summarily, it is evident that the hybridisation approach plays an important role in the enhancement of the properties of both fibre- and filler-reinforced polymer composite materials. The approach further increases the applications of various hybridised composite structures and their performances. However, it is necessary to consider the compatibility of the selected reinforcements (fillers and/or fibres) with the matrix used within a single hybrid composite system because of their interfacial adhesion.

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