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TITLE: Additive manufacturing of recycled carbon fibre reinforced composites with high fibre efficiency

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ABSTRACT:

Acting as reinforcement materials, carbon fibres can significantly enhance the mechanical properties of thermoplastics. With the rapid growth in global demand for carbon fibres and increasing emphasis on sustainability strategies, recycling carbon fibres represents a viable solution to meet these challenges. Material extrusion additive manufacturing (*i.e.*, 3D printing) can exploit the anisotropic characteristics of carbon fibres, enabling mould-free rapid prototyping and the fabrication of complex composite structures.

Previous research has shown that fibre efficiency (determined by fibre volume fraction, orientation, and length) has a critical impact on mechanical performance. However, increasing fibre length and volume fraction leads to deposition difficulties caused by fibre clogging, as evidenced by numerical simulations using computational fluid dynamics-discrete element method (CFD-DEM) and experimental observations obtained through X-ray computed tomography (XCT). These studies indicate that fibre breakage and disordered alignment occur during the deposition process, reducing fibre efficiency and consequently degrading mechanical properties.

To address this challenge, we developed a novel additive manufacturing method termed angled feeding extrusion (AFE), which was conceptualised and optimised for recycled carbon fibre composites with high fibre efficiency based on CFD-DEM simulations. The designed system was implemented and validated using a multi-axial printer. Specifically, the AFE approach increases the angle between the melt flow direction and the printer bed, thereby reducing deposition backpressure and preventing losses in fibre efficiency. Characterisation and mechanical testing demonstrate that AFE improves fibre efficiency, achieving a fibre length of 3.8 mm and a volume fraction of 30.3%. Compared with conventional additive manufacturing methods, tensile strength and modulus increased by 90% (178 MPa) and 254% (9.9 GPa), respectively.

Keywords: Material extrusion; Additive manufacturing; 3D printing; Recycled carbon fibre; Thermoplastic composites.