Enhanced Structural and Thermal Stability of Carbon Nanofibre-Reinforced Wet-Spun Coaxial Phase Change Fibres with Fatty Acids

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ABSTRACT

The increasing instability of the energy sector and the rising pressure to reduce carbon emissions have intensified the search for passive solutions that can lower energy use in buildings. Since the thermal properties of construction materials directly influence heating and cooling demands, thermal energy storage has become an important strategy for managing temperature fluctuations and advancing energy efficiency. In this context, phase change materials (PCMs) are particularly appealing because they can store and release thermal energy as latent heat. However, directly integrating PCMs into construction materials may cause leakage, physicochemical incompatibilities, and a decrease in mechanical performance during phase changes. Encapsulation is therefore an effective method for containing the PCM within a protective shell, maintaining its thermal performance, and minimising negative impacts on the host material's structural integrity. In this study, coaxial polymeric phase change fibres (PCFs) were successfully fabricated via wet-spinning, a technique that controls polymer precipitation in a coagulation bath to form continuous core-sheath structures. Linoleic acid (LA) and oleic acid (OA), both fatty acids and PCMs, were used as core materials, while cellulose acetate (CA) reinforced with carbon nanofibres (CNF, 0.05 and 0.10 wt.%) was used as the protective sheath. Bright-field microscopy confirmed the formation of well-defined coaxial structures and showed good dispersion of CNF within the sheath. Attenuated Total Reflectance Fourier Transform Infrared spectroscopy (ATR-FTIR) verified the preservation of chemical structures after processing and confirmed the presence of characteristic fatty acid functional groups in the encapsulated fibres. Thermogravimetric analysis (TGA) revealed a two-stage degradation profile, with fatty acid volatilisation occurring at 230–310 °C and CA decomposition at 310-400 °C. Differential scanning calorimetry (DSC) demonstrated consistent phase change behaviour, with higher melting enthalpy observed in CNF-reinforced PCFs, indicating improved thermal energy storage capacity. Dynamic mechanical analysis (DMA) showed that adding CNF enhanced the stress-strain response and increased the time to failure, suggesting improved structural reinforcement and mechanical stability. Overall, these findings demonstrated that wet-spinning is an effective method for encapsulating fatty acids into coaxial PCFs, while CNF reinforcement offered a promising approach to simultaneously improve thermal energy storage and mechanical strength. The developed composite material is a promising solution for sustainable, energy-efficient use in the built environment.

Keywords: Carbon nanofibres; Fatty acids; Polymeric coaxial fibres; Thermal comfort.

Biography:

Nathalia Hammes holds a Master's degree in Materials Engineering from the University of Minho (Portugal) and is currently a PhD candidate in the Doctoral Programme in Materials Engineering at the same institution. In 2024, she ranked first in the FCT doctoral scholarship call in the Materials Engineering panel. She is a member of the (RE)NERGY-BUILD project, where her research focuses on the development of wet-spun coaxial phase-change fibres for civil engineering applications, with particular emphasis on passive thermal regulation and energy-efficient materials for the built environment. Her work is centred on the design of functional polymeric fibres incorporating phase change materials to enhance thermal energy storage and contribute to more sustainable construction solutions. Alongside her research activities, she has published in peer-reviewed journals, mentored undergraduate and Master's students, and contributed to the organisation of international scientific conferences. She has also been recognised with an academic award for her achievements.