Filament coalescence in 3D printed magneto-rheological elastomers

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Abstract

Components manufactured by extrusion-based additive manufacturing technologies (EB-AM) are car-
acterised by a mesostructure formed by the coalescence of filaments. For optimal structural integrity,
good adhesion between filaments is desirable to reduce porosity and enhance their mechanical response.
Recently, AM technologies have taken a step further towards the so-called 4D printing. This new term
allows not only the control the structural characteristics of components but also includes other func-
tionalities with properties that vary in space and/or time. Therefore, understanding and predicting the
resulting mesostructure is crucial not only for improving mechanical behaviour but also for controlling
their additional functionality.

In this work, we propose the development of a physically-based virtual testbed to simulate the EB-AM
process, with the primary aim of controlling the final mesostructure of the EB-AM components to meet
specific functional requirements. Without loss of generality, we focus on direct ink writing (DIW), a
technique in which a pre-cured polymeric "ink" is extruded through a nozzle. In DIW, the material's
viscosity must be low enough to facilitate extrusion and coalescence with other filaments but, at the
same time, high enough to ensure shape fidelity. Therefore, it is necessary to understand the mechanics
of the coalescence between printed filaments and the role that viscosity and surface tension play in the
process.

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Our approach combines experimantal and computational tools. Firsts, we carry out a comprehensive rheological analysis of PDMS reinforced with magnetic particles as the base material. Then, we record the filament coalescence under different printing conditions. Finally, we implement a phase-field model with time-dependent properties to simulate the behavior of two immiscible phases (the printed material and its surrounding medium), accurately capturing the dynamics of filament fusion and enabling the optimization of DIW manufacturing processes.

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