Fiber orientation of a short-fiber suspension in axisymmetric hyperbolic and conical nozzle profiles with wall slip in Additive Manufacturing

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Abstract

Fused Filament Fabrication (FFF) additive manufacturing process can construct complex geometric components by depositing layer by layer using thermoplastic filaments containing short fibers through a nozzle that melts the resin creating a short fiber suspension. The orientation of the fibers during the extrusion from the nozzle can significantly influence the physical and mechanical performance of printed parts.

We investigate the effect of the nozzle wall slip on the orientation of these fibers. The suspension flows through a three-dimensional axisymmetric nozzle, and both hyperbolic and conical profiles are examined. Fiber orientation is described using the second-order orientation tensor formulation, which accounts for fiber–fiber interactions and employs a hybrid closure to approximate the fourth-order tensor. The contribution of the fibers to the extra stress is neglected, and the velocity field is represented by a high-order asymptotic expansion in terms of the nozzle's aspect ratio. The resulting evolution equations for the orientation tensor are solved numerically using a fully implicit finite-difference method.

Our results show that the fiber orientation gradually evolves from its initial pure-shear state at the inlet toward a more aligned configuration as the flow approaches the nozzle exit. The region of highest fiber alignment—most pronounced along the symmetry axis, where the flow is purely extensional—expands toward the walls as slip

factor increases. Differences between the hyperbolic and conical geometries are also discussed.