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Optimizing Nozzle Geometry for Extrusion-Based Additive Manufacturing to Accommodate Various Grades of Polyethylene

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Abstract

In additive manufacturing via material extrusion, viscoelastic polymer melts undergo complex flow deformations that involve both shear and extensional components. These deformations, influenced by nozzle geometry, contribute to variations in pressure drop, directly affecting extrusion performance. In nozzle designs with converging and cylindrical sections, flow behavior and pressure drop play a crucial role in process reliability and operational efficiency, requiring precise control.

This study examines the relationship between nozzle geometry and material properties, focusing on how polymer chain architecture, such as branching content and molecular weight, affects deformation behavior, flow characteristics and elastic response. To investigate this effect a predictive framework was developed by simulating non-Newtonian fluid flow through variable nozzle geometries, incorporating different constitutive models and experimental rheological data from various polyethylene grades. The framework aims to optimize convergence angles for maximizing flow rate while minimizing pressure drop.

To validate these predictions, experiments were conducted using a capillary rheometer equipped with a custom-designed capillary die that replicates nozzle geometry. The die featured a 30 mm barrel section with a 10 mm diameter and interchangeable conical-cylindrical sections to test different convergence angles. These modifications enabled precise measurements of pressure drop, flow rate, and viscosity under controlled conditions.

The findings provide practical guidelines for optimizing process parameters while advancing the fundamental understanding of polymer processing in additive manufacturing. By refining process control, these insights contribute to improved efficiency process and product quality in material extrusion- based additive manufacturing.