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ABSTRACT:

Digital Twinning of Thermoplastic Pellets Extrusion Process

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Extrusion of pellets for processing thermoplastic parts is gaining increasing attention as a sustainable alternative to thermosets and a promising material for 3D printing applications. However mechanical properties obtained are highly process dependent and require a detailed understanding of the thermal and rheological state of the polymer. This work presents a three-dimensional finite element modeling approach of PET-G pellets during the extrusion process for 3D printing developed at ENSTA Brest Campus and implemented in COMSOL Multiphysics [1-2]. This is a collaborative work with Colorado State University in charge of the design of a 3D printing device based on a Dyze Design industrial extruder.

The modeling approach couples creeping-flow Stokes equations with heat transfer in fluids, using temperature- dependent laws for viscosity, density and thermal properties of the polymer. Since it is an inelastic non-Newtonian fluid, viscosity depends on the shear rate and temperature. To address this fact, two different models were used: Power Law [3] and Cross [4-6], in order to compare the performance of the solutions between the approaches. A Frozen Rotor formulation [2] captures the shear-driven motion generated by the screw while keeping the computational cost tractable. The detailed representation of the screw, barrel, and die enable the model to resolve thermal gradients and the helical flow patterns characteristic of single-screw extrusion.

Simulations demonstrate complete polymer melting within the designed heating zones, with peak temperatures ranging from 220 °C to 240°C - consistent with PET-G's processing window. Beyond reproducing the thermal and flow physics, the model provides a practical framework to control outlet mass flow rate by adjusting boundary conditions such as heating-zone temperatures (three independent zones) and rotational speed of the screw, as well as geometric parameters, especially the nozzle diameter, offering a pathway toward optimized extrusion performance and the scaling up of the process. This initial study of single-screw extrusion proved to be quite effective, producing mass flow rate predictions with a margin of error of around 5% in relation to experimental measurements. A proposal for porosity development, based on density evolution during the process, is presented and highlights the importance of pellets initial moisture content on mass flow rate.

References :

- [1] COMSOL Multiphysics® v. 6.4. www.comsol.com. COMSOL AB, Stockholm, Sweden.
- [2] CFD Module User's Guide. COMSOL Multiphysics® v. 6.4. COMSOL AB, Stockholm, Sweden. 2026.
- [3] R. B. Bird, R. C. Armstrong, O. Hassager, Wiley, New York, 1987.
- [4] M. M. Cross, *Rheol Acta* 1979, 18, 609.
- [5] G. Santesarti, M. Marino, F. Viola, R. Verzicco, G. Vairo, *Journal of Non-Newtonian Fluid Mechanics* 2025, 342, 105438
- [6] H. H. Winter, *Rheol Acta* 2009, 48, 241.