

Review

Analytical and Numerical Models of Thermoplastics: A Review Aimed to Pellet Extrusion-Based Additive Manufacturing

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Abstract: Recent developments in additive manufacturing have moved towards a new trend in material extrusion processes (ISO/ASTM 52910:2018), dealing with the direct extrusion of thermoplastic and composite material from pellets. This growing interest is driven by the reduction of costs, environmental impact, energy consumption, and the possibility to increase the range of printable materials. Pellet additive manufacturing (PAM) can cover the same applications as fused filament fabrication (FFF), and in addition, can lead to scale towards larger workspaces that cannot be covered by FFF, due to the limited diameters of standard filaments. In the first case, the process is known as micro- or mini-extrusion (MIE) in the literature, in the second case the expression big area additive manufacturing (BAAM) is very common. Several models are available in literature regarding filament extrusion, while there is a lack of modeling of the extrusion dynamics in PAM. Physical and chemical phenomena involved in PAM have high overlap with those characterizing injection molding (IM). Therefore, a systematic study of IM literature can lead to a selection of the most promising models for PAM, both for lower (MIE) and larger (BAAM) extruder dimensions. The models concerning the IM process have been reviewed with this aim: the extraction of information useful for the development of codes able to predict thermo-fluid dynamics performances of PAM extruders.

Keywords: pellet extrusion; industry 4.0; polymer melting modeling; single-screw extrusion; additive manufacturing



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1. Introduction

Industry 4.0 has introduced new business models focused on consumers and product customization. As a natural consequence, both the quantity of the service provided and the added value have increased.

The main points of Industry 4.0 revolution are automation, interoperability, and transparency of information [1], combined with an underlying ethics conscious of the need for processes with low environmental impact.

Additive manufacturing (AM) plays a key role in the Industry 4.0 scenario, leading to the manufacturing of a physical three-dimensional object starting from a computer-aided design (CAD) model.

Moreover, AM allows substantial savings in terms of logistic costs, giving the opportunity to perform 3D printing once the printing file has been acquired, wherever the 3D printer is located.

AM satisfies the growing need for product customization, leading to the development of functional, flexible, and efficient parts and assemblies. Nevertheless, the most common additive manufacturing process, namely the fused filament fabrication (FFF), is characterized by a multitude of limitations.

FFF is an AM process which consists in manufacturing products starting by extruding a polymeric material given in the form of a filament, which is then gradually molten through an extrusion system. Initially, raw filament is pushed down by a pair of wheels,

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