



Modelling the solids inflow and solids conveying of single-screw extruders using the discrete element method

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Abstract

A new solids-conveying model for the single-screw extruder based on the Discrete Element Method (DEM) is proposed in this work. The polymer solids are treated as spherical particles moving in a 3-D environment which includes the feed hopper, the solids-inflow zone, and the solids-conveying region of an extruder, without inclusion of the plug flow assumption common to continuum models. Normal and tangential forces resulting from inelastic collisions with neighboring particles and surfaces dictate how each polymer pellet is conveyed through the model extruder. The DEM technique was implemented in this work to allow fundamental study of the local transport phenomena within the screw channel. Reported in this paper are results examining the cross- and down-channel velocity profile of solids in the screw; the residence time distribution; the cross-channel temperature profile; and the coordination number distribution. Two exit conditions were evaluated by the model: i) the open-discharge case where no compaction of the solids occurred; and ii) the restricted case where the axial pressure increased as the solids flowed towards the barrel exit. The predictions of the DEM simulations allowed for detailed observations of the solids movement in the screw, providing insight into the inherent flow fluctuations of extrusion systems.

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1. Introduction

Bulk transport of solids within screw conveyors and feeders is based on the Archimedean principle of screw conveying, with these devices representing the most common process operations in solids handling plants due to their reliability and continuous flow characteristics [1]. Conveyors are usually operated starved at approximately 45% of capacity, whereas screw feeders which are often located at the bottom of storage bins and silos, are flood-fed yielding the maximum feed rate [2]. A more complex screw conveying device is the plasticating single-screw extruder. In the plastics industry, single-screw extruders are usually flood-fed solid polymer pellets which eventually melt due to viscous dissipation and conduction from the heated barrel. Unlike screw conveyors, the screw channel of an extruder is

comparatively shallow in depth and includes a flight that is relatively thick in comparison. The restriction at the die end of an extruder generates high pressures (in the order of 10–30 MPa), leading to compaction of the polymer pellets within the solids conveying zone [3]. It is this pressure generation within the solid assembly which principally differentiates single-screw extruders from screw conveyors or feeders.

The majority of models found in the literature [3–6] for solids conveying within single-screw extruders make the plug flow assumption in their derivations. This simplifies the analysis, allowing the output rate and pressure development to be determined from force and torque balances on an elastic plug. The result is a useful tool giving reasonably good agreement with output rate data provided the appropriate coefficient of friction is selected; however, the predicted pressure is greater than experimental data, often by several orders of magnitude [7]. Models based on this approach lack the ability to describe local solids motion within the screw channel and the dynamic nature of the flow which is observed in practice [8]. There are a few notable

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