Steps for the Optimization of Pipe and Tubing Extrusion Dies

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Abstract

Degradation is a significant obstacle that harms both the extrusion and injection molding processing and recycling of plastics [1]. This chemical reaction adversely affects the flow and mechanical properties of the material and the surface finish of the products. Factors such as temperature, shear, and residence time history contribute to this negative effect and need further insight [1,2,3]. One application of extrusion that currently addresses this problem is the extrusion of pipes from polyethylene. During the processing of polyethylene pipes, the resin experiences exceedingly high residence times and small blemishes, referred to as gels, appear in extruded products [1]. A technique used to detect degradation is to identify changes in molecular weight MW, which is reflected by increases or decreases in the melt flow index MFI [1]. However, the use of modeling and simulation provides an additional illustration of the cause of degradation and can be a guide for preventing this defect in other applications concerning injection molding and extrusion. The study of residence time distribution (RTD), tracer curves, and Poincaré sections, traditionally applied in mixing, is the basis for the presented methodology regarding the elimination of degradation in pipe extrusion. This study used COMSOL Multiphysics 4.2a. This methodology follows the trajectory of the material inside the equipment and allows the detection of problems in the mechanical design of the tooling. The analysis modeled the trajectories and residence times in one of the customary pipe extrusion dies (lattice basket die). This die is adopted in the tubing extrusion of polyolefin by virtue of its capacity to produce high quality surface appearance and mechanical strength due to its borehole pattern, which materializes several weld lines around the surface instead of one weld line in the middle of the pipe [4]. The die is shown in Figure 1. However, the analysis results found that the borehole pattern of this die allows room for stagnation and recirculation regions that produce degradation of the resin because of longer residence times (Figure 2 and Figure 3). Considering that approximately 9% of polyolefin circulates or hardly flows inside the die, the residence time increases. Novel geometry profiles were simulated while seeking substitutes for the boreholes in the lattice basket that would not drastically alter the mechanical design of the die. These substitute boreholes would instead reduce the residence time. After modeling several profiles, a simple yet elegant solution was found. This study introduces the use of vertical and horizontal slots as a suitable, light and easily machineable geometrical profile that can replace the original borehole arrangement (Figure 4). The horizontal slots halve the residence time and the vertical slots retain three times less material. Smaller total pressure losses, higher volumetric flow rates and lower power uses under the same operation conditions [4] are benefits achieved with these reshaped cavity profiles. Additionally, the simulation allows the analysis of several models without having to build

all of them, saving time, resources and cost consumption.

Reference

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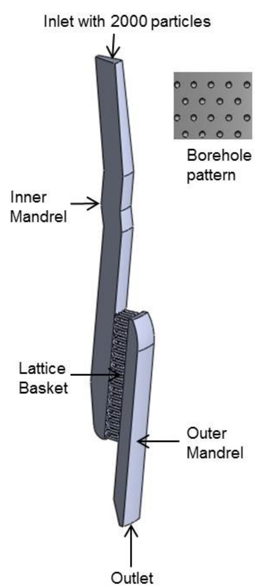
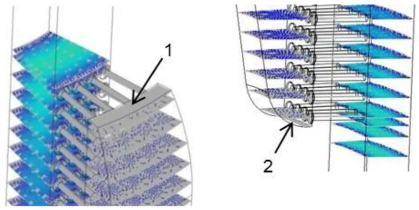
2. Moss S. and Zweifel H., Degradation and stabilization of high density polyethylene during multiple extrusions. Polymer Degradation and Stability, vol. 25, nº 2-4, pp. 217-245, 1989.
3. Hinsken H., Moss S., Pauquet J. and Zweifel,H., Degradation of polyolefins during melt processing, Polymer Degradation and Stability, vol. 34, nº 1-3, pp. 279-293, 1991.
4. Michaeli, W. Extrusion Dies for Plastics and Rubber. Munich: 3rd Edition. Hanser, 2003.

Figures used in the abstract



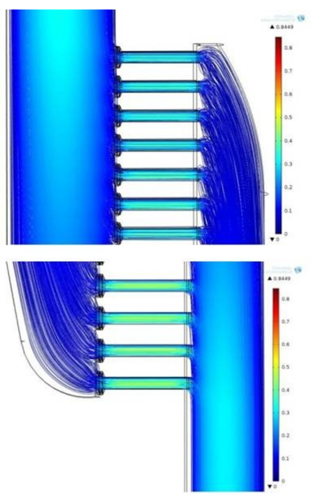
Five percent of the 3D geometry (18°) has been simulated. This schematic diagram covers all the meaningful details of pattern in the lattice basket die and reduces the computational cost. The complete pattern (360°) is composed of 2100 cavities.

Figure 1: Lattice basket (LB) die geometry.



Poincaré sections have been used to represent the trajectory of the 2000 particles traveling through the die. Zones without particles (1,2) represent low velocity regions that lead to stagnation points and/or recirculation regions.

Figure 2: Particle tracking in the LB die. Top corner of the outer mandrel and bottom corner of the inner mandrel.



The empty zones without tracer curves represent stagnation points and recirculation regions. The chamfers in the inner wall of the basket have a positive effect diminishing the empty zones. This concept is used later in the novelty design. This agrees with the undesired regions found in the streamlines profile and the Poincaré sections.

Figure 3: Tracer curves of the particles trajectory in the LB die. Top corner of the outer mandrel and bottom corner of the inner mandrel.

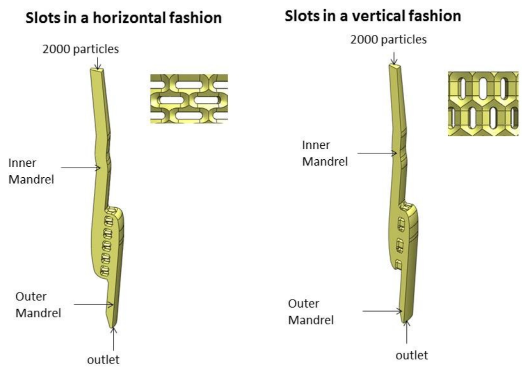


Figure 4: Slots in horizontal and vertical fashion.