PlasticFlow with polyXtrue software

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Elimination of Shark-Skin Instability in Sheet Extrusion of a Filled HDPE

Challenge

A United States based major manufacturing company wanted to extrude a 0.6 inch thick and 2 ft wide sheet using a highly filled High Density Polyethylene (HDPE). The filler was a heavy weight material, which was recovered as a by-product of a metal casting process.

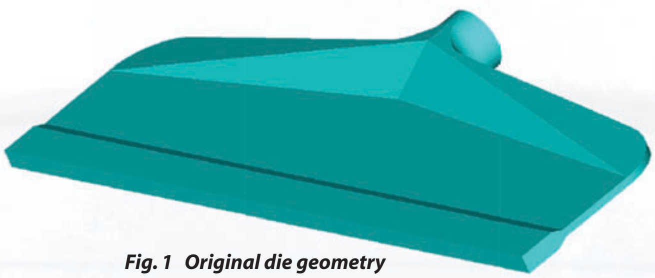

Fig. 1 Original die geometry

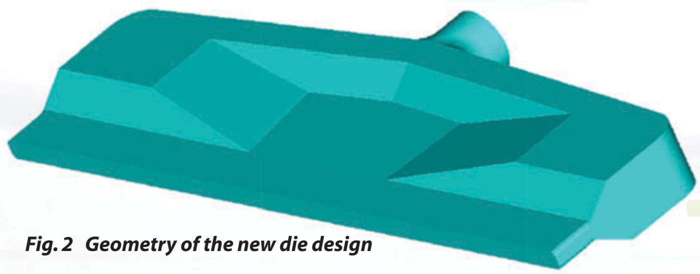

Fig. 2 Geometry of the new die design

Addition of the heavy weight metal to HDPE was important not only because it is good for environmental sustainability, but also provided the extra weight to the sheet which was important for this particular application of the HDPE sheet. However, when the manufacturing company used a sheet die designed by another die design company (Fig. 1), large fluctuations were encountered in the extrusion process and the extruded sheet surface was highly zigzagged. Such zigzagged surfaces, called shark-skin phenomena, are often observed in sheet extrusion. The zigzagged surface could not be eliminated even though a wide range of extrusion processing conditions was tried.

Solution

After contacting some other die designers, the manufacturing company selected Plastic Flow to resolve the shark-skin problem it was having with the HDPE/filler sheet extrusion. After analyzing the shark-skin formation in the HDPE/Filler sheet, Plastic Flow approached the problem scientifically to optimize the extrusion die by taking the following steps.

Material Characterization

To understand the source of shark-skin formation, the rheology of the HDPE/filler mixture was characterized. During the rheological characterization, it was determined that the particle size of the filler needed to be refined and be more uniform. With the finer filler particles, viscosity (Fig. 3), thermal conductivity, heat capacity and density of the HDPE/filler mixture was characterized.

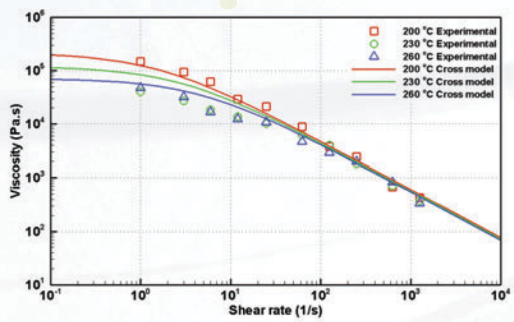

Fig. 3 Viscosity of HDPE/filler mixture

Die Design

After understanding the rheological behavior of HDPE/filler mixture, monoextrusion die module of the polyXtrue software was used to optimize the die channel geometry. Instead of using the conventional sheet dies designs, such as coat-hanger design, or fish-tail design, a completely non-conventional innovative die geometry (Fig. 2) was developed to achieve a highly uniform velocity distribution at the die exit (die balancing). While balancing the flow at the die exit, the pressure drop in the die was also reduced to less than 30% of the original value. Accordingly, for the pressure available from the extruder the throughput rate was increased more than three times of the original throughput rate. With the reduced pressure drop in the die, the shark-skin formation was also eliminated. Besides the primary and secondary manifolds typically used in sheet extrusion dies, the new die geometry in Fig. 2 has a feeder plate before the die land to divert the polymer to the two sides of the die, simultaneously reducing the pressure drop in the die.

Results

The new non-conventional die channel geometry developed by Plastic Flow using the polyXtrue software

- Eliminated the shark-skin formation during the extrusion
- Increased the uniformity of the velocity at die exit, and hence, the uniformity of sheet thickness
- Reduced the pressure drop in the die by more than 70%, and increased the production rate more than three times

> "…a completely non-conventional **innovative die geometry** (Fig. 3) was developed to achieve a highly uniform velocity distribution at the die exit (die balancing)."

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solutiondetails

Velocity Distributions

For the original and the new die designs, the velocity distributions at the inlet, exit and three intermediate cross-sections predicted by polyXtrue software are shown in Figs. 4 (a) and 4 (b). For the new die geometry, uniformity of the velocity distribution at the die exit is evident from Fig. 4 (b). For the original die geometry the velocity distribution at the die exit is significantly larger at the two locations near the middle and is low near the two ends.

(a) (b)

Fig. 4 Velocity distributions in (a) original die, (b) new improved die

Pressure Distributions

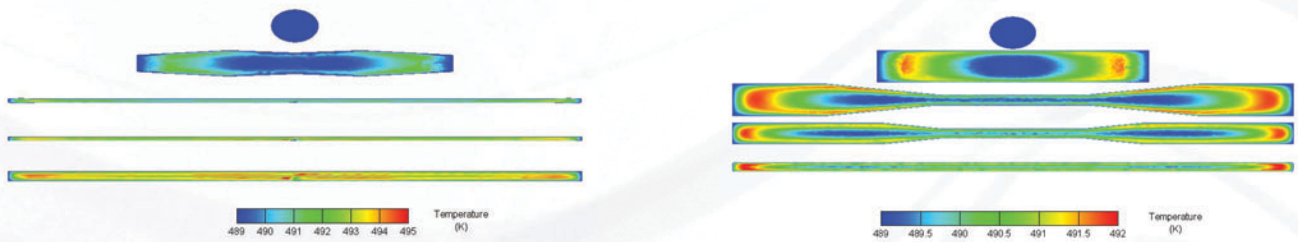
For the original and the new die designs, pressure distributions at the inlet, exit and three intermediate cross-sections are shown in Fig. 5. The total pressure drop in the improved die geometry is only about 8 MPa, whereas in the original die the predicted pressure drop is about 28 MPa. That is, for the same flow rate the pressure drop in the improved die geometry is only about 29% of the pressure drop in the original die.

(a) (b)

Fig. 5 Pressure distributions in (a) original die, (b) new improved die

Temperature Distributions

For the original and the new die designs, pressure distributions at the inlet, exit and three intermediate cross-sections are shown in Fig. 6. Starting with the temperature of 489 K (420 °F) at the entrance, due to shear heating the temperature near the walls of the improved die increased to 492 K. This small increase in temperature did not have any significant effect on the extrudate profile. Because of higher velocity, and hence, higher shear heating in the thinner region of the original die, the temperature in the original die increased to a higher value of 495 K.



(a) (b)

Fig. 6 Temperature distributions in (a) original die, (b) new improved die