PlasticFlow with polyXtrue software **successstories**

Virtual Fine-Tuning of a Bi-layer Profile Die

Challenge

Deceuninck NV, one of the top three European manufacturers of PVC windows and doors wanted to reduce the development time for the profile dies used for extrusion of the window frames.

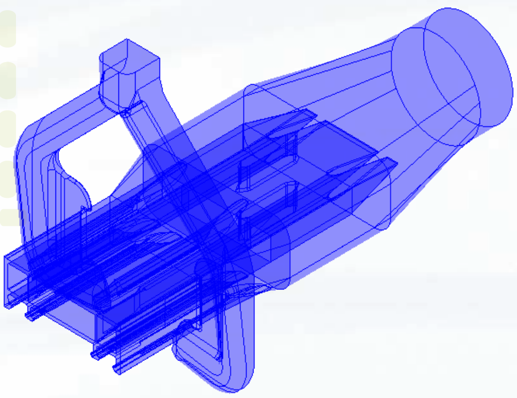

Fig. 1 Geometry of a bilayer profile die.

Deceuninck has been developing profile dies for extrusion of PVC window frames for decades (Fig. 1). With the initial design for each die developed based upon its past experience and the know-how it has developed over this period, the dies were then fine-tuned experimentally to obtain the required profile shape and thickness distribution. In each of these mechanical fine-tuning cycles, the flow channel in the die is modified by first plugging a portion of the channel by welding a piece of metal or by putting in an insert, and then re-machining the appropriate portion of the channel by wire EDM and by milling. This mechanical fine-tuning of a profile die is expensive and time consuming. At Deceuninck, each mechanical tuning of a profile die costs about €3,000 ($3,750) and takes 1.5 to 2 weeks of lead time. With 8 to 9 fine-tuning cycles required for a typical profile die at Deceuninck, the lead time for each profile die was about 3 months. The challenge was to cut down the lead time to less than 2 months.

Solution

After examining various software packages available for flow simulation in polymer extrusion dies, Deceuninck selected polyXtrue for virtual fine-tuning of its complex profile dies. User friendliness of its Graphical User Interface, ability to accurately predict the layer structure in coextruded products, and relatively small computation time required for a flow simulation prompted Deceuninck to select polyXtrue over other available options. An additional advantage of using polyXtrue was the availability of the pay-per-execution (PPX) version of the software, which allowed Deceuninck to validate the accuracy of predictions from polyXtrue with their experimental findings without investing upfront in the purchase of the software.

To simulate the flow in an extrusion die, polyXtrue requires the value of viscosity model parameters and thermal properties (thermal conductivity, density, and heat capacity). Deceuninck provided the viscosity data and the thermal properties of their PVC to Plastic Flow. The eXtruemat software was then used by Plastic Flow to fit the Cross-WLF model to the viscosity data (Fig. 2) and generate the material file required for a flow simulation using polyXtrue.

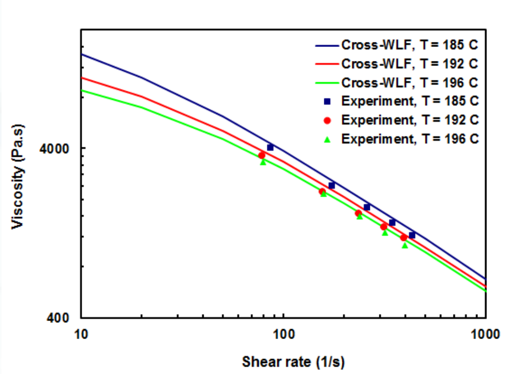

Fig. 2 Viscosity of PVC.

Deceuninck then used the polyXtrue PPX software to set up the flow problem with proper processing conditions and material properties. PolyXtrue PPX was employed by Deceuninck to virtually fine-tune nine monoextrusion and three coextrusion dies. These dies required an average of five virtual fine-tunings using polyXtrue before they were machined. Once the accuracy of the velocity, pressure, extrudate distortion and also the layer structure in coextruded products predicted by polyXtrue was validated by their experimental values, and the ability of the software for virtual fine-tuning the extrusion dies was confirmed, in March 2013, Deceuninck purchased a license of polyXtrue. Since then, all extrusion dies at Deceuninck are first fine-tuned virtually using polyXtrue before machining.

Results

- Before the polyXtrue software was purchased, Deceuninck required 8 to 9 mechanical fine-tunings in experiments to reach the final geometry of a coextrusion die and 6 to 7 mechanical fine-tunings for monoextrusion dies. With the virtual fine-tunings using polyXtrue, it now requires only 5 to 6 mechanical fine-tunings for coextrusion dies and 3 to 4 mechanical fine-tunings for monoextrusion dies.

- The reduction in the number of mechanical fine-tunings has cut down the lead time for extrusion dies at Deceuninck by 3 to 4 weeks; from about 3 months to about 2 months.

- The use of polyXtrue has resulted in savings of about €6,000 - €9,000 ($7,500 - $11,250) for each die design.

Virtual fine-tuning using polyXtrue reduced the lead time from three months to two months, resulting in savings of €6,000 - €9,000 ($7,500 - $11,250) for each die.

solutiondetails

In the bilayer coextrusion die shown in Fig. 1, the core polymer, which enters the die from the circular entrance on the right, is a recycled PVC, whereas a virgin PVC is used for the skin layer on the two sides. The skin layer is the only visible portion of the profile when installed on a window.

Velocity Distribution

Fig. 3a shows the velocity distributions in ten different cross-sections of the profile die predicted by the polyXtrue software. The velocity distribution at the die exit is also shown in Fig. 3b. The die for which the velocity distribution shown in Fig. 3a and Fig. 3b was obtained after four virtual fine-tunings using polyXtrue. The initial design of this die had much larger variation in the velocity distribution at the die exit (see Fig. 3c).

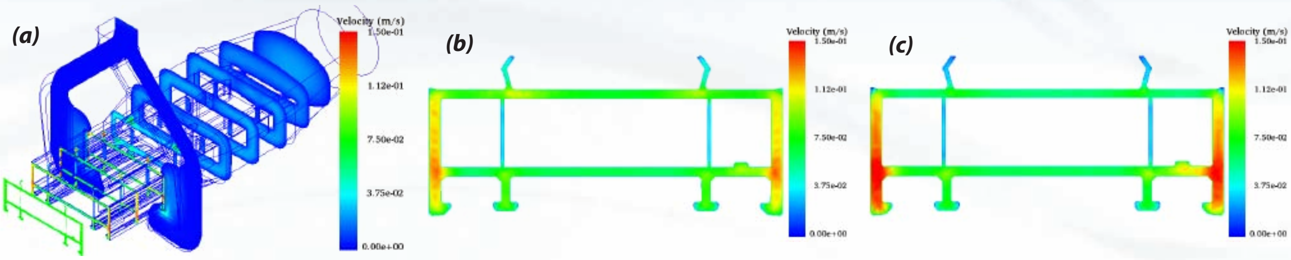

Fig. 3 Velocity distribution (a) in cross-sections of the final die, (b) at the exit of the final die, (c) at the exit of the initial die.

Layer Structure and Extrudate Distortion

The evolution of the interface shape between the core polymer and the skin layer, starting from the lines of first contact between the two layers, to the die exit and the extrudate beyond the exit including calibrator, is shown in Fig. 4. The external walls of this profile were in contact with the calibrator walls. Distortion of the internal walls of the profile, along with the layer structure predicted by polyXtrue, is shown in Fig. 5. The shape of the final profile, and the layer structure in the final product extruded in experiments, which is shown in Fig. 6, are in good agreement with the predictions shown in Fig. 5.

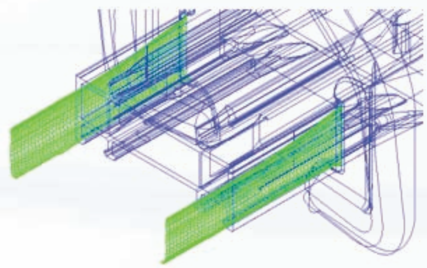

Fig. 4. Interface shape between the two layers.

Fig. 5. Predicted shape of the extrudate profile (red), layer structure (green), and shape of the profile at the die exit (blue).

Fig. 6. Shape of the profile and layer structure in experiments.

Stagnant Flow in Feedblock of the Skin Layer

In the feed block for the skin layer of this die, stagnant flow and corresponding polymer degradation, was observed in experiments (Fig. 7). Even though this stagnation was captured in the simulation (Fig. 8), unfortunately it was not noticed before the die was machined. The flow stagnation was later eliminated by putting in an insert and milling the feed channel again (Fig. 9).

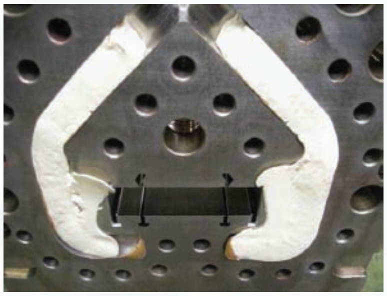

Fig. 7. Degraded polymer near the bottom of the feed channel for the skin layer.

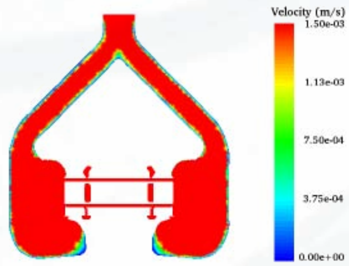

Fig. 8. Predicted velocity distribution showing the stagnant flow.

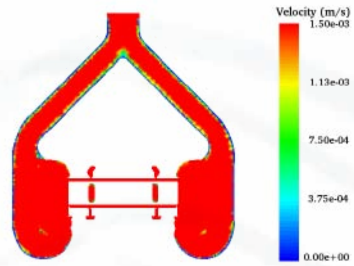

Fig. 9. Velocity distribution in the feed channel modified to eliminate stagnation.

Pressure Distribution

Predicted pressure distribution in the die is shown in Fig. 10. In the experiments, the pressure was recorded by the two transducers located near the entrances of the core (35.4 MPa) and skin (29.9 MPa) layers, which are in excellent agreement with the corresponding predicted pressures of 36.1 and 30.4 MPa, respectively.

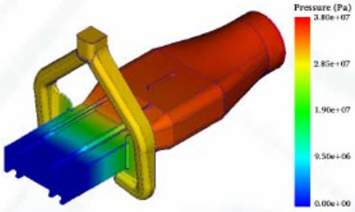

Fig. 10. Pressure distribution in the die.