Cutting Extrusion Die Design Costs

By reducing the number of trial-and-error prototypes, simulation can save hundreds of thousands of dollars annually in designing PVC extrusion dies.

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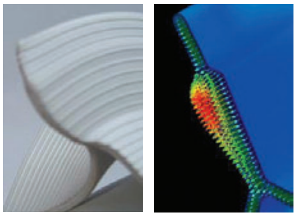
In the polymer processing industry, cost savings can be a crucial consideration, with the price of tooling often part of the deciding factor in winning contracts. A significant portion of this cost comes from fine tuning done in the succession of trial-and-error physical prototype iterations that are necessary to design profile dies that meet exacting customer requirements.

Gamma Point is an industrial consulting company that specializes in thermoplastic polymer process development — in particular, optimizing processes such as injection molding, extrusion, blow molding and thermoforming. The recent addition of ANSYS POLYFLOW software to its portfolio of engineering tools allows extrusion dies to be designed much more efficiently. The company works in close cooperation with Plastinov, a technology transfer organization affiliated with Université Paul Verlaine-Metz.

In one client-led project, the company used the software to design an extrusion die for making plastic parts for construction equipment. To reduce design time and costs, Gamma Point needed to optimize the die design using fewer iterations. In setting up the ANSYS POLYFLOW simulation, the engineers used an isothermal generalized Newtonian–Cross law approach because thermal regulation in the extrusion process was within acceptable limits, and limited viscous heating was exhibited at the specified flow rate.

Engineers also accounted for partial slip along the wall — the phenomenon during the extrusion process in which the flow rate slows at the extremities of the die profile as resin slips along the die wall face and encounters drag resistance. This difference in flow behavior between maximum velocity in the die center and lower velocities near the extrusion wall tends to produce deformed parts, usually with bulging in the middle of the plastic part due to more resin exiting the die in that region. The team checked a sample die for these thermal and slip effects, and the numerical model correlated well with the bulging deformation seen in experimental extruded parts.

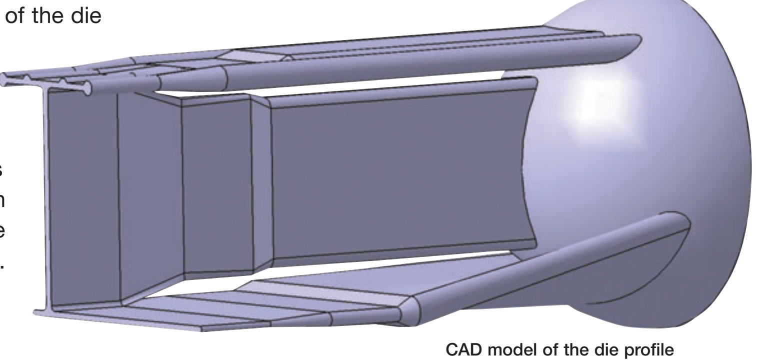


Validation of the simulation model (right) with an extruded part (left) shows good correlation. Note the bulge in the high-velocity region predicted by simulation.

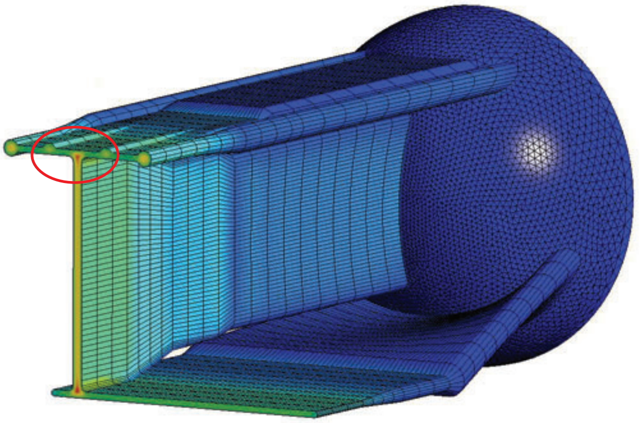
The next step was to evaluate the original CAD model of the extrusion die developed by the client. The extruded part to be made from this die is a combination of three sections: a vertical structure with T-junctions joining upper and lower horizontal arms, each fed by separate upstream cavities to better balance the flow across the critical regions of the outlet section.

Engineers evaluated the CAD model geometry using ANSYS POLYFLOW software to calculate simulated flow velocities across the entire die profile and extrusion path. Color-coded displays showing velocities and flow paths through adaptive sections feeding resin to the various regions of the profile provided considerable insight into flow characteristics from the extruder throughout the length of the die. Indeed, one of the significant advantages of the simulation software is that it enables engineers to easily visualize resin behavior inside the entire envelope of the die.

Simulation results indicated significant flow differences throughout the die velocity distribution, in which the maximum outlet velocity



CAD model of the die profile



Simulation calculated outlet velocities for resin exiting the die. The highest velocity is shown in the circled area of the upper T-junction.

Staggering Benefits

Plastics extrusion companies have reported savings of up to $20,000 per new product using ANSYS POLYFLOW software for die development. A significant portion of these savings was achieved by reducing engineering design time as well as die fabrication expenses and extrusion line costs, which typically range from $250 to $500 per hour.

One company using simulation for die design experienced a 200 percent ROI the first year and higher for succeeding years. Dies were designed and adjusted in two days instead of two weeks. Savings in avoiding lost production and increasing efficiency was estimated at $5,000 per day, leading to a complete payback after the first product.

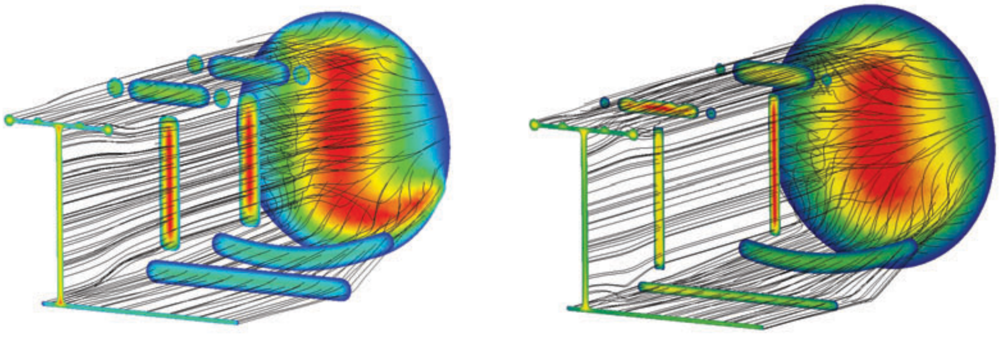
reaches 293 mm/s at the T-junction between the two upper sections of the profile, while the smallest local velocity at the core of flowing PVC is only 144 mm/s. A factor of two between the smallest and largest velocities is unacceptable, as this difference would invariably lead to large part deformations during the extrusion process — with the ultimate result rejected parts.

To achieve a more uniform velocity distribution, engineers modified key dimensions of the die — most important was the adaptive flow sections feeding resin to the various regions of the profile. This process requires considerable experience with die design and involves incrementally increasing or decreasing the thicknesses of the adaptive flow sections to selectively speed up or slow down resin velocity. Engineers made successively small dimensional changes, checked the resulting velocity and then performed more iterations until velocity differences were negligible.

Traditionally, such dimensional changes would be performed through a trial-and-error process in which the design would be changed and a new die cut and tested by running a sample extrusion. From a conservative perspective, reaching an optimal velocity distribution would require up to eight trial-and-error iterations costing about $6,000 per die and taking a week total.

Using ANSYS POLYFLOW, an optimal flow velocity was reached in only four iterations — half the number needed with traditional trial-and-error prototypes. About one hour was required to modify the mesh, while computational time did not exceed 30 minutes on a standard PC. The cost of a single simulation iteration was estimated at $1,100, for a total cost benefit of almost $5,000 per die. Savings come from decreased waste and scrap, reduced energy needs, and less downtime for labor and tooling during unproductive trial-and-error testing when no actual parts are being manufactured. As a result, the cost of the software license was covered after designing a second die. For a typical mid-sized shop producing less than 50 dies a year, annual savings could potentially exceed a quarter-million dollars — an outstanding return on investment (ROI).

Engineering simulation can provide crucial help to manufacturing centers that must resolve critical issues related to business survival, including cost and time savings in developing extrusion dies. Clearly, companies leveraging this technology have an obvious advantage in markets in which competition is fierce and contracts usually hinge on which company can come up with quality products at the lowest price. ■



Simulation shows color-coded resin velocities and flow paths inside the length of the extrusion die, with uneven flow for the original die (left) and more balanced velocity distribution for the optimized design (right).