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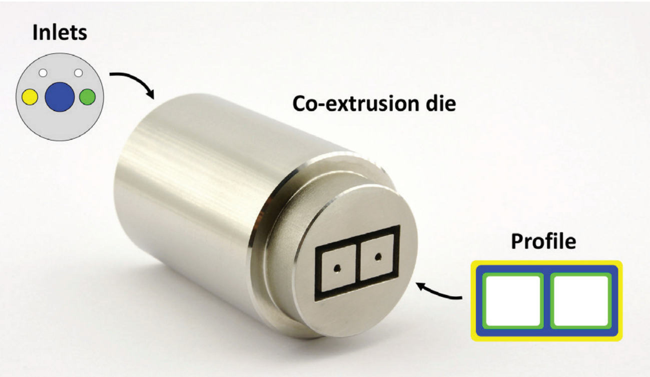
Digital design and additive manufacturing of co-extrusion dies

Simulation-driven and automated design as an enabler for novel applications in process engineering

An additivETH success story by Ralph Rosenbauer

New approaches for parts with complex internal structures
One of the main advantages of additive manufacturing (AM) lies in the ability to produce parts with complex geometries that can not be realized using conventional techniques, or only at high costs. This is especially the case for flow components with internal fluid channels and manifolds that branch multiple times and are nested within each other. A typical field of application for such designs are co-extrusion dies, which are used, for example, in the extrusion of profiles consisting of different materials.



Metal additive manufacturing allows producing very compact and functionally integrated co-extrusion dies for polymer profiles (Source: pd|z).

Advantages of co-extrusion and use cases
The use of co-extrusion allows the realization of multi-layer profiles with enhanced properties: For example, chemically resistant layers can be applied to the inside or outside of hollow profiles. Similarly, the mechanical stability of extruded shapes can be improved by integrating cores as a reinforcement, or incompatible materials can be joined using separating layers. Furthermore, multi-layer profiles also open up exciting opportunities for sustainable manufacturing, which is becoming increasingly important: Until now, the use of recycled plastic has in many cases been hindered either by the slightly lower quality or lack of bright colors. The use of co-extrusion processes allows such recycled material to be extruded and covered with not-recycled plastic, thus significantly increasing market acceptance.

Interdisciplinary cooperation as a key for success
Therefore, co-extrusion of plastics offers a lot of potential for the realization of both innovative and sustainable products. Two key competencies are required to exploit this potential: Firstly, knowledge of the design and production techniques for dies, and secondly, a detailed understanding of the flow conditions of the polymer melts within the die. To tackle these challenges, two research groups from Swiss universities teamed up: The Product Development Group (pd|z) of the ETH Zurich and the Institute of Materials Engineering and Plastics Processing (IWK) of the Eastern Switzerland University of Applied Sciences (OST). This allowed to combine the knowledge of automated design and AM

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3D-Printing (also known as Additive Manufacturing or short AM) is considered a disruptive technology that affects manufacturing, products, and value chains.
Researchers of ETH drive these transformations by developing innovative materials, processes and use cases for AM.
With the initiative «additivETH success stories», the Competence Center for Materials and Processes features research projects highlighting the potential but also upcoming challenges of AM implementation.

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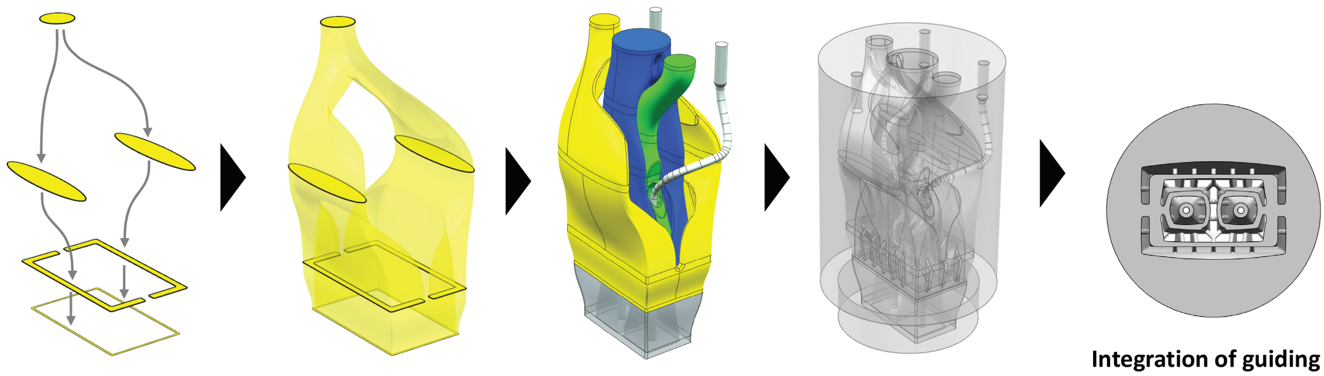

The use of tools for the automated design of manifold reduces the effort for designing complex-shape co-extrusion dies (Source: pd|z).

from pd|z with the simulation-based design of extrusion dies and experimental know-how from IWK.

Design automation for AM

One of the main advantages of AM processes over conventional machining techniques is the high degree of design freedom, which allows producing complex-shaped components. At the same time, however, the creation of complex freeform geometries in CAD using basic geometry operations is very time-consuming for designers. This leads to a high demand for expert solutions, that support designers in the design of complex parts and automate recurring and time-tedious standard tasks.

Toolbox for automated design

To reduce the effort for the design of complex-shaped dies, pd|z developed a design toolbox, which includes predefined functional elements and building blocks such as flow channels with different AM-optimized cross-sections, flow distributors, and guiding vanes. By providing access to these elements, the time required for component design can be reduced significantly, since the elements do not have to be completely designed from the scratch, but only tailored to the specific requirements of a die. In addition, the fully parametric design of the features significantly facilitates and accelerates subsequent design iterations.

Design for AM

To produce the coextrusion dies, laser-based powder-bed fusion of stainless steel was used within this case study. Although this method offers in general a very high degree of freedom of design, it also has certain material and process related limitations, as almost all processes in the field of AM. These include limitations such as minimum wall thicknesses but also as restrictions of the overhang angles, which often require an adaptation of channel geometries. To support the designer concerning these restrictions, the toolbox provides a manufacturability analysis of the die geometry.

Optimizing material flow

The optimization of the material flow within the extrusion die is important to distribute the polymer melt uniformly to the die outlet under a minimized pressure loss. This is where the expertise of IWK comes into play: Due to the many years of experience in the extrusion of plastics, the material behavior in the die could be predicted very precisely by means of Computational Fluid Dynamics (CFD) simulations. This was done in a two-stage process: In a first step, the conditions at the individual nodes of the dies were simulated and subsequently optimized. Based on the design with pre-optimized distributors, the material flow in the entire die and especially at the discharge point was simulated in a second process step in order to optimize the merging of the individual flow distributors. The simulation results served as a basis to make iterative changes to the die geometry using the parametric building blocks. The use of this digital design process chain allowed to significantly reduce the time needed to develop and optimize the die.

Encouraging test results

After fabrication of the die and post-processing (e.g. milling of functional surfaces), experimental tests were carried out at the facilities of IWK. The results of the first tests provide extremely convincing proof of the success: Already the first iteration of dies produced results that perfectly match the results of the simulations. This impressively demonstrates the great potential of the integrated process chain that was developed by the two research groups as an interdisciplinary collaboration. Future works aim to further explore the benefits of AM as a tool for novel applications in process engineering.

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Reference

M. Biedermann, S. Walker, D. Schwendemann, M. Meboldt, Rethinking Co-Extrusion: Additive Manufacturing and Simulation-Based Design as a Duo for Extrusion Dies, Kunststoffe International 2021 (01) p. 26-29.