# Understanding and Controlling Primary Shaping Manufacturing Processes

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## ABSTRACT

Using a mold or die, primary shaping manufacturing processes form material from an initially unshaped state (usually melt) into a desired shape. All of these processes have in common that the exact design of the mold cannot be determined directly and intuitively from the product shape. This is due to the non-linear behavior of the material regarding the flow and solidification processes. Consequently, shape optimization as a means of numerical design can be a useful tool in mold development.

The core of our optimization tool [1] is the in-house flow solver XNS, which combines a space-time method with either polynomial or isogeometric shape functions with a GLS stabilization. XNS is able to exploit the common communication interfaces for distributed-memory systems. The flow solver has been coupled with the open-source optimization frameworks NLOPT and Dakota. For geometry representation, no matter the function representation, we utilize an in-house spline library which supports both NURBS and T-splines. Spline representations are very natural in engineering design, as they allow the shape optimization result to be easily transferred back into the CAD -based design process. Furthermore, they require a low number of optimization parameters and allow the incorporation of manufacturing constraints. Obviously, isogeometric analysis aligns well with this type of shape optimization.

Topics discussed will be our approach to shape optimization as well as methods for simulating the flow through, in and behind the mold/die. Furthermore, advances in the topics of solidification and free-surface flows with boundary-conforming isogeometric methods will be shown [2].

## REFERENCES

[1] S. Elgeti, M. Probst, C. Windeck, M. Behr, W. Michaeli, and Ch. Hopmann, “Numerical shape optimization as an approach to extrusion die design”, *Finite Elements in Analysis and Design*, Vol. **48**, pp. 35-43 (2012).

[2] F. Zwicke, S. Eusterholz, S. Elgeti, “Boundary-Conforming Free-Surface Flow Computations: Interface Tracking for Linear, Higher-Order and Isogeometric Finite Elements”, *Computer Methods in Applied Mechanics and Engineering*, Vol. **326C**, pp. 175-192 (2017).