Cluster of Excellence

Integrative Production Technology for High-Wage Countries

Automated Optimisation of Profile Extrusion Dies
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Introduction

Profile extrusion is an established process for the mass production of plastics profiles. However, the development and manufacturing of the profile die is combined with high efforts and costs. These are mainly caused by elaborate running-in trials before the start of production. Because of this, a cost-effective use of profile extrusion in small series is not possible yet. Nevertheless, the customer demands are increasingly individualised, and product life cycles continue getting shorter resulting in smaller lot sizes. Numerical flow simulations have the potential to provide substantial time and cost savings in the design of profile dies. However, the currently available simulation tools lack the ability to automatically improve the flow channel geometry based on calculation results. Therefore, an optimisation framework for the design of profile extrusion dies is being developed in the demonstrator for the automated optimisation of profile extrusion dies. The framework combines the flow simulation with an optimisation algorithm. This combination enables an automated optimisation of the flow channel geometry in profile extrusion dies.
Practical Issues

Due to the almost unlimited complexity of possible profile cross-sections, an analytically exact design of the profile extrusion die is usually not possible. Instead, the design and manufacturing often take place in form of a “trial and error” process. Starting from a first draft, the die designer changes the flow channel geometry iteratively based on empirical knowledge and insights from the running-in trials. This happens via deposition or removal of material until the produced profile satisfies the previously defined quality criteria. Depending on the complexity of the geometries this can take up to 15 iterations. This type of production is very time-consuming and costly, the extruder is not available during the running-in trials for the regular production and considerable costs occur for the experimental materials. A shortening of the design process is offered by flow simulations with the stabilised FEM (Finite-Element-Method) which transfers the iterative design process from the machine to the computer. Through the numerical analysis of the flow processes, the running-in process is simplified as vulnerabilities can be detected even before the manufacturing of the die. However, in this case the experience and the knowledge of the die maker are still necessary to decide how the geometry has to be changed, in order to achieve the design goals. Therefore, the design process is still dominated by its iterative, time-intensive nature.
**Approach**

The fundamental approach to finding a solution to the problem is to imitate the real process of continuous improvement of the die. The realisation of this process is the usage of optimisation algorithms, which minimise a so-called objective function. The objective function mainly reflects the quality of the die. In order to simulate the real process, it is necessary to model the reality within certain limits. Here we use several methods that replicate all the relevant properties and the behaviour of the real process, but are still calculable by high performance computers or ideally ordinary computers within acceptable times. It is crucial for this optimisation application, to get to the target in as few steps as possible.

The background is, that one tries to simulate as few geometries as possible, because each simulation is time consuming and computationally intensive and, in the end, again costly. In this respect, this demonstrator goes beyond the numerical and experimental components and integrates “best practices” of the industry and the manufacturing process. Another future step is the use of SLM (Selective Laser Melting) produced components and modules within the dies, so that previously not only manufacturable but also rapidly deployable modules could be used.

**Technical Challenges**

Due to the non-intuitive behaviour of the plastics, the representation of reality is one of the biggest technical challenges. The core property which complicates the behaviour of the plastics to such a degree is called “viscoelasticity”. Viscoelasticity is defined as the superposition
of elastic and viscous flow behaviour; its mathematically
description is very complicated. This additional complexity
also flows into the simulation. Furthermore, the definition
of the objective function has a decisive influence on the
optimisation process. Both the choice of the measured
quantity and the actual mathematical formulation play an
important role. Ultimately, the goal is to achieve the ma-
ximum efficiency in the implementation of the parametric
design and optimisation algorithms and hereby realise a
minimum number of numerical iterations. It is necessary
and also especially challenging to involve institutions into
a close work process to validate theoretical simulations
in practical experiments and vice versa, to influence the
models.
Technical Equipment

**Experiments:**

- **Hardware:**
  - Brabender laboratory extruder 19/10 DW
  - D = 19 mm
  - L = 25 D
  - Throughput 0.8 to 4 kg/h

**Simulation:**

- **Hardware:**
  - Bull Cluster, IT Center RWTH
    - 27880 Cores, Intel Westmere/Nehalem
    - 94192 GB Ram
  - 3D Visualisation (Powerwall)

- **Software:**
  - XNS
  - Paraview

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