Technical University of Denmark

DTU

Popular science summary of the PhD thesis

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Title of the PhD thesis	Integration of soft tooling by additive manufacturing and multiphysics simulation in polymer profile extrusion process chain
PhD school/Department	DTU Construct

Science summary

* Please give a short popular summary in Danish or English (approximately half a page) suited for the publication of the title, main content, results and innovations of the PhD thesis also including prospective utilizations hereof. The summary should be written for the general public interested in science and technology:

The die design process in polymer extrusion has traditionally relied on a trial-and-error approach, resulting in significant costs in tooling development. Additive manufacturing (AM) offers considerable flexibility and design freedom, allowing the production of optimized extrusion dies with complex and free-form geometry. Furthermore, polymer-based AM has advanced in the printing of durable polymers and composite materials, leading to the opportunity for the application of soft tooling through AM in the polymer extrusion process chain. Simulation has the potential to revolutionize die design by offering optimized solutions and reducing the need for test iterations when making design changes. Therefore, this Ph.D. project aims to explore the integration of soft tooling by AM and multiphysics simulation in the polymer extrusion process chain to facilitate the production of small batches and highly customized products.

The state-of-the-art in polymer extrusion highlights the importance of extrusion dies and calibration slides to influence the dimension and surface quality of extrudates as the final products of polymer extrusion. Fused Filament Fabrication (FFF) and Masked Stereolithography (MSLA) were the AM processes selected to manufacture the extrusion dies and calibration slides. Furthermore, a single-piece streamlined die design with free-form geometry was implemented for three die profiles. Extrusion pilot production with soft tooling by AM was performed, indicating that the AM carbon fiber- polyether ether ketone (CF-PEEK) die withstood the demanding process conditions of polymer extrusion. Additionally, dimensional evaluation and surface characterization were performed to identify the repeatability and precision of AM parts and the effect of the AM extrusion die and AM calibration slides on the extrudates.

Simulation enables the prediction of melt flow rate and pressure drop, which is critical in the die design process. Flow simulation for polymer extrusion was established using non-isothermal flow conditions and incorporating extruded material properties and boundary conditions derived from actual rheology and extrusion tests. The simulation was then experimentally validated with polypropylene (PP) and acrylonitrile butadiene styrene (ABS) extruded materials. Streamlined die design with free-form transition geometry has a lower pressure drop, which is beneficial for the lifetime of soft tooling. Finally, fluid-structure interaction (FSI) simulation was developed to evaluate the wear of soft tooling in polymer extrusion and address the main challenge of integrating soft tooling in the polymer profile extrusion process chain.

Please email the summary to the PhD secretary at the department