Design and Manufacture of Molded Micro Products Using Concurrent Engineering - DTU Orbit (06/10/2019)

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The matter of this thesis is the design and manufacture of micro parts made by micro and powder injection molding. Multiple aspects of the design process towards the final micro component were investigated with the aim of establishing the optimal micro part and mold design in a holistic design approach. The focus was on simulation-aided design for manufacture and assembly.

First, the state-of-the-art of injection molding technology and of process simulations in the area of micro injection molding is presented in the theoretical part of this thesis as foundation for the following issues. Furthermore, the mathematical background of injection molding simulations is outlined.

In correspondence to the holistic design procedure, the experimental part of the thesis commences with the discussion of the conducted comprehensive material characterization of several feedstocks. The characterization contained mainly the thermal and rheological material properties and led to a model enabling process simulations of powder injection molding.

Subsequently, the process simulations of polymer micro injection molding were evaluated regarding the comprehensiveness of the model and the experimental validation. The simulation-assisted approach was applied in the design for manufacture and assembly of a microfluidic plastic part and its feed system in the early product development phase and in absence of the mold. In two design iterations based on the design of experiment approach, the most suitable material and gate concept were selected, and the part quality was successfully optimized, so that the part complied with the requirement of a maximum flatness of 10 µm by implementing a 900 µm wide pin gate.

Process simulations were also utilized for the design optimization of the actual component and the mold of a second microfluidic device. The concurrent investigations covered the whole development from the first concept to the manufactured mold. Hence, the material selection and testing, the iterative simulation-aided optimization of the gating conception, and the implementation of the mold are presented. The examination on the gate design resulted in the realization of a film gate with 560 µm thickness minimizing the risk of degradation due to excessive shear and the best packing performance. The molded parts of the two aforementioned micro components were moreover employed in additional simulation validations.

Similar to the polymer injection molding, the powder injection molding in this thesis starts with the simulation validation. The established material models of the characterized feedstocks were used for a comparison between simulations and experiments to assess the applicability of simulations in powder molding. In an additional short shot study, the impact of the melt cushion on the flow length and injection pressure could be revealed.

Afterwards, the focus was on the design optimization of the mold and cooling of a ceramic micro-mechanical component. The comprehensive analysis elaborated on different facets of the simulation model and their influence on the simulation outcome regarding part quality. The process simulations were proven as valuable tool for the part, mold, and cooling optimization.

Keywords: design for manufacture and assembly, micro injection molding, powder injection molding, process simulation.