Multiphysics Simulation of the Material State in Single Screw Extruder

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Abstract

To receive a stable quality in the injection molding process in the view of mechanically and thermally highly stressed components made by reactive resin systems, it is necessary to understand the material state along the processing chain. Up to date no measuring technology is available for an online-monitoring of the material state over the cross-section along the screw extruder. It leads to that a reliable simulation technology is necessary. The goal of this study is to simulate the material state as precise as possible, for example the prediction of the distribution of temperature, density, viscosity and pressure over the complete cross-section by using the software COMSOL Multiphysics®. In the current work the plastification unit of the injection molding machine should be modeled, in which the material is transformed from the solid state to the liquid state followed by the homogenization.

Due to the extremely high complexity of the plastificattion unit in the injection molding machine, at the beginning of the modelling two simplifications are used. At first and instead of the complex plastification unit, a single-screw extruder with a similar geometry is applied. Additionally and in respect of the flow behavior, a comparable material to the reactive resin, is simulated. The chosen material is the TPE with different contents of the zinc oxide, so that different material flow behaviors will be achieved. The numerical results from the aforementioned model will be compared with those from experiments. The models are evaluated through the comparison of results from experiments and simulation.

The material is carried forward by the driving power of the extruder screw in the cylinder and heated. The heating is caused by heating elements in the cylinder wall, friction between the surfaces of the extruder and the material as well as internal friction of the material itself. Because of the heating the material starts with a phase transition from the solid state to the liquid state. Therefor different states of the material (distribution of temperature, density, pressure and viscosity) are indicated along the extruder screw. The physical mechanisms considered in this simulation are the energy transformation, the heat transfer, the mass transfer and the phase transition.

In order to simulate the described mechanisms the COMSOL Multiphysics® module „rotating machinery with non-isothermal flow" is used where the flow is adapted as a laminar and non-stationary. A linear fitted model, depending on the temperature and the material composition, is applied to calculate the viscosity. Considering the material properties of the used TPE-material, p-V-T-diagram is implemented for the calculation.

As results, the increment of the temperature and the mass flow at the end of the extrusion process are calculated and compared with experiments, which as material properties can

be measured directly. The advantages of the simulation are getting properties, like the distribution of the temperature, the density, the pressure and the viscosity over the material cross section, which cannot be measured or not accurate enough. The numerical and experimental results achieved in the single-screw extruder show a good correspondence.

Figures used in the abstract

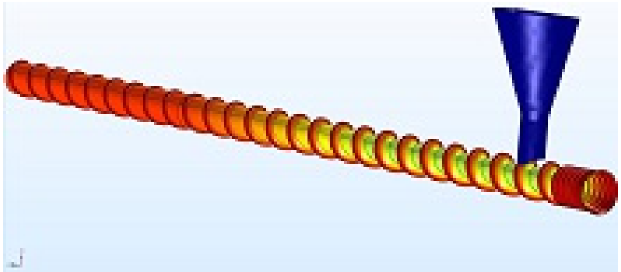

Figure 1: Temperature distribution in a three-zone screw.