Optimization of Extrusion Processes for Non-Newtonian High-Viscous Fluids with Wall Slip and Shear Thinning Effects

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Abstract

Simulation of the flow behaviour of non-Newtonian fluids with high viscosities, for example elastomers, rubbers, pvc, plastics, carbon fibres, aluminium, technical ceramics etc., leads to special material models with specific material parameters. Such parameters are the yield stress and the viscosity-function, describing the flow within a fluid. Another important physical effect is the wall gliding effect causing wall slip.

In this presentation, a material model consisting of 4 material parameters describing the flow itself and also the wall slip is presented. Based on the 4 material parameters yield stress τf, viscosity function η, wall slip stress τG and k-factor it is possible to simulate the flow of non-Newtonian materials including all relevant effects.

The investigations of the flow behaviour are based on COMSOL Multiphysics® using the Modules CFD, Structural Mechanics and the Fluid-Structure-Interacton Interface and are set up as a multiphysics simulations. It is shown, how the flow of a technical ceramics in a complex extrusion line with forming dies is modelled with COMSOL Multiphysics®.

For correct modelling of the flow for the most non-Newtonian fluids it is essential to define a material model including the flow behaviour within the fluid and the flow behaviour close to the wall in forming devices or extrusion lines. The wall slip effect will have a crucial effect on the flow and neglecting it yields to wrong or not reliable simulation results.

If deformation exceeds the yield stress, the flow behaves non-linear and leads to a visco-plastic deformation. The viscosity function is characterising the flow behaviour as a function of deformation rate tensor and results in many cases in a shear-thinning effect. The parameter wall slip stress is similar to the yield stress and is a measure when deformation occurs close to the walls. The k-factor is a combination of the description of the roughness of the walls and the viscosity function. It is important to emphasize that the viscosity function close to the wall is different from the viscosity function within the flow.

The corresponding material parameters are measured in our laboratory and provide the basis for the simulation.

In a two-way coupled FSI it is shown how the non-Newtonian material interacts with the device and is influenced by special geometric parts. Furthermore the mechanical stress on a strainer is presented.

Also, based on comparison of measured and simulated data, the reliability of the simulation is proved. Further it is demonstrated that the optimization of the shape of the forming die yields to a better production cycle improving quality and reducing costs and time.