Analysis and Optimal Control of Melt Spinning Processes

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Abstract

The melt spinning process for artificial fibers has been studied by many research groups throughout the world during the last four decades. However, all these works considered the forward problem of simulating the process for a given set of parameters. In this study we focus on the problems of parameter estimation and optimization.

The phase-portrait of the melt spinning process is studied using simple mathematical models. Newtonian, power-law, Maxwell-Oldroyd and non-Newtonian models are considered. It is found that for the Maxwell-Oldroyd model, we can not set any arbitrary value for the final take-up velocity.

An optimal control problem for a mathematical model of a melt spinning process is considered. Newtonian, non-Newtonian, Maxwell-Oldroyd and crystallinity models are used to describe the rheology of the polymer, the fiber is made of. The extrusion velocity of the polymer at the spinneret as well as the velocity and temperature of the quench air and fiber length serve as control variables depending on the rheology of the polymer. A constrained optimization problem is derived and the first–order optimality system is set up to obtain the adjoint equations. Numerical solutions are carried out using a steepest descent algorithm.

The stability of the melt spinning process with respect to parameters is investigated using the method of linear stability analysis. Newtonian and non-Newtonian models are considered. The velocity and temperature of the quench air are considered as parameters. It is found that the non-Newtonian model with the increasing air velocity and air temperature, the critical draw ratio increases, i.e. stability improved.