How to make fibers, films and filaments – a mathematical perspective

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The manufacture of long, thin polymeric fibers and films is a key objective of the chemical industry. For polymers with thermally stable melts melt-spinning (non-isothermal fiber spinning) is a particularly effective production technique, which is characterized by a complicated interaction of thermomechanical forces. In this process fibers (or films) are formed by extruding the molten polymer from a pressurized reservoir, stretching and cooling the material, and winding the solidified filament (film) on a take-up device. Whilst non-isothermal fiber spinning is remarkably stable, the related isothermal regime exhibits detrimental flow instabilities.

In this lecture we will give a mathematical description of fiber spinning and compare the isothermal and non-isothermal flow regimes. In particular, we will address the following issues:

1. We introduce an appropriate version of the 1D Matovich-Pearson thin filament equations of viscous liquids. This model will account for the physical chemistry and temperature dependence of the fiber surface.

2. We study the validity of the monotonicity hypothesis (i.e. the spatial monotonicity of the fiber average temperature) which allows a fixed domain representation of the non-isothermal flow equations.

3. We discuss the linear stability of equilibrium solutions by means of semigroup theory. An asymptotic description of the spectrum of the semigroup generator will be given.

If time permits, some recent results on the linear stability of the related non-isothermal thin film equations will be presented.

References