Numerical modelling of the effect of operating parameters in the plastic blown film process

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The process of film blowing, the industrial process by which thin polymer film is manufactured, is of great commercial and theoretical interest: commercial, because of the scale of the plastics industry, and theoretical, because of the scientific complexity of the process itself. Typically, this involves viscoelastic polymers such as low density polyethylene and polypropylene. While there are a number of descriptors of the ongoing process, two are of particular interest, the bubble geometry and bubble temperature profile. Also of interest are the effects of such processing parameters as mass flow, extruder temperature, tensile axial force, and take-up velocity on these quantities.

The modelling process involves four highly non-linear ordinary differential equations, with the viscoelasticity of the film material contributing to the non-linearity. In addition, the boundary conditions at the die exit and the freeze-line height contribute to the complexity of the problem, and can give rise to instabilities in any numerical studies. In this investigation, the well-established method adopted by Luo and Tanner is employed, by which integration of the governing differential equations starts at the freezing line, with assumed film temperature, film thickness and bubble radius at that point and proceeds backwards towards the die-exit, furnishing equations for the film conditions there. Discrepancies between these values and the required conditions there are minimized using the Nelder-Mead optimization method. The outputs of this optimization procedure gives two parameters that involving pressure drop in the bubble and the axial tensile force.

Unlike Luo and Tanner who used the Maxwell constitutive equation, this study considers the viscoelastic Kelvin model, thus avoiding any assumption regarding the stress profile at the die exit. Rheological data obtained from literature sources have been fitted to the Kelvin constitutive equations, and the numerical analysis described above is carried out using the package Matlab. The stability of the solutions and the sensitivity of the outputs to critical operating parameters such as cooling are discussed.