Numerical analysis of the fountain flow instability

T.M. Smit*†, M.A. Hulsen† and P.D. Anderson†

* Dutch Polymer Institute (DPI)
P.O. Box 902, 5600 AX Eindhoven, the Netherlands
e-mail: t.m.smit@tue.nl

† Polymer Technology Group
Faculty of Mechanical Engineering, Eindhoven University of Technology
De Rondom 70, 5612AP, Eindhoven, the Netherlands

ABSTRACT

Instabilities in polymer processing limit production rates and may influence the aesthetic or mechanical properties of the final product. One example is the fountain flow instability, which takes place during the mold filling stage of an injection molding process. It has been shown experimentally that these instabilities manifest themselves in the form of a periodic oscillation of the flow front stagnation point between the two walls of the mold channels. The onset is determined by a critical Weissenberg number, the ratio of material response time scales to flow time scales. Different values have been predicted in previous work[1][2].

We use the finite element method and a number of stabilization techniques for flows of convective and viscoelastic nature (DEVSS-G/SUPG[3], LCR[4]) to do a full non-linear, transient simulation of a branched polymer melt propagating through a mold channel. We investigate the onset and behavior of the fountain flow instability with special focus on describing the contact point where the polymer is deposited on the mold wall. High stress and velocity gradients require special local treatment of the sharp interface method used to describe the free surface deformation[5].

A perturbation is applied to the steady state flow field after which we analyze the behavior of the system. For low Weissenberg numbers, we observe that the perturbation vanishes, indicating a stable system. For high Weissenberg numbers we observe oscillating behavior as the perturbation grows, as observed in experiments [6].

This research forms part of the research programme of the Dutch Polymer Institute, project 788

REFERENCES

[1] A. C. B. Bogaerds, M. A. Hulsen, G. W. M. Peters, and F. P. T. Baaijens, "Stability analysis of injection molding flows," *Journal of Rheology*, vol. 48, p. 765, 2004.

[2] M. G. H. M. Baltussen, M. A. Hulsen, and G. W. M. Peters, "Numerical simulation of the fountain flow instability in injection molding," *Journal of Non-Newtonian Fluid Mechanics*, vol. 165, no. 11-12, pp. 631–640, 2010.

[3] F. P. T. Baaijens, "Mixed finite element methods for viscoelastic flow analysis: a review," *Journal of Non-Newtonian Fluid Mechanics*, vol. 79, no. 2, pp. 361–385, 1998.

[4] M. A. Hulsen, R. Fattal, and R. Kupferman, "Flow of viscoelastic fluids past a cylinder at high Weissenberg number: Stabilized simulations using matrix logarithms," *Journal of Non-Newtonian Fluid Mechanics*, vol. 127, no. 1, pp. 27–39, 2005.

[5] C. van der Walt, M. A. Hulsen, A. C. B. Bogaerds, and P. D. Anderson, "Transient modeling of fiber spinning with filament pull-out," *Journal of Non-Newtonian Fluid Mechanics*, vol. 208, pp. 72–87, 2014.

[6] M. Bulters and A. Schepens, "flow mark surface defects on injection moulded products: 1 proposed mechanism," in *Proceedings of the Annual Meeting of the American Institute of Chemical Engineers*, 2000.