# Stability of viscoelastic flows : flow mark surface defects in injection molding of polymer melts

*Citation for published version (APA):*
Bogaerds, A. C. B., Grillet, A. M., Peters, G. W. M., & Baaijens, F. P. T. (2001). *Stability of viscoelastic flows : flow mark surface defects in injection molding of polymer melts*. Poster session presented at Mate Poster Award 2001 : 6th Annual Poster Contest.

*Document status and date:*
Published: 01/01/2001

*Document Version:*
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

*Please check the document version of this publication:*

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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Download date: 04. Oct. 2023

# Stability of Viscoelastic Flows:

## Flow Mark Surface Defects in Injection Molding of Polymer Melts

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## Introduction

Unstable flows in polymer processing can result in severe limitations on production rates and final product properties. For instance, flow instabilities during injection molding can result in surface defects on polymer parts often referred to as flow marks (figure 1) [1].

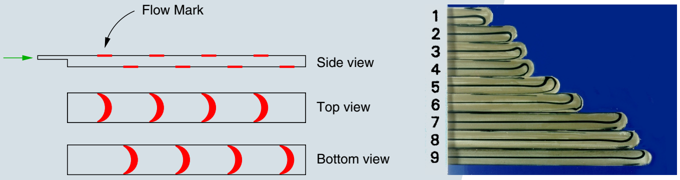

**Figure 1:** *Flow marks in a model injection molding flow. Experiments by M. Bulters and A. Schepens [1].*

In an attempt to understand these complex flow phenomena, we have our goals set at:

- Determining the onset of instability
- Isolating rheology dependence

## Problem Definition

To analyze these polymer flows, we need to carefully address two important questions:

1. What numerical tools can be applied?
2. Which rheological model can describe the relevant physics of the polymer melt?

### Numerical Tools

In general, a flow is called stable or unstable depending on whether small perturbations imposed on the steady solution decay or grow in time. Thus, the growth rate of a randomly imposed disturbance can be obtained from direct time integration of the governing equations using a finite element technique. Additionally, for simple flows the 1-dimensional generalized eigenvalue problem can be solved for a spectrum of disturbance wavelengths (figure 2).

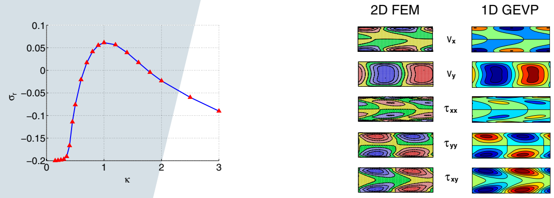

**Figure 2:** *Poiseuille flow of a PTT fluid, maximum growth of a perturbation with spatial wavenumber* $\kappa \approx 1$ *and We=5.0.*

### Constitutive Models

We consider the widely used exponential Phan-Thien Tanner (PTT) model and the recently proposed eXtended (XPP) Pom-Pom model [3] which is an extension of the original Pom-Pom model as it was introduced by [2].

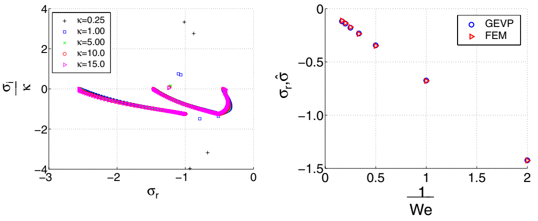

**Figure 3:** *Spectrum (left) and growth rates (right) of Poiseuille flows of an XPP fluid.*

## Flow Stability

Before moving on to complex flows, we first study the dynamics of planar Poiseuille flows. Figure 2 and figure 3 show the temporal behavior of the PTT and the XPP model for this simple flow. The instability observed with the PTT equations makes this model not suited for stability analyses.

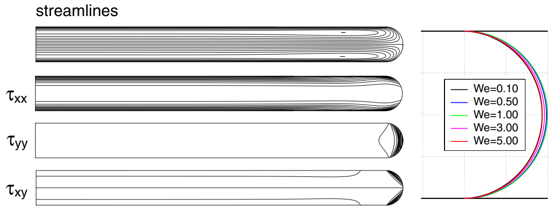

**Figure 4:** *Steady state solution for XPP fluid for We=5.0 and shape of the free surface.*

Figure 4 shows the steady state solution for the dimensionless Weissenberg number We=5.0 which is still computed to be stable for infinitesimal disturbances (figure 5).

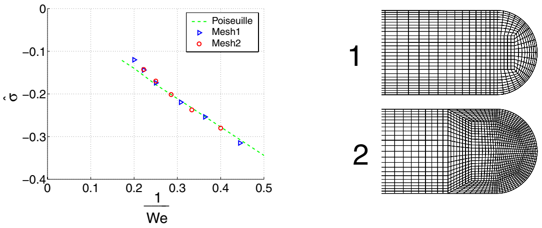

**Figure 5:** *Computed growth rates for an XPP fluid, green line corresponds to growth rates in the upstream channel (Poiseuille flow).*

## Conclusions

As is demonstrated here, the dynamics of complex polymer flows can efficiently be investigated using transient finite element techniques. Obviously, the choice for the constitutive model plays an important role in the analysis of these flows. In the future, we will extend our analysis towards higher Weissenberg numbers in order to investigate the experimentally observed instability.

### References:

[1] M. Bulters, A. Schepens: *Proceedings of the 16$^{th}$ Annual Meeting of the Polymer Processing Society, Shanghai (2000).*

[2] T.C.B. McLeish & R.G. Larson: J. Rheol. 42(1), 81-110 (1998)

[3] W.M.H. Verbeeten et al: J. Rheol. 45(4), 823-844 (2001)