

Flow instabilities of fiber spinning

Citation for published version (APA):

Walt, van der, C., Hulsen, M. A., Bogaerds, A. C. B., Meijer, H. E. H., Eindhoven, van, S. J. L., & Bulters, M. (2009). *Flow instabilities of fiber spinning*. Poster session presented at Mate Poster Award 2009 : 14th Annual Poster Contest.

Document status and date:

Published: 01/01/2009

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.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Flow Instabilities in Fiber Spinning

C. van der Walt, M.A. Hulsen, A.C.B. Bogaerds, H.E.H. Meijer, S.J.L. van Eijndhoven[†], M. Bulters[‡]

[†] Mathematics for Industry, TU/e

[‡] DSM



Introduction

In solution spinning of ultra-high molecular weight polyethylene (UHMwPE), a gel is processed by an extruder through a spinneret. The extrudate is drawn through the air at high speeds and then cooled in a water bath. The end-result is a fiber with a high degree of molecular orientation and therefore exceptional tensile strength. Flow instabilities in the form of draw resonance, unwanted wave like phenomena, impose limitations on the production rates and the quality of the fibers [1, 2]. Additionally, in solution spinning of UHMwPE is the pull out of a filament from the spinning die due to pronounced shear thinning behavior or combined with wall slippage [3]; see Figure 1.

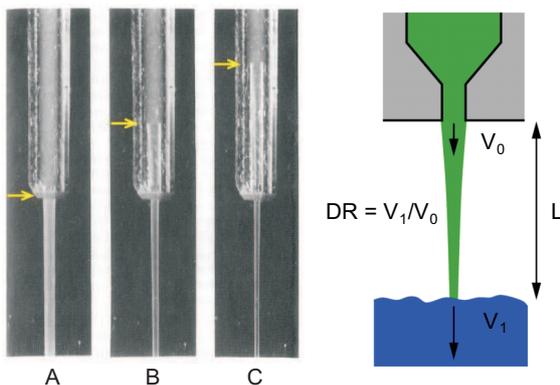


Figure 1 (Left) Pull out of a filament from a glass capillary as observed experimentally in [3] with increasing draw ratio from A to C. (Right) Schematic drawing of a single filament in the air gap.

Objective

The objective of this work is to investigate the influence of the pull out effect on the stability of a single isothermal filament in the air gap.

Modeling Strategy

The pull out effect can be understood according to [3] by equating in the detachment point the spinning tension necessary to obtain a prescribed draw ratio, DR , (which pulls the fluid from the wall) with the first normal stress difference that occurs during shear flow in the upstream region (hence pushes the fluid towards the wall). See the intersection of the red and blue line in Figure 2. The first normal stress difference is determined by the applied shear rate and the polymer's viscoelasticity. The spinning tension is determined by the elongational viscosity, the draw ratio, and the stretching length.

The position of the detachment point fluctuates and this is determined by the intersection angle of the spinning tension line and the first normal stress difference line. It is known that if

the speed is prescribed the filament becomes unstable beyond a critical draw ratio. On the other hand spinning with a fixed force leads to no instabilities [4]. Including pull out, we are somewhere between these two cases. Hence, our working hypothesis is that freedom of the position of the detachment prevents instabilities from happening elsewhere, e.g., draw resonance. We will proceed with our modeling strategy as follows:

- Assume different profiles for the averaged normal stress difference indicated by the red line in Figure 2.
- Determine the transient solution of the 1D isothermal model with a moving boundary.
- Investigate how the angle of intersection between the two lines in Figure 2 effects the stability of the detachment point and the filament formation.

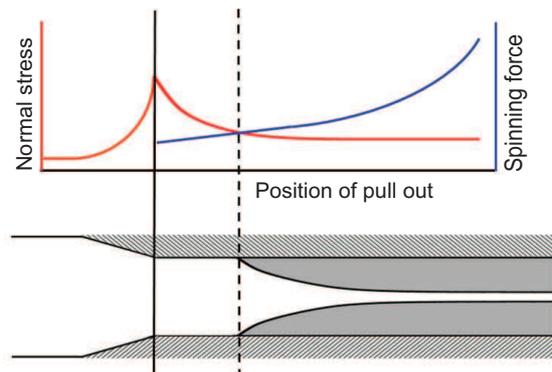


Figure 2 Development of the averaged normal stress as a function of the detachment point and the spinning tension as function of the capillary length. The intersection of the two lines determines the detachment point.

Future Work

- Determine the averaged normal stress difference through modeling and experiments.
- Investigate different constitutive models to describe the behavior of UHMwPE in elongation.
- Incorporate the non-isothermal characteristics of the spinning line into the model.

References:

- [1] Petrie C.J.S. and Den M.M., Instabilities in Polymer Processing (American Institute of Chemical Engineers Journal, 1976).
- [2] Hatzikiriakos S.G. and Migler K.B., Polymer Processing Instabilities, Control and Understanding (Marcel Dekker, New York, 2005).
- [3] Bulters M.J.H. and Meijer H.E.H., Analogy Between the Modeling of Pullout in Solution Spinning and the Prediction of the Vortex Size in Contraction Flows (Journal of Non-Newtonian Mechanics, 1990).
- [4] Renardy M., Draw Resonance Revisited (Journal of Applied Mathematics, 2006).