Linking the fountain flow instability to polymer melt rheology

polymer technology

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Linking the fountain flow instability to polymer melt rheology

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Introduction

During the injection molding process of a polymer melt, an instability at the flow front may arise (Figure 1). This “fountain flow instability” is in turn often responsible for defects on the final product, such as those illustrated in Figure 2.

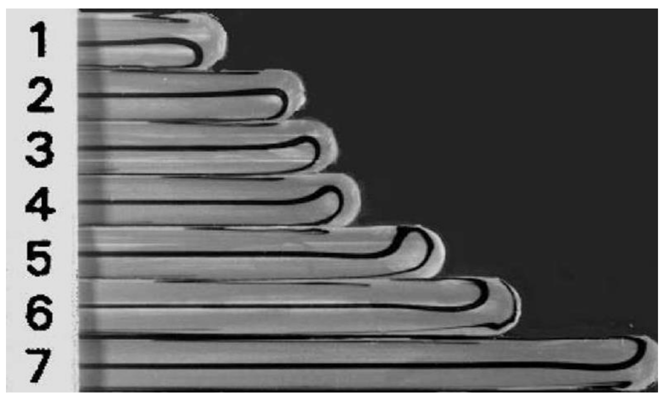

Figure 1: Fountain flow instability [1]

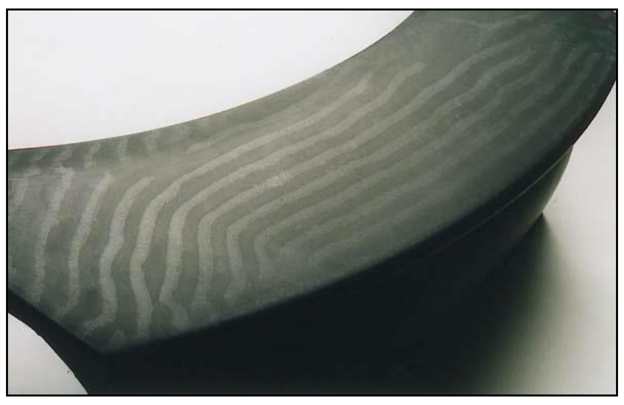

Figure 2: Defects on final product due to instability [2]

The onset of the fountain flow instability is often quantified as a function of the Weissenberg number Wi.

$$Wi = \lambda\dot{\gamma}$$

$$\lambda = \text{relaxation time}$$

$$\dot{\gamma} = \text{deformation rate}$$

Above a critical Weissenberg number, the flow front may undergo the instability, during which the interface oscillates periodically as it advances.

Characterization of melt rheology

We aim to characterize the rheological fingerprint of a polymer melt that is known to undergo the fountain flow instability when subjected to injection molding in industry. This particular compound contains rubber and talc. Under extension, strain softening is encountered for this system.

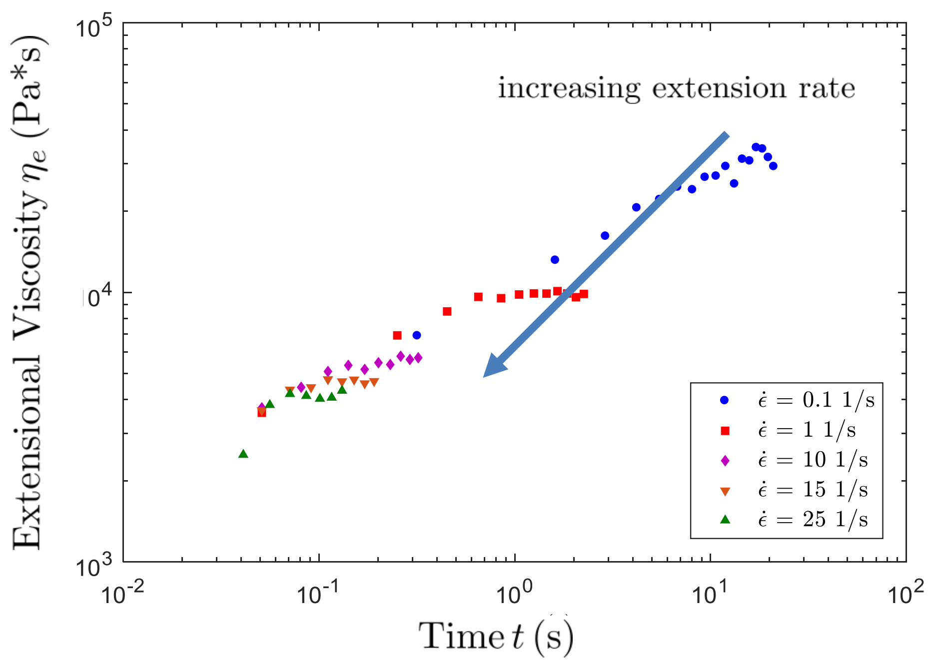

Figure 3: Extensional rheology of melt containing rubber and talc

Visualization of instability

We have developed a setup to mimic the injection molding process, and visualize the flow front as well as the corresponding fountain flow instability. This setup consists of a capillary rheometer used in conjunction with a custom-designed piece that allows tracking of the interface using microscopy (Figures 4 and 5). We have performed preliminary experiments in which oscillations at the flow front are visible, which suggests that the flow front is undergoing the fountain flow instability (Figure 6).

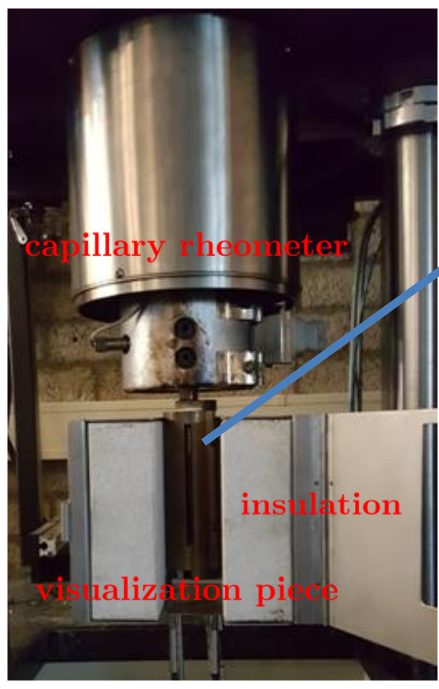

Figure 4: Experimental setup

Figure 5: Custom-designed piece to vizualize flow front

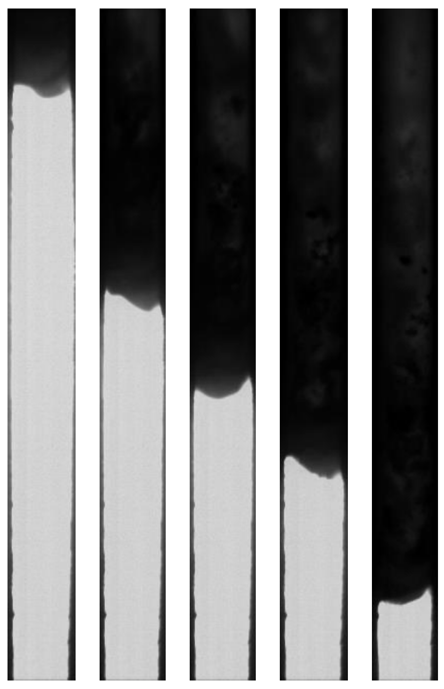

Figure 6: Unstable moving flow front corresponding to the polymer melt characterized in Figure 3

Linking the melt rheology and instability

We aim to quantify the critical Weissenberg number as a function of the rheological properties of various polymer melts. Since the melts implemented in injection molding contain varying amounts of rubber and talc, the compositions of these two additives will be varied systematically. Our central hypothesis is that the added talc yields strain softening, which in turn accentuates the fountain flow instability.

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[1] M. Bulters and A. Schepens (2000)

[2] Figure courtesy of DSM

This research forms part of the research program of the Dutch Polymer Institute (DPI), project #788