Extensional Rheology of Polymer Melts

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ABSTRACT

The last decade has seen an immense development in the extensional rheology of polymeric systems. This is due to a combination of novel synthesis techniques for preparation of well-defined model polymers and the development of new instrumentation for the measurement of extensional flow properties under controlled flow conditions. This presentation will provide an overview and evaluation of available techniques for extensional rheology.

INTRODUCTION

The pioneering work in the extensional rheometry of polymer melts is due to Joachim Meissner[1,2], who developed a series of rheometers for the quantitative characterization of polyolefins. In separate and later developments

FILAMENT STRETCHING REOMETRY

McKinley and Sridhar developed a so-called Filament Stretching Rheometer (FSR) for extensional rheometry albeit initially for polymer solutions. The FSR principle was adapted later by Bach et al. for polymer melts and tested on polyolefins. Illustrated in Fig. 1, the DTU-FSR has been used to characterize a number of systems including polyethylene (LDPE and HDPE) melts and polystyrene melts. However the DTU-FSR is a research instrument that is still not commercially available.

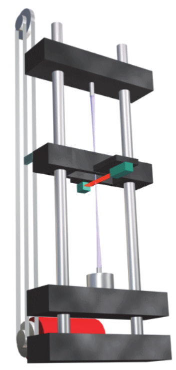

Figure 1. Principle of DTU Filament Stretching Rheometer (DTU-FSR).

One advantage of the DTU-FSR is its ability to measure steady extensional viscosity of polymer melts. Thus in Figure 2 we compare the steady extensional viscosity of two mono-disperse polystyrene melts with the Doi-Edwards (DE) tube theory prediction[3]. The non-dimensional abscissa is the stretch rate multiplied by the fundamental time constants of the two melts. The ordinate is the extensional viscosity divided by the zero shear rate viscosity.

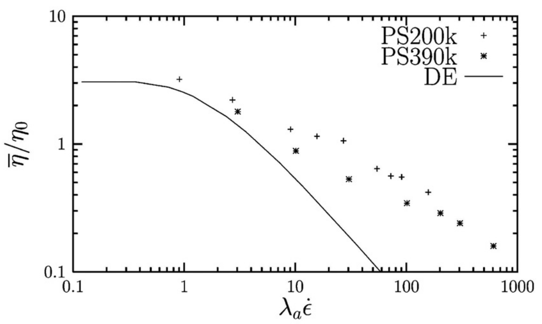

Figure 2. Normalized steady extensional viscosity of two monodisperse polystyrene melts compared to the Doi-Edwards tube theory.

DUAL CYLINDER ROLL-UP DEVICES

Currently available commercial instruments for polymer melts are based on the dual cylinder roll-up configuration[4] illustrated in Fig. 2.

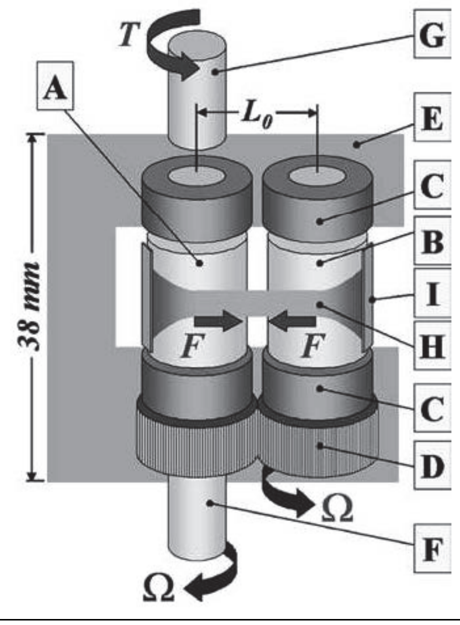

Figure 2. Principle of the Sentmanat Extensional Viscosity (SER) fixture. From M. L. Sentmanat, Rheol Acta, **43**, 657 (2004).

These kinds of devices are readily mounted on most commercial rotational rheometers. However while the dual cylinder devices are capable of producing transient values of extensional viscosity in start-up of steady extensional flow they are not capable of measuring steady viscosities. This is due to the lack of a control scheme and an upper limit on the overall deformation as illustrated in Fig. 3. Other advantages and limitations of these devices will be illustrated in the presentation

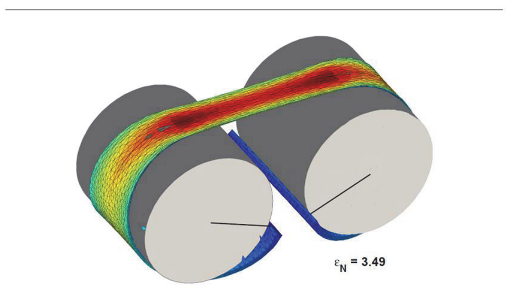

Figure 3. Illustration of deformation in dual cylinder roll-up devices.

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