Rheology

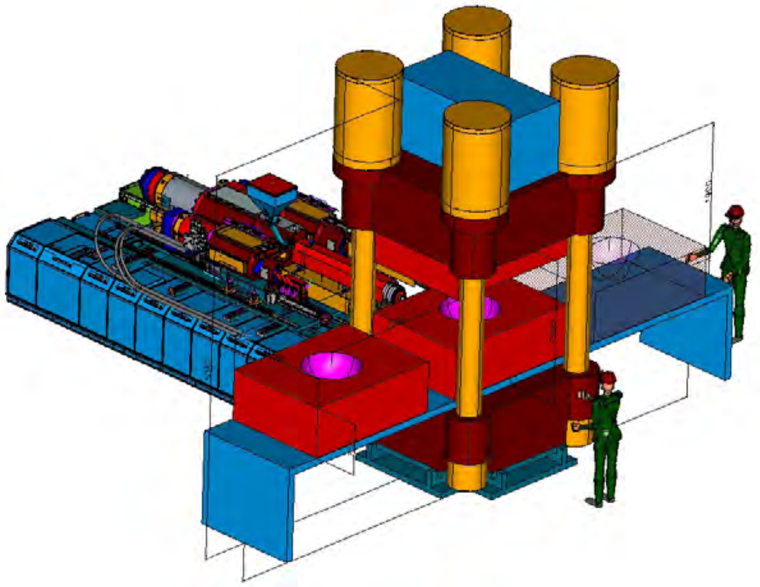
A Tool for Characterization of Materials and Optimization of Polymer Processing

POLYMER ENGINEERING

UNIVERSITÄT BAYREUTH

Rheology of Polymer Materials

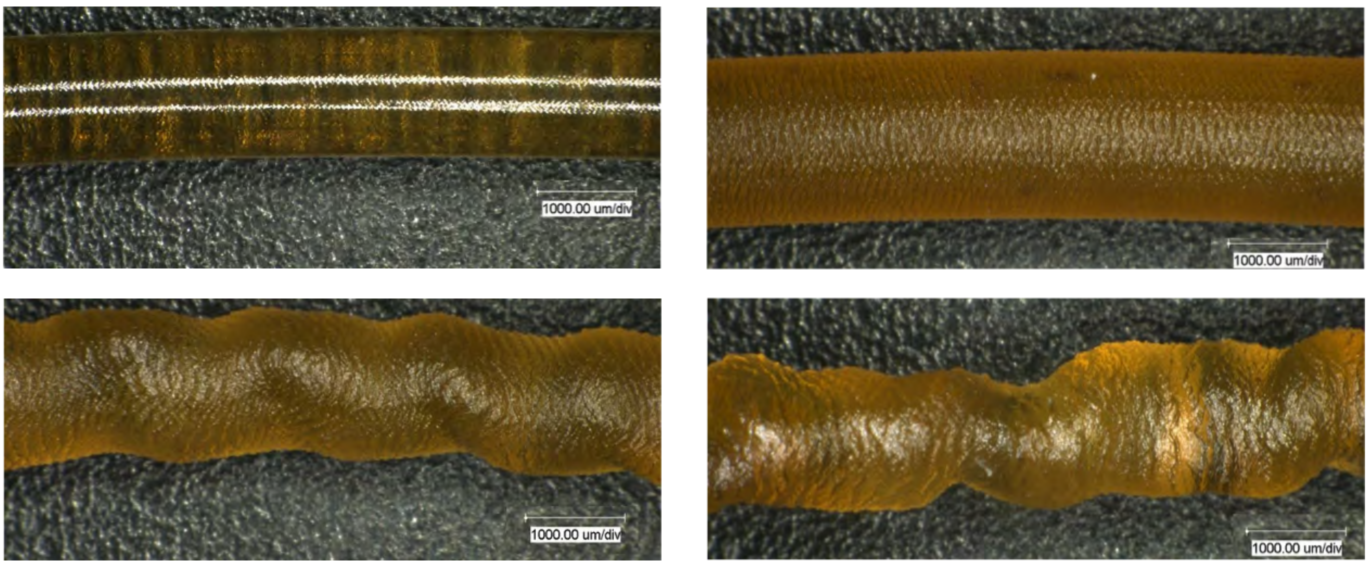
LINEAR AND NONLINEAR FLOW PROPERTIES



“Polymer Engineering“ stands for scientific and practical research and teaching in the field of polymer materials. The department of Polymer Engineering at the University of Bayreuth, the business area of plastics at the New Materials Bayreuth GmbH and the department of Polymer Engineering at the TuTech Innovation GmbH in Hamburg embody these brand under the guidance of Prof. Dr.-Ing. Altstädt. The main research at all three locations is focused on materials, processing and production, with the aim to develop high performance plastic products. The focus of the research is the systematic analysis and use of causal relationships between processing, structure and properties of polymer materials. This allows a strategic approach to the development of innovative products with the help of modern polymer materials and processing methods.

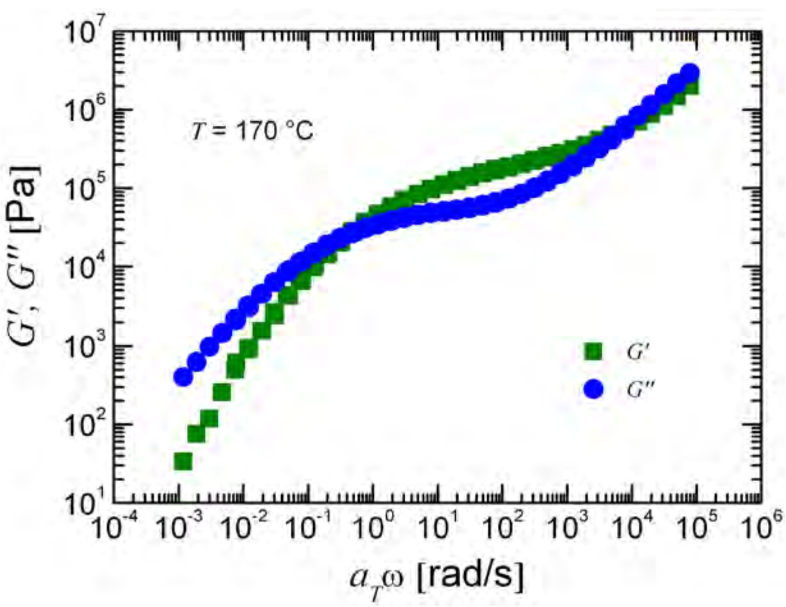
The research activities in the field of rheology of polymers are broadly based at the Department of Polymer Engineering.

A large number of experimental facilities for the investigation of the flow properties of polymer melts as a function of temperature, time and deformation rates are available. Our equipment allows the determination of the rheological properties of polymer melts for technologically relevant processes at low and large deformation rates. A variety of polymeric materials (e.g., homopolymers, polymer blends and nanocomposites) are commonly investigated.



Rotational rheometry

CHARACTERIZATION OF MATERIALS AND OPTIMIZATION OF PROCESSING



The rheological properties of polymeric materials are generally characterized in shear and elongational flows. Standard experiments in shear can be performed using rotational rheometry.

Frequently performed experiments are:

• **Linear viscoelastic shear oscillations**: The sample is deformed with a harmonic shear strain at different angular frequencies. These experiments allow to measure the complex modulus and the complex viscosity. The zero shear rate viscosity and the temperature shift factors can be determined in this test mode.

• In **step shear rate experiments**, the sample is deformed with a constant shear rate and the resulting shear stress is measured. In these experiments, the transient and the steady shear viscosity can be determined.

• **Creep experiments** are ideally suited for determination of the flow properties at large times. In a creep test, the sample is deformed with a constant stress. After the creep interval, the externally applied stress is set to zero, and the polymeric sample can recover. Then the recovered shear strain and the recovered shear compliance are measured.

These experiments allow to determine the viscosity and elasticity of a polymeric melt as a function of time, frequency, temperature and shear rate. Different materials can be compared and information, e.g., about a possible formation of a network, is attained.

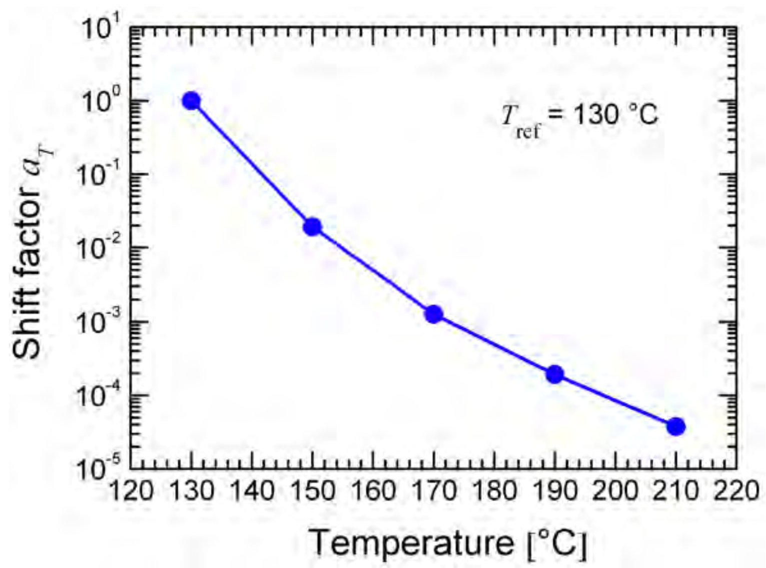
Analysis

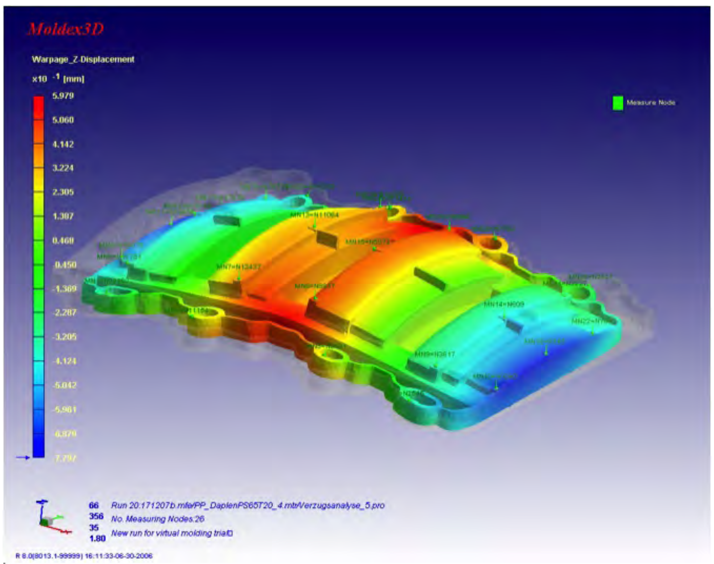
DATA INTERPRETATION

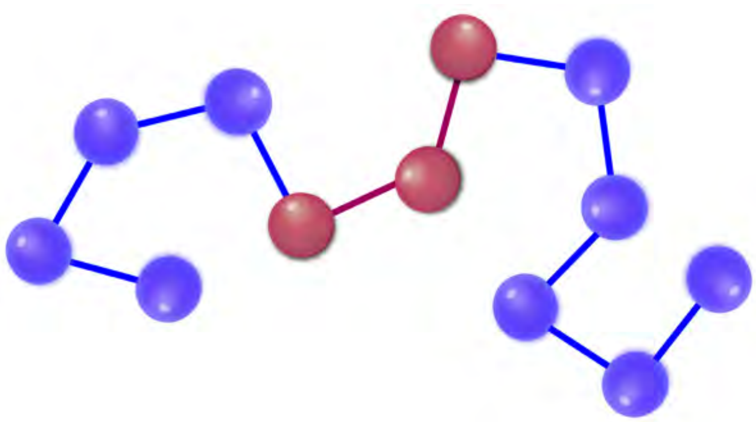
Optimizing the development of new materials and processing of polymers requires a profound understanding of the flow properties. We routinely apply the following methods:

- **Bagley- and Rabinowitch-Weissenberg corrections** in capillary flows
- Test of the **time-temperature superposition** principle and calculation of the shift parameters
- Analysis of the **relaxation time spectrum**
- Determination of melt strength and drawability of polymer melts based on the data of **Rheotens tests**

Furthermore, software tools are available in order to simulate flow phenomena during processing. The design of injection moulds is a highly cost-intensive procedure. Simulation software allows the reduction of time and costs of designing new moulds and the modification of existing ones. The software tool Moldex3D ® visualizes the flow field in injection moulding and supports the efficient construction of injection moulds.







Rheological Properties Relevant for Foaming

INVESTIGATING THE VISCOSITY AT PROCESSING CONDITIONS

The flow behaviour in elongation is highly relevant during foam expansion. In the Department of Polymer Engineering, the extensional properties are investigated using the Rheotens apparatus and the “Elongational Viscosity Fixture (EVF)“ tool. For investigating the shear viscosity at processing conditions a slit die at our tandem extruder line can be used.

- **Rheotens apparatus:**
Measurement of melt strength and drawability

- **Elongational viscosity fixture:**
Transient elongational viscosity

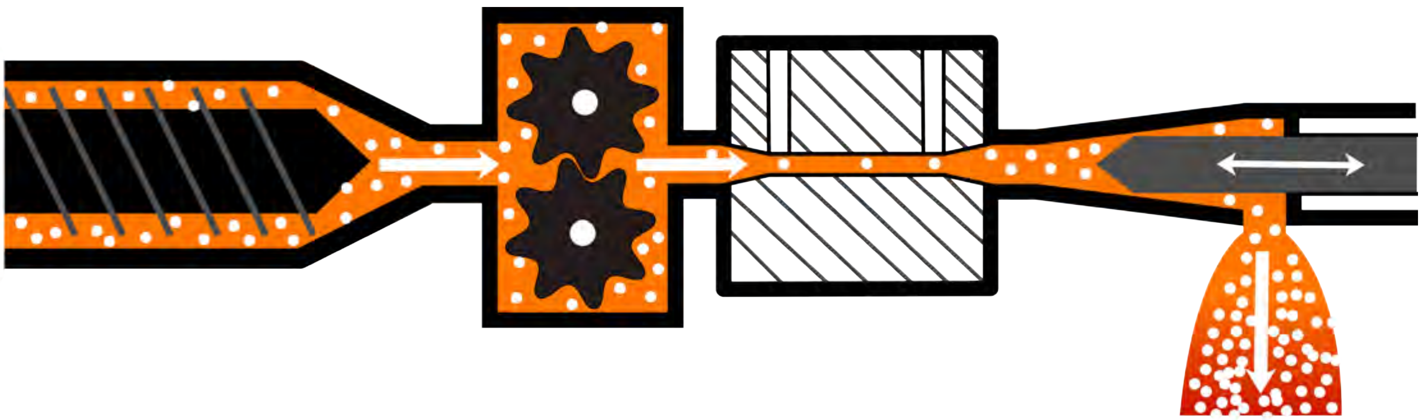
- **In-line rheometry:**
Measurement of flow curves under processing conditions: pressure and gas concentration variable

In a Rheotens experiment, a polymer melt is extruded through a cylindrical die. The extruded trand is accelerated using checkered wheels. The velocity of the wheels continuously incrases until the strand ruptures. The draw-down force is measured such that apparent values of the elongational viscosity as a function of elongational rate can be determined. The Rheotens is a simple test in order to determine elongational properties of polymer melts.

Using more sophisticated rheometers, the true elongational viscosity can be determined. For measuring transient elongational viscosity the so-called elongational viscosity fixture is used.

The extensional viscosity is an important property in polymer processing especially in foaming, blow film extrusion and fibre spinning.
By measuring the extensional viscosity, one can determine the degree of strain hardening of a polymer melt in the parameter range of processing.

To obtain a quantitative understanding of rheology during foaming it is essential to quantify rheological properties of the melt under processing conditions. With our in-line rheometer high pressures can be applied to deterimine the influence of pressure on viscosity.
Furthermore gas can be incorporated into the melt and its‘ effect on melt viscosity quantified.



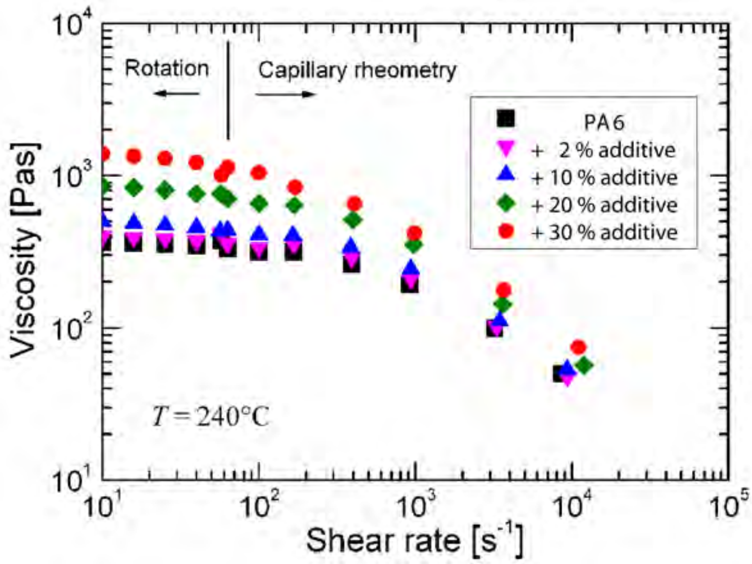
Capillary Rheometry

RHEOLOGY FOR PROCESSING

Processing of polymers is usually associated with high shear rates. The flow properties at high shear rates can be determined using the methods of capillary rheometry. In these experiments, the polymer melt flows through a circular or a slit die with a defined shear rate. Then the pressure drop along the die is measured and apparent and true values of the shear viscosity are determined. Typical experiments are:

- **Measurement of the flow curve** (viscosity as a function of shear rate at different temperatures). The viscosity is determined based on the pressure drop at the die and the thoughput. Bagley- and Rabinowitch-Weissenberg corrections are applied in order to calculate the true viscosity.

- **Extrudate swell measurements**: These experiments allows the measurement of polymer melt elasticity (recoverable deformation). The diameter of the extruded strand is measured as a function of temperature, shear rate and pressure.



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