APPLICATION **NOTE**

From Low to High Shear Rates: NETZSCH Reaches Them All

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Introduction

The shear rate of interest for rheological measurements is dependent on the application. In a fast process like spraying, where the material is rapidly pushed through an orifice, high shear rates up to 100,000 s^{-1} are involved. On the contrary, the extrusion of a polymer, which has much higher viscosity, is done at significantly lower speeds; typically more than 1000-time lower. Even lower shear rates are used to describe very slow processes as levelling.

Rheometer Versions

The choice of the rheometer depends on the required shear rate. While Kinexus, as a rotational rheometer, is the instrument of choice to measure in the low shear rate range, one will work with a Rosand capillary rheometer to reach high shear rates up to 1,000,000 s^{-1}.

In the following, the viscosity curve of a polypropylene material is obtained over almost 7 decades. For that, both a NETZSCH Kinexus rotational rheometer and NETZSCH Rosand capillary rheometer are used (see measurements conditions in table 1).

Remarks about the Measurement Conditions

- Kinexus Rotational Rheometer

A frequency sweep was performed, and not, as one might think, a rotation measurement. Here, the Cox-Merz rule was used that stipulates that for unfilled polymers, complex shear viscosity vs frequency gives the same values as shear viscosity vs shear rate. Oscillation measurements have the advantage over rotation measurements that the material is measured at rest. Thus, the polymer is not subjected to centrifugal forces and will not run out of the gap as it might happen during rotational measurements at high shear rates.

You will find more information about this topic in Application Notes 236 and 243 [1, 2].

- Rosand Capillary Rheometer

The 1 mm-diameter die was used to get shear rates up to 10,000 s^{-1}, while higher shear rates were reached with the 0.5 mm-diameter die.

Table 1 Measurement conditions

Instrument	**Kinexus**
Sample	Polypropylene
Geometry	Plate-plate, diameter: 25 mm
Temperature	190°C
Measurement gap	1 mm
Frequency	10^{-3} to 10 Hz
Shear stress	1,000 Pa
Instrument	**Rosand**
Temperature	190°C
Capillary die	Diameter: 1 mm and 0.5 mm, Length: 16 mm
Zero die	Diameter: 1 mm and 0.5 mm, Length: 0.25 mm
Pressure transducer capillary side	10,000 Psi (689.5 bar)
Pressure transducer zero side	1,500 Psi (103.4 bar)

NGB · Application Note 253 · EN · 1022 · Technical specifications are subject to change.

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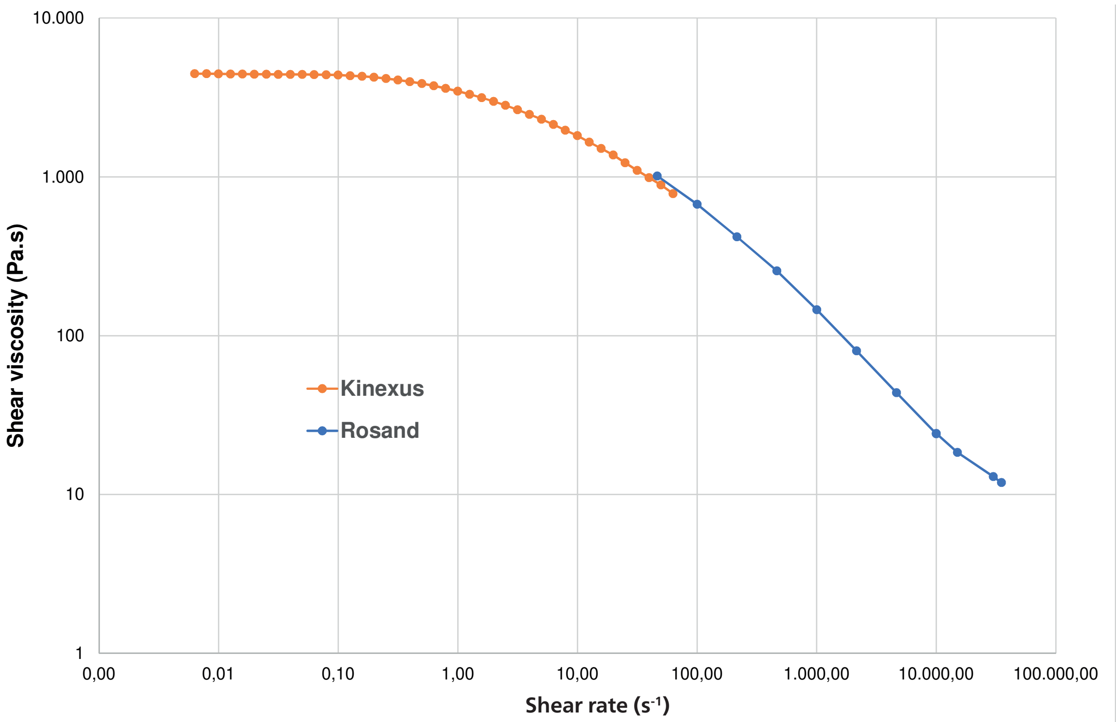
Measurement Results

Figure 1 depicts the composite viscosity curve of polypropylene measured in the rotational and capillary rheometers. In the low shear rate range, the material shows a Newtonian behavior: The shear viscosity does not depend on the shear rate. In this zero-shear plateau, the shear viscosity amounts to 4400 Pa·s.

For higher shear rates, the polymer is shear-thinning: Its shear viscosity decreases with increasing shear rates. In this range, the applied shear stress is high enough to disentangle the polymer chains. They can slide against each other, facilitating the flowing, and explaining the shear viscosity decrease.



1 Resulting curves of measurements performed with Kinexus (rotational rheometer, orange) and Rosand (capillary rheometer, blue)

Conclusion

With this unique combination of rotational and capillary rheometer measurements offered by NETZSCH, very broad shear rate ranges are achieved. This is important, for example, for polymers, because their behavior depends strongly of the shear rate to which they are subjected.

References

[1] AN 236: How to Obtain Shear Viscosity of a Polymer Melt with an Oscillation Measurement: The Cox-Merz-Rule. www.netzsch-thermal-analysis.com
[2] AN 243: How to Apply the Cox-Merz Rule: A Step-by-Step Guide. www.netzsch-thermal-analysis.com

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