Rheology Solutions
for the Polymer Industries

Explanation and Evaluation of Die Swell

RHEO292

Company Profile

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Rheology Solutions has an established applications laboratory equipped with a comprehensive range of instruments to meet the requirements of material characterisation. Specialist contract testing services are also available and contracts can be tailored to suit discrete tests or protracted testing requirements involving a series of tests over a period of weeks or months.

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Tim’s Top Tips: Rheology Solutions for the Polymer Industries

Explanation and Evaluation of Die Swell

Key Words: *Die swell, rheology, rotational, liquid, viscosity, normal force, viscoelasticity, force and displacement measurements, optical measurements, pilot scale, instrumented extruder.*

About The Author

Tim has a background in engineering and specifically in rheology, with a B.Eng and Ph.D. in Chemical Engineering and has held postdoctoral research positions in engineering rheology. Tim's research has continued for the last seven years and recent interests and publications include the application of rheology and rheometry to mineral, food, polymer and surface coatings systems. His current position encompasses the managment of customer contract testing and also includes customer focussed education and training. Additionally he is available to provide technical input for existing or proposed materials characterisation systems for both laboratory and production.

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Introduction

Often the polymer industries must overcome problems related to (and often dominated by) the flow properties of their product, though the relationships between these properties and production related issues are not always immediately apparent. It is the purpose of this series of articles, “Rheology Solutions for the Polymer Industries”, to help illuminate the issues faced by the industry, how they relate to the flow properties of problem materials and how they can be successfully measured and controlled with a view to better processing.

Definitions

Die swell occurs when an extrudate has larger diameter than the die. It is caused by the release of stresses in the extrudate leaving a contraction – the extrudate ‘remembers’ it’s original shape and attempts to return to it. Die swell can result in an extrudate with several times the diameter of the die, depending on the process and conditions.

Background and Discussion

Melt state blending is achieved using a compounder or extruder. Materials are fed, in powder or pellet form into the extruder, melted, mixed and transported to the die where the blend is extruded, whereupon the swelling of the extrudate can be observed. The exact nature of the mechanism is still being debated, but it can be said that as a polymer flows through a contraction it exerts both shear (stress) forces and normal forces (acting perpendicular to the direction of the flow, eg pressure) at the die wall, and at the same time it is acted upon by normal (pressure) forces.

Die swell is primarily driven by the release of normal forces at the die exit. As the polymer is forced into the narrow die channel, it is extended in the direction of flow and compressed in the normal direction. This type of flow results in anisotropies (different properties) in the microstructure of the polymer chains in x- (direction of flow), y-, and z- (normal to flow) directions. Simply put, the polymer is unevenly compressed in the three directions and the release of the compressive forces at the end of the die causes contraction of the polymer chains in the flow direction and their expansion in the normal directions, resulting in an extrudate diameter larger than that of the die.

It has been shown that other parameters can also impact on the magnitude of swell. These include:

- Product throughput and the length of the die, more time can be afforded for the relaxation of the material either by elongating the die, or by holding it in a short die for longer by reducing throughput.

- Thermal gradients. A hot melt and a cold die wall can cause up to 5% extra swell due to temperature driven viscosity differences at the centre of the extrudate and at the die wall.

Note: Working definitions are provided at the end of the paper.

Analysis of die swell using viscometers and rheometers

Rheology Solutions Instrument

HAAKE ViscoTester VT550

CR viscometer (ViscoTester) for measuring the flow properties of polymer systems

Rheology Solutions Instrument

HAAKE MARS

CS rheometer (MARS) for measuring the flow properties of polymer systems

Small sample volumes are required for most rheometers and viscometers, unless they are in-line. In the case of a laboratory viscometer or rheometer, the material is placed in a gap between a holding cup or a flat plate and a cylindrical, conical or flat plate sensor. The sensor moves (rotates or oscillates), resulting in a measured force and displacement of the sensor and sample. The force and displacement are used to measure the flow properties of the material. These flow properties – normal stresses, shear viscosity, and viscoelastic properties – are dictated by the internal structures of the melt. The relevance of properties measured using viscometers and rheometers to die swell is that the changes in the properties measured are a direct result of the changing microstructure in the materials. This microstructure is generated by the dispersion and size of individual polymer molecules, and the dispersion of particles or droplets in a two phase system, and by the extent of mixing for miscible materials. The microstructure dictates how easily flow can be initiated for the material, the normal forces generated by flow, and how it will continue to flow once flow has begun (viscosity, viscoelasticity).

Increasing viscoelasticity can indicate that crosslinking or ordering of the material has commenced. Increasing normal forces in the system indicate greater propensity of the material to swell at the die exit. Many rheometers can measure the first normal stress difference, N1, (the difference between the stress

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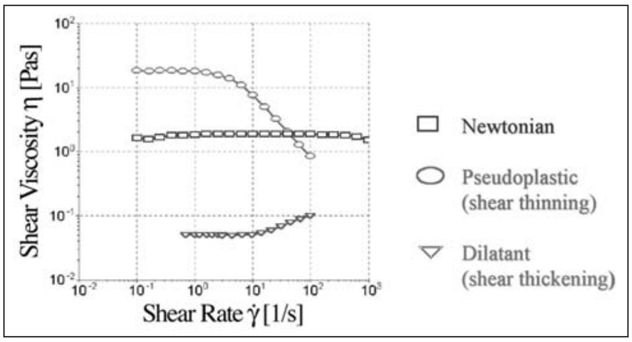
in the x-direction (flow) and the z-direction (perpendicular). For the most common polymers N1 is positive. The second normal stress difference, N2, (the difference between the forces in x- and z-directions) is commonly negative. Most research to date has been based on the relationship between the first normal stress difference and die swell. Potential issues surrounding these types of tests may include:

- *Shear properties difficult to comprehend:*

Shear viscosity is simply the resistance of the material to flow. Except for a few materials, shear viscosity is a function of shear rate, and should be measured at a variety of shear rates in order that a clear picture of the behaviour of the material as it changes can be obtained (a single point can usually not fully define the viscosity curve).

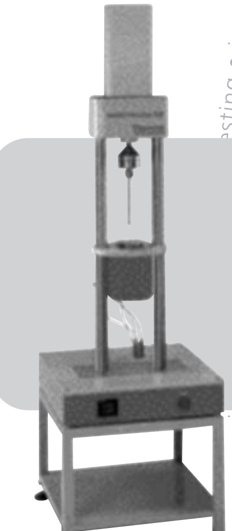


Knowledge of a single point viscosity for shear thickening or shear thinning polymers can not fully define their behaviour

The primary shear properties of interest are viscosity and yield stress which dictate how a material can spread, flow etc. It is important to remember that testing should be done under conditions similar to those encountered during the process. For shear rate driven processes, a Controlled Rate (CR) test is appropriate, and for a stress driven process, a Controlled Stress (CS) measurement is the most suitable.

The first normal stress difference can also be measured in shear and is responsible for some of the potential difficulties explored in the next section (eg the measuring gap emptying). High normal forces indicate that the polymer is likely to swell substantially at the die exit. Including N1 on the previous plot can give a good indication of the relationships between normal forces and the shear rates and stresses in the process, assuming that measurements can be obtained at these (usually quite high) stresses and shear rates.

- *Shear properties difficult to measure on a rotational instrument:*



Rheology Solutions Instrument
HAAKE RheoCap S
Capillary measurements can provide high shear data which may not be available from rotational measurements

Rotational instruments have some limitation for measurements in steady shear. The motors with which they are equipped, though of a high specification can not always rotate through highly viscous polymer melts. There are several potential solutions for this issue:

- Cox-Merz rule: The Cox Merz rule basically states that the complex viscosity (measured using dynamic, oscillatory techniques) is quantitatively equal to the steady shear viscosity (by rotational techniques) when the shear rate, g', and angular velocity, w, are plotted together against the viscosities. This is the case for many polymer melts, and where steady shear rotational measurements can provide data up to 10-100s-1, oscillatory data can increase this to over 600s-1.

- Capillary measurements: Capillary viscometers have long been used for rheological data collection in the polymer industries, primarily because of the high shear rates attainable with these instruments. Capillaries measurements are more time consuming and difficult than oscillatory or steady shear and cleaning can be an issue.

Rheology Solutions Instrument

HAAKE ProFlow - On-line Melt Rheometer

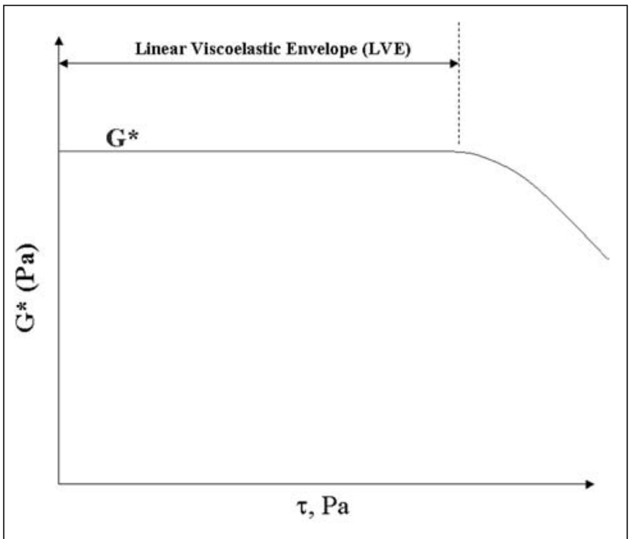
Capillary measurements can be made on-line with a melt pump and appropriate data collection

If used in conjunction a PC, software and with a melt pump to ensure steady, surge free flow, capillaries can be used directly on the end of, or in a side stream from, an extruder for direct continuous measurements.

In addition to the problem of the low torque available from rotational instruments, relative to capillary ones, there also exists the problem that highly elastic materials will not remain in the measuring gap, even at low shear. This is known as the Weissenberg effect and is quite common, especially for high molecular weight materials. The Weissenberg effect, like die swell, is related to the normal stresses developed by polymeric systems in shear flow. As soon as the measuring geometry has begun to empty, the measurements are no longer valid. It is difficult to overcome, and can not be completely avoided. Its onset can be retarded by using smaller cone angles for measurements.

- *Viscoelastic properties not repeatable:*

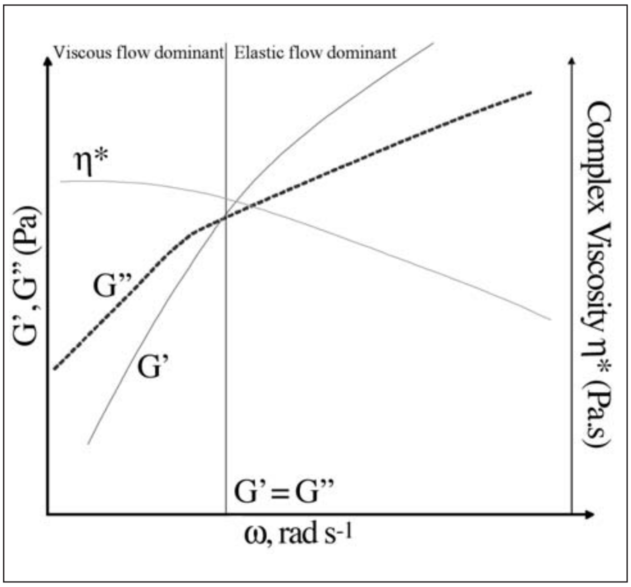
Viscoelastic properties are generally measured by means of a frequency sweep (oscillating a sensor at different rates in the sample) in the Linear Viscoelastic Envelope (LVE).



In the LVE, properties are independent of the amplitude or force applied during oscillatory measurements

Measurements not carried out in the LVE are not repeatable, and are usually not comparable for different materials.

- *Viscoelastic properties difficult to understand:*



Viscoelastic flow properties tell us about the undisturbed (in the LVE) structure of the material

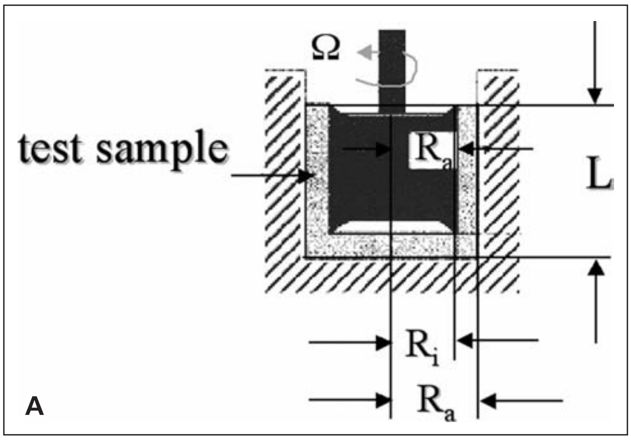
In general the viscoelastic properties measured are the viscous and elastic moduli and the complex viscosity. The complex viscosity is a measure of the resistance of the material to flow and the comments made for shear viscosity regarding the importance of measuring at appropriate rates of deformation are valid here also. Higher viscosity materials will require higher forces to initiate and continue flow. At low frequencies, for polymeric systems, the viscoelastic moduli show the contribution of high molecular weight (MW) species, the crossover point of the moduli shows the point at which the moduli are equal and is often used as a quality control point for materials. Changes in the magnitude of the moduli at the crossover point imply changes in molecular weight distribution, and changes in the frequency at which the crossover point occurs implies a change in the mean MW of the system. Higher molecular weight and changing molecular architecture can result in different die swell behaviour, even if the processing conditions are unchanged. Some practical and theoretical training can often help nervous operators overcome the perceived complexity of viscoelastic measurements and assessing the data.

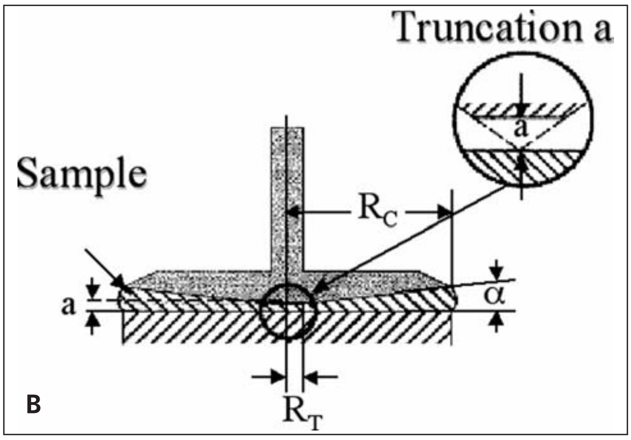
- *Relative vs absolute data:*

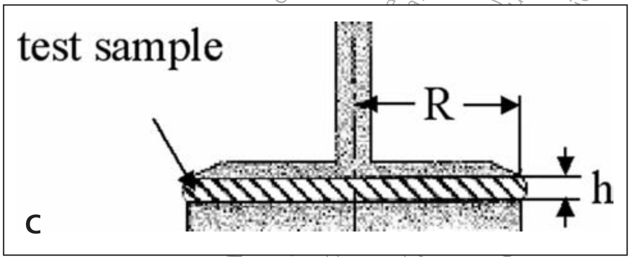
Rheology Solutions Instrument
HAAKE ViscoTester VT7L Plus

Relative viscometer for QA/QC measurements (large gap between sensor and holding cup)

Some of the early model instruments, for example those meeting the 'Brookfield' standard, ISO 2555, for testing provide the user with relative data for most materials, because the gap between the holding cup and the rotating sensor is large.







Fully defined (viscometric) measuring geometries (a) concentric cylinder, (b) cone & plate, (c) parallel plate for rheometry and viscometry

In contrast, most modern viscometers can provide absolute data because the measuring gap is small and the sensor geometry is fully defined. For any given material at the same temperature, a measurement made using a cone/plate sensor geometry gives an absolute measurement, and the same answer as one made with a concentric cylinder apparatus. For absolute measurements, or those needing to be reliably comparable between two different polymer systems, viscometric geometries should be used.

- *Structural disruption on loading:*

Most materials have internal structures, made up of sometimes delicate internal particle-particle, liquid-particle and liquid-liquid associations. These can be disrupted by shear stresses, for example by stirring, or by closing the measuring geometry of a viscometer or rheometer. This is particularly true of materials exhibiting normal stresses, which can be exacerbated by swiftly closing the measuring geometry. This problem can often be overcome by allowing the material to rest afterwards, so that the structure relaxes fully. In cases where the structure does not relax in time, then the measurements can at least be made repeatable by using computer controlled geometry closure, rather than a manual equivalent, and if necessary zeroing the normal force sensor before commencement of shearing.

Analysis of die swell using pilot scale torque compounders

Rheology Solutions Instrument

PolyLab OS – Extruder

Small-scale equipment for measuring the flow and deformation of polymers under process conditions

Rheology Solutions Instrument

PRISM 36 PC

Small-scale equipment for measuring the flow and deformation of polymers under process conditions

Pilot scale, instrumented compounders can provide valuable information on the capabilities of different materials or compounder/die configurations

Melt state blending is achieved using a compounder or extruder. Materials are fed, in powder or pellet form into the extruder, melted, mixed and transported to the die where the blend is extruded, cooled and fragmented. It is possible to directly measure die swell at the die exit and to obtain a relative measure for different systems or materials showing die swell. These measurements are carried out using optical or laser sensors at the die exit to physically measure the diameter of the extrudate.

Rheology Solutions Instrument

HAAKE Die Swell Tester

Die swell testers can physically measure extrudate swell, allowing determination of the conditions most likely to cause excessive swell

The efficiency and suitability of a melt blending configuration can be examined from two standpoints, processability and blending efficiency. Processability is a relative measure and can be designated qualitatively using laboratory or pilot scale compounding equipment. This equipment may measure relative processability only - extruder torque (usually through the current), rpm, temperature etc - as a function of the agitator arrangement and material being processed. Usually this type of equipment can be arranged in a similar way to the process instrument eg co-rotating twin screw and gives basic processing data, allowing the potential for different materials to be assessed in terms of their processabilities. It is usually possible to include a die swell tester at the die exit of any of these machines and to change their configuration and the processing conditions to provide simultaneous processing data and die swell.

More sophisticated equipment can include variable configuration instrumented processing devices (single-, or twin-screw etc), offering direct determination of the torque (torsion bar or similar), and rheology dies, in which not only processability, but also fundamental flow properties of each material can be scientifically, quantitatively measured. These dies can be used with die swell testers to give simultaneous information regarding the extensional, viscous and swelling properties of the material in question relative to the processing conditions for the test. Potential problems which may occur for melt state blending are:

- *Too high torque/energy consumption for the compounder:*

Increasing temperature or rpm of the extruder can alleviate the problem, but either may impact on the final properties of the processed material, and the latter may also impact on the residence time of the material in the compounder. Another solution is to alter the agitator configuration, removing some of the high energy mixing or reversing elements and replacing them with conveying elements. This solution may compromise the degree of mixing of the materials in the machine. Rheological analysis of the final product can help clarify this.

- *Melt properties in spec for MFI (melt flow index) but material not performing as expected:*

MFI is a single point measurement on a curve. It is common for MFI measurements to be misleading because in general MFI is a measure (inaccurate/relative) of the shear viscosity of the material at a single shear rate. The solution is to generate a curve, preferably of shear or complex viscosity vs. shear rate, or to examine the viscoelastic crossover point as an alternative QC criterion.

- *Final melt properties out of specification?*

Measuring melt flow properties, such as viscoelastic, shear and extensional viscosity can be achieved in-line using rheological piezo actuators (viscoelastic properties) and dies (extensional and shear flow). These properties are a measure of the molecular structure of the melt and relate to process properties, for example in compression, blow moulded or extruded parts. They can provide precise scientific data for comparing the effects of changing process variables on the properties of a melt, which are directly related to die swell. If it is not possible to install rheological dies in-line, rheological measurements may be made off-line, on a rheometer. Most modern rheometers can provide the user with simple measurements giving absolute measures of shear and viscoelastic flow properties.

- *Residence time too low or too high:*

Changing the screw configuration by adding or removing reversing elements may be a solution, provided that the degree of mixing remains acceptable. Alternatively, changing the feed rate of the material, or the rpm of the agitators directly influence residence time (increase either for reduced residence time).

Summary

Table 1 summarises the possibilities for measuring misting using the techniques discussed. Each of the techniques is ranked between 0 and 5 for each of the potential issues and solutions, where:

5=Excellent	4=Good	3=Adequate
2=Possible	1=Difficult	0=Not Possible

Determining the most suitable type of instrument is not simply a matter of adding up the ranking for each. Rather, identify which measurement technique, variable etc is most relevant and appropriate for your application/product. Often, more than one technique is required to ensure consistency, reproducibility and accuracy is achieved.

More and more polymer companies are now including in-line viscosity, pilot scale mixing and compounding and rheology to support, supplement and further direct their R&D and recipe modifications.

Table 1: Assessment of strengths/weaknesses for each technique

Technique:	**CR Viscometers**	**CS Rheometers**	**Instrumented Mixer/ Compounder + Die Swell Tester**
Measures			
Solids	0	1	2
Melts	5	5	5
Semi-Solids	4	2	5
Liquids	5	5	5
Sensors			
Large variety	5	5	4
Rigid samples easily measured	0	2	3
Structural disruption on loading avoidable	3	3	0
Test Method			
Absolute*	5	5	3
Relative*	5	5	5
Quickly varied	5	5	4
Widely varied	5	5	4
Objective measurements	5	5	5
Rapid test completion	4	4	4
Primary Variable Parameter			
Load/Force	0	5	5
Displacement	5	5	5
Number of Participants			
Single operator	5	5	5
Results			
Intuitively comprehended	3	2	5

* *Depending on the test, these parameters may be viewed alternatively as either a strength or as a weakness*

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Other Notes Available in the Tim's Tips - Rheology Solutions for the Polymer Industries Series are:

- Explanation and evaluation of Compounding (Rheo289)
- Explanation and evaluation of Processability (Rheo290)
- Explanation and evaluation of Die Swell (Rheo292)

Other Information Available for the Polymer Industries include:

- Rheology Solutions for Polymer Industries Information Kit
- Applications Laboratory and Contract Testing Capabilities Statement for Polymer Industries
- Technical Literature for Polymer Industries

Focused on providing our **customers** with materials characterisation **solutions** through knowledge, experience and support.

Polymer Dictionary

Industry Term: **Absolute.**
Definition: Data which can be compared with another reading colleted under the same conditions. Absolute data is expressed in scientific units.
Governing Properties: N/A.
Rheology Solutions Instrument: HAAKE ViscoTester, VT550, HAAKE RheoStress, HAAKE MARS, HAAKE PolyLab & RheoMex.

Industry Term: **Blending / Mixing.**
Definition: Combining materials to give the desired physical or chemical properties.
Governing Properties: Blending efficiency relies upon the viscosity of the materials at high shear. Matching viscosities often allows better blending. Viscoelastic properties also play a significant role in blending efficiency. An excellent way to assess the potential for blending different materials is using an instrumented extruder.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS, HAAKE PolyLab & RheoMex, PRISM Extruder, Marimex ViscoScope.

Industry Term: **Complex Viscosity.**
Definition: The viscosity measured by dynamic rheometry, related to both the viscous and elastic portions of flow for a viscoelastic fluid.
Governing Properties: This is a property governed by the viscoelastic properties of the material - elastic and viscous moduli (G’ and G”). It is measured on a CS rheometer using a frequency sweep.
Rheology Solutions Instrument: HAAKE RheoStress, HAAKE MARS.

Industry Term: **Crossover Point.**
Definition: The point at which the viscous modulus is quantitatively equal in to the elastic modulus.
Governing Properties: This is a property governed by the viscoelastic properties of the material - elastic and viscous moduli (G’ and G”). It is measured on a CS rheometer using a frequency sweep.
Rheology Solutions Instrument: HAAKE RheoStress, HAAKE MARS.

Industry Term: **Die Swell.**
Definition: Die swell occurs when an extrudate has larger diameter than the die. Caused by the release of stresses in the extrudate leaving a contraction – the extrudate ‘remembers’ it’s original shape and attempts to return to it.
Governing Properties: Die swell is influenced by normal stresses in the system, and by the viscoelastic properties of the melt. It is possible to measure these using a CS rheometer (first normal stress difference and frequency sweep measurements). In addition, die swell is related to the length of the die, a die swell test can be used to directly measure die swell on production- or small-scale extruders.
Rheology Solutions Instrument: HAAKE RheoStress, HAAKE MARS, HAAKE PolyLab & RheoMex, HAAKE PolyLab with RheoMex & Die Swell Tester, HAAKE PolyDrive.

Industry Term: **Dispersion.**
Definition: A system consisting of a dispersed substance and the medium in which it is dispersed.
Governing Properties: N/A.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS, HAAKE PolyLab & RheoMex, PRISM Extruder, Marimex ViscoScope.

Industry Term: **Elastic and Viscous Moduli.**
Definition: Many liquids have a solid-like (elastic) component and a liquid-like (viscous) component. The elastic and viscous moduli, G′ and G″ respectively, are measures of the contribution of these two to the deformation of the liquid.
Governing Properties: These are properties governed by the viscoelastic properties of the material - elastic and viscous moduli (G′ and G″). They are measured on a CS rheometer.
Rheology Solutions Instrument: HAAKE RheoStress, HAAKE MARS.

Industry Term: **Extensional Viscosity.**
Definition: The extensional viscosity of a liquid is the resistance to flow of the liquid as it is being stretched. This is a different property to (and independent of) either the shear viscosity or the complex viscosity
Governing Properties: The extensional viscosity depends on the temperature, the rate of deformation of the liquid. It can be measured on an extensional viscometer.
Rheology Solutions Instrument: HAAKE CaBER.

Industry Term: **Frequency Sweep.**
Definition: This technique is an analysis of the dependency of the rate dependent viscoelastic properties; it is usually carried out in the LVE of the test material.
Governing Properties: N/A.
Rheology Solutions Instrument: HAAKE RheoStress, HAAKE MARS.

Industry Term: **Linear Viscoelastic Envelope (LVE).**
Definition: The LVE is the region in which the internal structure of a material remains unchanged as the imposed stress or deformation is gradually increased.
Governing Properties: Measured on a CS rheometer using a stress sweep or a strain sweep.
Rheology Solutions Instrument: HAAKE RheoStress, HAAKE MARS.

Industry Term: **Relative.**
Definition: Data which can be compared with another reading collected under identical test conditions. Units are not scientific and the instrument and conditions also need to be specified with the data.
Governing Properties: N/A.
Rheology Solutions Instrument: PRISM EuroLab, HAAKE VT01/02, HAAKE VT6/7, HAAKE PolyLab, Marimex ViscoScope.

Industry Term: **Rheology.**
Definition: The flow and deformation of matter.
Governing Properties: N/A.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: **Shear Rate.**
Definition: The rate of change of velocity through a cross-section of a flowing system.
Governing Properties: The shear rate is depended on the flow yield of the liquid. It can be measured by a CS rheometer and imposed by a CR viscometer.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: **Shear Viscosity.**
Definition: The shear viscosity is the resistance of a fluid to flow when a shear stress is exerted upon it.
Governing Properties: Shear viscosity depends on temperature and usually shear rate or shear stress. It can be measured on a viscometer or a rheometer, using viscometric measuring geometries.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: **Thixotropy.**
Definition: Thixotropic fluids show shear thinning behaviour combined with a time dependency. The viscosity of a thixotropic fluid drops when subjected to a constant shear rate for a period of time. The viscosity of thixotropic fluids often recovers substantially over a period of time after the shearing forces have been removed.
Governing Properties: Thixotropy depends on the rate of structural recovery in the material. It can be measured using a flow curve on a CR or CS instrument, or by measuring the recovery of the moduli after shearing on a CS rheometer.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: **Viscoelasticity.**
Definition: Materials, which are partly elastic (i.e. solid) and partly viscous (i.e. fluid). When they are deformed some of the energy is stored (solid) while the remainder is lost through flow (fluid).
Governing Properties: N/A.
Rheology Solutions Instrument: HAAKE RheoStress, HAAKE MARS.

Industry Term: **Viscosity.**
Definition: The resistance of a fluid to flow.
Governing Properties: N/A.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: **Yield Stress.**
Definition: The minimum shear stress required to initiate flow in a fluid.
Governing Properties: Governed by the structural properties of the material at rest, measured by extrapolation using a flow curve, or using the vane technique, both on a CR or CS instrument. It can also be measured using a CS rheometer by a stress ramp.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

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Notes

- ViscoTester 550 and RotoVisco are controlled rate viscometers, RheoStress is a controlled stress rheometer, MARS is a Modular R&D Controlled Stress Rheometer and CaBER 1 is an extensional rheometer all of which are HAAKE brand names of Thermo Electron Corporation (Karlsruhe, Germany) GmbH.
- ViscoScope torsional motion viscometer is a brand name of Marimex Industries Corporation.
- AGS Series uniaxial universal tester is a brand name of Shimadzu Oceania Corporation
- PolyLab is a torque rheometer, RheoMex is a add on (to the PolyLab) instrumented extruder, Die Swell tester is an add on to the PolyLab and RheoMex and RheoMix is an add on (to the PolyLab) instrumented mixer, MiniLab is a micro rheology compounder, RheoCap is a single bore capillary rheometer, ProFlow is an on-line melt system, MFI - Melt Flow Indexer, pvT - Pressure Volume Temperature, PolyDrive is an instrumented mixer or extruder, all of which are HAAKE brand names of Thermo Electron Corporation (Karlsruhe, Germany) GmbH.
- Pilot Mixer is a small chamber pre-mixer, TSE - twin screw extruder (16mm, 24 mm, 36 mm etc) are PRISM brand names of Thermo Electron Corporation (Stone).
- FT is an optical Film Testing system, MT is a optical Melt Testing system, and are brand names of Optical Control Systems (OCS) GmbH.

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Information Request Form

Tim's Top Tips – Rheology Solutions for the Polymer Industries

Explanation and Evaluation of Die Swell

To ensure a speedy response to your enquiry, please take the time to ensure you complete accurately all the relevant sections below.

Contact Details:

Name .... Position ....
Company .... Department ....
Address ....
Suburb .... State .... Postcode ....
Telephone .... Fax ....
Email ....

Please send me more information on the following products:

☐ HAAKE RheoStress RS600 – Controlled Stress Rheometer
☐ HAAKE CaBER 1 – Extensional Rheometer
☐ HAAKE ViscoTester VT6 Plus / VT7 Plus – QA Viscometer
☐ HAAKE PolyLab & RheoMix – Pilot Scale Torque Rheometer with Instrumented Mixer
☐ HAAKE ProFlow – In-Line Melt Rheometer
☐ PRISM Extruders – Twin Screw Extruders
☐ Shimadzu AGS-J – Uniaxial Universal Tensile Tester
☐ Contract Testing
☐ Technical Literature *(Please specify)*

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☐ HAAKE VT550 – Controlled Rate Viscometer
☐ HAAKE MARS - Modular R&D Controlled Stress Rheometer
☐ HAAKE RheoCap S – Capillary Rheometer
☐ HAAKE PolyLab & RheoMix – Pilot Scale Torque Rheometer with Instrumented Extruder
☐ PRISM Change Bowl Mixer – Instrumented Mixer for Dry Blending
☐ Marimex ViscoScope – In Line Process Viscometer
☐ Rheology Solutions for Polymer Industries Kit
☐ Training & Seminars
☐ Other *(Please specify)*

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Comments: ....
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Please return your completed form to Rheology Solutions Pty Ltd by fax to 03 5367 6477 or post to Rheology Solutions Pty Ltd. PO Box 754, Bacchus Marsh, Victoria 3340 or send an email to info@rheologysolutions.com

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