Tim's Top Tips - How To Measure Flow And Viscosity Curves For Mining Slurries

How To Measure Flow And Viscosity Curves For Mining Slurries

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

How To Measure Flow And Viscosity Curves For Mining Slurries

Key Words: Rheology, rotational, liquid, viscosity, thixotropy, yield stress.

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 management 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.

Introduction

Often the hydrometallurgical 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 Mining 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

A flow curve is a data plot showing the results of an experiment, relating the shear rate to the shear stress. A viscosity curve is calculated from the flow curve, and shows the relationship between the shear viscosity and the shear rate for a material.

Background and Discussion

A flow curve is used to define the interdependency of the shear rate and shear stress for a material. To generate a flow curve either a range of shear rates or of shear stresses can be imposed on the material, and the other of the pair — the response of the material — is measured. A viscosity curve shows the viscosity of a material at each shear rate from the flow curve. Flow and viscosity curves can be presented either on logarithmic or linear axes. They describe the flow behaviours at a variety of shear rates, so that pump, pipe, impeller, etc sizing can be correctly achieved. They are also important because they define the type of flow behaviour one can expect from a material — Newtonian, pseudoplastic (shear thinning), dilatant (shear thickening) etc. See Figures 1 and 2.
Measurement Techniques and Pitfalls

CS or CR?
A flow curve can be collected either in Controlled Rate (CR), (impose a shear rate and measure the shear stress) or in Controlled Stress (CS), (impose a shear stress and measure the resultant shear rate). In theory, for materials with no time dependent properties both CS and CR flow curves should yield identical results. The main difference lies in the sensitivity of the instrument at low shear rates. CS instruments generally combine an air bearing with a high-end motor to provide good control and measurement of very small deflections, and also of high rpm measurements. CR instruments generally do not have the same level of control and detection at low rpm.

To make a CR or CS measurement you will need:

• A viscometer or rheometer
In general a viscometer can make only CR measurements – in other words flow and viscosity curves are the main purpose of the instruments. A rheometer is capable of much more, including viscoelastic measurements, creep and recovery measurements and so. CS instruments have an air bearing so that these extra measurements can be made. The air bearing also allows flow curves to be generated by imposing a shear stress and measuring the shear rate resulting from it.

• Theory
The theory for this type of measurement is that the flow behaviour is defined for a range of shear rates and shear stresses so that its reaction to different processing conditions (pumping, mixing, storage etc) can be predicted. The range of shear rates or shear stresses tested is usually defined by those present in the process. The viscosity of a material is calculated as follows:

\[ \eta = \frac{\tau}{\gamma}. \]  

(1)

\( \eta \) = viscosity, mPa.s or cP (1mPa.s = 1cP)
\( \tau \) = shear stress, Pa or mPa
\( \gamma \) = shear rate, s\(^{-1}\)
A suitable sensor system

Viscometric geometries should be used to make measurements to generate flow and viscosity curves. Viscometric geometries include cone and plate, cup and bob, plate and plate (all for rotational instruments) and capillaries (for a flow-through device such as a capillary viscometer). Typically rotational devices are used and the viscometric geometries which apply are shown in Figure 3.

Experimental Procedure

The experimental layout can be one shown in Figure 2.

- The material is loaded and the measuring geometry closed.
- A lower and an upper shear rate (CR) or shear stress (CS) is chosen, as is the number of measurement points between them.
- Progressive shear rates or shear stresses are imposed, either by moving smoothly through them, or by discreet step changes from one to the next.
- The reaction of the material to the imposed shear rate (reaction = shear stress) or shear stress (reaction = shear rate) is measured and the viscosity calculated according to equation (1).
- The results of the experiment are flow and viscosity curves, as illustrated before in Figures 1 and 2.

1.0 The ramp test

The following discussion is based on a CR ramp test, but the arguments hold equally for CS tests.

The ramp technique involves a smooth, incremental transition from one shear rate to the next. During a ramp test, the shear rate is continually changing between the lowest designated test shear rate and the highest one. The rate of change of the shear rate is user defined and the number of data points is usually high so that a continuous curve is generated between the upper and lower shear rates selected.

![Figure 3: Fully defined (viscometric) measuring geometries (a) concentric cylinder, (b) cone & plate, (c) parallel plate for rheometry and viscometry](image-url)

![Figure 4: Input for ramp test](image-url)
1.1 Benefits of the ramp test

- **The complete picture**
  A ramp test can provide a complete picture of how the material will behave between the set experimental limits.

- **Early warning of problems with technique or measurement**
  Having data for the complete range of shear rates allows the user to investigate the possibility of settling, chaotic flow in the measuring gap, and slip at the measurement geometry walls. Steps can then be taken to adjust the technique or measurement parameters for better quality data. Data from a step test might not reveal this information so readily, especially if only a few data points are taken.

- **Intuitive interpretation of the data**
  The meaning of the data is easily understood and applied once the appropriate process shear rates or shear stresses are known.

- **Simple measurement and simple analysis**
  The measurement is quite simple to execute and the data is straightforward to process.

1.2 Potential problems with the ramp test

- **Solid fraction size**
  For mineral slurries, often there is a solid fraction, which has particles of considerable size. If this size is close to the size of the measuring gap, then one or more particles may ‘bridge’ the gap and cause an artificially high shear stress. The problem can be solved by using particles no more than 1/3 of the gap size (1/10 for concentrated pastes). Also, often larger particles contribute little to the overall flow behaviour of the material and can be removed without large penalties for the applicability of the measurement.

- **Sensor inertia**
  Sensors, in particular concentric cylinders and large diameter cones or plates may be quite heavy. As the rate of rotation changes through the ramp test, this weight causes the sensors to accelerate to a higher speed than expected by the control software in the viscometer or rheometer and so the shear rate experienced by the material is higher than that ‘imposed’ by the controller. This results in a shift in shear stresses and viscosities for the flow curve from the actual ones. This effect can be reduced or removed by allowing sufficient time for the ramp. A general rule of thumb is to allow at least 1s of test time for every 1s⁻¹ of shear rate in the ramp. So, a ramp from 0-100s⁻¹ should take at least 100s to complete.

- **Time**
  Because of the potential problems with inertia, ramp tests covering very wide ranges of shear rate can take considerable time to complete.

- **Temperature control**
  At high shear rates, shear heating can be an issue. Shear heating is caused by internal frictional heat generated as the lamina of fluid move over each other. When the measuring gap is small this can usually be successfully controlled, but prolonged exposure to high shear rates can still be a problem.

- **Settling slurries**
  If a material tends to settle, long test times tend to reduce the likelihood of successful test outcomes. The longer the test takes, the more likely the solid fraction is to have settled out of the measurement space, or at least created a concentration gradient through it. Sometimes it is possible to ramp from high to low shear rates, rather than the other way around, allowing the material to be kept in suspension longer, and if possible to reduce ramp times as much as practicable. Alternatively using a modified step test with high shear steps to resuspend materials between descending ‘measurement’ steps can also be successful.

- **Chaotic flow**
  One of the key assumptions for rheological measurements is that the flow in the measuring gap is laminar. Too high shear rates can cause the flow regime to become turbulent and the measurements are unreliable. The onset of chaotic flow can be overcome or delayed by changing the measuring geometry or the measurement gap.

- **Slip**
  Multi-phase systems, like mineral slurries tend to slip at the boundary of the measuring geometry. A major assumption for rheological measurements is that the first layer of material ‘sticks’ to the walls of the measuring geometry. Plate & plate or concentric cylinder geometry walls can be roughened or serrated to reduce or remove the slip phenomenon.

- **Time dependent materials**
  Sample handling and experimental technique can be crucial for repeatably measuring time dependent (e.g. thixotropic) materials. The same handling procedure (pouring, mixing, resting, loading into the test equipment etc) and experimental procedure (rest time, ramp time and upper & lower limits) is critical for repeatable measurements, and it must be remembered that for time dependent materials the results are relative only – they depend on the technique used to generate them.
2.0 The step test

The following discussion is based on a CR step test, but the arguments hold equally for CS tests.

The step technique involves a transition from one shear rate to the next by discrete step changes. During a step test, the shear rate is constant for a fixed time before changing abruptly to the next shear rate. The number of steps and the shear rate at each step is user defined. The number of data points is usually much lower than for a ramp test so that single point values appear (usually you can interpolate between the points with a smooth curve) between the upper and lower shear rates selected.

Figure 5: Input for step test

2.1 Benefits of the step test

Step tests can be modified to cope better with shear heating and settling than a ramp test. (See potential problems, following).

- **Sensor inertia**
  Because the shear rate is unchanged for the duration of each step, the controller has time to adjust the speed of rotation of the sensor so that it is exactly as specified. Step tests are generally more accurate in this respect than ramps, in particular if a short ramp time is chosen.

- **Intuitive interpretation of the data**
  The meaning of the data is easily understood and applied once the appropriate process shear rates or shear stresses are known.

- **Time**
  Because a few user defined shear rates can be chosen and the step time can be fixed to only a few seconds, step tests can be completed quickly in comparison to ramp tests, particularly if a large range of shear rates is important.

- **Simple measurement and simple analysis**
  The measurement is quite simple to execute and the data is straightforward to process.

2.2 Potential problems with the step test

- **Solid fraction size**
  For mineral slurries, often there is a solid fraction, which has particles of considerable size. If this size is close to the size of the measuring gap, then one or more particles may 'bridge' the gap and cause an artificially high shear stress. The problem can be solved by choosing a measurement geometry so that maximum particle size is no more than 1/3 of the gap size (1/10 for concentrated pastes). Sometimes larger particles contribute little to the overall flow behaviour of the material and can be removed without large penalties for the applicability of the measurement.

- **Early warning of problems with technique or measurement**
  Having data for the complete range of shear rates allows the user to investigate the possibility of settling, chaotic flow in the measuring gap and slip at the measurement geometry walls. Data from a step test may not reveal this information readily, especially if only a few data points are taken.

- **Temperature control**
  At high shear rates, shear heating can be an issue. Shear heating is caused by internal frictional heat generated as the lamina of fluid move over each other. When the measuring gap is small this can usually be successfully controlled, but prolonged exposure to high shear rates can still be a problem. To reduce this, the material can be 'rested' between steps to allow it to cool by inserting zero- or low-shear steps between high shear ones. Short step times can also reduce this problem.

- **Settling slurries**
  If a material tends to settle, long test times tend to reduce the likelihood of successful test outcomes. The longer the test takes, the more likely the solid fraction is to have settled out of the measurement space, or at least created a concentration gradient through it. Sometimes it is possible to step from high to low shear rates, rather than the other way around, allowing the material to be kept in suspension longer, and if possible to reduce step times as much as practicable. Alternatively using a modified step test with high shear steps to resuspend materials between descending ‘measurement’ steps can also be successful.

- **Chaotic flow**
  One of the key assumptions for rheological measurements is that the flow in the measuring gap is laminar. Too high shear rates can cause the flow regime to become turbulent and the measurements are unreliable. The onset of chaotic flow can be overcome or delayed by changing the measuring geometry or the measurement gap.
• **Slip**  
Multi-phase systems, like mineral slurries tend to slip at the boundary of the measuring geometry. A major assumption for rheological measurements is that the first layer of material ‘sticks’ to the walls of the measuring geometry. Plate & plate or concentric cylinder geometry walls can be roughened or serrated to reduce or remove the slip phenomenon.

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Sample handling and experimental technique can be crucial for repeatably measuring time dependent (eg thixotropic) materials. The same handling procedure (pouring, mixing, resting, loading into the test equipment etc) and experimental procedure (rest time, ramp time and upper & lower limits) is critical for repeatable measurements, and it must be remembered that for time dependent materials the results are relative only – they depend on the technique used to generate them.

**Rheological Models**

Rheological models are essentially convenient curve fits for typical data sets generated by viscometers, most often to help describe the shape of different types of flow curves (see Figure 1). These models have been shown to be useful in this respect for many different fluids and they are mathematical equations with adjustable parameters, representing as closely as possible the observed experimental behaviour.

**Newtonian Model**

One of the first and most basic of these is a Newtonian model. Newtonian models are characterised by a linear relationship between shear rate and shear stress (i.e. the viscosity is constant), and an intercept of 0.00 Pa on the shear stress axis. This is expressed mathematically as follows:

\[ \tau = \eta \cdot \gamma \]  

(2)

Where the constant of proportionality (the slope of the flow curve) is \( \eta \), the viscosity.

**Ostwald-de-Waele Model**

In cases where the viscosity is not constant, but the material still has a zero intercept on the stress axis, the Ostwald-de-Waele (derived from the mathematical ‘power law’) is used. This model has extra parameters, \( K \) and \( n \) to help describe shear thinning and shear thickening materials as shown in Figure 1.

\[ \tau = \tau_0 + K \cdot \gamma^n \]  

(3)

For shear thinning liquids, \( n<1 \), for shear thickening liquids, \( n>1 \), for Newtonian liquids, \( n=1 \).

**Bingham Model**

In general none but the most dilute systems are Newtonian, and usually in mineral slurries there is a yield stress. This yield stress is seen in the flow curve by a positive intercept on the shear stress axis. Bingham proposed the most basic rheological model to include a yield stress, \( \tau_c \):

\[ \tau_c = \tau_0 + \eta \cdot \gamma \]  

(4)

Unfortunately, although this model can overcome one limitation (existence of a yield stress) of the Newtonian model, it is not always sufficient to say that when the yield stress has been overcome the relationship between shear stress and shear rate is linear. In fact this is usually not the case, and the yield stress estimated in this way is usually significantly overestimated.

**Herschel-Bulkley Model**

Therefore model with a combination of both shear thinning (or, less commonly, shear thickening) and a yield stress is desirable for mineral slurries. The most commonly encountered model in this case is the Herschel-Bulkley model:

\[ \tau = \tau_0 + K \cdot \gamma^n \]  

(5)

Other more complex models also exist, with more parameters to better model complicated flow curves, but to cover them all would be outside the brief of this note. The most commonly used models for describing flow curves mathematically in the minerals industry are those mentioned here. The mathematical models are independent of whether a step test or a sweep was used to generate the data, nor do they depend on whether a CS or CR technique has been used. Clearly, the greater the quantity of data that is available, the better the fit will be and the more accurately the chosen model will predict flow behaviour for a given liquid.
Summary

Table 1 summarises the possibilities for measuring a flow or viscosity curve 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 measurement or 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.

Table 1: Assessment of strengths/weaknesses for each technique

<table>
<thead>
<tr>
<th>Technique:</th>
<th>Ramp</th>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapid</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Easy</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Accurate</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Small sample volume</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Temperature control</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Measuring system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rheometer or viscometer</td>
<td>Both</td>
<td>Both</td>
</tr>
<tr>
<td>Large variety of sensors</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Structural disruption on loading avoidable</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Slip avoidable</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of Participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single operator</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures materials with large particles &amp; agglomerates</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Settling suspension measurements</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Direct determination of yield stress from measurement</td>
<td>Yes – in CS mode</td>
<td>No</td>
</tr>
<tr>
<td>Shear heating reduced</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Detection of slip, turbulence, shear heating etc</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Inertia avoidable</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Results</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intuitively comprehended</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

* Depending on the test, these parameters may be viewed alternatively as either a strength or as a weakness
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- How to Measure Thixotropy (Rheo329)

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- Applications Laboratory and Contract Testing Capabilities
- Statement for Mining Industries
- Technical Literature for Mining Industries

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

## Industry Term: Bingham
**Definition:**
A flow curve exhibiting a linear relationship between shear-rate and shear stress, with a positive intercept on the stress axis. The curve is of the form:

\[ \tau = \tau_0 + \eta \gamma \]

**Governining Properties:**
Measured using a flow curve generated on CS rheometer or a CR viscometer.

**Rheology Solutions Instrument:**
HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

## Industry Term: Capillary Rheometer
**Definition:**
A rheometer which measures flow properties through a capillary.

**Governining Properties:**
The pressure on the liquid and the pressure drop of the liquid through the capillary. The capillary geometry dictates the shear forces experienced by the liquid as it flows.

**Rheology Solutions Instrument:**
HAAKE RheoCap.

## Industry Term: Controlled Rate
**Definition:**
Mode of operation for a rheometer or viscometer. Controls the shear rate imposed on the sample.

**Governining Properties:**
CR mode is usually available using a CS rheometer or a CR viscometer.

**Rheology Solutions Instrument:**
HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

## Industry Term: Controlled Stress
**Definition:**
Mode of operation for a rheometer or viscometer. Controls the shear stress imposed on the sample.

**Governining Properties:**
CS mode is usually available using a CS rheometer but not on a CR viscometer.

**Rheology Solutions Instrument:**
HAAKE RheoStress, HAAKE MARS.

## Industry Term: Creep
**Definition:**
Small deformation flow.

**Governining Properties:**
Measured using a creep curve, in CD or CS mode, using a CS rheometer but usually not on a CR viscometer.

**Rheology Solutions Instrument:**
HAAKE RheoStress, HAAKE MARS.

## Industry Term: Dilatant
**Definition:**
A flow curve exhibiting a shear thickening relationship between shear rate and shear stress, with a zero intercept on the stress axis. The curve is usually of the form:

\[ \tau = K \gamma^n \]

**Governining Properties:**
Measured using a flow curve generated on CS rheometer or a CR viscometer.

**Rheology Solutions Instrument:**
HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.
Industry Term: Flow Curve.
Definition: A flow curve is a plot showing the relationship between shear rate and shear stress.
Governing Properties: It can be measured using a CS rheometer of a CR viscometer.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: Herschel Bulkley.
Definition: A flow curve exhibiting a shear thinning relationship between shear rate and shear stress, with a positive intercept on the stress axis. The curve is of the form:
\[ \tau = \tau_0 + K \gamma^n \]
Governing Properties: Measured using a flow curve generated on CS rheometer or a CR viscometer.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: Newtonian Model.
Definition: A flow curve exhibiting a linear relationship between shear rate and shear stress, with a zero intercept on the stress axis. The curve is of the form:
\[ \tau = \eta \gamma \]
Governing Properties: Measured using a flow curve generated on CS rheometer or a CR viscometer.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: Ostwald-de-Waele.
Definition: A flow curve exhibiting a shear thinning relationship between shear rate and shear stress, with a zero intercept on the stress axis. The curve is of the form:
\[ \tau = K \gamma^n \]
Governing Properties: Measured using a flow curve generated on CS rheometer or a CR viscometer.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: Pseudoplastic.
Definition: A flow curve exhibiting a shear thinning relationship between shear rate and shear stress, with a zero intercept on the stress axis. The curve is of the form:
\[ \tau = K \gamma^n \]
Governing Properties: Measured using a flow curve generated on CS rheometer or a CR viscometer.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

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.
**Viscoelastic.**

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:**
N/A.
Industry Term: Viscometer.
Definition: An instrument for measuring the viscosity of a liquid at specified temperature and atmospheric conditions, by measuring the force required to move one layer over another without turbulence; also referred to as viscometer.
Governing Properties: Viscometers usually have mechanical bearings in their motor and generally operate in rotational mode only.
Rheology Solutions Instrument: HAAKE ViscoTester 550, HAAKE RotoVisco.

Industry Term: Viscosity Curve.
Definition: A viscosity curve is the (usually non-linear) relationship between viscosity and shear rate derived from a flow curve on a CS rheometer or CR viscometer.
Governing Properties: Viscosity is the shear stress divided by the shear rate. These are measured on a CR viscometer or CS rheometer using a flow curve.
Rheology Solutions Instrument: HAAKE ViscoTester VT550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.

Industry Term: Viscosity.
Definition: The resistance to flow of a fluid.
Governing Properties: Viscosity is the shear stress divided by the shear rate. These are measured on a CR viscometer or CS rheometer using a flow curve.
Rheology Solutions Instrument: HAAKE ViscoTester VT550, 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.

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 RheoCap is a capillary rheometer, all of which are HAAKE brand names of Thermo Fisher Scientific (Karlsruhe, Germany) GmbH.
- ViscoScope torsional motion viscometer is a brand name of Marimex Industries Corporation.

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Tim’s Top Tips – Rheology Solutions for the Mining Industries

How To Measure Flow And Viscosity Curves
For Mining Slurries

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

▶ Please provide me more information on the following:
☐ HAAKE VT550 – Controlled Rate Viscometer
☐ HAAKE RotoVisco – Controlled Rate Viscometer
☐ HAAKE RheoStress – Controlled Stress Rheometer
☐ Marimex ViscoScope – In Line Process Viscometer
☐ Rheology Solutions for Mining Industries Kit
☐ Technical Literature for Mining Industries
☐ Training & Seminars (Please specify)
☐ HAAKE Temperature Control Range – Refrigerated Circulators
☐ HAAKE Temperature Control Range – Heating Circulators
☐ HAAKE RheoStress RS600 – Modular Controlled Stress Rheometer
☐ HAAKE MARS – Modular R&D Controlled Stress Rheometer
☐ Contract Testing
☐ Other (Please specify)

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

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

For all your rheology and service needs please contact:
Tel: 03 5368 7477   Fax: 03 5367 6477
Email: info@rheologysolutions.com
Website: www.rheologysolutions.com

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