Application Note: Viscosity Measurement of Newtonians and non-Newtonians

Application

Measuring the viscosities of Newtonians and Non-Newtonians using a VROC™

Test Conditions

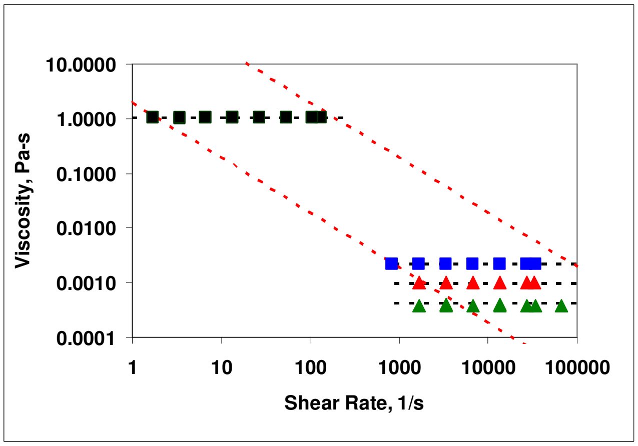
- Test samples: Glycerol (99.5%), Isopropyl alcohol, de-ionized water, 2-butanone, Xanthan gum (0.5wt.%) in water, and Cetylpyridinium chloride / sodium salicylate 100 / 50 mM (3.2 / 0.76 wt%) in 100 mM NaCl solution (0.56 wt%).
- VROC™: B1 type.
- Full-scale pressure of the chip: 35k Pa.
- Flow channel depth: 98.7 µm.
- Temperature: ambient condition, 22.4~22.8 °C.

Measurement Procedure

1) Load the sample into a syringe, and then mount the syringe onto a syringe pump.
2) Using the VSS_RateSweep program, measure the viscosity as a function of shear rate (flow rate). For Non-Newtonians, apply the Weissenberg-Rabinowitsch correction to extract the "true viscosity".
3) Repeat procedure 1, using an appropriate solvent to clean the flow paths after testing.

Newtonians

The viscosity of Newtonians is constant and independent of shear (or flow) rate. Since the viscosity is constant, the VROC™ can be operated near, or at the full-scale limit of the chip, thereby measuring the viscosity with extreme accuracy. Because the VROC™'s accurate reading, it can measure viscosities of Newtonians as low as 0.2 centi-poise. The graph on the top right shows measured viscosities of tested liquids as the shear rate is varied.

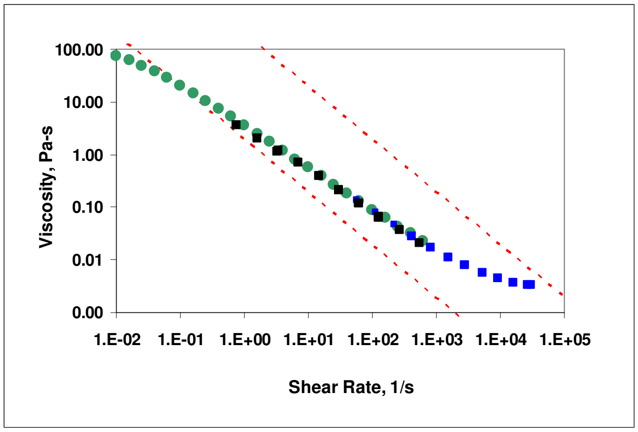


Symbol	Sample description
■ (black)	Glycerol 99.5% ACS
■ (blue)	Isopropyl alcohol
▲ (red)	De-ionized water
▲ (green)	2-Butanone
— — — (red)	Low and high measuring limits of the chip
— — — (black)	Values cited for each liquid at CRC handbook

As anticipated, VROC™ measures constant viscosity liquids irrespective of shear rates for each Newtonian liquid.

Non-Newtonians

Unlike Newtonians, Non-Newtonians typically show a shear rate dependent viscosity. Commercial grade Keltrol Xanthan gum solution from Cp Kelco was tested as a model Non-Newtonian liquid. The liquid is known to be highly elastic and shear thinning (viscosity decreases in a faster rate with shear rate as shown in the graph below).

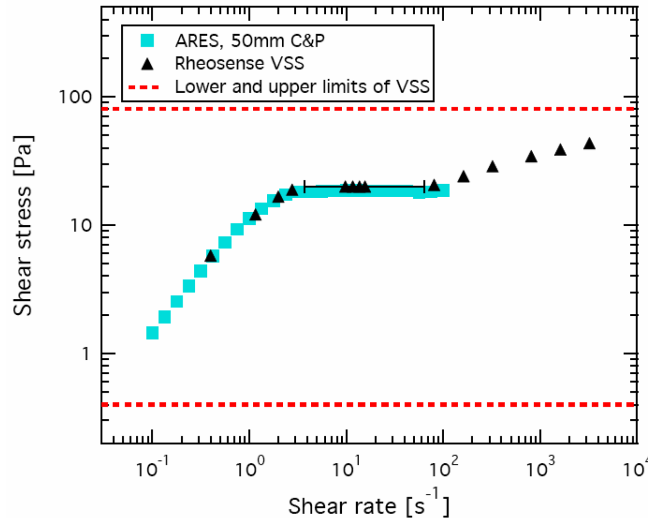


Symbol	Description
●	Rheometer data from the supplier
■	VROC™ with 100 micro-liter syringe
■	VROC™ with 5 ml syringe
——	Low and high measurable limits of the chip

VROC™ measures the viscosities at low shear rates with a 100 ul volume syringe in agreement with the supplier's input values. In addition, VROC™ can measure viscosities at shear rates beyond the rheometer's limits with a 5 ml volume syringe. A macro size rheometer can not measure viscosities at higher shear rates due to the onset of flow instability (ref 1). These instabilities are suppressed to a greater degree in a small scale flow as those in VROC™.

Non-Newtonian – More complex liquids

Flow behavior of Non-Newtonians can often be too complex to be identified without employing sophisticated rheometers and paying careful attention to detail. VROC™ can demonstrate it's ability to identify the very complex behavior of Cetylpyridinium chloride/Sodium Salicylate 100/50 mM (3.2/0.76 wt%) in a 100 mM NaCl solution (0.56 wt%) (ref 2). The liquid shows an unusual plateau in shear stresses versus shear rate curve, as shown in the graph on the top right, which are clearly captured by VROC™.



Ref. 1: Macosko, C. *Rheology: Principles, Measurements and Applications*. Wiley/VCH, Poughkeepsie. NY,1994.

Ref. 2: C. Pipe, N.J. Kim, and McKinley, G. *Microfluidic Rheometery on a Chip*.4th AERC, April 12-14, 2007, Italy, April 2007.