

Application

Measuring the viscosities of Newtonians and non-Newtonians using a Viscometer-on-a-Chip (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%).

Viscometer-on-a-Chip: B1 type

Full scale pressure of the chip: 35k Pa

Flow channel depth: 98.7 μm

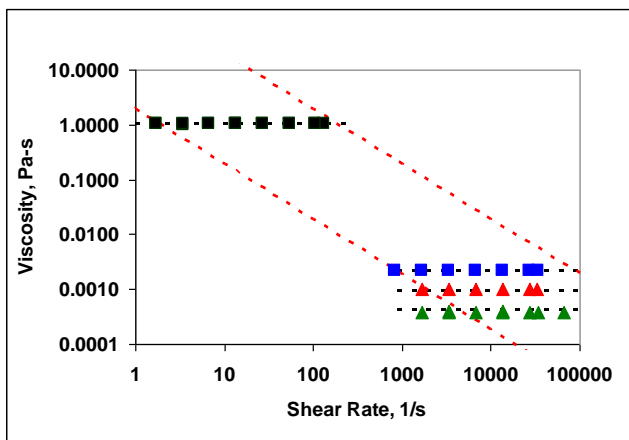
Temperature: ambient condition, 22.4~22.8 °C

Measurement Procedure

- 1) Test sample was loaded into a syringe, which was later mounted onto a syringe pump.
- 2) Using VSS_RateSweep program, viscosity was measured as a function of shear rate (flow rate). For non-Newtonians, Weissberg-Rabinowitsch correction was applied to extract the “true viscosity”.
- 3) Repeat the same procedure 1) using an appropriate solvent to clean the flow paths after testing.

Newtonians

Viscosity of Newtonians is constant independent of shear rate (flow rate). Since viscosity is constant, the VROC can be operated near or at the full scale limit of the chip thereby measuring the viscosity with highest accuracy. Therefore, VROC can measure viscosities of various Newtonians as low as 0.2 centi-poise. The graph below shows measured viscosities of tested liquids as the shear rate is varied.

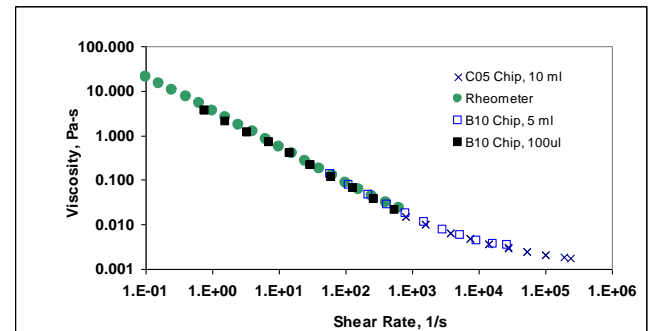


Symbol	Sample description
■	Glycerol 99.5% ACS from Aldrich
■	Isopropyl alcohol from Aldrich
▲	Deionized water
▲	2-Butanone from a hardware store
---	Low and high measurable limits of the chip
---	Values cited for each liquid at CRC handbook

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

Non-Newtonians

Unlike Newtonians, non-Newtonians show typically 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).



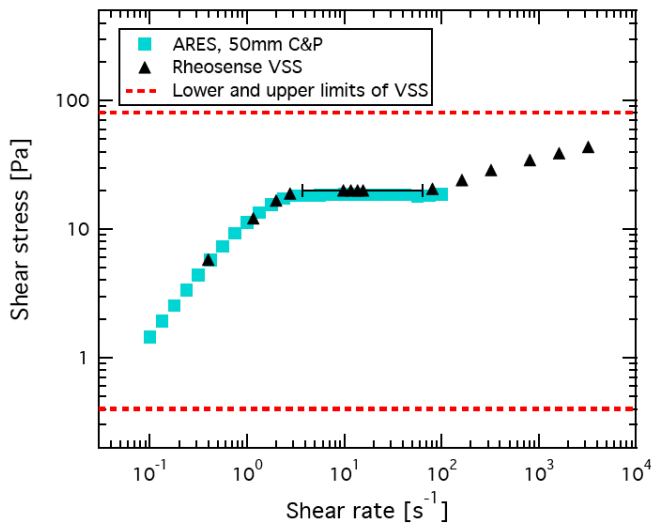
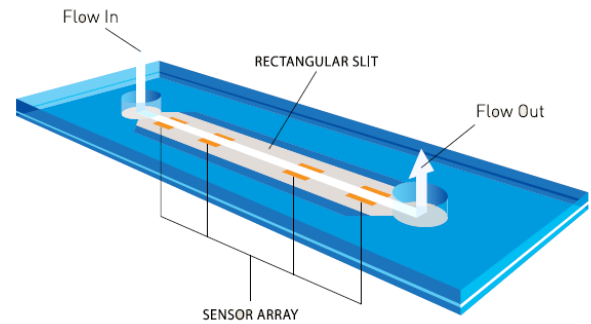
Symbol	Description
●	Rheometer data from the supplier
■	B10 chip with 100 microliter syringe
■	B10 chip with 5 ml syringe
×	C05 chip with 10 ml syringe

VROC measures the viscosities at low shear rates with 100 μl volume syringe in good agreement with the supplier’s values. In addition VROC measures viscosities at much higher shear rates beyond the rheometer limits with 5 ml volume syringe. Macro size rheometer can not measure viscosities at higher shear rates due to onset of flow instability (ref). 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 be often too complex to be identified without employing sophisticated rheometers and careful observation. VROC has been demonstrated that it can identify the very complex behavior of Cetylpyridinium chloride / sodium salicylate 100 / 50 mM (3.2 / 0.76 wt%) in 100 mM NaCl solution (0.56 wt%) (ref 2). The liquid shows an unusual plateau in shear stresses vs. shear rate curve as shown in the graph below, which are clearly captured by VROC. In addition, VROC can explore the regions beyond the limits of the rheometer.



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

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

