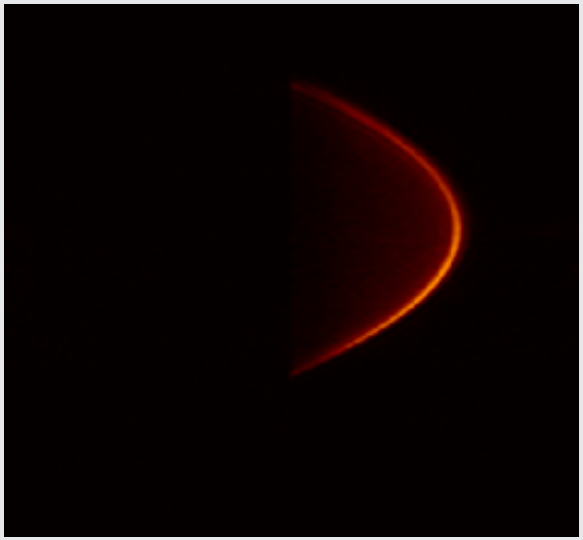
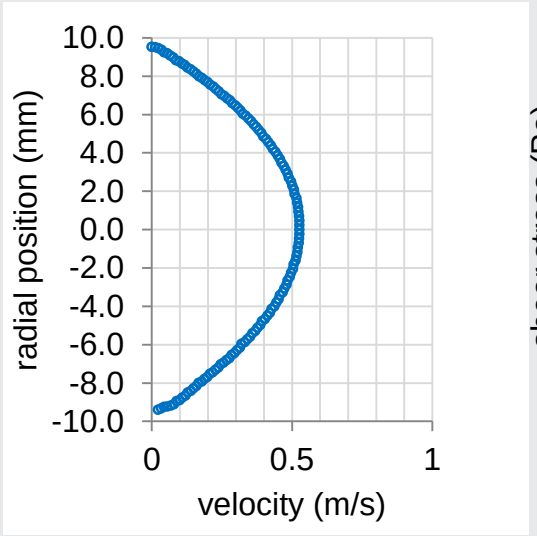
Aspect Imaging
Online MRI-based Rheometer (FlowScan™)

Based on principles of capillary viscometry

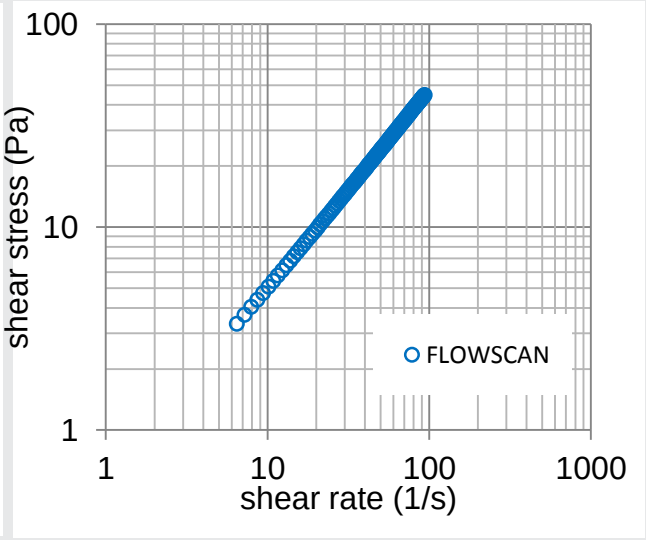
- Assumptions:
  - flow is laminar
  - flow is steady state
  - fluid properties are constant
  - no slip at walls
  - axial velocity component only



FlowScan velocity image

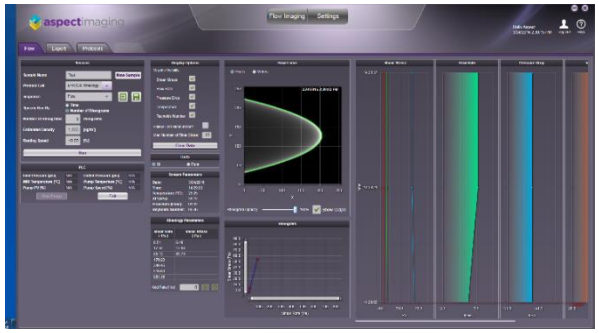


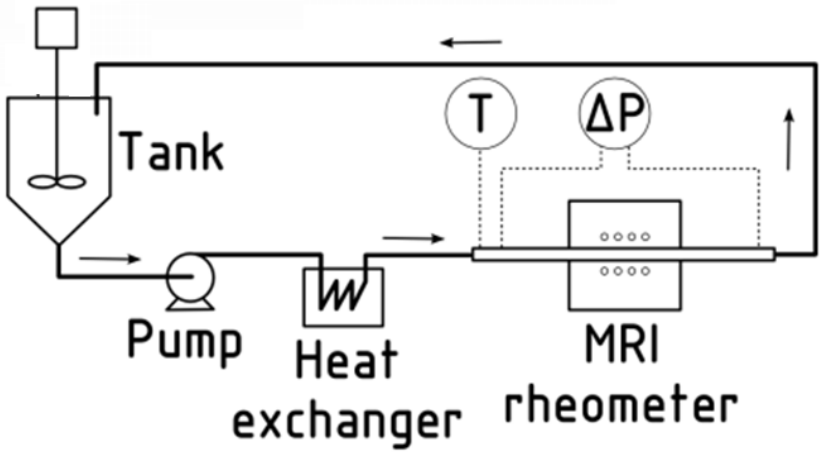
Velocity profile

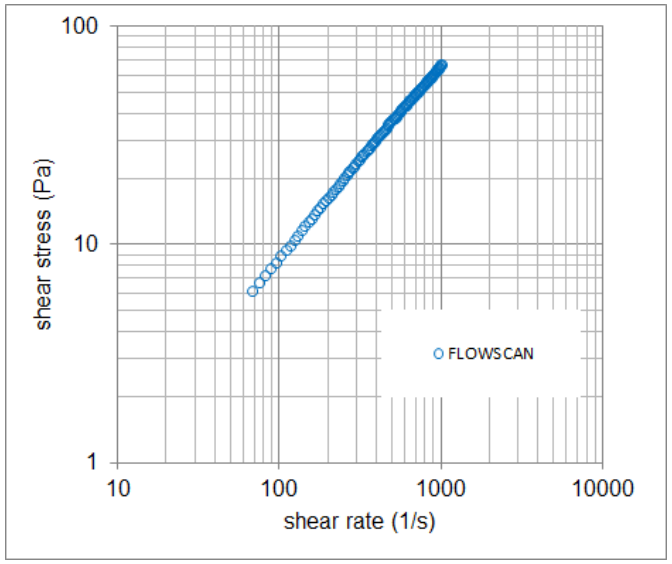


Rheogram

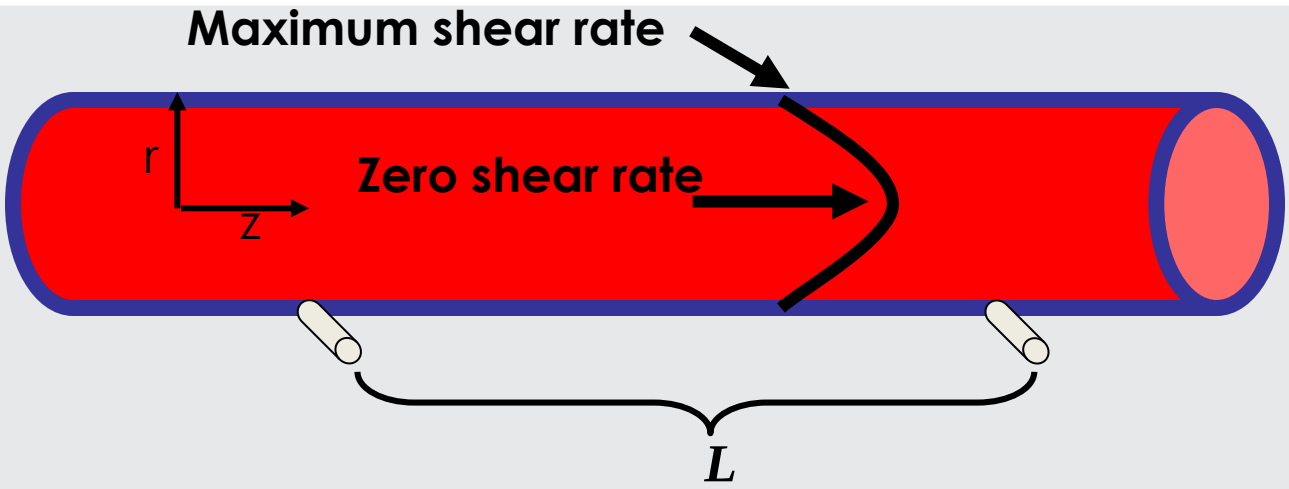
FlowScan™ System

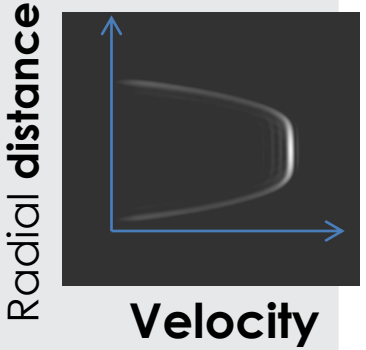






Viscosity as a function of shear rate





Velocity profile

Pressure difference

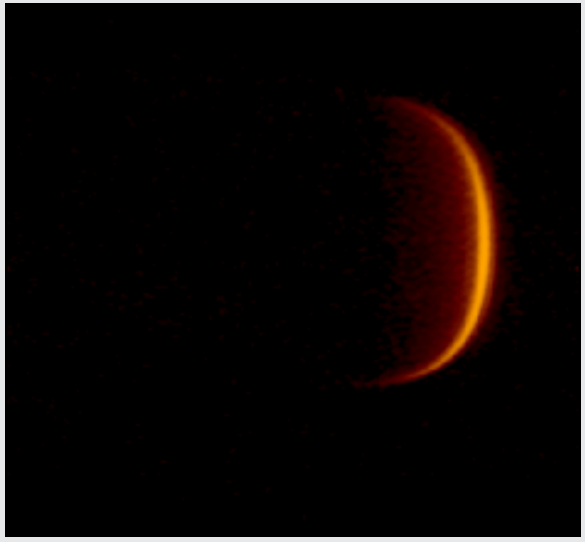
SHEAR RATE

SHEAR STRESS

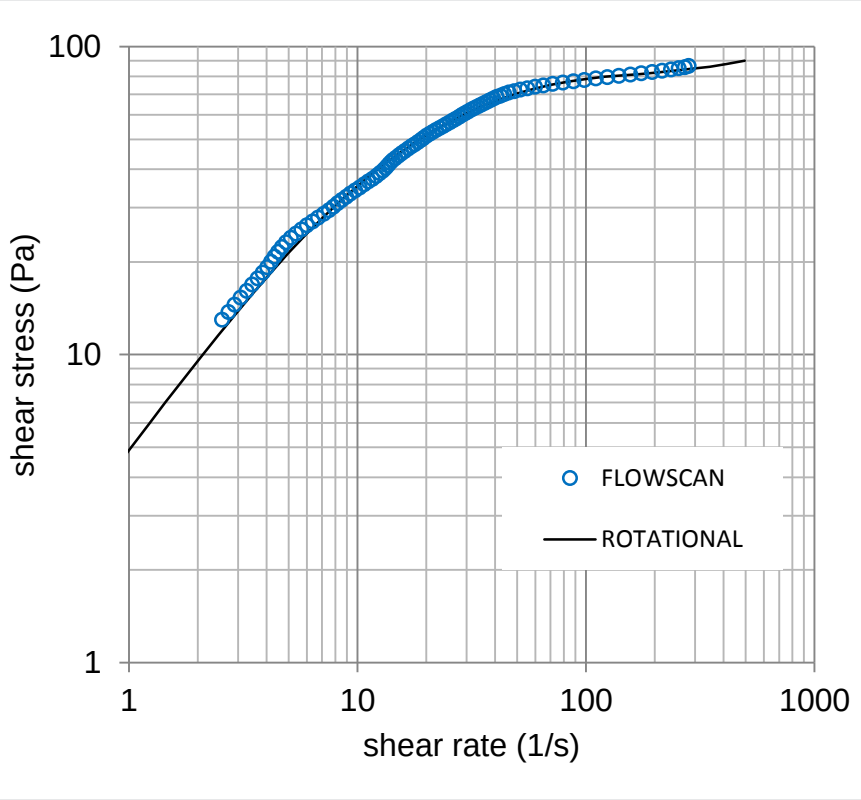
VISCOSITY

$$\dot{\gamma}(r) = \left| \frac{dV_z}{dr} \right| \quad + \quad \sigma(r) = -\frac{(\Delta P)}{2L} r \quad \Rightarrow \quad \frac{\sigma}{\dot{\gamma}}$$

Real-Time Rheology of Personal Care Products: **Liquid Hand Soap**

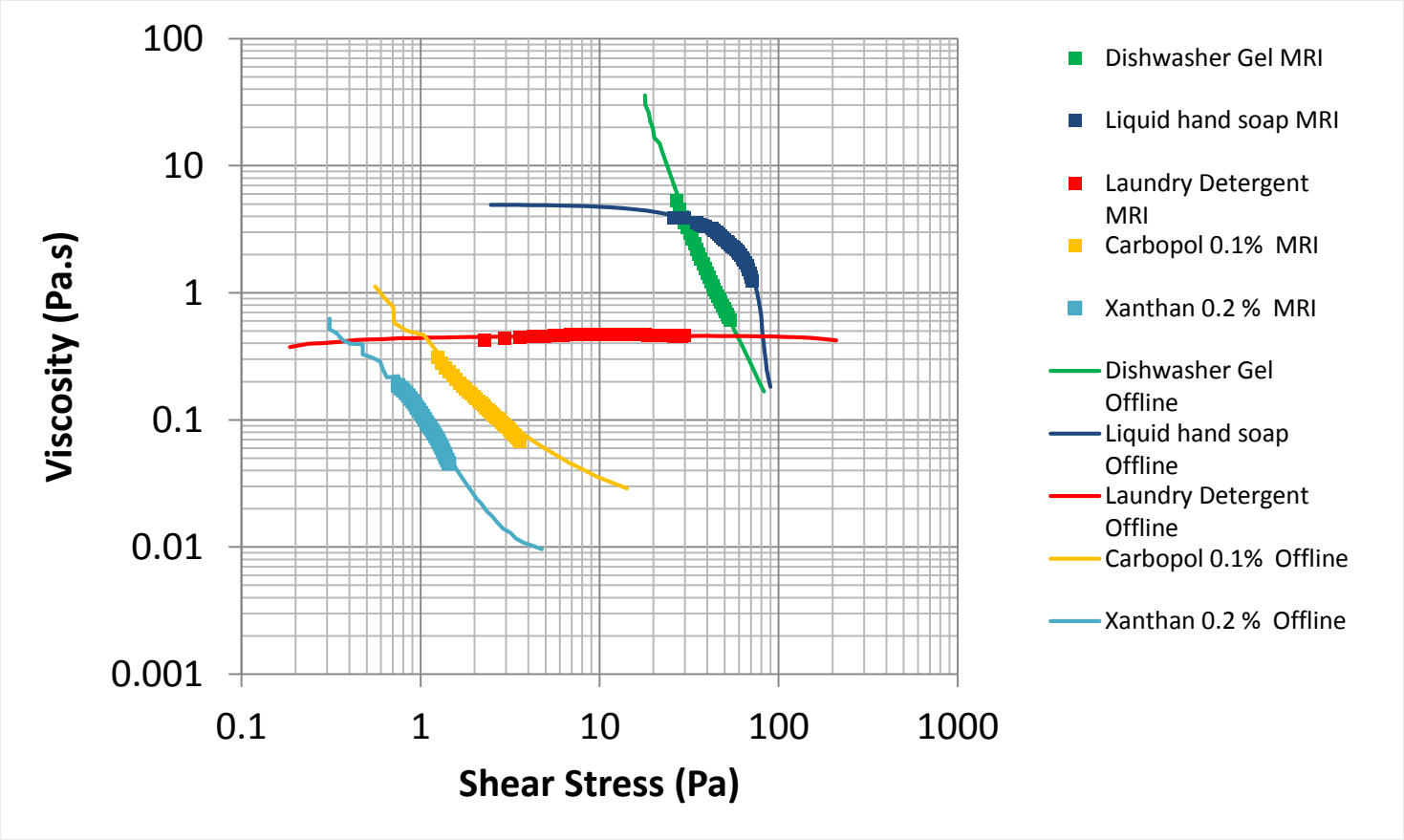


FlowScan-derived velocity image



rheogram

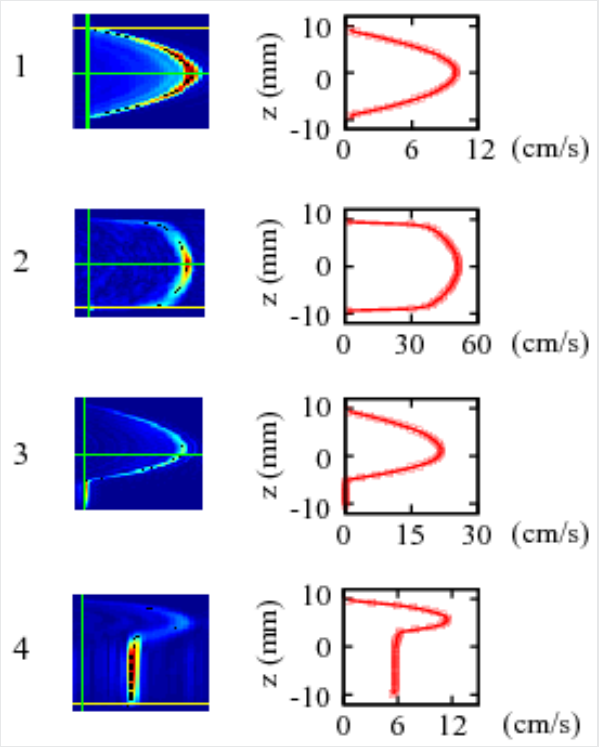
Overview of Rheological Properties of Personal Care Products:

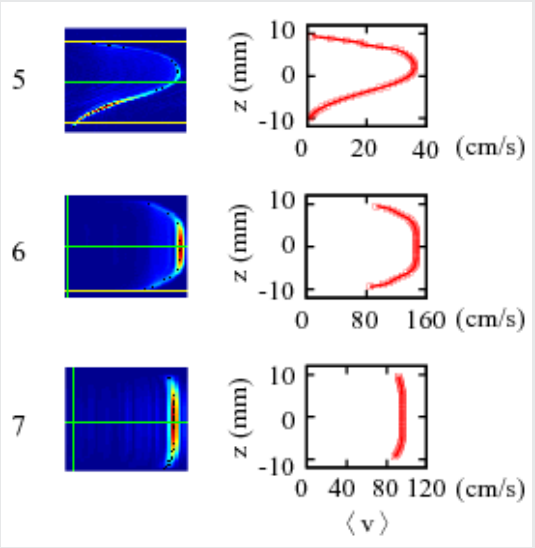


Online FlowScan (MRI) data vs. offline rheometer

The capability of “seeing” the flow

Tozzi et al. Acta mechanica, 224 (10) (2013)



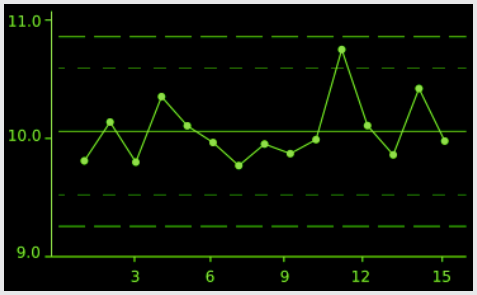


- Wall slip (6,7)
- Settling particles (3,4,5)
- Yield stress (6,7)
- Turbulence(2)

Early detection of changes in flow conditions

Challenges in processing non-Newtonian materials

- Need to fine-tune quality in real-time
  - Finding optimum of product performance vs. cost
- Need to maximize throughput
  - Automation of measurement and the production process
- A shift towards larger batch sizes
  - Need for early detection of defects
  - Minimize wastage and product rejects



Rheograms in quality and process control:
Measurement of product performance

Two methods of rheological measurement:

1. OFFLINE MEASUREMENT/ TEST
(via conventional rotational rheometer)

- Versatile (many tests possible)
- Slow, laborious
- Sample handling issues
- Moving parts require maintenance
- Issues with particulates

Rheograms in quality and process control

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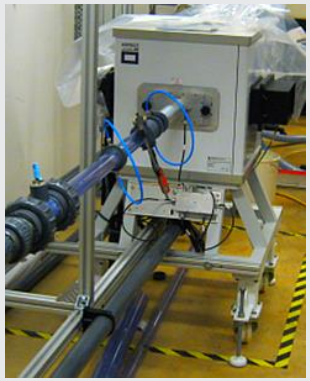
2. REAL-TIME, IN-LINE RHEOLOGY
(via MRI or **M**agnetic **R**esonance **I**maging)

- Measures flow curves plus other properties not detected by conventional instruments
- Fast (real-time)
- Automated, non-invasive, maintenance-free
- Avoids issues of particulates (gap-effect and settling)



FlowScan™

Real-time non-intrusive liquid measurement platform : Rheology applied to oil-based drilling muds

Michael McCarthy

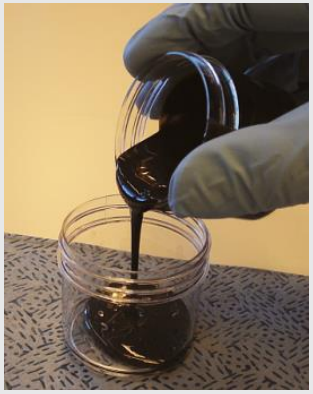
aspectai

FlowScan™: Real Time Drilling Fluids Rheology Data is Important

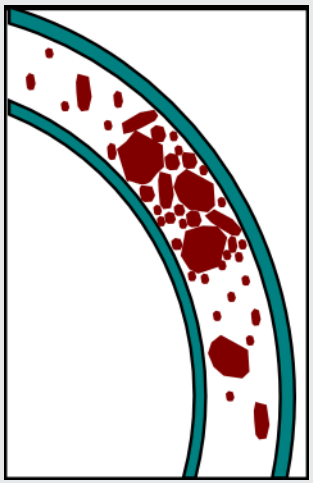
- **Rheology Data**
  - Real Time Hydraulics Modeling
  - Plastic Viscosity & Yield Point Determination
  - Hole Cleaning Efficiency
  - Dilution Economics
  - Annular Flow Dynamics
  - Pressure Loss Calculations
  - Surge & Swab Calculations

Challenges for Measurement of Drilling Muds

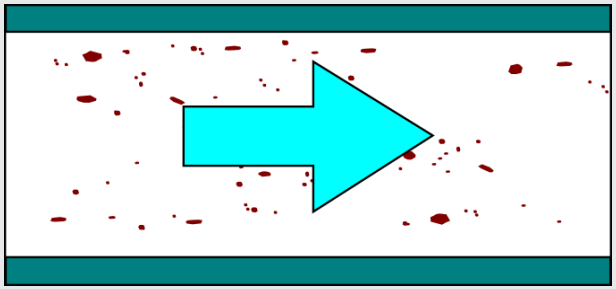
- Fluid is **extremely challenging**
  - Multiphase, multicomponent, opaque fluid
  - Often with large suspended solids



- **Available instruments** are not adequate
  - Utilize small gaps that **plug regularly**
  - Require an operator, can be **slow**
  - Off-line techniques measure only small amounts of mud and can easily lead to **sampling errors**

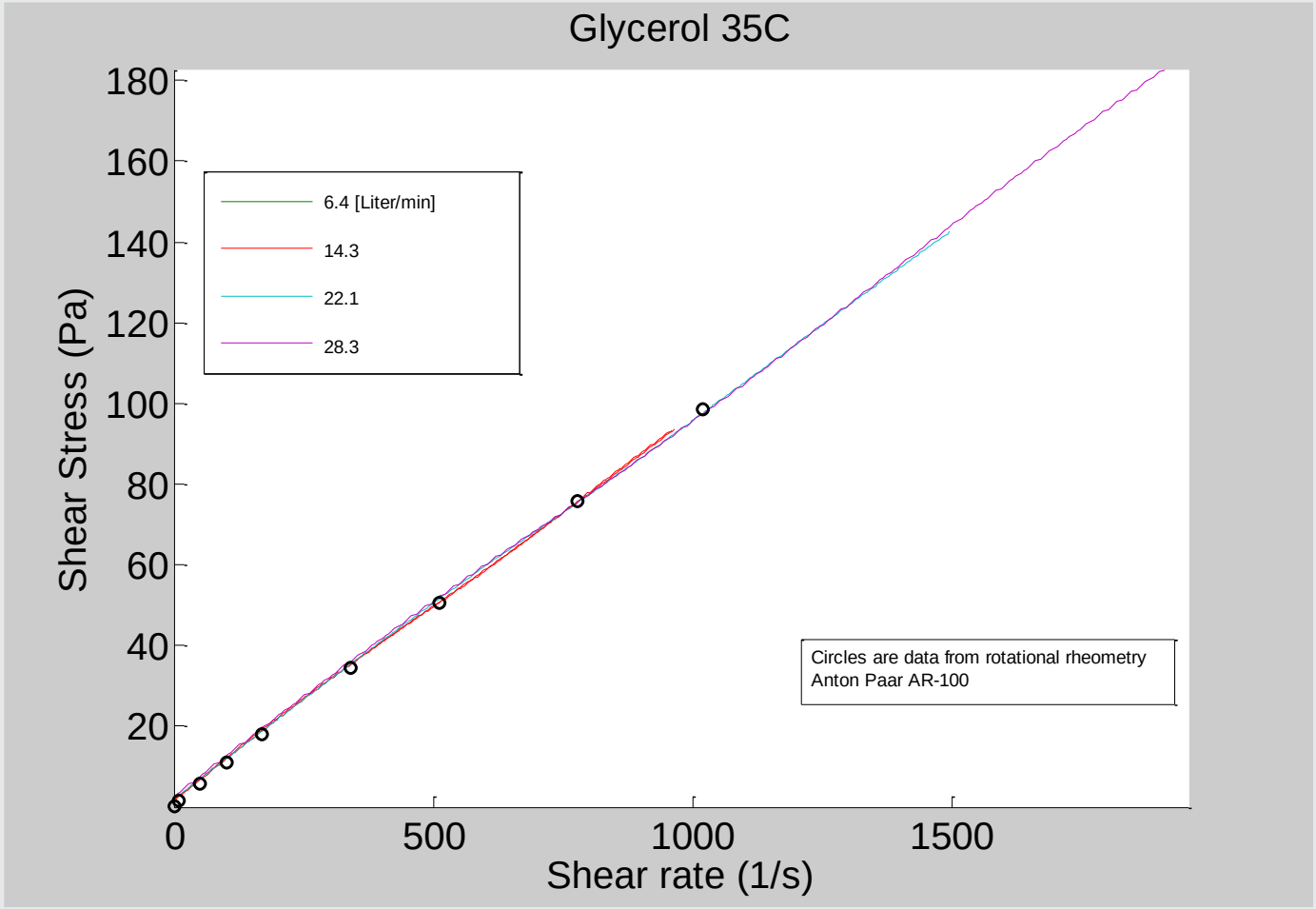


How does FlowScan™ Overcome these Challenges?

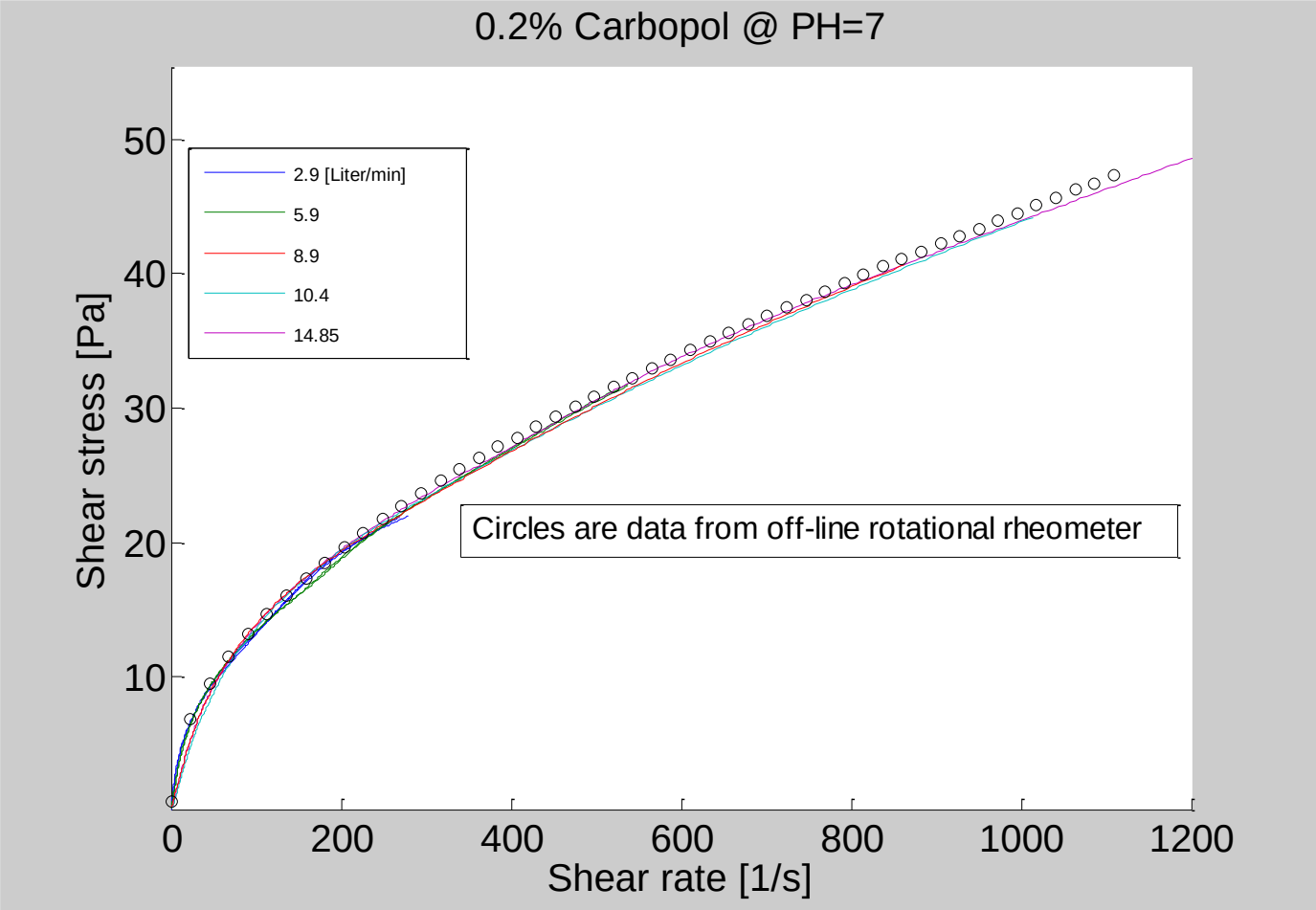


- **No obstructions to flow**
  ➔the entire pipe cross section is open
- **Many gallons of material analyzed for each flow curve**
  ➔ minimize sampling errors, high data integrity
- **Measurement is automated and runs continuously**
  ➔ Updated about every 5 minutes
- **Multi-parameter measurements from a single instrument**

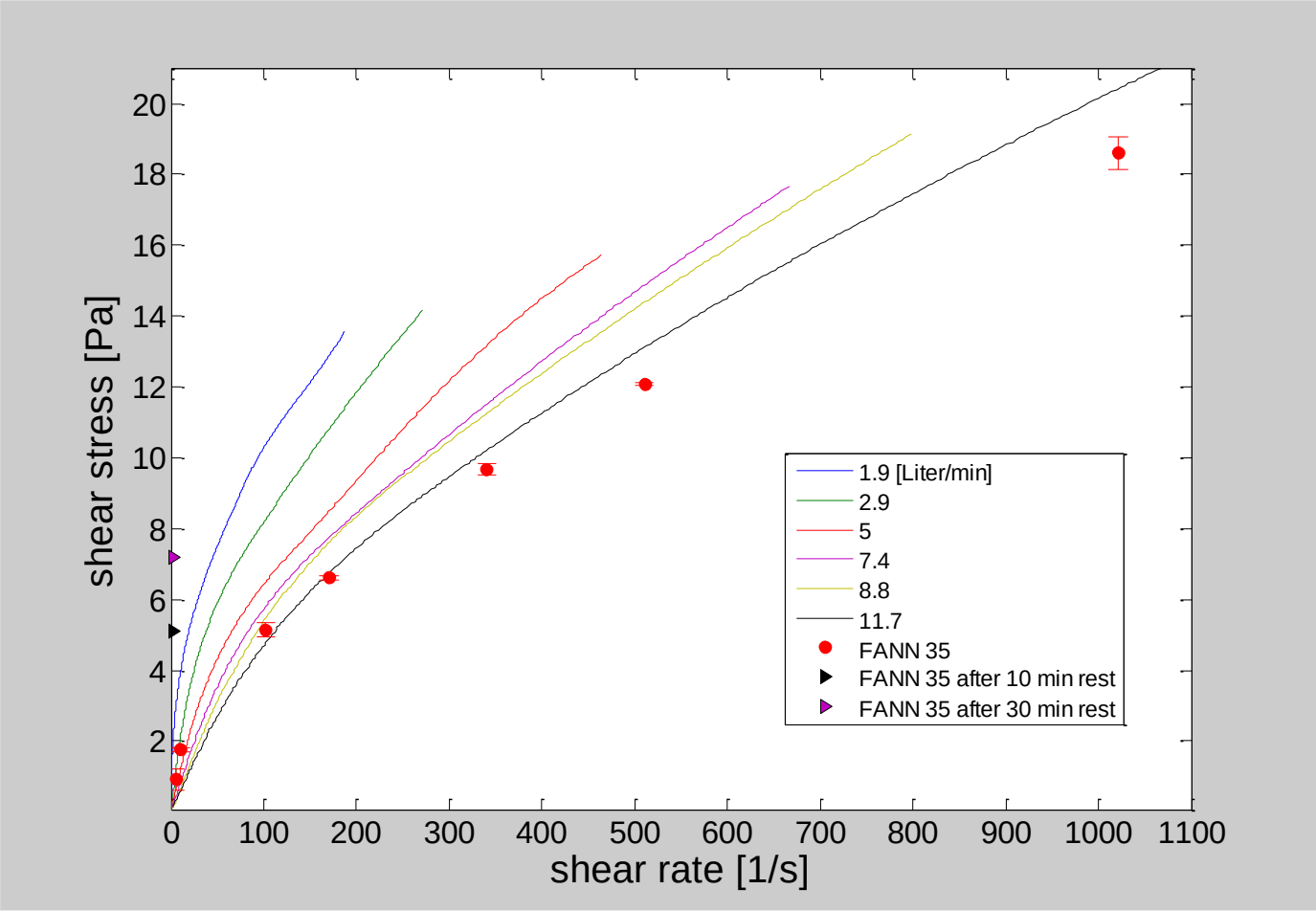
Newtonian Fluid Results



Non-Newtonian Fluid : Carbopol



Drilling Mud



MRI Advantages (traditional rheometer cannot achieve the following)

- Directly measures flow field no assumptions required
- Speed of data acquisition
- Same instrument from laboratory to process line
- Capable of additional measurements including
  - Composition
  - Droplet size distribution
  - Uniformity (degree of mixing)

Thank You

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