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

\[ \dot{\gamma}(r) = \left| \frac{dV_z}{dr} \right| \]

\[ \sigma(r) = -\frac{(\Delta P)}{2L} r \]

\[ \frac{\sigma}{\dot{\gamma}} \]

Velocity profile
Pressure difference
Radial distance
Velocity
SHEAR RATE
SHEAR STRESS
VISCOSITY
Zero shear rate
Maximum shear rate
Velocity as a function of shear rate
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


- 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

2 methods of rheological measurement:

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2. REAL-TIME, IN-LINE RHEOLOGY (via MRI or Magnetic Resonance Imaging)
   - 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
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

Shear rate (1/s) vs. Shear Stress (Pa) for Glycerol 35C.

Circles are data from rotational rheometry using Anton Paar AR-100.

Glycerol 35C

- 6.4 [Liter/min]
- 14.3
- 22.1
- 28.3
Non-Newtonian Fluid: Carbopol

0.2% Carbopol @ PH=7

Shear rate [1/s]
Shear stress [Pa]

Circles are data from off-line rotational rheometer
Drilling Mud

The graph shows the relationship between shear stress [Pa] and shear rate [1/s] for different flow rates and rest times.

- **1.9 [Liter/min]**
- **2.9**
- **5**
- **7.4**
- **8.8**
- **11.7**

**Legend:**
- Red circle: FANN 35
- Black triangle: FANN 35 after 10 min rest
- Purple diamond: FANN 35 after 30 min rest
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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