Dynamic Shear Rheometers (DSRs) & Rheological Applications

Georges Mturi, CSIR

Test & Measurement Conference, 16-18 September 2019
Overview

- Rheology
- Rheometry
- Dynamic Shear Rheometers
- SASOR
Rheology

- Rheology is literally Greek for “flow science”

- The technical definition is the science of deformation and flow.

- Rheology is a branch of physics and physical chemistry.
Rheology
Rheology

• In practice, rheology is used as a problem solving tool to answer the questions:
  – Will the material **pour out**?
  – Will it be **stable**?
  – Will it **spray**?
  – Will it **settle**?
  – Will it **crack**?
  – Will it **deform**?

Different industries…
…different questions?
Rheology

• Testing
  – Typically, testing can either be in terms of **flow** (viscosity) and/or **deformation** (oscillation).
    • Flow – mimics processing conditions
    • Deformation – quantifies viscoelasticity (performance)
Rheometry

• Measuring technology used to determine rheological data:
  – Instruments – flow cups, capillary viscometers, rotational/oscillatory viscometers/rheometers, etc.
  – Measuring systems
  – Tests
  – Analysis methods
Dynamic Shear Rheometer

• Measures fundamental material rheological properties.
Dynamic Shear Rheometer

- Measures material rheology

Polymers
Coatings
Food
Cosmetics
Pharmaceuticals
Petrochemicals
Bitumen
Automotive
Adhesives/sealants
Building materials
Mining
...etc.
Dynamic Shear Rheometer

- Providing the science of material performance.

Stale
Fresh
Dunked
Dynamic Shear Rheometer

• Providing the science of material performance.

Source: Malvern
Dynamic Shear Rheometer

The two bitumen are of the same penetration grade

- Harder binder
  - Stiff enough to carry traffic
  - Soft/flexible enough not to crack

- Softer binder
  - Fluid enough for the mixture to remain workable during compaction
  - Fluid enough to coat the aggregate
  - Viscous enough not to run off the aggregate during mixing or transport

Temperature

Hardness / Stiffness

25°C
Dynamic Shear Rheometer

Why pay more?
Dynamic Shear Rheometer

- DSR is not necessarily for replacing traditional tests that work
- DSR is an effective tool to give notably better solutions
  - Instead of waiting days to simulate the drain-out properties of an emulsion, why not do a 30 minute thixotropic test?
Dynamic Shear Rheometer

...6 hours later ... still stuck in traffic...

Does damage occur at a single loading rate?
**Dynamic Shear Rheometer**

<table>
<thead>
<tr>
<th>Energy ratio</th>
<th>Frequency (Hz)</th>
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<tbody>
<tr>
<td>(A-E1 Elvaloy mod.)</td>
<td>50/70pen EXP</td>
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<tr>
<td>50/70pen EXP</td>
<td>35/50pen</td>
</tr>
<tr>
<td>1.00E-01</td>
<td>1.00E+00</td>
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<tr>
<td>0.10</td>
<td>1.00</td>
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\[
W_{\text{dis},1/4} = -\left(0.5\varepsilon_0\sigma_0\cos\delta\right) - \left(0.25\varepsilon_0\sigma_0\sin\delta\right) + \left(0.5\sigma_0\varepsilon_0\cos\delta\right) - \left(0.5\sigma_0\varepsilon_0\cos\delta\right)
\]

\[
W_{\text{st},1/4} = 0.5\pi \tan \delta
\]

\[
\gamma_{\text{unr}} = \frac{100\sigma_0}{G^*} \left(1 - \frac{1}{\tan \delta \sin \delta}\right)
\]

\[
J_{\text{rec}} = \frac{G'}{G''}^2
\]

\[
S(t) = \frac{1}{D(t)} \approx \frac{3G^*(\omega)}{[1 + 0.2\sin(2\delta)]}
\]

\[
J' = \cos \delta / G^*
\]

Source: CAPSA 2015
Dynamic Shear Rheometer

- Rheology effect from chemical interactions

Source: Akzo Nobel
SASOR

• SASOR was officially launched at the 1st Rheology Conference in September 2006 and was inaugurated as part of European Society of Rheology since 2010.

• Aim is to promote the science within Southern Africa by organising regular meetings
  – academia and industry and international experts in the field
  – demonstrate the advantages of rheology as a tool to improve industrial processes and product performance.
SASOR 2010

CHALLENGES IN RHEOLOGICAL CHARACTERISATION OF ROAD BITUMENS

S.E. Zoorob, G.A.J. Mturi, J. O'Connell
SASOR 2016
SASOR 2018: 7th RHEOLOGY CONFERENCE and SHORT COURSE
25-28 September 2018,
STIAS (Stellenbosch Institute for Advanced Study)
Wallenberg Research Centre in Stellenbosch, South Africa.

www.sasor.co.za
<table>
<thead>
<tr>
<th>Year</th>
<th>Course Title</th>
<th>Instructor(s)</th>
</tr>
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<tbody>
<tr>
<td>2006</td>
<td>Rheology and engineering applications of multi-component materials</td>
<td>Prof Alex Malkin, Prof Raj Chhabra</td>
</tr>
<tr>
<td>2007</td>
<td>Rheology of food emulsions</td>
<td>Dr Peter Fischer</td>
</tr>
<tr>
<td>2008</td>
<td>Rheology of polymers</td>
<td>Prof Raj Chhabra</td>
</tr>
<tr>
<td>2009</td>
<td>Rheology of multi-component materials</td>
<td>Prof Alex Malkin, Prof Irina Masalova</td>
</tr>
<tr>
<td>2011</td>
<td>Rheology of polymers and polymer processing</td>
<td>Prof Jeffrey Giacomin, Prof Gerry Fuller, Dr Massimo Baiardo, Dr Loredana Pop, Dr Samir Mukhopadhyay</td>
</tr>
<tr>
<td>2013</td>
<td>Application to Polymers, Emulsions and Suspensions: Product formulation – Rheology – Processing</td>
<td>Prof Jan Mewis, Mr Peter Goosen</td>
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Cape Peninsula University of Technology
in association with SASOR is presenting a:
CEMENT AND CONCRETE RHEOLOGY SHORT COURSE

18-19 November 2015
Location: Plastic Federation, 18 Gazelle Ave, Corporate Park South, Midrand
We look forward to see you at our next event

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