C. Street, G. Frazee, C. Fredrickson, I. Harvey, T.H. Killilea

October 2014

Rheology as a Tool for Sealant Formulation – Part I

Acknowledgements: K. Kirkwood, R. Simon, K. Porter
Speaker Introduction

• Carrie Street – Materials Engineer II, Engineered Polymer Solutions
  – BS in Chemical Engineering (University of Oklahoma 2007)
  – PhD in Chemical Engineering (University of Delaware 2012)
  – Engineered Polymer Solutions (2012 – Present)
    • Lead physical sciences research team
    • Fundamental understanding of physical and thermal behavior of polymers and formulated systems
Agenda

• Sealant Formulation Strategy

• Rheology
  – Background and Key Terms

• Quantitative Measurements
  – Target Parameters

• Conclusions
Water Based Latex Sealants: Start to Finish

Iterative process based on experience/trial and error
Standard Tests for Wet Sealants

- Dispensing (ASTM C1183)
- Slump (ASTM D2202)
- Tooling – Sliding
- Tooling – Tapping

Slump: www.pgtgage.com/adhesionsealant.html
Sealants: Start to Finish

Formulation ➞ Application ➞ Final Properties

Rheology

- Quantify physical properties
- Use target parameters to *Accelerate Product Development*
Rheology for Physical Properties

\[ G' = \text{elastic character} \quad G'' = \text{liquid character} \]

Examples:
- rubber
- sealants
- water

Apply Force \((\gamma, \text{strain})\)
Rheology Procedure to Simulate Tooling

adapted from Mezger, “The Rheology Handbook,” European Coatings Tech Files
Relating Rheology to Standard Tests: Pressing Finger/Tool

- Elastic character: Increasing force
- Liquid character: Improving tooling-tapping

$G'(\text{Pa}) \uparrow G''(\text{Pa})$

$t (s)$

(increasing Force)$

$eps$
Relating Rheology to Standard Tests: Tooling

- **liquid character**
- **elastic character**

Graph showing:
- $G'$ (Pa) and $G''$ (Pa) vs. $t_s$ (s)
- Decrease in $G'$ and $G''$ to ease tooling
Relating Rheology to Standard Tests: Removing Finger/Tool

- Liquid character
- Elastic character

Graph showing:
- $G'$ (Pa) vs. $G''$ (Pa)
- $t$ (s)

Improve tooling-sliding (decreasing Force →)
Design of Experiments Formulation Variables

- Pigment to Binder
- Surfactant
- Volatile Oil

Two Thickener Levels
(low and high)

understand multiple factors
Target Parameters for Product Development

- Increase surfactant
- Increase thickener
- Increase volatile oil
- Decrease P:B

Precision formulation for optimum application

- Liquid character
- Elastic character
Advantage of Rheology: Tooling-Tapping

- Rheology provides resolution and directionality

Rheology provides resolution and directionality
Advantage of Rheology: Tooling-Sliding

- Rheology provides resolution and directionality

Rheological Measure vs. Standard Rating

- Volatile Oil Level
- Thickener Level

Rheology provides resolution and directionality
Conclusions: Rheology for Sealant Formulation – Part I

- Quantitative physical properties as target parameters for product development

- Accelerated product development
Future Work

Formulation ➔ Application ➔ Final Properties

Rheology

- Quantify final performance properties
- Use target parameters to **Accelerate Product Development**