Effective Foam Control in Metalworking Coolants & Industrial Fluids

Advantages of 3D Organo-Modified Siloxane Defoamers

Mary Taylor
Münzing
KSTLE October 2, 2008
Presentation Overview

- What is Foam
- Why Control is necessary
- Mechanisms of Foam
  - Stabilization
  - De-Stabilization
- Defoamer Composition
- Choosing and Testing Defoamers
- Advantages of 3D Organo-Modified Siloxane Defoamers
Simply Stated

Foam is a (stable) dispersion of gas phase in a liquid system
Why is foam a problem?

The specifics are different for every industry

- **Use/Applications defects**
  - Metalworking – insufficient lubrication
  - PCB- Insufficient cleaning
  - Wood Preservatives- insufficient penetration into lumber

- **Production**
  - Insufficient fill of containers
  - Reduced speed
  - Vacuum and pump problems

- **Safety**
  - Tank overflow
Why is foam a problem?

- Reduction of Machine Speeds and Feeds
- Increased Down Times
- Loss of Hydraulic Pressures
- Reduced Plant Hygiene and Safety
Foam Stabilization

pure water

surfactant system
Foam Stabilization

- Electrostatic Repulsion
- Surface Viscosity
- Gibbs Elasticity
- Marangoni Effect
Foam Stabilization

-When the cell wall of foam drains, the two air-liquid interfaces approach.
-Electrostatic repulsion from the adsorbed and oriented surfactant prevents further drainage and cell rupture is prevented.
Foam Stabilization

- Stretching of the cell wall causes a surfactant deficiency
- Unequal surface tensions
- Migration of surfactant to achieve equal surface tension restores or heals the cell wall (Marangoni effect)
Defoaming mechanisms

• Drainage due to gravity
• Defoamer Spreading
• Hydrophobic Dewetting
Foam (De)Stabilization

Thinner Films

DRAINAGE DUE TO GRAVITY

GAS DIFFUSION THROUGH THE LAMELLAE

\[ \Delta P = 4\gamma \left( \frac{1}{R_1} + \frac{1}{R_2} \right) \]

DRAINAGE TO PLATEAU BORDERS
**Defoamer Spreading**

Spreading from antifoam particle drags underlying liquid

air

---

water

---

air

film thins in vicinity of particle

---


Hydrophobic Dewetting

Defoamers break the cell wall:

• bridging-dewetting
• bridging-stretching
• pin-effect

Note:
The defoaming active (whether a liquid droplet or solid particle) must have the correct size.
What is a defoamer?

- Defoamers must enter the cell wall and spread

- Defoamer droplets need to have the right size to rupture the cell wall

- Defoamers need to be *incompatible* with the system

- However, too incompatible will lead to defects in the final application

- Thus: defoamers must have the right balance between *(in)compatibility* and efficiency
## Defoamer Components

<table>
<thead>
<tr>
<th>Carriers</th>
<th>Transport of active ingredients to the surface, spread on the surface and prevent formation of a surfactant’s layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrophobic ingredients</td>
<td>Absorb surfactant molecules and enter into lamellae double layer</td>
</tr>
<tr>
<td>Emulsifiers</td>
<td>Adjust emulsifiability (compatibility) of defoamers in the system</td>
</tr>
<tr>
<td></td>
<td>Eases spreading of the defoamer at the surface</td>
</tr>
<tr>
<td>Others</td>
<td>Adjust of viscosity, prevent separation, fouling,</td>
</tr>
</tbody>
</table>
# Defoamer composition

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carriers</strong></td>
<td>Oils, water, solvents, modified Polyethersiloxanes, Oleo-ABCs</td>
<td>75 – 90%</td>
</tr>
<tr>
<td><strong>Hydrophobic ingredients</strong></td>
<td>Waxes, hydrophobic silica, metal soaps, paraffines, amides, polyalkylene glycols, polyurethanes</td>
<td>5 – 10%</td>
</tr>
<tr>
<td><strong>Emulsifiers</strong></td>
<td>Surfactants</td>
<td>0 – 5%</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>Biocides, thickeners, protective colloids</td>
<td>0 – 20%</td>
</tr>
</tbody>
</table>
The key is the “Active particle”

Different active particles have different persistence strengths

- 3D Compounds: stable droplet
- SPE: semi-stable droplet
- Glycol emulsified: semi-stable droplet
- Silica: very hard particle
- Stearate: Hard particle
- Wax: soft particle
- Oil emulsified: unstable droplet

For some particles, the process may “destroy” the particle or break it into smaller particles that are too small to effectively defoam.

- Note, the 3D siloxane compound is the **ONLY** truly stable particle

- When effective, 3D compound is most effective.
Silicone, siloxane, SPE, …

**SILOXANE** (Si + O + CH3 + …)

**Silicone**
- “Silicone Fluid”
- “Silicone Oil”
- “PDMS”
- Polydimethylsiloxane
- very specific chemical structure:

\[
(CH_3)_3Si-O-Si-O-Si(CH_3)_3
\]
- the “bad actor”
- problems with washability
- very hydrophobic:
  - a good defoamer
  - but leads to defects

**SPE**
(Siloxane Polyether)
- a silicone backbone with polyether chains either (a) grafted on side or (b) incorporated into backbone
- PEG/PPG ratio in polyether will determine compatibility (including with water)
- the water affinity portions (i.e. the polyether portions) make this material “washable”

**3D Organo Modified Siloxane**
- a 3-dimensional crosslink siloxane
- presence of other components increases compatibility and washability
- very stable, very good persistence
3D Organo-Modified Siloxane

Performance Advantages

✓ High Efficiency
  ▪ Highly Surface Active
✓ High Persistence
  ▪ High Surface Area
✓ High washability
✓ Excellent Spreading & Dispersability
✓ High Compatibility
Defoamer Selection & Testing
Defoamer Selection & testing

- Compatibility is the key to long term persistence
- Balance between incompatibility & efficiency
  - Too compatible the carrier acts like a surfactant or oil
- Defoamer selection is primarily influenced by the chemistry of the Metalworking Fluid not the machining process
- Other influencers are water hardness & filtration
- Manufacturing process
Testing Procedures

INOCULATION OF CONCENTRATE
Compatibility Evaluations

- Oiling Out of Defoamer

Rating 1-5 (1=Best No Surface Defects)
Compatibility Evaluations

Precipitation In Concentrate

Rating 1-5
(1=Best No PPT)
Compatibility Evaluations

Rating 1-5 (1=Best No Haze)

Loss Of Clarity
Defoamer Performance
Handshake Test
Defoamer Performance
Burrell Wrist Action Shaker
Defoamer Performance
Peristaltic Pump Recirculation
Recirculation with Filtration
CNOMO Tester
Defoamer Performance
Defoamer Performance

**ASTM D-3519**

*(Blender Test)*
Defoamer Performance
Filtration Recirculation
Defoamer Performance
ASTM D892
Compatibility vs. Efficiency

![Graph showing compatibility vs. efficiency with data points for air content and surface defects.](image-url)
Predicting defoamer behavior in any single metalworking fluid is difficult because of the complex interaction of multiple components.

There is no substitute for laboratory testing!

Why not let us work for you
Münzing 3D Organo-modified Siloxane Defomoodmers Formulated for:

- Compatibility
- High Efficiency (Speed to Knock Down)
- High Persistence (Time of control)
- Dispersability & Washability
Value of 3D Organo-Modified Siloxanes & Technical Support

- Study A – Customer Submitted 5 Systems
  - Custom formulated 3D Organo-modified siloxane defoamer improved compatibility & efficiency over current competitive product
    - Customer consolidated from 3 defoamers to 1

- Study B-Post Add Recirculation Test
  - Persistence-Up to 2 X more persistent over PDMS or Oil/Wax Emulsion
  - Efficiency-Up to 4 X reduction in additions over PDMS or Oil/Wax Emulsion

- Study C-Post Add Recirculation Test
  - Competitive SPE vs. 3D Siloxane comparison
    - 3 Hours Recirculation at Time Zero → 16.5% Improvement
    - 1 Minute off system recovery → 86% improvement
    - 5 Minutes off system recovery → 86% improvement

- Study D-Post Add Recirculation Test
  - Competitive SPE vs. 3D Siloxane comparison
    - With 100 ppm water & filtration Minimum 40% improvement
Study A- Product Consolidation

Compatibility Rating 5 Different Metalworking Fluids

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Rating 1-15 (lowest value best)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi 206</td>
<td>3</td>
</tr>
<tr>
<td>Semi C804</td>
<td>7</td>
</tr>
<tr>
<td>Semi M203</td>
<td>6</td>
</tr>
<tr>
<td>Semi 3030</td>
<td>5</td>
</tr>
<tr>
<td>Semi 500</td>
<td>5</td>
</tr>
</tbody>
</table>

Competitive

3D Siloxane
Study A - Product Consolidation

Hand Shake Data, Time to Zero

<table>
<thead>
<tr>
<th>Product</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi 206</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi C804</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi M203</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi 3030</td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi 500</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Competitive**
- **3D Siloxane**
Study A - Product Consolidation

Burrell Wrist Action Shaker, Time to Zero

<table>
<thead>
<tr>
<th>Product</th>
<th>Semi 206</th>
<th>Semi C804</th>
<th>Semi M203</th>
<th>Semi 3030</th>
<th>Semi 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (s)</td>
<td>60</td>
<td>10</td>
<td>30</td>
<td>20</td>
<td>60</td>
</tr>
</tbody>
</table>

Legend:
- Blue: Competitive
- Green: 3D Siloxane
Study A- Product Consolidation

Peristaltic Recirculation Semi 206

Foam Height, ml

Time, minutes

Pump Turned Off

Competitive control

3D Siloxane
Study A- Product Consolidation

Peristaltic Recirculation Semi C840

Time, minutes

Foam Height, mls

Competitive control
3D Siloxane

Pump Turned Off
Study A - Product Consolidation

Peristaltic Recirculation Semi M203

Foam Height, mls

Time, minutes

- Competitive control
- 3D Siloxane

Pump Turned Off
Study A- Product Consolidation

Peristaltic Recirculation Semi 3030

Foam Height, mls

Pump
Turned Off

Time, minutes

Competitive control
3D Siloxane
Study A - Product Consolidation

Peristaltic Recirculation Semi 500

Foam Height, ml

Time, minutes

Competitive control  3D Siloxane

Pump Turned Off
Study B- Post Add Recirculation

Post Add Recirculation Tank Side Defoaming Study
Foam Height Equivalent Additions

High Efficiency

Average Foam Height

3D Organo Modified Siloxane  SPE Competitor  Oil Wax Defoamer  10% Silicone emulsion
Study B - Post Add Recirculation

High Persistence

Post Add Recirculation Tank Side Defoaming Study
Foam Height 1 minute after pump shut down

- 3D Organo Modified Siloxane
- SPE Competitor
- Oil Wax Defoamer
- 10% Silicone emulsion
Study C - Post Add Recirculation

Average Foam Height 18 different systems
After 3 Hours time 0  1 minute pump off  5 minutes pump off

- 3D Siloxane Defaomer
- SPE Competitive
Study D - Post Add Recirculation

Foam Height after pump shutdown

Foam Height, ml

- DI
- 100ppm
- DI+Filter
- 100ppm Filter

SPE Competitor
3D Siloxane
Committed to Technical Support and Innovation

- Chemical Technologies
- Oil and Fat Chemicals-
  - Sulfonation
  - Esterification
  - Amidation
  - Phosphation
  - Chlorination
- Polymer Chemicals
  - Polymerisation
  - Polycondensation
  - Polyaddition
- Compounding/Formulating