Wire Drawing Soap Lubrication: Principles And Factors Affecting Selection

CONDAT CORPORATION
Wire Products
Rod: The Starting Material
The tool: Wire Drawing machines

Dry Draw Bench

Courtesy of Lamnea Bruk, Ljusfallshammar, Sweden
Powder: The lubricant
Heat Generation In Wire Drawing

Heat $\propto 85\%$ generated

+ 15\%

(FRICTIONAL HEAT)
Wire Drawing Die Temperature Profile

Watercooled Area

Lubricant

Wire

120°C

60°C 90°C

65°C

70°C

80°C 87°C

70°C 15°C 30°C

60°C 150°C 200°C 250°C 300°C 336°C
# Heat Generation As A Function Of Lubricant

<table>
<thead>
<tr>
<th>DIE#</th>
<th>OBSERVED BLOCK TEMP. °C W/ LUBE(S) A</th>
<th>OBSERVED BLOCK TEMP. °C W/ LUBE(S) B</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIPPER</td>
<td>100</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>93</td>
</tr>
<tr>
<td>3</td>
<td>126</td>
<td>107</td>
</tr>
<tr>
<td>4</td>
<td>OBSTRUCTED VIEW</td>
<td>OBSTRUCTED VIEW</td>
</tr>
<tr>
<td>5</td>
<td>145</td>
<td>118</td>
</tr>
<tr>
<td>6</td>
<td>135</td>
<td>119</td>
</tr>
<tr>
<td>7</td>
<td>124</td>
<td>116</td>
</tr>
<tr>
<td>DEAD BLOCK</td>
<td>175</td>
<td>143</td>
</tr>
</tbody>
</table>
Pre-coats

Carrier Coatings

Provides “carrier” sites for the wire drawing lubricant.

Improves the wire drawing lubricants qualities

• Viscosity
• Hydrodynamic Lubrication
• Boundary Lubrication
Zinc Phosphate With Reactive Stearate

- Zinc Phosphate
- Reacted Lubricant
- Non-Reacted Lubricant
- Base Metal
Non-Responsive Pre-coats

Formulated

- Neutralizes excess pickling & zinc phosphate acid
- Contains wetting agents to improve coating uniformity
- Provides viscosity modifiers for the wire drawing lubricant
- Provides crystalline sites for additional dry drawing lubricant pickup
- Provides a physical barrier between work and tooling
- Imparts corrosion protection
Non-Reactive Pre-coats

Borax

- Neutralizes excess pickling acid
- Creates crystalline sites for additional dry drawing lubricant pickup
- Provides viscosity modifiers for the dry drawing lubricant
- Provides a physical barrier between work and tooling
- Hygroscopic
Non-Reactive Pre-coats

**Lime**

- Neutralizes excess pickling acid
- Creates an amorphous dry-in-place coating to aid in dry drawing lubricant pickup
- Provides viscosity modifiers for the dry drawing lubricant
- Provides a physical barrier between work and tooling
- Non-hygrosopic
- Imparts corrosion protection
Dry Drawing Lubricant Components

- Lubricant Base
- Viscosity Modifiers
  - Increase viscosity and softening point
  - Increase hydrodynamic lubrication
- Extreme Pressure Additives
  - Increase boundary lubrication
- Miscellaneous
  - Coloration (identification)
  - Thermal stability enhancement
  - Corrosion inhibition
Dry Drawing Lubricant Components

• Primary Component
  • Fatty acid soaps

• Viscosity Modifiers
  • Soda ash, lime, borax, talc, clays, waxes, etc.

• Extreme Pressure Additives
  • Sulfur, chlorine, phosphates, graphite & MoS$_2$

• Miscellaneous Additives
  • Dyes, antioxidants, corrosion inhibitors
Principles Of Lubrication

Lubrication Is Achieved From Two (2) Mechanisms:

1. Hydrodynamic Lubrication

2. Boundary Lubrication
Principles Of Lubrication

1. Hydrodynamic Lubrication

   - Referred to as “full film lubrication”
   - Complete separation of moving components under load conditions
   - Minimizes friction and eliminates wear

Hydrodynamic Lubrication
Hydrodynamic Lubrication

* Extreme Magnification for Demonstrative Purposes
Hydrodynamic Lubrication

Ways to Improve Hydrodynamic Lubrication:

- Increase the amount of lubricant entering the die.
  - Use mechanical devices i.e., pressure dies and applicators to apply more lubricant
- Increase the viscosity at the lubricant’s softening point.
Pressure Dies

CONVENTIONAL

PARAMOUNT SYSTEM

PRESSURE DIE ON ROD BREAKDOWN – TYPICALLY 0.020 ABOVE ROD SIZE
PRESSURE DIE INTERMEDIATE WIRE – TYPICALLY 0.010 ABOVE WIRE SIZE
Lubricant Applicators

Courtesy of Wire Lab Company, Cleveland, OH
Principles Of Lubrication

2. **Boundary lubrication**
   - Required when the lubricant film is not thick enough to separate the two surfaces in relative motion to each other.
   - The friction is controlled by the lubricant’s chemical properties rather than its viscosity.
   - The lubricant reacts with the wire surface to create a material that is softer than either the die or wire substrate.
     - The softer surface deforms more easily, protecting the die and wire surfaces from wear.

Boundary Lubrication

REACTED FILM SURFACE DEFORMS READILY
Boundary Lubrication

* Extreme Magnification for Demonstrative Purposes
Boundary Lubrication

• Inadequate boundary lubrication results in metal to metal contact leading to increased die wear and wire breaks
• Boundary lubrication becomes significant during:
  • Slow drawing speeds
  • Constant stopping / starting of machines
  • Poor rod or wire surface condition
• EP additives are used to promote boundary lubrication
Dry Soap Ripper Box Lubrication

Provides Approximately 85% Of The Total Lubricant Residual On The Finish Wire

• Intermediate lubricant boxes slow the depletion rate of the lubricant coating
Dry Soap Ripper Box Lubrication

Coated 0.250” Low Carbon Rod Drafting 6 Holes To 0.128”

• Example 1: Soap A in ripper & box 2 / Soap B in box 3,4,5, dead block coiler
  • Coating weight 354 → 170 mg / ft²

• Example 2: Soap A in ripper box / Soap B in box 2,3,4,5, dead block coiler
  • Coating weight 354 → 332 mg / ft²
Dry Soap For Wire Drawing

1. NORMAL POWDER BEHAVIOR
2. LUBRICANT PULVERIZES – FLOWS INTO THE DIE
3. LUBRICANT TRANSFORMS INTO A PLASTIC LIKE STATE
4. LUBRICANT FLOWS BASED ON ITS VISCOSITY
Dry Soap Softening
Point Definition

The temperature range at which the lubricant soap transforms from a rigid or solid state to a viscous, elasticized state when a light force is applied to the lubricant particles.

- Depending on the chemistry used, soaps with softening points in the range of 110 - 260°C are formed.
Dry Soap Softening
Point Definition

![Graph showing the dimension change (%)](graph.png)
Temperature Effects On Powdered Lubricants

Temperatures Too High
Softening Point Too Low
Temperature Effects On Powdered Lubricants

Temperatures Too Low
Softening Point Too High
Dry Soap Classification

Titer? Richness / Leanness? Solubility?

- High titer, rich, soluble soap
- Low titer, lean, insoluble soap
Dry Soap Classification

Dry Wire Drawing Soaps Are Classified By Their Solubility In Water

1. SOLUBLE
   FATTY ACID + CAUSTIC SODA (LYE) \( \Rightarrow \) SODIUM SOAP + H2O

2. INSOLUBLE
   FATTY ACID + LIME \( \Rightarrow \) CALCIUM SOAP + H2O
Dry Soap Solubility Effect On Softening Point

![Graph showing the effect of solubility on softening point]

- Dimension Change (%) vs Temperature (°C)
  - Sodium Soap
  - Calcium Soap

Vincent Marrel – Mexico City - September 2007
Dry Soap Classification

Dry Soaps Are Classified By The Amount Of Fatty Acids Present

Lean - Low In Fat Content <50%

Rich - High In Fat Content >50%

Lean Soap
30% Fatty Acid
70% Additive

Rich Soap
70% Fatty Acid
30% Additive
Dry Soap Classification

Viscosity Modifiers

Choice of thickener depends on application and end product use

Dry Soap Classification
Viscosity Modifiers

EFFECT OF TEMPERATURE ON VISCOSITY

LUBRICANT WITH VISCOSITY MODIFIERS

LUBRICANT WITHOUT VISCOSITY MODIFIERS
Dry Soap Fat Content Effect On Softening Point

![Graph showing the effect of dry soap fat content on softening point. The graph plots dimension change (%) against temperature (°C). Two lines represent different calcium levels: rich calcium and lean calcium. The rich calcium line shows a sharper drop in dimension change at a lower temperature compared to the lean calcium line.](image-url)
Dry Soap Classification

Dry Soaps Are Classified By The Titer Of The Fatty Acid

- The titer is a measurement related to the melting point of the fatty acid and correlates with the amount of unsaturation and molecular weight distribution

(Saturated)  
- Stearic Acid  
  \( \text{TITER}^\circ \text{C} \)  
  52 – 60  
  HIGH

(Unsaturated)  
- Tallow Fatty Acid  
  \( \text{TITER}^\circ \text{C} \)  
  38 – 44  
  LOW
Dry Soap Titer Effect On Softening Point

![Graph showing the effect of dry soap titer on softening point](image_url)
Residual Weight Vs. Lubricant Type

TEMPERATURE = CONSTANT
Dry Soap Box

- Rod or Wire
- Lubricant
- Cooling
- Drawing Die
- Wire
Factors Affecting Wire Drawing Dry Lubricant Selection

- Composition of the metal to be drawn
- Surface condition of rod and wire
  - Bare metal
  - Coated metal
  - Pre-coat chemistry
- Drawing speed
- Drafting practices
- Die design
- Machine design and constraints
- Down stream use of wire
## Effect Of Residual Film On Die Life And Wire Quality

<table>
<thead>
<tr>
<th>More residual film or better die life</th>
<th>Less residual film or cleaner and brighter surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply heavier Precoat residuals</td>
<td>Apply lighter Precoat residual</td>
</tr>
<tr>
<td>Use leaner (more filler – less fatty acid) lubricant</td>
<td>Use richer lubricant</td>
</tr>
<tr>
<td>Use higher titer soaps (higher melting point FA)</td>
<td>Use low titer soap</td>
</tr>
<tr>
<td>Use EP additives</td>
<td>No moly or sulfur to be used</td>
</tr>
<tr>
<td>Use straight calcium based lubricants</td>
<td>Use partially soluble or soluble soaps</td>
</tr>
</tbody>
</table>
## Lubricant Variables Affecting Residual Film Thickness

### VARIABLES

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>RESIDUAL FILM THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Fat</td>
<td>30</td>
</tr>
<tr>
<td>Titer of Fatty Acid °C</td>
<td>60</td>
</tr>
<tr>
<td>% Thickener</td>
<td>70</td>
</tr>
<tr>
<td>EP Additives</td>
<td>Present</td>
</tr>
<tr>
<td>Soap Type</td>
<td>Calcium</td>
</tr>
<tr>
<td>Grind Size</td>
<td>Fine</td>
</tr>
<tr>
<td></td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
</tr>
<tr>
<td></td>
<td>Sodium</td>
</tr>
<tr>
<td></td>
<td>Coarse</td>
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### External Factors Affecting Residual Film Thickness

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>RESIDUAL FILM THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rod Surface</td>
<td></td>
</tr>
<tr>
<td>Rough</td>
<td>Smooth</td>
</tr>
<tr>
<td>Borax</td>
<td>200 g / l (27 oz / gal)</td>
</tr>
<tr>
<td>Lime</td>
<td>12% Triple Dip</td>
</tr>
<tr>
<td>Phosphate</td>
<td>21 g / m² (2000 mg / ft²)</td>
</tr>
<tr>
<td>Temp. of Wire</td>
<td>70°C</td>
</tr>
<tr>
<td>Drawing Speed</td>
<td>90 mpm (300 fpm)</td>
</tr>
</tbody>
</table>
## External Factors Affecting Residual Film Thickness

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>RESIDUAL FILM THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die Box (Pressure Dies)</td>
<td>All Boxes   Ripper Only No Boxes</td>
</tr>
<tr>
<td>Mechanical (Applicator)</td>
<td>All Boxes   Ripper Only No Boxes</td>
</tr>
<tr>
<td>Dies Included Angle</td>
<td>8° 10° 12° 14° 16° 18° 20° 22° 24°</td>
</tr>
<tr>
<td>Bearing Length</td>
<td>20% 80%</td>
</tr>
</tbody>
</table>