Advantages and Disadvantages of Low VOC Vegetable Based Metalworking Fluids

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Outline

• Metalworking Types
• Potential Areas for Use
• Advantages and Disadvantages
• Summary
Metalworking Fluids – Rule 1144

Are:

• Metal Removal Fluids  
  Coolants, cutting oils
• Metal Protecting Fluids  
  Rust inhibitors
• Metal Forming Fluids  
  Stamping, drawing, forging
• Metal Treating Fluids  
  Quench oils

Are Not:

• Metal Cleaning Fluids  
  Parts washing soaps, detergents
Natural Vegetable Oils - Manufacturing

- Canola, Rapeseed
- Soybean
- Sunflower
- Mostly triglycerides
Triglycerides

Glycerol

Three Fatty Acids
Mineral Oil / Petroleum Oil

- No fatty acids
- No glycerol
- Alkanes, cycloalkanes, and various aromatic hydrocarbons
- Contain nitrogen, oxygen, and sulfur, and trace amounts of metals such as iron, nickel, copper and vanadium

- Lubricating oil = 16 carbon atoms
- Paraffin wax = 25 carbon atoms
- Asphalt = 35++ carbon atoms
Structures are Different

• Vegetable
• Mineral

Therefore performance should be different

• AND IT IS – Each has advantages and disadvantages over each other
Vegetable oil applications

Metalworking
- Metal removal fluids – emulsions, straight oils
- Metal protecting - Low VOC Rust Protectors
- Metal forming – wire drawing, stamping

Other
- Conventional and Fire resistant hydraulic oils
- Gear oils
- Way oils
- Spindle oils
Volatile Organic Compounds

VOC expressed as grams / liter
Per ASTM E1868-10

<table>
<thead>
<tr>
<th>Viscosity Grade cSt @ 40 Degrees C</th>
<th>Paraffinic Oil</th>
<th>Naphthenic Oil</th>
<th>Vegetable Oil - Canola</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4</td>
<td>400</td>
<td>718</td>
<td>NA</td>
</tr>
<tr>
<td>9.6</td>
<td>50</td>
<td>130</td>
<td>NA</td>
</tr>
<tr>
<td>20.5</td>
<td>10</td>
<td>64</td>
<td>NA</td>
</tr>
<tr>
<td>39.0</td>
<td>&lt; 1*</td>
<td>5*</td>
<td>&lt; 1**</td>
</tr>
</tbody>
</table>

* Blended, two base stocks
** Food grade
Lubricity

- Determined by many standard lubricity tests
- Mineral oil = good
- Vegetable oils = better

**Note:** Without additive vegetable oils will generally outperform mineral oil in standard lubricity tests

**Reference**
- Pin and V block
- 4 ball
- Tap torque
- Hydraulic pump/wear tests, such as ASTM D2882 and ASTM D2271
Pin and V Block

- V blocks are clamped around the spinning pin and pressure is increased until failure.
Four Ball

- One ball spins on top of three under pressure to scar the surface of the three.
Tapping Torque

• Measures the amount of torque required to thread a standardized part.
Hydraulic Pump/Wear Tests

- ASTM D-2882 – V104C pump test
Flash Point

- Mineral Oil = 300°F – 400°F (typical 390°F)
- Canola Oil = 620°F - 625°F
- Soybean = 605°F - 615°F
- Method ASTM D92
Biodegradability

Biodegradation is a process of chemical breakdown or transformation of a substance caused by micro-organisms (bacteria, fungi) or their enzymes.

- Mineral Oil  = Considered to be slow to biodegrade
- Canola, Soy  = Considered readily biodegradable

- Reference: OECD 301 B (Organization for Economic Cooperation and Development)
  ASTM D-5864
  CEC EC-L-33-A-94 (Coordinating European Council)
Biodegradable – both good and bad

• Triglyceride – Breaks down into free fatty acids

• Fatty acids + Calcium + oil + alkali = grease
  – Especially problematic in wastewater treatment using Acid Alum treatment

• Can be so thick that it can be unpumpable

• Grease has no reclaimable potential!
Aquatic Toxicity

- Daphnia
- Fat head minnow
  - LC50 > 100 mg/L – “Practically Non-toxic”
  - LC50 > 1,000 mg/L – “Relatively Harmless”

- Note: Additive make or break toxic properties of fluids
Comment on Additives

Same for Mineral and Vegetable Oils

Aquatic Toxicity

Additive Percent by Weight
Oil and Grease Measurement

- EPA method 1664 and Standard Methods 5520B,F are used to determine oil and grease and hydrocarbons in wastewater – (hexane extraction, silica gel)

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Dose mg/L</th>
<th>Response 5520B mg/L</th>
<th>Recovery %</th>
<th>Hydrocarbon 5520F mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral Oil</td>
<td>109</td>
<td>95</td>
<td>87.2</td>
<td>79</td>
</tr>
<tr>
<td>20.5 cSt Naphthenic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canola Oil</td>
<td>105</td>
<td>100</td>
<td>95.8</td>
<td>6</td>
</tr>
<tr>
<td>39 cSt Food Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Visible Sheen

- Mineral oil = Yes
- Vegetable oil = Yes
Renewable Resource

- Mineral Oil = no
- All vegetable oils = yes
Competes with existing food crops

- Mineral oil = no
- Vegetable oils = yes
Oxidative Stability

• Low oxidative stability: oil will oxidize rather during use, becoming thick and polymerizing to a plastic-like or tar-like consistency

• Mineral Oil = Good
• Vegetable oil = Poor
Residue on Machines

• No standard tests

• Mineral oil = low residue, cleanable

• Vegetable oils = poor oxidative stability – may form very sticky residues and be very hard to clean

• Some vegetable oils are more stable than others
  – As measured by iodine value
  – Monounsaturated based oils are better (75% or higher)
Hydrolytic Stability

• Stability when exposed to water

• Mineral = Good – may for invert emulsions

• Vegetable oil = poor, breaks down to release acids
Pour Point

• Cold weather stability
  – Not really applicable to metalworking fluids

• Mineral Oil = minus 30 F
• Vegetable oils = +5 - +25F
Viscosity Index

- Maintains Viscosity at high temperature
- Viscosity Index (VI); for example, 223 for soybean oil vs. 90 to 100 for mineral oil
  - Higher number is better
- Mineral oil = fair
- Vegetable oil = very good
Misting from Machining Operations

• Mineral Oil = Medium
• Vegetable oil = low
Dermal Sensitivity

- Likelihood to cause Dermatitis
  - Mineral oil = known to cause dermatitis
  - Vegetable oil = minimal dermal issues
  - Again – Additives can be irritants
Carcinogenicity Potential

• Likelihood to cause cancer

• Mineral Oil = low if solvent refined and severely hydro treated

• Vegetable oil = naturally low
Can be recycled

Waste Infrastructure – Mineral Oil

- Mineral Oils
- Comes From a Variety Of Sources
- Manufacturing Plant
- Evaporation
  - Loss
  - Parts
  - Chips
- Oily Waste Water
- Loss
- Wastewater Treatment
- Treated Wastewater
- Oil Sludge
- Reclaiming
  - Re-Refining
  - Feed Stock For Reuse
- Incineration
- Feed Stock For Reuse

Reuse
Can be recycled – Maybe not

Waste Infrastructure – Mineral Oil + vegetable oil

Mineral oils come from a variety of sources + vegetable oils

Evaporation

Manufacturing Plant

Loss

Parts

Chips

Oily wastewater

Loss

Loss

Treated wastewater

Reclaiming

Re-Refining

Incineration

Viscous sludge

Landfill

Feedstock for reuse???
What about cost

• Base stock cost for vegetable oils generally track crude oil pricing
• Vegetable oils are generally more expensive
  – Mineral oil require multiple refining steps
  – Naphthenic oils are in limited supply, thus more costly
• Always exceptions to the rule
• Depending on the application and additive level, finished good price will vary
Summary – Vegetable Oils

- Vegetable Oils compete favorably with mineral oil
  - VOC, Lubricity, Dermal Sensitivity

- Additives needed to correct for
  - Pour point, oxidative stability, hydrolytic stability
  - Additives increase toxicity
  - Additive can increase dermal sensitivity

- May not be readily recycled
# Comparison Chart

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Vegetable</th>
<th>Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Lubricity</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Flash Point</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Biodegradable</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Aquatic Toxicity</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Petroleum Hydrocarbons</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Visible Sheen</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Renewable Resource</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Food Crop - Compete</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Oxidative Stability</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Machine / Part Residue</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Hydrolytic Stability</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Pour Point</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Misting</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Dermal Sensitivity</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Carcinogenic Potential</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Can Be Recycled</td>
<td>Poor</td>
<td>Poor</td>
</tr>
</tbody>
</table>

**SCORE**

- **Vegetable**: Score = 10
- **Mineral**: Score = 6
Summary

• Vegetable oils are in use right now
• Can meet manufacturing demands
• Disposal of residuals needs research
• Costs are generally higher for vegetable oils than mineral oils
Thank You

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