Honeywell: Specialty Additives

Lubricants for PVC

Vivek Ranjan

Honeywell

Vinylplast 2013
Honeywell’s Businesses

- $36.5 billion in revenues, about 55% of sales outside of U.S.
- 132,000 employees and close to 1,300 sites in more than 70 countries
- Morris Township, NJ global corporate headquarters

Aerospace

Automation and Control Solutions

Performance Materials and Technologies

Transportation Systems
Performance Materials and Technologies

A global leader in developing and manufacturing advanced materials and process technologies. These materials and technologies are used by people every day in a wide range of industries and applications, from petroleum refining to environmentally friendlier refrigerants to bullet-resistant vests.

Products:
- Process technology, equipment, catalysts, adsorbents, and services for the refining, petrochemical, and natural gas industries
- Fluorine technology, including non-ozone-depleting and low-global-warming-potential refrigerants and blowing agents
- Specialty films, additives, and chemicals
- Advanced fibers and composites for armor and industrial applications
- Intermediate products, including nylon feedstock caprolactam, nylon resin, ammonium sulfate fertilizers, and chemical intermediates.
- Electronic materials and chemicals

Businesses:
- Honeywell’s UOP
- Fluorine Products
- Resins and Chemicals
- Specialty Products
- Electronic Materials
- $5.7 billion in revenues (2011)
- Morristown, NJ headquarters
## Typical Rigid PVC Formulation

<table>
<thead>
<tr>
<th>Formulation Ingredient</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC Resin</td>
<td>• Suspension • Mass • CPVC</td>
<td>Structure; Shape; Strength.</td>
</tr>
</tbody>
</table>
| Heat Stabilizer        | • Lead • Organotin • Mixed Metal • Organic | • Acid scavenger.  
• Eliminate and/or replace labile chloride which initiates dehydrochlorination.  
• Interrupt color development. |
| Fillers/pigment        | • Calcium Carbonate • Talc • TiO2 | • Inert materials added to improve economics without diminishing physical properties.  
• Pigments provide protection from UV light.  
• Color |
| Impact modifier        | • Acrylic (core-shell) • CPE • MBS | • Brittle/ductile transition |
| Process Aids           | • High molecular weight copolymers. | • Promote fusion by transfer of shear forces.  
• High molecular weight helps control PVC melt rheology. |
| Lubricant              | • Esters • Salts of fatty acids • Paraffins • PE-waxes | • Lubricants facilitate flow through processing equipment and dies, or release from metal surfaces (eg. calendar rolls). |
PVC Compound Evaluation by Torque Rheometry

- Fusion time
- Fusion Peak
- Compaction
- Equilibrium
- Stabilizer Depleted
- Polymer Crosslinking
Mechanism of Lubrication in PVC

Internal lubrication

- Internal lubricant
- PVC particle

External lubrication

- External lubricant
- PVC particle
- Metal
External Lubrication

Internal Effect
- Polar Groups
- Short Chains
- Branched Molecule
- Strong Affinity to PVC
- Weak Affinity to Metal
- Reduces Melt Viscosity
- No Clarity Issues

External Effect
- Non Polar
- Long Chain
- Linear Molecule
- No Affinity to PVC
- Strong Affinity to Metal Surfaces
- No Effect on Melt Viscosity
- Non Clear Applications

Illustration courtesy of www.SpecialChem.com
Honeywell’s Product Range

Honeywell Synthesized Waxes

- Ethylene
  - Low Density Polyethylene Homopolymer
    - Maleic Anhydride
      - Ethylene Maleic Anhydride Copolymer
    - Oxidation
      - Low Density Oxidized Polyethylene
  - High Density Polyethylene Homopolymer
    - Oxidation
      - High Density Oxidized Polyethylene
    - Maleic Anhydride
      - Propylene Maleic Anhydride Copolymer
  - Propylene
    - Polypropylene Homopolymer
      - Oxidation
        - Polypropylene Vinyl Acetate
        - Maleic Anhydride
          - Oxidized Ethylene Vinyl Acetate
    - Ethylene
      - Ethylene & Vinyl Acetate
        - Maleic Anhydride
          - Oxidized Polyethylene
        - Acrylic Acid
          - Ethylene Acrylic Acid Copolymer
  - Ethylene & Acrylic Acid
    - Maleic Anhydride
      - Ethylene Maleic Anhydride Copolymer
    - Oxidation
      - Ethylene Acrylic Acid Copolymer

Further Value Added Product Offerings

- Rheochem Blends
- Other Raw Materials
- ACumists

Honeywell’s Product Range
Factors that influence PVC Fusion

**Fusion:** The breakdown of PVC primary particles into a homogeneous melt.

**Fusion Delay:**
- External Lubricants: Paraffin wax, PE homopolymer waxes.
- High filler loading.
- Low processing temperatures.

**Fusion Promotion:**
- Calcium Stearate.
- Processing Aids.
- High Density Oxidized PE waxes: A-C® 316(A), A-C® 307(A)
Effect of Fusion Behavior on Extrudate

- **Under Fused**
  - Gloss Reduction
  - Poor Die Flow, edge tear
  - Poor melt strength
  - Impact properties not developed

- **Over Fused**
  - High extrusion torque
  - Loss of melt strength
  - Entrapped volatiles
  - Poor surface appearance, melt fracture, drag lines
  - Poor impact strength

- **Optimum**
  - Maximized machine output
  - Good physical properties
  - Excellent surface appearance
Single Ingredients:
A-C® Polymers
A-C® Polyethylene Homopolymers

A-C® 617, A-C® 6A

• Advantages:
  - Extremely efficient external lubricant
  - Good cost/performance ratio
  - Improved gloss with A-C 617

• Disadvantages:
  - Quite concentration sensitive
  - Not recommended for clears
  - Not recommended where printing or laminating is to be performed
  - Strong fusion delay
Low Density Oxidized Polyethylenes

A-C® 629A, A-C® 680A

- Advantages:
  - Will give good clarity printability and laminatability when used at recommended levels
  - Will not adversely affect H.D.T. or impact
  - Excellent cost/performance ratio
  - Good processing latitude when used at recommended levels
  - Excellent metal release
Low Density Oxidized Polyethylenes

A-C® 629A, A-C® 680A

- Gloss:
  - Lower compared to homopolymers
- Fusion:
  - No significant influence on fusion behavior
- Transparency:
  - More compatible with PVC
  - But low viscosity and risk for haze
  - A-C® 680A can be used at low dosage (< 0.15 phr) in transparent applications
- Surface Finish:
  - Positively affect surface finish
High Density Oxidized Homopolymers

A-C® 307A, A-C® 316A

• Advantages:
  - Excellent metal release
  - Promote mixing and homogenization
  - Excellent clarity (A-C 316A)
  - Increase the fusion speed
  - No affect on H.D.T.
  - Increased impact strength
  - Improved profile surface
Copolymer:

EVA: A-C® 400A

- Improves gloss
- Neutral affect on fusion
- Used in combination with LD & HD Ox PE’s
  - Reduced melt pressure
  - Reduced chatter in calibrator
A-C Wax Performance Features

Range of Formulating Options to Balance Desired Properties
# A-C® PE Waxes for PVC Applications

### Table: A-C® Waxes (product list)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PE wax type</td>
<td>low-density homopolymer</td>
<td>low-density homopolymer</td>
<td>oxidized low-density homopolymer</td>
<td>oxidized high-density homopolymer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical form</td>
<td>powder</td>
<td>powder</td>
<td>powder</td>
<td>powder</td>
<td>powder</td>
<td>powder</td>
<td>powder</td>
</tr>
<tr>
<td>Drop point °C °F</td>
<td>106 223</td>
<td>113 235</td>
<td>102 216</td>
<td>104 219</td>
<td>108 226</td>
<td>140 284</td>
<td>140 284</td>
</tr>
<tr>
<td>Viscosity 140°C (284°F) cps</td>
<td>375</td>
<td>450</td>
<td>180</td>
<td>200</td>
<td>250</td>
<td>85000 (150°C)</td>
<td>8500 (150°C)</td>
</tr>
<tr>
<td>Acid number mg KOH /g</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
<td>16</td>
<td>16</td>
<td>5 to 9</td>
<td>16</td>
</tr>
<tr>
<td>Specific gravity g/ccm</td>
<td>0.92</td>
<td>0.93</td>
<td>0.91</td>
<td>0.93</td>
<td>0.93</td>
<td>0.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

### Applications

**Profile Extrusion**
- A-C® 6A: 0.1 – 0.5
- A-C® 8A: 0.1 – 0.5
- A-C® 617A: 0.1 – 0.5
- A-C® 629A: 0.1 – 0.8
- A-C® 680A: 0.1 – 0.7
- A-C® 307A: 0.05 – 0.2
- A-C® 316A: 0.05 – 0.3

**Pipe Extrusion**
- A-C® 6A: 0.1 – 0.4
- A-C® 8A: 0.1 – 0.4
- A-C® 617A: 0.1 – 0.4
- A-C® 629A: 0.1 – 0.4
- A-C® 680A: 0.1 – 0.4
- A-C® 307A: 0.05 – 0.2
- A-C® 316A: 0.05 – 0.2

**Siding Extrusion**
- A-C® 6A: 0.1 – 0.5
- A-C® 8A: 0.1 – 0.5
- A-C® 617A: 0.1 – 0.5
- A-C® 629A: 0.1 – 0.5
- A-C® 680A: 0.1 – 0.5
- A-C® 307A: 0.05 – 0.2
- A-C® 316A: 0.05 – 0.3

**Injection Molding**
- A-C® 6A: 0.1 – 0.6
- A-C® 8A: 0.1 – 0.6
- A-C® 617A: 0.1 – 0.6
- A-C® 629A: 0.1 – 0.6
- A-C® 680A: 0.1 – 0.6
- A-C® 307A: 0.05 – 0.2
- A-C® 316A: 0.05 – 0.2

**Flexible Extrusion**
- A-C® 6A: 0.1 – 0.4
- A-C® 8A: 0.1 – 0.4
- A-C® 617A: 0.1 – 0.4
- A-C® 629A: 0.1 – 0.4
- A-C® 680A: 0.1 – 0.4
- A-C® 307A: 0.1 – 0.4
- A-C® 316A: 0.1 – 0.4
High Performance Lubricants (HPL)
HPL Overview

Honeywell’s High Performance Lubricants are specialty PVC lubricant systems designed to meet the needs of rigid PVC processors by helping to achieve and maintain optimum productivity and product performance.

- Manufacturing cost savings made possible by HPL through
  - Higher yields
  - Lower energy consumption
  - Reduced downtime

- Lower overall raw material costs
  - Higher filler loading
  - Optimization of heat stabilizer, impact modifier dosage
## HPL: Performance Features and Benefits

### Performance of HPL 1-pack versus a conventional lubricant package:

<table>
<thead>
<tr>
<th>Benefit</th>
<th>HPL Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput</td>
<td>+ 10 – 30%</td>
</tr>
<tr>
<td>Melt Pressure</td>
<td>10+ % Lower</td>
</tr>
<tr>
<td>Melt Temperature</td>
<td>Lower</td>
</tr>
<tr>
<td>Dynamic Heat Stability</td>
<td>Significantly Improved</td>
</tr>
<tr>
<td>Static Heat Stability</td>
<td>No difference</td>
</tr>
<tr>
<td>Fusion Torque</td>
<td>10+ % Lower</td>
</tr>
<tr>
<td>Dosage (Efficiency)</td>
<td>30 - 50% Lower</td>
</tr>
<tr>
<td>Gloss</td>
<td>+ 15%</td>
</tr>
<tr>
<td>Color</td>
<td>Improved</td>
</tr>
</tbody>
</table>
## HPL: Performance Features and Benefits

<table>
<thead>
<tr>
<th>Benefit</th>
<th>HPL Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weatherability</strong> (Ca/Zn better than Pb)</td>
<td>No difference (up to 12,000 hrs)</td>
</tr>
<tr>
<td><strong>Plate-out</strong></td>
<td>Generally significantly reduced</td>
</tr>
<tr>
<td><strong>Process Robustness</strong></td>
<td>Greatly enhanced, facilitating:</td>
</tr>
<tr>
<td></td>
<td>- CPE vs acrylic impact modifier.</td>
</tr>
<tr>
<td></td>
<td>- Increased filler level.</td>
</tr>
<tr>
<td></td>
<td>- Reduced stabilizer level</td>
</tr>
<tr>
<td></td>
<td>➡️ <strong>Overall formulation cost reduction</strong></td>
</tr>
<tr>
<td><strong>Supply Chain Stability</strong></td>
<td>HPL is based on natural RMs – NOT oil.</td>
</tr>
<tr>
<td></td>
<td>Paraffin availability in structural decline.</td>
</tr>
</tbody>
</table>

HPL formulation tailored to maximize the benefits of most value to customer (not all benefits can be realized together).

**Versatile Technology: Multiple Benefits**
# Addressing Key Challenges

<table>
<thead>
<tr>
<th>Customer Challenge</th>
<th>HON Value Proposition</th>
<th>Proof of Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material cost</td>
<td>• Lower compound cost</td>
<td>• 15~30% reduction in lubricant usage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Better wall thickness control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lower use levels/different type of stabilizer, impact modifier and higher filler loadings</td>
</tr>
<tr>
<td>Manufacturing Cost</td>
<td>• Increased output rates</td>
<td>• 10-15% profile, 20-40% pipe</td>
</tr>
<tr>
<td></td>
<td>• Lower energy cost</td>
<td>&gt;50% compounding</td>
</tr>
<tr>
<td></td>
<td>• Increased productivity</td>
<td>• 5-20% reduction in Amperage draw</td>
</tr>
<tr>
<td></td>
<td>• Less wear and tear</td>
<td>• No plate-out issues</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low pressure &amp; temperature of operations</td>
</tr>
<tr>
<td>Operational cost</td>
<td>• Reduced working capital</td>
<td>• Lower inventory levels</td>
</tr>
<tr>
<td></td>
<td>• No / delayed capital investments</td>
<td>• Capacity expansion at variable cost</td>
</tr>
<tr>
<td></td>
<td>• Zero qualification time</td>
<td>• Already qualified in multiple applications</td>
</tr>
<tr>
<td></td>
<td>• No change in quality</td>
<td>• Meet / exceed all specs; improved aesthetics</td>
</tr>
<tr>
<td></td>
<td>• Compliant with industry codes</td>
<td>• Listed by NSF, PPI</td>
</tr>
</tbody>
</table>
Energy Efficiency

Energy Consumption reduced by 24%

Significant Energy Savings
HPL Increases Compound Stability

Profile Formulation

- Control
- HPL
- HPL with 25% Reduced Stabilizer

Increased Dynamic Heat Stability at Reduced Stabilizer Levels
Examples of Successful Projects

1. Higher output: improved productivity, cash flow by lowering overall cost

2. Higher filler loadings: reduced $/lb and $/ft$^3$

3. Weatherable products: superior color hold for Southwest

4. Low Sn formulations: up to 10% reduction proven in comm. scale

5. One-pack convenience: complex formulations made simple

6. Additives optimization: lowered lubricant, impact modifier dosage

Goals are customer, plant, equipment-specific
Case study from US PVC Pipe Producer

- Customer three week trial with HPL 6410 in place of conventional package.
- Plant capacity is 70 M lbs of PVC pipe per year.

<table>
<thead>
<tr>
<th>Benefit</th>
<th>HPL Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubricant Dosage</td>
<td>Dosage of RL415 was 1.5 phr, HPL dosage is 1.2 phr</td>
</tr>
<tr>
<td>Stabilizer Dosage</td>
<td>Reduction from 0.5 phr to 0.4 phr</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>Overall plant energy costs reduced by 6%; individual extruders were reduced by up to 15%</td>
</tr>
<tr>
<td>Overweight</td>
<td>Reduced by 0.5% (3.0% - 2.5%) due to improved wall control</td>
</tr>
<tr>
<td>Gloss</td>
<td>Improved with HPL</td>
</tr>
<tr>
<td>Plate out/Die Drool</td>
<td>Significant reduction which reduces clean-outs and equipment shutdowns</td>
</tr>
<tr>
<td>Vent Powder Reduction</td>
<td>Reduced amount of compound collected in vacuum system by 90%</td>
</tr>
</tbody>
</table>

Actual benefits may vary depending upon processing equipment and parameters.
Customer Benefits with HPL

- Only easily quantifiable data was used in calculations.
- Other benefits such as gloss improvement and die drool reduction were not quantified.

Total Annual Savings for customer is $324,000
# Broad Range of Applications

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large diameter pipe</td>
<td>&gt;3x filler loading&lt;br&gt;Optimized use of additives: stabilizer, acrylics</td>
</tr>
<tr>
<td>Hydraulic pipe</td>
<td>0.05phr lower lubricant dosage&lt;br&gt;15% higher output</td>
</tr>
<tr>
<td>Stabilizer-Lubricant one-pack</td>
<td>&gt;15% higher throughput&lt;br&gt;10% reduction in usage level</td>
</tr>
<tr>
<td>Window profile extrusion</td>
<td>17% higher output rate&lt;br&gt;Savings of up to 20% on heat stabilizer&lt;br&gt;Reduced energy consumption&lt;br&gt;10% lower melt pressure&lt;br&gt;15% lower amperage</td>
</tr>
<tr>
<td>Injection molding</td>
<td>200% increase in filler loading&lt;br&gt;Up to 50% reduction in lubricant dosage</td>
</tr>
<tr>
<td>Siding</td>
<td>Formulation flexibility – CPE vs. acrylics&lt;br&gt;Higher filler loadings, output rates</td>
</tr>
</tbody>
</table>
Performance requirements for switching from Pb to Ca/Zn-stabilized Window Profile Formulations

• Customer Feedback:
  - Wider processing window
  - Increased output
  - Reduced plate-out
  - Scrap reduction
  - Improved thermal stability

• High Performance Lubricant Concept
  - Balanced lubrication (internal↔external)
  - High efficiency vs. “conventional” lubricants
  - Improved productivity
  - Customer specific solutions, “tailorable”
  - Excellent compatibility with all lubricant classes

Customer CTQ’s met with HPL Solution
Summary & Conclusions

• Without lubrication processing of rigid PVC would be impossible.

• An optimized lubrication system will optimize processing output, physical properties and final part appearance.

• Honeywell offers an extensive range of lubricants to optimize the value created by our customers.

• Honeywell’s technical team of experienced PVC formulators is available to assist customers in application development, formulation development and lubricant system optimization.