HMH - A NATURAL SOLUTION TO YOUR BURNING ISSUES

Dr. Chris DeArmitt FRSC
- HMH work by Stefan Viering
THE LKAB GROUP IN BRIEF

• World leading producer of upgraded iron ore
• Delivered 25.5 Million MT in 2013, plan to grow to 37 Million MT by 2017
• Two underground mines in Kiruna and Malmberget and open pit mining in Svappavaara
• Producer of 90% of EU’s iron ore
• ~4,400 employees
• 30 companies in 15 countries
  – E.g. Drilling, Concrete, Explosives, Railway, Harbour, Construction.
• Turnover 2013: SEK 23.65 Billion
FOCUS CREATES SPECIALISATION

We focus our R&D resources on mineral and application development in the areas of:

- Civil Engineering and Construction
- Polymers and Coatings
- Refractory and Foundry
MAGNIF – HIGH PURITY MAGNETITE
ROTARY KILN
MAGNETITE ORE

1. Density 5.2 g cm⁻³
2. Moh Hardness ~6
3. Semi-conductive
4. Thermally conductive
5. High specific heat capacity
6. Extremely pure

1. Sound deadening, weights
2. Solid surfaces
3. Anti-static, shielding, induction & microwave heatable
4. Lowers cycle time
5. Heat storage
6. Food contact approved
PHLOGOPITE MICA – VHAR REINFORCEMENT
# MINERAL REINFORCEMENTS COMPARED

<table>
<thead>
<tr>
<th>Particle Dimensions (Malvern)</th>
<th>Talc</th>
<th>Calcined Clay</th>
<th>Wollastonite</th>
<th>Phlogopite Mica PW80</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{50}$</td>
<td>12</td>
<td>3</td>
<td>3.5</td>
<td>37</td>
</tr>
<tr>
<td>$D_{90}$</td>
<td>40</td>
<td>10</td>
<td>13</td>
<td>95</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
</tbody>
</table>
SEM OF PHLOGOPITE MICA PW80

Mag = 2.00 K X
WD = 12 mm
EHT = 5.00 kV
Detector = SE2
Photo No. = 685
# REINFORCEMENT COMPARISON IN PA6

<table>
<thead>
<tr>
<th>Property</th>
<th>Talc 40%</th>
<th>Calcined Clay 40%</th>
<th>Wollastonite 40%</th>
<th>Phlogopite Mica 40%</th>
<th>GF 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus (MPa)</td>
<td>7400</td>
<td>6120</td>
<td>5514</td>
<td>10370</td>
<td>11980</td>
</tr>
<tr>
<td>Flexural Strength (MPa)</td>
<td>120</td>
<td>150</td>
<td>135</td>
<td>155</td>
<td>290</td>
</tr>
<tr>
<td>Tensile Modulus (MPa)</td>
<td>7470</td>
<td>6313</td>
<td>5450</td>
<td>11160</td>
<td>13215</td>
</tr>
<tr>
<td>Break Stress (MPa)</td>
<td>74</td>
<td>87</td>
<td>83</td>
<td>95</td>
<td>195</td>
</tr>
<tr>
<td>Break Strain (%)</td>
<td>2.8</td>
<td>6.4</td>
<td>8.4</td>
<td>1.7</td>
<td>2.6</td>
</tr>
<tr>
<td>Unnotched Charpy (kJm⁻²)</td>
<td>28.5</td>
<td>80</td>
<td>No Break</td>
<td>29</td>
<td>79</td>
</tr>
<tr>
<td>Notched Charpy (kJm⁻²)</td>
<td>3.5</td>
<td>6.4</td>
<td>6.4</td>
<td>4.0</td>
<td>12.8</td>
</tr>
<tr>
<td>Shrinkage (%)</td>
<td>0.65</td>
<td>1.31</td>
<td>1.06</td>
<td>0.58</td>
<td>0.1</td>
</tr>
<tr>
<td>Shrinkage</td>
<td></td>
<td>(%)</td>
<td>0.97</td>
<td>1.66</td>
<td>1.64</td>
</tr>
<tr>
<td>Warpage (%)</td>
<td>0.32</td>
<td>0.35</td>
<td>0.58</td>
<td>0.29</td>
<td>0.88</td>
</tr>
</tbody>
</table>
# REINFORCEMENT COMPARISON IN PA6

![LKAB Minerals logo](image)

<table>
<thead>
<tr>
<th>Property</th>
<th>GF25% Talc15%</th>
<th>GF 25% Clay 15%</th>
<th>GF 25% Wollastonite 15%</th>
<th>GF 25% Phlogopite Mica 15%</th>
<th>GF 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus (MPa)</td>
<td>9843</td>
<td>9350</td>
<td>9080</td>
<td>10550</td>
<td>11980</td>
</tr>
<tr>
<td>Flexural Strength (MPa)</td>
<td>210</td>
<td>213</td>
<td>226</td>
<td>231</td>
<td>290</td>
</tr>
<tr>
<td>Tensile Modulus (MPa)</td>
<td>11400</td>
<td>9950</td>
<td>10100</td>
<td>12200</td>
<td>13215</td>
</tr>
<tr>
<td>Break Stress (MPa)</td>
<td>140</td>
<td>144</td>
<td>144</td>
<td>165</td>
<td>195</td>
</tr>
<tr>
<td>Break Strain (%)</td>
<td>2.4</td>
<td>3.4</td>
<td>2.6</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Unnotched Charpy (kJm⁻²)</td>
<td>52.3</td>
<td>43.6</td>
<td>50.3</td>
<td>60</td>
<td>79</td>
</tr>
<tr>
<td>Notched Charpy (kJm⁻²)</td>
<td>7.4</td>
<td>5.6</td>
<td>6.9</td>
<td>8.6</td>
<td>12.8</td>
</tr>
<tr>
<td>Shrinkage = (%)</td>
<td>0.22</td>
<td>0.26</td>
<td>0.23</td>
<td>0.22</td>
<td>0.1</td>
</tr>
<tr>
<td>Shrinkage</td>
<td></td>
<td>(%)</td>
<td>0.91</td>
<td>0.99</td>
<td>1.04</td>
</tr>
<tr>
<td>Warpage (%)</td>
<td>0.69</td>
<td>0.73</td>
<td>0.81</td>
<td>0.59</td>
<td>0.88</td>
</tr>
</tbody>
</table>

**Note:** LKAB Minerals data from accredited external laboratory.
ULTRACARB – NATURE’S OWN FLAME RETARDANT
HMH: A BLEND OF TWO MINERALS

**Huntite:** magnesium calcium carbonate

\[ \text{Mg}_3\text{Ca} (\text{CO}_3)_4 + 1 \text{ kJ/g} \rightarrow 3\text{MgO} + \text{CaO} + 4\text{CO}_2 \]

**Hydromagnesite:** hydrated magnesium carbonate

\[ \text{Mg}_5(\text{CO}_3)_4(\text{OH})_2 \cdot 4\text{H}_2\text{O} + 1 \text{ kJ/g} \rightarrow 5\text{MgO} + 4\text{CO}_2 + 5\text{H}_2\text{O} \]
THE THREE STAGE FR MECHANISM OF HMH
HYDROMAGNESITE & HUNTITE DECOMPOSITION

- **Residual Mass (%)**
- **Temperature**
  - Celsius: 0, 200, 400, 600, 800
  - Fahrenheit: 390, 750, 1110, 1470

Graph showing the decomposition of Hydromagnesite and Huntite at various temperatures.
TOTAL HEAT RELEASE OF HMH AND ATH

Data retrieved from 50kW cone calorimeter
PARTICLE MORPHOLOGY

HMH

ATH

Huntite
## NATURAL HMH VERSUS SYNTHETIC ATH

<table>
<thead>
<tr>
<th></th>
<th>HMH</th>
<th>ATH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
<td>Platy</td>
<td>Spherical</td>
</tr>
<tr>
<td><strong>FR activity range</strong></td>
<td>220°C – 700°C</td>
<td>180°C – 280°C</td>
</tr>
<tr>
<td><strong>Evaporation enthalpy</strong></td>
<td>-1000 kJ/kg</td>
<td>-1000 kJ/kg</td>
</tr>
<tr>
<td><strong>Water release</strong></td>
<td>&gt;220°C</td>
<td>&gt;180°C</td>
</tr>
<tr>
<td><strong>Cementicious char</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Bulk density (at feeding)</strong></td>
<td>0.3g/cm³ (0.3g/cm³)</td>
<td>0.6 g/cm³ (0.4g/cm³)</td>
</tr>
<tr>
<td><strong>BET surface</strong></td>
<td>10m²/g (15m²/g)</td>
<td>4m²/g (7m²/g)</td>
</tr>
<tr>
<td><strong>Processing temperature</strong></td>
<td>&lt;220°C @ 1 bar</td>
<td>&lt;180°C</td>
</tr>
<tr>
<td><strong>High shear kneading</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
THE FOUR-FLIGHTED BUSS KNEADER

BUSS
MX-Series
MX-30 SETUP

FR1  Polymer  Additive  FR2

FR3
KNEADER CONFIGURATION

Screw MX 30 l/d=22

Four-flighted

Screw MKS 30 l/d=20

Three-flighted
EVA + ULTRACARB LH3 + PATH

Ingredients

- 26.5% Elvax 265 A (EVA)
- 3.75% Compoline CO/LL (MAH)
- 6.5% Eltex PF6130 AA (LLDPE)
- 1.5% Silmaprocess AL 1142A (Processing aid)
- 0.75% Silmastab AE 1527 (Stabilizer)
- 30.5% UltraCarb LH3 (oil abs. 25 ml/100g)
- 30.5% fine pATH (oil abs. 30 ml/100g)

Instructions

Feed polymers, additives and processing aids in the first hopper of a Buss Co-Kneader MX-30, feed the UltraCarb LH3 in port 2, and the ATH in port 3. Let it run at 600 rpm and 15kg/h.

Tensile Strength: 11 MPa
Elongation @ Break: 230%
Dispersion: very good
LOI: 35.5
EVA + ULTRACARB LH3

Ingredients
26.5% Elvax 265 A (EVA)
3.75% Compoline CO/LL (MAH)
6.5% Eltex PF6130 AA (LLDPE)
1.5% Silmaprocess AL 1142A (Processing aid)
0.75% Silmastab AE 1527 (Stabilizer)
61.00% UltraCarb LH3

Tensile Strength: 13 MPa
Elongation @ Break: 186%
Dispersion: very good
LOI: 34.5

Instructions
Feed polymers, additives and processing aids in the first hopper of a Buss Co-Kneader MX-30 and split feed the UltraCarb LH3 in port 1+2 and let it run at 600 rpm and 15kg/h. Do not exceed 260°C (750rpm) as the EVA may start to degrade.
EVA + ULTRACARB LH3 + PLASTOMER

Ingredients

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.0% Elvax 265 A (EVA)</td>
<td></td>
</tr>
<tr>
<td>6.5% Lucene LC180 (Plastomer)</td>
<td></td>
</tr>
<tr>
<td>3.75% Compoline CO/LL (MAH)</td>
<td></td>
</tr>
<tr>
<td>6.5% Eltex PF6130 AA (LLDPE)</td>
<td></td>
</tr>
<tr>
<td>1.5% Silmaprocess AL 1142A (Processing aid)</td>
<td></td>
</tr>
<tr>
<td>0.75% Silmastab AE 1527 (Stabilizer)</td>
<td></td>
</tr>
<tr>
<td>61.00% UltraCarb LH3</td>
<td></td>
</tr>
</tbody>
</table>

Instructions

Feed polymers, additives and processing aids in the first hopper of a Buss Co-Kneader MX-30 and split feed the UltraCarb LH3 in port 1+2 and let it run at 600rpm and 15kg/h.

Tensile Strength: 15 MPa
Elongation @ Break: 276%
Dispersion: very good
LOI: 32.5
CONCLUSIONS

• Natural mixtures of hydromagnesite and huntite are effective fire retardants

• Hydromagnesite is more active in the early stages of the fire providing an endothermic release of gas similar to ATH

• Huntite provides additional fire retardant activity not seen with ATH

• Varying the ratio of minerals allows tuning

• With proper processing, excellent FR and mechanical performance are possible in EBA, conventional EVA based cables or PVC

• Natural Mixtures of hydromagnesite and huntite offer much more than simply ATH replacement

• They are fully natural, non-synthetic, products
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