Automotive Magnesium Applications and Life Cycle Environmental Assessment

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Presentation Outline

- Mg applications
- Life Cycle Assessment – E and CO$_2$
- FMC’s perspective and programs
Why Magnesium?

- Reduce output of greenhouse gases
- Reduce dependence on imported oil
- Improve driving affordability

**Fuel Economy**
- Federal & State Requirements
- Corporate Mandates
- Competitive Pressure

**Emission Standards**
- Federal & State Requirement

**Safety**
- Reduce Cg
- Brakes, Airbags
- Crash Structures

**NVH**
- Stiffness
- Insulation

**Performance**
- 4W Drive
- Traction Control
- Powertrain Features

**Heavy Extras**
- Convertibles
- Power Accessories
- Electronic Devices
Material Comparison

Light

Stiff

Strong

Stiffness

Tensile Strength

Mg  Al  Steel

0.7  1  2.5

0.8  1  2
Magnesium Supply Base

- Norsk Hydro
- US Magnesium
- Timminco
- Pechiney
- RIMA & Brasiliera de Magnesio
- Dead Sea Magnesium
- Solikamsk & Avisma
- PRC, China (356,000 tonnes, yr 2003)

Total world wide volume 2003 < 600,000 tonnes
Average Magnesium Usage per Vehicle NA (Kilograms)

2000 MY (Kg)
Mg = 3.6
(AI = 111.6)
Potential Mass Reduction Opportunities with Magnesium

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Potential replacement</th>
<th>Mass in Mg</th>
<th>Mass saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powertrain</td>
<td>88</td>
<td>58</td>
<td>30</td>
</tr>
<tr>
<td>Chassis</td>
<td>80</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>Body</td>
<td>12</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Interior</td>
<td>31</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total (Kg)</strong></td>
<td><strong>211</strong></td>
<td><strong>119</strong></td>
<td><strong>92</strong></td>
</tr>
</tbody>
</table>

*Based on P2000 Ford*
Current Steering Wheel Armature
Light weight solutions

Cam cover, AZ91D
1.15 Kg

Transmission housing
AZ91D, 9.10 Kg
Light weight solutions

- door inner, AM50, 4.5kg, weight save 45% over steel-version
- tailgate, AM50, 2.7kg, weight save 40% over steel-version
Light weight solutions

IP cross members (Jaguar & Ford GT)
Light weight solutions

Radiator Support
Life Cycle Assessment

Definition -

Life Cycle Assessment (LCA), a tool to support product and process development as part of the Design for Environment efforts on a strategic or operational level.

Goal -

• Perform external/internal LCA study fully meeting ISO 14040-x and review requirements.

• Identify environmental hot-spots along the life cycle.
Life Cycle Assessment

System Boundaries -

Include the whole life cycle (from resource depletion to material production, part(s) production, assembly, use and end-of-life treatment including transports).

Data Quality Requirements -

· time-related, geographical, & technology coverage
· precision, completeness and representativeness
· consistency and reproducibility of the methods used
· sources and representativeness
· uncertainty of the information
Life Cycle Assessment

Minimum Data Required -

a) process flow diagram

b) electricity (in kWh/kg process product), electricity source (% hard coal, % natural gas, % nuclear, etc.)

c) steam and heat (in MJ/kg process product), energy source (hard coal, natural gas, etc.)

d) yield (kg input/ kg process product)

e) CO₂, CH₄, SF₆, HFC and any other emissions leading to global warming (kg/kg process product)

f) SO₂ emissions and any other emissions leading to acidification (kg/kg process product; specify)

g) Non-methane Votile organic Carbons (NMVOC) emissions and NOx emissions (kg/kg process product)
Life Cycle Assessment

Life Cycle Impact Analysis Categories include –

- Global Warming (in CO$_2$ equivalency) using IPCC data for CO$_2$, CH$_4$, N$_2$O, HFCs, CFCs, PFCs, SF$_6$
  (IPCC – Intergovernmental Panel on Climate Change)
- Acidification Potential (kg SO$_2$ equivalency)
- Summer Smog Potential (kg Ethene equivalency)
- Winter Smog Potential (kg SO$_2$ + kg dust)
- Ozone depletion (in kg R11 equivalency)
- Emissions effecting health of Fauna/Flora
- Nutrification Potential (in kg Phosphate equivalency)
Life Cycle Assessment

In general, the environmental Burdens can be itemized by life cycle stage,

\[ \{B\} = \{B\}_\text{MP} + \{B\}_\text{ASSM} + \{B\}_\text{OP} + \{B\}_\text{MN} + \{B\}_\text{SHP} + \{B\}_\text{EOL} \]

MP – material production
ASSM – part manufacture & vehicle assembly
OP – vehicle operation & use
MN – vehicle maintenance & repair
SHP – shipment to market
EOL – vehicle end of life
## Life Cycle Assessment

**vehicle weight reduction vs. Life Cycle Energy (LCE) and Life Cycle CO₂ emissions**

Various Warming Gases & Production Energy Rates per unit pound of material (Ford LCI database)

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Al (virgin)</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ lb/lb</strong></td>
<td>3.5</td>
<td>8.14</td>
<td>6.0</td>
</tr>
<tr>
<td><strong>Fluorocarbons, lb/lb</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF₄ (6500 GWP) &amp; C₂F₆ (9200 GWP)</td>
<td></td>
<td>4.8 ~ 5.9 E-4</td>
<td></td>
</tr>
<tr>
<td><strong>SF₆ lb/lb (IPCC 23900 GWP)</strong></td>
<td></td>
<td></td>
<td>5.0 E-4</td>
</tr>
<tr>
<td><strong>Total CO₂ equivalency, lb/lb</strong></td>
<td>3.5</td>
<td>11.3 ~ 12.1</td>
<td>18</td>
</tr>
<tr>
<td><strong>Production Energy, BTU/lb</strong></td>
<td>21400</td>
<td>87100</td>
<td>64500</td>
</tr>
<tr>
<td><strong>Production efficiency</strong></td>
<td>98 %</td>
<td>98 %</td>
<td>98 %</td>
</tr>
<tr>
<td><strong>Substitution factor</strong></td>
<td>100 %</td>
<td>55 %</td>
<td>33 %</td>
</tr>
</tbody>
</table>
Life Cycle Assessment

vehicle weight reduction vs. Life Cycle Energy (LCE) and Life Cycle CO$_2$ emissions

Vehicle Operational Parameters per unit weight reduction

<table>
<thead>
<tr>
<th></th>
<th>Taurus</th>
<th>Expedition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Energy, BTU/lb</td>
<td>103300</td>
<td>93500</td>
</tr>
<tr>
<td>Total CO$_2$ equivalency, lb/lb</td>
<td>16.1</td>
<td>14.6</td>
</tr>
<tr>
<td>Baseline Mass, lb</td>
<td>3076</td>
<td>5300</td>
</tr>
</tbody>
</table>

Baseline Values of LCE and CO$_2$ in its Life Cycle (10 yrs)

<table>
<thead>
<tr>
<th></th>
<th>Taurus</th>
<th>Expedition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro Hwy, MPG</td>
<td>28.3</td>
<td>15.5</td>
</tr>
<tr>
<td>LCE, BTU E+6</td>
<td>758</td>
<td>1381</td>
</tr>
<tr>
<td>CO$_2$ equivalency, lb</td>
<td>115500</td>
<td>208000</td>
</tr>
</tbody>
</table>
Life Cycle Assessment
vehicle weight reduction vs. Life Cycle Energy (LCE)
and Life Cycle CO₂ emissions

Impact of weight reduction 500 lbs on LCE reduction

<table>
<thead>
<tr>
<th></th>
<th>Taurus</th>
<th>Expedition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al for Steel</td>
<td>3.5 %</td>
<td>1.6 %</td>
</tr>
<tr>
<td>Mg for Iron/Steel</td>
<td>7.5 %</td>
<td>3.8 %</td>
</tr>
</tbody>
</table>

Impact of weight reduction 500 lbs on CO₂ reduction

<table>
<thead>
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<th>Expedition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al for Steel</td>
<td>4.5 %</td>
<td>2.1 %</td>
</tr>
<tr>
<td>Mg for Iron/Steel</td>
<td>6.0 %</td>
<td>3.0 %</td>
</tr>
</tbody>
</table>
FMC’s Policy Letter No. 17
Protecting Health and the Environment

• Engineering Material Specification for RESTRICTED SUBSTANCE MANAGEMENT STANDARD, WSS-M99P9999-A1

• The requirements established by this Standard apply to all products supplied to Ford. They apply equally to Full Service Suppliers, proprietary, and Ford specified items.
SF6 prohibited at Ford starting 1/31/2004

<table>
<thead>
<tr>
<th>Row Number</th>
<th>Substance</th>
<th>Type of Restriction (a)</th>
<th>Threshold (not to be exceeded) (b)</th>
<th>Applications affected / Comments</th>
<th>Effective date</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>Polybrominated diphyl ethers (PBDEs)</td>
<td>Prohibited</td>
<td></td>
<td>All products except those containing Decabromodiphenyl oxide</td>
<td>Immediate</td>
</tr>
<tr>
<td>60</td>
<td>Polyvinylchloride (PVC)</td>
<td>Restricted</td>
<td></td>
<td>All Products</td>
<td>Immediate</td>
</tr>
<tr>
<td>61</td>
<td>Products of endangered species</td>
<td>Prohibited</td>
<td>0.001%</td>
<td>All Products</td>
<td>Immediate</td>
</tr>
<tr>
<td>62</td>
<td>Reproductive substances</td>
<td>Restricted</td>
<td>0.001%</td>
<td>All Products</td>
<td>Immediate</td>
</tr>
<tr>
<td>63</td>
<td>Sanitizing substances</td>
<td>Restricted</td>
<td></td>
<td>All Products</td>
<td>Immediate</td>
</tr>
<tr>
<td>66</td>
<td>Sulfur hexafluoride</td>
<td>Prohibited</td>
<td></td>
<td>Open systems (a system where under normal working conditions a leakage rate above 1% per year occurs), e.g. tire inflation gas.</td>
<td>Immediate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prohibited</td>
<td></td>
<td>Processing (casting) of Magnesium</td>
<td>31 Jan 2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restricted</td>
<td></td>
<td>Closed systems (a system that is normally hermetically closed), e.g. electrical installations</td>
<td>Immediate</td>
</tr>
</tbody>
</table>

Notes:

a) “Prohibited”, “Restricted”, and “Reportable” substances are defined in Appendix 1, “Definitions”.
b) Certain substances are subject to a specified upper threshold, stated as weight percent content in a material (see the definition of “Material” in Appendix 1). Where no threshold is specified, the substance concerned should not be present in quantities greater than trace levels as established by best industry practice. Thresholds for heavy metals are to be calculated on the basis of the elemental form of the metal.
Current Advanced Programs

**Powertrain program** (USCAR consortium)

- Engine Block, Bedplate, Oil Pan & Front Cover - Ford
- Newly developed high temp Mg alloys

**Chassis program** (USCAR consortium)

- Engine Cradle - GM Corvette ‘06
- Commercial Mg alloys (34 -> 22#)
Current Advanced Programs (cont.)

*Cost-Reduced Magnesium Die Castings Using Heated Runners (CORMAG) –*

- Mg Casting Lab at Ford
  - cold chamber (400 ton)
  - hot chamber (300 ton)
Issues with Using Large Quantities of Magnesium in Auto Industry

The magnesium “industry” is unlike the polymer, aluminum, and steel industries:

- significant R&D
- full technical and commercial support
  alloy development, design & modeling, casting, manufacturing, failure analysis, corrosion, quality, training, etc.
Summary

• Introduce Mg automotive applications

• Life Cycle Assessment confirms the environmental performance gains (E & CO₂) resulted from Mg on cars and SUVs

• Abandon SF₆ at Ford and need to use alternative cover gases

• Conduct R&D programs with leverage and develop Mg supplier basis