State of the Industry Report and Research & Development

Shanghai Automotive and Die Casting Exhibition

October 31, 2013
Presented by Steve Udvardy
GDP Growth is Slow and Getting Slower

China: 7.6%
India: 5.5%
Australia: 3.7%
Japan: 3.2%
Canada: 2.5%
United States: 2.1%
Germany: 0.5%
France: 0.25%
United Kingdom: -0.5%

Source: tradingeconomics.com

Problematic
Large Impact on China

EU Gross Domestic Product Quarter over Quarter

Source: Eurostat, forecast 3Q 12 – 4Q 13 Dekabank

© CAEF, www.caef.eu
Economists Predict "Tepid" Growth In 2013
44 professional economic forecasters, all members of the National Association of Business Economists predict that next year "will have only tepid growth." The economists "have pretty much discounted all the political rhetoric about what will happen to the economy if the 'Bush-era tax cuts' are not renewed. ... Instead, the economists in the survey say the dominant force behind the US economy will be the slowing economies in China and Europe."

Growth in Recovery Periods: 5-6%
Obama’s Policies Are Stunting Economic Expansion

President Obama's tough restrictions on oil and gas development in the Gulf, off the Atlantic and Pacific Coasts and in Alaska do not reduce U.S. petroleum consumption but merely shift exploration and production to costlier and riskier locations abroad. EPA limits on CO2 emissions encourage manufacturers to locate in countries where similar regulations do not apply. Both kill U.S. jobs without an environmental benefit.

Difficult Decisions to be Made
(Energy, Trade, Tax)

Unnecessary outsourcing > half the $600B trade deficit
Businesses Understand the Economic Uncertainty Created by Federal Policies and are Holding Money on the Sidelines

Mega-Corps: $1.73T in cash
$500B could add 2.4M jobs and 1+% GDP
The authors show that since 2009, U.S. commercial banks and large nonfinancial corporations have been carrying huge cash hoards and other liquid assets, totaling $1.4 trillion. Small businesses, by contrast, have been locked out of credit markets. The authors examine the impact on job creation of mobilizing these excess liquid assets into productive investments, finding that U.S. employment could expand by about 19 million jobs by the end of 2014, with unemployment falling below 5 percent. The paper discusses policies to transform these hoards into job-generating investments, both for the national economy and, specifically, the Los Angeles and Seattle regions.

Die casters can create jobs but…
Manufacturing Capacity Utilization Trending Downward
U.S. GDP Below 2% for all of 2012

Growing GDP is Pertinent to Reducing Unemployment
What Should be Worked on at the Federal Level

• Create Scientific Requirements for EPA Regulations
• Implement an Energy Policy that Makes Us Oil Independent
• Balance Our Trade
• Eliminate Corporate Tax
• Get out of the Way of Business and Give Business the Confidence to Spend Domestically

This Could Add 3% to Our GDP
Casting Production Main Regions

- CAEF: 16%
- China: 45%
- USA: 9%
- Mexico: 2%
- Canada: 1%
- Brazil: 4%
- India: 10%
- Japan: 5%
- Korea: 2%
- Taiwan: 1%
- Rest of the World: 0%
- Russia: 5%

Source: CAEF, moderncasting, national associations, Data 2010

U.S. is 4th in Tons of Metal Castings Produced
Two lenses for understanding the global foundry market

Metal type based segmentation

<table>
<thead>
<tr>
<th>Metal Type</th>
<th>Total Production</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous casting</td>
<td>91.4 m/100%</td>
<td>76.9 m/84%</td>
</tr>
<tr>
<td>Gray iron casting</td>
<td>43.3 m/47%</td>
<td></td>
</tr>
<tr>
<td>Ductile iron</td>
<td>23.5 m/26%</td>
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</tr>
<tr>
<td>Steel casting</td>
<td>10.2 m/11%</td>
<td></td>
</tr>
<tr>
<td>Non-ferrous casting</td>
<td>14.5 m/16%</td>
<td></td>
</tr>
<tr>
<td>Aluminum casting</td>
<td>10.9 m/12%</td>
<td></td>
</tr>
<tr>
<td>Copper base casting</td>
<td>1.7 m/2%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1.9 m/2%</td>
<td></td>
</tr>
</tbody>
</table>

Region based segmentation

Top 3 countries

1. China
   - 39.6 million metric tons
   - 26,000 metal casting plants

2. India
   - 6.1 millions metric tons
   - 4,600 metal casting plants

3. US
   - 8.2 million metric tons
   - 2,060 metal casting plants

1. 2010 global production numbers; 36 countries provided data
   Source: 45th Census of World Casting Production

Draft—for discussion only

2011 Data
HPDC is 70-75% of Non-ferrous Castings in U.S.
## China Leads in DC Production - North America Leads in Productivity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>2.12</td>
<td>2.91</td>
<td>7000</td>
<td>303</td>
<td>416</td>
</tr>
<tr>
<td>European Union</td>
<td>1.14</td>
<td>1.21</td>
<td>710</td>
<td>1606</td>
<td>1704</td>
</tr>
<tr>
<td>Germany</td>
<td>0.39</td>
<td>0.42</td>
<td>190</td>
<td>2053</td>
<td>2211</td>
</tr>
<tr>
<td>Italy</td>
<td>0.4</td>
<td>0.41</td>
<td>210</td>
<td>1905</td>
<td>1952</td>
</tr>
<tr>
<td>France</td>
<td>0.12</td>
<td>0.13</td>
<td>80</td>
<td>1500</td>
<td>1625</td>
</tr>
<tr>
<td>Other</td>
<td>0.23</td>
<td>0.25</td>
<td>230</td>
<td>1000</td>
<td>1087</td>
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<tr>
<td><strong>North America</strong></td>
<td><strong>1.03</strong></td>
<td><strong>1.14</strong></td>
<td><strong>545</strong></td>
<td><strong>1890</strong></td>
<td><strong>2092</strong></td>
</tr>
<tr>
<td>United States</td>
<td>0.78</td>
<td>0.88</td>
<td>450</td>
<td>1733</td>
<td>1956</td>
</tr>
<tr>
<td>Canada</td>
<td>0.12</td>
<td>0.13</td>
<td>55</td>
<td>2182</td>
<td>2364</td>
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<tr>
<td>Mexico</td>
<td>0.11</td>
<td>0.13</td>
<td>40</td>
<td>2750</td>
<td>3250</td>
</tr>
<tr>
<td>India</td>
<td>0.47</td>
<td>0.52</td>
<td>390</td>
<td>1205</td>
<td>1333</td>
</tr>
<tr>
<td>Japan</td>
<td>0.96</td>
<td>1.01</td>
<td>610</td>
<td>1574</td>
<td>1656</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.21</td>
<td>0.21</td>
<td>130</td>
<td>1615</td>
<td>1615</td>
</tr>
<tr>
<td>Russia</td>
<td>0.23</td>
<td>0.18</td>
<td>580</td>
<td>397</td>
<td>310</td>
</tr>
<tr>
<td>Other Asia</td>
<td>0.44</td>
<td>0.48</td>
<td>1090</td>
<td>404</td>
<td>440</td>
</tr>
<tr>
<td>Korea</td>
<td>0.24</td>
<td>0.26</td>
<td>600</td>
<td>400</td>
<td>433</td>
</tr>
<tr>
<td><strong>Eastern Europe</strong></td>
<td><strong>0.23</strong></td>
<td><strong>0.25</strong></td>
<td><strong>500</strong></td>
<td><strong>460</strong></td>
<td><strong>500</strong></td>
</tr>
<tr>
<td>All Other</td>
<td>0.51</td>
<td>0.53</td>
<td>900</td>
<td>567</td>
<td>589</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7.27</strong></td>
<td><strong>8.44</strong></td>
<td><strong>12500</strong></td>
<td><strong>582</strong></td>
<td><strong>675</strong></td>
</tr>
</tbody>
</table>
Worldwide Automotive Production
Global Outlook: A growth industry – But with very different trends in the three major regions

Global LV volumes sold 2007-2016 (Million units)

North America

- Western Europe
  - 2007: 16.8
  - 2009: 15.0
  - 2011: 14.4
  - 2012: 13.6
  - 2016: 15.4

- Eastern Europe
  - 2007: 5.4
  - 2009: 3.4
  - 2011: 4.7
  - 2012: 4.6
  - 2016: 6.6

- China
  - 2007: 8.0
  - 2009: 13.0
  - 2011: 18.1
  - 2012: 19.6
  - 2016: 27.1

- Japan
  - 2007: 5.2
  - 2009: 4.6
  - 2011: 4.1
  - 2012: 5.2
  - 2016: 4.5

C/S America

- Worldwide
  - 2007: 69.5
  - 2009: 63.7
  - 2011: 75.3
  - 2012: 78.3
  - 2016: 97.6

- Other*
  - 2007: 10.8
  - 2009: 10.9
  - 2011: 13.1
  - 2012: 13.6
  - 2016: 17.2

* India, ASEAN, South Korea, Africa

Sources: Global Insight, AlixPartners analysis

www.alixpartners.com
Key drivers of the growth – China and India with catch-up potential (II)

Forecast: 200/1000 by 2020
The 2020 EU CO₂ Emission Targets of 95g/km is a huge challenge for the automotive industry

Average CO₂ emissions for new cars in the EU versus 2015 and 2020 targets

Equates to 3.6 ltr / 100km (petrol) respectively 4.2 ltr / 100 km (Diesel)

- 130 g of CO₂/km
- 95 g of CO₂/km

Implications on the industry

1. Downsizing of vehicles and engines
2. Improved powertrains
3. Weight reduction

Source: [www.eea.europa.eu](http://www.eea.europa.eu)
Doing the Math

- Auto DC Aluminum content to grow from 114# in 2012 to over 143# in 2020.
- Auto production in 2020 = 107.1 M
- $107.1 \times 143 = 15.9$ Billion pounds of aluminum die castings in 2020 – just for automobiles!!
- The U.S. produced 1.4 Billion pounds in 2012 for automotive use.
- This doesn’t include any Structural Conversions.
Weight reduction: “Cars on a diet” is key to reduce CO₂ emissions

How does the car’s material composition in the future look like?

- Other
- Magnesium
- Aluminum
- Polymer / Composite
- High-/ Med-Strength Steel
- Conventional Steel

Key Challenges of the Industry

- Improve cost efficiency ratio
- Develop new materials
- Develop new production techniques
- Usage of recyclable materials

A 10% reduction in vehicle weight can result in a 6% - 8% fuel-economy improvement

Magnesium is Challenging in the U.S.


www.alixpartners.com
Consumption Will Skyrocket Worldwide as GDP Per Capita Improves
### Per Capita Aluminum Consumption Growth of Top 20 Populated Countries (Kg/Person/Year)

<table>
<thead>
<tr>
<th>Country</th>
<th>2006</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia</td>
<td>0</td>
<td>0.74</td>
<td>0.78</td>
<td>0.82</td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.08</td>
<td>0.8</td>
<td>0.88</td>
<td>0.98</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>0.16</td>
<td>1.07</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0.21</td>
<td>1.12</td>
<td>1.24</td>
<td>1.4</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.28</td>
<td>2.34</td>
<td>2.77</td>
<td>3.42</td>
</tr>
<tr>
<td>India</td>
<td>0.97</td>
<td>1.82</td>
<td>2.6</td>
<td>4.17</td>
</tr>
<tr>
<td>Vietnam</td>
<td>1.03</td>
<td>1.71</td>
<td>2.42</td>
<td>3.84</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1.24</td>
<td>1.7</td>
<td>2.02</td>
<td>2.48</td>
</tr>
<tr>
<td>Egypt</td>
<td>1.48</td>
<td>1.88</td>
<td>2.33</td>
<td>3.02</td>
</tr>
<tr>
<td>Iran</td>
<td>2.59</td>
<td>4.8</td>
<td>7.05</td>
<td>10.9</td>
</tr>
<tr>
<td>Brazil</td>
<td>5.45</td>
<td>4.86</td>
<td>6.14</td>
<td>7.94</td>
</tr>
<tr>
<td>Turkey</td>
<td>5.88</td>
<td>6.86</td>
<td>11.5</td>
<td>18.6</td>
</tr>
<tr>
<td>Thailand</td>
<td>6.29</td>
<td>6.44</td>
<td>10.3</td>
<td>16.3</td>
</tr>
<tr>
<td>China</td>
<td>6.63</td>
<td>8.86</td>
<td>20.9</td>
<td>28.7</td>
</tr>
<tr>
<td>Mexico</td>
<td>6.75</td>
<td>6.75</td>
<td>8.58</td>
<td>11.2</td>
</tr>
<tr>
<td>Russia</td>
<td>7.37</td>
<td>16.2</td>
<td>24.9</td>
<td>28.7</td>
</tr>
<tr>
<td>France</td>
<td>14.92</td>
<td>28.8</td>
<td>29.1</td>
<td>29.3</td>
</tr>
<tr>
<td>Japan</td>
<td>26.61</td>
<td>29</td>
<td>29.3</td>
<td>29.4</td>
</tr>
<tr>
<td>United States</td>
<td>30.74</td>
<td>29.4</td>
<td>29.4</td>
<td>29.4</td>
</tr>
<tr>
<td>Germany</td>
<td>31.78</td>
<td>28.9</td>
<td>29.2</td>
<td>29.3</td>
</tr>
<tr>
<td><strong>World Total</strong></td>
<td><strong>43,000</strong></td>
<td><strong>58,700</strong></td>
<td><strong>91,900</strong></td>
<td><strong>119,000</strong></td>
</tr>
</tbody>
</table>

Double by 2025!
Per Capita Consumption of Aluminum

- Germany
- United States
- Japan
- France
- Russia
- Mexico
- China
- Thailand
- Turkey
- Brazil
- Iran
- India

Legend:
- 2025
- 2020
- 2015
- 2006
Agricultural Equipment Demand

Significant Growth Seen Worldwide
Output Must Double by 2050
John Deere Spends Millions on Non-ferrous Castings
Where is the United States Heading in 2013?
US Die Casting Plants

![Graph showing the decline of US Die Casting Plants from 1960 to 2012 with specific numbers at each decade: 1078 in 1960, 953 in 1970, 866 in 1980, 754 in 1990, 630 in 2000, and 420 in 2012. The graph is sourced from NADCA.]
Geographic Distribution

Here’s Where US Die Casters Are Located
## Aluminum Markets

<table>
<thead>
<tr>
<th>Sector</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jewelry, Games, Toys</td>
<td>0.01%</td>
</tr>
<tr>
<td>Builder's Hardware</td>
<td>0.11%</td>
</tr>
<tr>
<td>Instruments/Measuring Devices</td>
<td>0.13%</td>
</tr>
<tr>
<td>Computer/Business Equipment</td>
<td>0.14%</td>
</tr>
<tr>
<td>Medical/Dental</td>
<td>0.28%</td>
</tr>
<tr>
<td>Plumbing, Valves, Fittings, HVAC</td>
<td>0.35%</td>
</tr>
<tr>
<td>Telecommunications/Electronic Equipment</td>
<td>0.38%</td>
</tr>
<tr>
<td>Lawn &amp; Garden</td>
<td>0.53%</td>
</tr>
<tr>
<td>Power &amp; Hand Tools</td>
<td>0.53%</td>
</tr>
<tr>
<td>Auto Aftermarket</td>
<td>0.53%</td>
</tr>
<tr>
<td>Aircraft/Aerospace/Military</td>
<td>0.55%</td>
</tr>
<tr>
<td>Industrial Machinery</td>
<td>0.76%</td>
</tr>
<tr>
<td>Motors/Industrial Control</td>
<td>0.81%</td>
</tr>
<tr>
<td>Furniture &amp; Door Hardware</td>
<td>1.59%</td>
</tr>
<tr>
<td>Pumps/Compressors</td>
<td>1.72%</td>
</tr>
<tr>
<td>Sports &amp; Recreation</td>
<td>1.77%</td>
</tr>
<tr>
<td>Electrical Equipment, Lighting</td>
<td>3.26%</td>
</tr>
<tr>
<td>Appliances</td>
<td>3.40%</td>
</tr>
<tr>
<td>Other</td>
<td>3.54%</td>
</tr>
<tr>
<td>Auto Primary - All Other</td>
<td>9.15%</td>
</tr>
<tr>
<td>Engines - Non-Auto</td>
<td>11.41%</td>
</tr>
<tr>
<td>Auto Primary - Powertrain</td>
<td>58.97%</td>
</tr>
</tbody>
</table>
Industry Employment Data

Unemployment (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Employees</th>
<th>National Unemployment</th>
<th>Die Casting Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>66,351</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>65,695</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>60,964</td>
<td>7.2</td>
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</tr>
<tr>
<td>2009</td>
<td>41,059</td>
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<tr>
<td>2010</td>
<td>45,986</td>
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<tr>
<td>2011</td>
<td>48,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>48,200</td>
<td></td>
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</tr>
</tbody>
</table>

Die Casting Industry Employment

2006: 66,351
2007: 65,695
2008: 60,964
2009: 41,059
2010: 45,986
2011: 48,000
2012: 48,200

Sources: NADCA
Die Casting Industry Employment Vs Productivity

Change in Employment and Productivity

NADCA
Machine Size & Distribution

- **Over 1500**
- **801 to 1500**
- **401 to 800**
- **Under 400**

Year Details:
- **1990**: Over 1500 = 189, 801 to 1500 = 1026, 401 to 800 = 2403, Under 400 = 1326
- **1996**: Over 1500 = 254, 801 to 1500 = 801, 401 to 800 = 1982, Under 400 = 1821
- **1998**: Over 1500 = 269, 801 to 1500 = 1069, 401 to 800 = 2143, Under 400 = 2044
- **2000**: Over 1500 = 411, 801 to 1500 = 1437, 401 to 800 = 2939, Under 400 = 2797
- **2002**: Over 1500 = 390, 801 to 1500 = 1343, 401 to 800 = 2877, Under 400 = 3032
- **2006**: Over 1500 = 436, 801 to 1500 = 1339, 401 to 800 = 2580, Under 400 = 3176
- **2008**: Over 1500 = 389, 801 to 1500 = 1072, 401 to 800 = 1851, Under 400 = 2071

NADCA
"We lowered our forecast because of a change from the significant economic growth in the first half to a flatter growth in the second half,"
"There is a level of uncertainty among consumers," Schuster said, adding the 2013 auto sales forecast was also lowered because he expects the level of uncertainty to extend into next year.
McAlinden and the Center for Automotive Research's long-range forecast

**Light Vehicle Sales in United States (Million)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales (Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>14.2</td>
</tr>
<tr>
<td>2013</td>
<td>14.6</td>
</tr>
<tr>
<td>2014</td>
<td>14.9</td>
</tr>
<tr>
<td>2015</td>
<td>15.5</td>
</tr>
<tr>
<td>2016</td>
<td>16.3</td>
</tr>
<tr>
<td>2017</td>
<td>17.1</td>
</tr>
</tbody>
</table>
Housing Starts Becoming Encouraging!
Still a Long Way To Go.
# 2013 Shipment Forecast

<table>
<thead>
<tr>
<th></th>
<th>NADCA CEO Forecast 2013 - Q1-'13</th>
<th>Actual Shipments 2013 - Q2</th>
<th>CEO Forecast 2nd Half 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Total</td>
<td>3.4%</td>
<td>3.9%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Aluminum - Auto</td>
<td>3.4%</td>
<td>4.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Aluminum - Non-Auto</td>
<td>3.3%</td>
<td>3.7%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Magnesium Total</td>
<td>14.0%</td>
<td>10.0%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Magnesium - Auto</td>
<td>16.0%</td>
<td>12.0%</td>
<td>13.0%</td>
</tr>
<tr>
<td>Magnesium - Non-Auto</td>
<td>8.0%</td>
<td>5.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Zinc Total</td>
<td>3.9%</td>
<td>-6.0%</td>
<td>-1.0%</td>
</tr>
<tr>
<td>Zinc - Auto</td>
<td>1.0%</td>
<td>-7.0%</td>
<td>-5.0%</td>
</tr>
<tr>
<td>Zinc - Non-Auto</td>
<td>6.1%</td>
<td>3.5%</td>
<td>5.7%</td>
</tr>
</tbody>
</table>
2013 Forecast

Aluminum will be up 11.61%
  • 16.4% Auto
  • 2.4% Non-Auto

Zinc will be down 4.3%
  • Auto light-weighting will drive volume reductions in zinc.

Magnesium will be up 1%
Conclusions

• Die casting shipments levels are promising over the next several years.
• Applications in new castings are up.
• Automotive sales projections are up worldwide.
• 2013 U.S. shipments will be better than 2012 for aluminum and magnesium, slightly worse for zinc.
• The U.S. administration must make decisions that will shape our economy in a job creating manner.
NADCA
Research & Development Program
R&D Program Primary Goal

To provide technological advancement for the die casting industry in order to:

• Promote profitable growth
• Enhance the ability of die casting to compete with other processes
• Enhance competitiveness of die casters in the domestic and global market place
NADCA R&D
Strategic Plan & Roadmap

Applying R&D efforts to areas identified as strategic to the die casting industry

Major Strategic Areas

• Products and Markets
• Materials Technology
• Manufacturing Technology
• Environmental Technology
<table>
<thead>
<tr>
<th>CURRENT PROJECT</th>
<th>Products &amp; Markets</th>
<th>Materials</th>
<th>Manufacturing</th>
<th>Environmental</th>
<th>Industry Health</th>
</tr>
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<tbody>
<tr>
<td>AMC (DOD Funds)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>149</td>
<td>Reverse Engineering Tools &amp; Productivity Improvements for Spare Part Components</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>150</td>
<td>Computational Tool for Short Run Insert Production and Improved Yield</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>151</td>
<td>Rapid Tooling for Short Run Metal Mold and Increased Productivity</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>152</td>
<td>High Production Rate Process for MMC Components</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>153</td>
<td>High Performance Die Casting Alloys</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>CMC (DOE Funds)</td>
<td></td>
<td></td>
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<tr>
<td>132</td>
<td>Mechanical Performance of Dies Continuation</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>133</td>
<td>Design Support for Tooling Optimization</td>
<td>X</td>
<td></td>
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<tr>
<td>134</td>
<td>The Development of Smart Die Coatings</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>135</td>
<td>Improved Die Casting Process to Preserve the Life of the Die Casting Dies</td>
<td>X</td>
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<td>Improvements in Efficiency of Melting for Die Casting</td>
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<td>X</td>
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<td>137</td>
<td>Innovative SSM Processing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Current R&D Projects

13 Current Projects - $3.5 Million

- High Performance Alloys
- Improving Casting Integrity
- Increasing Die Life
- Modeling Techniques
- Enhancing Productivity
- Energy Efficiency
# Current R&D Projects

## Cast Materials

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<td>Thin Wall Zinc</td>
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<td>SSM 206 Alloy</td>
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<td>Standards and Transition</td>
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<td>Characterization of T5 Heat Treating of 380 Die Castings Phase II</td>
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## Die Materials & Die Surface Engineering

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<th>Project Description</th>
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<td>Die Material Properties at 46-48 HRC</td>
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## Computer Modeling and Design Aids

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<th>#</th>
<th>Project Description</th>
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## Process Technologies

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<td>179</td>
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</tr>
</tbody>
</table>
Completed R&D Projects

93 Completed Projects – 18 Years $54 M

- Cast Materials
- Die Materials and Coatings
- Product Process/Tooling/Design Integration
- Process Technologies
- Die Technologies
- Sensors
R&D Program Guidance

• Technology Administration Group
  – Project Management & Administration
  – Oversight of Technical Committees

• Technical Efforts Guided by Main Committees
  – Research & Development Committee
  – Die Materials Committee
  – International Technical Council

• Committee Composition
  – Members from industry
  – Academia
  – Headquarters staff
Funding Sources

- U.S. Department of Energy
  - Office of Industrial Technologies
  - Vehicle Technologies Office
- U.S. Department of Defense
  - Defense Logistics Agency
  - Benet Laboratories
- NADCA
**Bi-Metallic Cores**

**Problem:** H13 Cores in a Tecumse/Peerless aluminum housing have a record of overheating and soldering.

**Action:** Extract heat more efficiently from core to lower maximum temperature, prevent soldering and allow shorter cycle times.

**Result:** Temperature was reduced by 100F, cycle time was reduced 27% (55 to 40 seconds) and occurrence of soldering was greatly diminished.
Bi-Metallic Cores

Why Bi-metallic (H13 over Copper)?

• Just H13 doesn’t draw heat out as fast as Cu
• Cu dissolves in molten Al but H13 does not
• Optimization of bi-metallic cores has balanced longevity of the H13 laser deposited layer and ability of the core to extract heat more quickly
Direct Metal Deposition of H13 on Copper - the POM Method
New Die Steels

What’s New Compared to Premium Grade H13?

• Superior Grade H13
• Various Other New Grades
• Advantages
  – Higher Impact Strength
  – Higher Thermal Fatigue Resistance
  – Potential for Higher Hardness
St. Clair Die Casting

- **Problem 1:** An aluminum tank track heat sink casting was placing a high thermal load on the die and causing short die life.
- **Problem 2:** Demand increased and higher productivity was needed
- **Action:** 1) Utilize a new die steel to prolong die life, 2) use new steel to move cooling lines closer to the cavity surface (from 0.69-0.87 inch to 0.50 inch).
New Die Steels

• **Results:**
  – Switching to the new die steel improved die life from 50,000 to 200,000 shots
  – Subsequently moving the cooling lines reduced cycle time from 57 to 50 seconds (12% gain)
  – Over 70,000 shots have been achieved with closer lines
Materials for Faster Heat Extraction

Use of High Thermal Conductivity Materials
Also for Improved Properties

- Faster solidification = less cycle time and smaller DAS
- Smaller DAS leads to higher properties
- Materials
  - Laser deposited H13 (LD-H13) on copper (General Die Casters)
  - Toolox 44 cores (Nemak)
  - Anviloy cores (Nemak, General Die Casters)
Multi-Layer Coatings

Optimized Ti-TiN-TiAlN-Al$_2$O$_3$ Coating

Process: Pulsed closed field unbalanced magnetron sputtering (P-CFUBMS) or modulated pulsed power (MPP)

- Working layer
- Intermediate layer
- Adhesion layer
- H13 steel substrate
- • plasma nitrided
  • ferritic nitro-carburized

NADCA
Multi-Layer Coatings

Smart Die Coating Architecture

- Working layer
- Optimized Tribological coating
- “Smart” layer
- Die substrate (Ferritic Nitrocarburized)
- Technical examples of the optimized tribological layers

Compositionally graded
Piezoelectric layer
Thin film electrodes /adhesion layer
Graded CrAlN
Graded CrN
Cr

Graded CrAlN
Graded CrN
Cr
High Performance Aluminum

• Problem
  – An increase in performance and durability was required for a 50 HP Marine Propeller

• Action
  – Mercury marine developed high ductility
    high toughness solder resistant alloy
  – Marketed as Mercalloy 366

• Results
  – Higher deflection in load vs. deflection testing
  – Best energy absorption as determined by drop testing
  – No soldering observed in 500,000+ castings
High Performance Aluminum

- Can Reduce Fe if Sr is Added
High Performance Aluminum

- Four examples: variants of A360, A380, 383 and 384 with low Fe and 0.05-0.07% Sr

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Ni</th>
<th>Zn</th>
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<tbody>
<tr>
<td>A360</td>
<td>9.0-10.0</td>
<td>1.3</td>
<td>0.6</td>
<td>0.35</td>
<td>.4-.6</td>
<td>.5</td>
<td>.5</td>
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<tr>
<td>B360</td>
<td>9.0-10.0</td>
<td>0.4</td>
<td>0.25</td>
<td>.25-.35</td>
<td>.4-.6</td>
<td>.1</td>
<td>.5</td>
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<tr>
<td>A380</td>
<td>7.5-9.5</td>
<td>1.3</td>
<td>3-4</td>
<td>0.50</td>
<td>.10</td>
<td>.5</td>
<td>3</td>
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<tr>
<td>F380</td>
<td>8.5-9.5</td>
<td>0.4</td>
<td>3-4</td>
<td>.25-.35</td>
<td>.1-.3</td>
<td>.1</td>
<td>1</td>
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<td>9.5-11.5</td>
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<td>.10</td>
<td>.5</td>
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<tr>
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<td>.25-.35</td>
<td>.1-.3</td>
<td>.5</td>
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<td>10.5-12.5</td>
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<td>3-4.5</td>
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<td>.10</td>
<td>.5</td>
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<td>D384</td>
<td>10.5-11.5</td>
<td>0.4</td>
<td>3-4.5</td>
<td>.25-.35</td>
<td>.1-.3</td>
<td>.1</td>
<td>3</td>
</tr>
</tbody>
</table>
Thin Wall Zinc

• A New Zn-Al Alloy (HF Alloy)
  – Higher Al and lower Mg than the ZAMAK alloys
  – Nominal composition: 4.5%Al, 0.006%Mg, 0.013%Cu, 0.005%Fe, 0.003%Pb, <0.0001%Cd and <0.001%Sn
  – A 40% increase in fluidity when compared to Alloy 7

• Lakeside Success Story
  – This casting had fill issues
  – New alloy eliminated scrap due to lack of fill
Thin Wall Zinc

How Thin?

Casting trials at Brillcast demonstrated wall thicknesses down to 0.012 inch!
Creep Resistant Zinc

• Target Objective
  – Temperature capability of 140°C (284°F)
  – Creep stress of 31 Mpa (4500 psi)
  – Exposure time 1000 Hrs
  – Maximum creep elongation of 1%

• Thirty-Six Alloy Formulations Evaluated

• Two Alloys with Significant Improvement
  – ID’s #4 and #16

• Commercial Application
  – #16 a.k.a. Alloy ZCA-9
Creep Resistant Zinc

**Composition Range of Creep Resistant Alloys**
5.5-7% Al, 2.4-3.6% Cu, 0.1-0.75% Ti, 0.0004-0.004% B, Bal Zn

**Several-fold Improvement as Compared to Common Zn Alloys**

![Average Creep Performance Comparison (140C & 31MPa)](image_url)
Creep Resistant Zinc

• Problem or Opportunity
  – An opportunity to reduce cost using a die casting as opposed to a sintered iron crankshaft and pin was seen.

• Implementation Strategy
  – Creep resistant ZCA-9 alloy was die Panther crankshaft.
  – Perform product qualification tests.

• Results
  – Successfully passed tests - only Zn alloy that worked
  – Manufacturing costs reduced by 30%
  – Potential savings - $600K/year based on 6 million parts/year.
Heat Treatment of Castings

• T5 and T6 is Possible for Some Al Alloys and Provides Improved Strength
  – T5 – Quench from ejection and age
  – T6 – Short term solution treatment, quench and age
Heat Treatment of Castings

A380 with 0.29% Mg

Aging Temp °C

0.2% YS

UTS

Elong

Quality Index

“Capability” data
Heat Treatment of Castings

- 180°C for 4 hrs

![Graph showing the effect of Mg concentration on strength and elongation](image)
Structural Castings

Shock Tower Example

- BMW X5 Vehicle
- Alloy: Aural 2™
- Process: High-Q-Cast™
- Function
  - Strut & A-arm mounting
  - Transfer forces into the body via the spring support and A-arm
  - Suspension mounting & A-arm alignment
  - Resist axial loads
Structural Castings

- Shock Tower Requirements
  - Cast varying walls
    - 5mm (.196”)
    - 9 mm (.354”)
  - Low porosity
  - Elongation for
    - Crash worthiness
    - Self piercing rivets
  - Heat treatable
  - Coatable
• Requirements Cont.
  – Mechanical Properties
    • Yield $\geq$ 120 N/mm$^2$ (17ksi)
    • Tensile $\geq$ 180 N/mm$^2$ (26ksi)
    • Elongation $\geq$ 10%
  – Dynamic Testing

<table>
<thead>
<tr>
<th>Cycles</th>
<th>Load</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0kN / +75kN</td>
<td>1Hz</td>
</tr>
<tr>
<td>100,000</td>
<td>0kN / +40kN</td>
<td>5Hz</td>
</tr>
</tbody>
</table>
Structural Castings

• Performance
  – 40% Weight savings
  – Eliminated 5 part steel assembly
  – Exceeded requirements
  – Elongation allowed self piercing riveting
  – Allowed thin wall heat treatment
Structural Casting Applications
Innovative SSM Processing

• Objective
  – Optimize the Continuous Rheoconversion Process (CRP) for commercial applications, develop SSM alloys, optimize heat treatment processes for SSM castings

• Achievements
  – CRP put into commercial practice
  – Established Criteria for SSM alloy design
  – Optimized 380/383, 206, 319, 6061, and 7075 alloys for SSM Applications
  – Established T5 and T6 heat treatment cycles
Innovative SSM Processing

One Industrial Prototype

CRP Reactor Incorporated in a 840T Bühler Machine
Innovative SSM Processing

Marketed by Buhler as LTC

LTC Data Logging with Buhltemp System
(Water Temperature and Flow Data)
Innovative SSM Processing

CRP Processed vs Squeeze Castings

A356-%Elongation

Elongation (%)
## PQ² Optimization

### Example Part Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Part Mass</td>
<td>5.75 lbm</td>
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<tr>
<td>Avg. Wall Thickness</td>
<td>0.25 in</td>
</tr>
<tr>
<td>Min Wall Thickness</td>
<td>0.18 in</td>
</tr>
<tr>
<td>Machine Dry Shot Speed</td>
<td>120 in/s</td>
</tr>
<tr>
<td>Machine Accumulator Pressure</td>
<td>1600 PSI</td>
</tr>
<tr>
<td>Hydraulic Cylinder Diameter</td>
<td>4.50 in</td>
</tr>
<tr>
<td>Locking Force</td>
<td>400 tons</td>
</tr>
<tr>
<td>Plunger Tip Diameter</td>
<td>3.00 in</td>
</tr>
<tr>
<td>Shot Sleeve Length</td>
<td>16.00 in</td>
</tr>
<tr>
<td>Gate Area</td>
<td>$\approx 0.8 \text{ in}^2$</td>
</tr>
<tr>
<td>Machine Power</td>
<td>254,000 ft-lb/s</td>
</tr>
</tbody>
</table>
SHS Composite/HyperCast Material

\[ y\text{Ti} + y\text{C} + x\text{Mg} \text{ (melt)} = x\text{Mg} + y\text{TiC} \]

\[ y\text{Ti} + y\text{C} + x\text{Al} \text{ (melt)} = x\text{Al} + y\text{TiC} \]
SHS Composite/HyperCast Material

Al/TiC Microstructure

TiC particles are formed through SHS technology
SHS Composite/HyperCast Material

47% Improvement - UTS
122% Improvement - YS

Properties Measured:
- Tensile (UTS and YS)
- Hardness
- Elongation
- Wear
- Modulus

Properties of Castings
Research Results

• Many Companies Have Derived Benefits
  – Improved Alloy Performance
  – Longer Die Life
  – Reduced Scrap
  – Enhanced Dimensional Control
  – Reduced Down-Time
  – Shorter Development & Lead-Times
  – Greater Energy Efficiency
  – Enhanced Environmental Management
  – Higher Productivity
  – Lower Operating Costs
  – Increased Profitability
The NADCA R&D Program

• Charts the Future of Die Casting Technology
• Contains Diverse Portfolio of Projects
• Delivers Beneficial Results of High Value to Funding Sources and Industry
Thank you!