Metallic Materials & Processes

Enabling Lightweight System Initiatives

Alcoa – Howmet
Presentation at NDIA
GARM SYMPOSIUM
27 APRIL 2005
Purpose

• Establish that Metallic Materials and processes are key enablers for achieving development and production objectives for Lightweight systems

• Illustrate that Lightweight Initiatives are enabled by:
  – Materials technology
  – Innovative processes
  – A total systems approach
  – Rigorous cost value analysis

• Confirm that a balanced approach to design, materials, processes, and cost will enable solutions
Objectives

• Demonstrate that advances in Titanium alloys and processes have resulted in
  – Meeting Lightweight Systems objectives and
  – Offering direct applications for achievement of key challenges in armament and protection systems

• Illustrate that “new” aluminum alloys offer mechanical properties and other characteristics which will meet design/performance challenges
Challenges

- Lightweight materials with application specific properties
- Forming high precision complex geometric shapes/contours repeatedly
- Reducing part count – improving manufacturability
- Achieving wrought properties with cast materials
- Introducing “new” materials and processes via concurrent engineering
- Lead-time reduction
Enablers

• “New” alloys responsive to application needs
• Quality control of complex processes
• Stereolithography enabled schedule and cost reductions
• Castings yielding near wrought properties
• Demonstrated capability to form complex parts at near net shape – reducing part count, lead time, cost, etc.
• Expanded metals industry links to applications engineering
Applications

- Weapon structures and mechanisms
- Muzzle brakes
- Projectile components
- Warheads
- Structural elements
- Propulsion modules
- Protection systems (armor)
Realizing the Benefits

- Lightweight Systems Initiatives are critical to the development and realization of enhanced legacy systems and supporting Transformation goals.
- Advanced Metallic Materials and Processes have been and are being applied successfully to meet requirements and enable superior Combat operational capability resulting from light weight.
Alcoa Capabilities

- Aluminum Sheet & Plate
- Aluminum Extrusions
- Titanium, Aluminum & Superalloy Investment Castings
- Aluminum Sand Castings
- Titanium, Aluminum & Superalloy Forgings
- Advanced Titanium, Aluminum & Superalloys
- Enclosures
- Prime Services
- Machining
- High Temperature & Wear Resistant Coatings
- High Technology Fasteners
- Design
Howmet Castings – Overview

- Leading Manufacturer of Titanium, Aluminum and Superalloy Precision Investment Castings
  - Military & Commercial Engines and Airframes
  - Lightweight Armament
  - Missiles and Munitions
- Total Solution Provider
  - Machining, Coating (high temp and wear resistant), Supply Chain Management and Design Services
- Supplier of Superalloy and Titanium Ingots, Ceramic Cores and Crucibles, and Advanced Tooling
- Headquartered in Cleveland, Ohio
  - Part of Alcoa Investment Cast and Forged Products
Examples of Titanium & Aluminum Castings
Titanium Armament

• Market need for light-weight artillery
  – Greater transportability/rapid deployment
• Cast titanium offers:
  – Light weight and high strength
  – Lower cost than fabrications
  – Reduced manufacturing time
  – Potentially better performance than fabrications
M777 Howmet Titanium - In The News

- Machine Design
  November 2003
- Modern Casting
  December 2003
- Engineered Casting Solutions
  Winter 2004
- Marine Corps Gazette
  June 2004
- Materials World
  June 2004
"The successful implementation of thin-walled titanium castings has been crucial in achieving full-rate production requirements of the howitzer while maintaining quality."
# M777 Part Count Reduction

<table>
<thead>
<tr>
<th>Titanium Structure</th>
<th>Fabrication</th>
<th>Casting</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cradle</td>
<td>324</td>
<td>172</td>
<td>47%</td>
</tr>
<tr>
<td>Body</td>
<td>215</td>
<td>11</td>
<td>95%</td>
</tr>
<tr>
<td>Saddle</td>
<td>116</td>
<td>5</td>
<td>96%</td>
</tr>
<tr>
<td>Stabilizers</td>
<td>70</td>
<td>2</td>
<td>97%</td>
</tr>
<tr>
<td>Spades</td>
<td>120</td>
<td>2</td>
<td>98%</td>
</tr>
<tr>
<td>Trails</td>
<td>98</td>
<td>2</td>
<td>98%</td>
</tr>
<tr>
<td>Elevating Yoke</td>
<td>19</td>
<td>1</td>
<td>95%</td>
</tr>
<tr>
<td>Buffer Yoke</td>
<td>11</td>
<td>1</td>
<td>91%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>973</strong></td>
<td><strong>196</strong></td>
<td><strong>80%</strong></td>
</tr>
</tbody>
</table>

*http://www.machinedesign.com/ASP/strArticleID/56460/strSite/MDSite/viewSelectedArticle.asp
Projectile Castings

Nose Cone

Base
Examples of Other Titanium Parts

- HTC currently ships >$2M of brackets, mounts and clevises annually
- HTC will ship >$7M in turbocharger wheels for the commercial transportation market this year (~117,000 units)
Examples of Aluminum Castings

Howmet’s Bethlehem Casting Component Eliminates 50 Man-hours of Assembly

Dimensions: 36” x 24” x 14”
Large Structural Aluminum Parts

Dimensions: 48” x 20 dia”
Electronic Enclosures
Investment Casting Process

Die Construction → Wax Injection → Wax Assembly → Shell Build

Rapid Prototype can be used instead of tooling

Dewax → Casting → Shell Removal → Cut-off

Heat Treat → Finishing → FPI/Visual → X-Ray Inspection

SPEED ★ REACH ★ AGILITY ★ SURVIVABILITY
## Casting Capabilities – Aluminum/Titanium

<table>
<thead>
<tr>
<th>Process</th>
<th>Material</th>
<th>Pour Capacity</th>
<th>Working Envelope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aluminum</strong></td>
<td>200 and 300 series aluminum</td>
<td>750 lbs</td>
<td>48” x 75”</td>
</tr>
<tr>
<td><strong>Small Titanium</strong></td>
<td>Ti 6-4, Ti 6-2-4-2, Ti 5553</td>
<td>200 lbs</td>
<td>&lt;32” diameter</td>
</tr>
<tr>
<td><strong>Large Titanium</strong></td>
<td>Ti 6-4, Ti 6-2-4-2, Ti 5553</td>
<td>1,600 lbs</td>
<td>&lt;62” diameter</td>
</tr>
</tbody>
</table>
Advancements in Investment Casting

- **Exciting “New” Alloys**
  - Cast titanium with forged properties
  - High strength aluminum casting alloy under development

- **Automation/Robotics Enabling Efficient High Volume Production**
  - Satisfying demands for commercial transportation vehicles

- **Ability to produce very small and large 3D single piece castings**
  - Titanium parts up to 62” in diameter
  - Aluminum parts up to 70” in length

- **Lead times down from 16 weeks to 4-6 weeks**
- **Development hardware available in a few weeks utilizing SLA and electronic technologies**
# Cast Material Properties

## Titanium

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Treatment</th>
<th>$\sigma_{\text{uts}}$ (ksi)</th>
<th>$\sigma_y$ (ksi)</th>
<th>% el.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti 6-4</td>
<td>HIP+Anneal</td>
<td>130</td>
<td>120</td>
<td>6</td>
</tr>
<tr>
<td>Ti 6-2-4-2</td>
<td>HIP+Anneal</td>
<td>125</td>
<td>115</td>
<td>8</td>
</tr>
<tr>
<td>Ti 5553</td>
<td>Stabilized</td>
<td>168</td>
<td>153</td>
<td>9</td>
</tr>
</tbody>
</table>

## Aluminum

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Treatment</th>
<th>$\sigma_{\text{uts}}$ (ksi)</th>
<th>$\sigma_y$ (ksi)</th>
<th>% el.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A356</td>
<td>T6</td>
<td>32-45</td>
<td>28-34</td>
<td>3-5</td>
</tr>
<tr>
<td>D357</td>
<td>T6</td>
<td>45-50</td>
<td>36-40</td>
<td>2-3</td>
</tr>
<tr>
<td>C355</td>
<td>T6</td>
<td>41-50</td>
<td>31-40</td>
<td>2-3</td>
</tr>
<tr>
<td>A201</td>
<td>T7</td>
<td>60</td>
<td>50</td>
<td>3-5</td>
</tr>
</tbody>
</table>
Development Capabilities

- Pre-Production Use of Electronic Data
  - Solidification Modeling
  - Concurrent Engineering
  - Wax Tooling
  - Inspection

- Rapid Prototyping
  - SLAs
  - Complex Pattern Fabrications
  - 1-2 Week Lead-times
  - Electronic Files are Critical
Evolution of Alcoa Design Activities

Audi Space Frame → A3I → ALSI

**ALSI Objective**
To integrate Alcoa’s *proven* capabilities into the design of *new* and *legacy* military ground vehicles:
- Design methodology
- Depth of material expertise
- Breadth of manufacturing capabilities

**ALSI Goal**
To partner with military ground vehicle OEM’s to provide the Army with *cost-effective weight reduction* through the implementation of Alcoa/OEM solutions.

**GOAL:** 25%-50% reduction in weight *(system dependent)*
Conclusions

• Advanced Metallic Materials have enabled achievement of key lightweight system initiatives and are in the process of supporting others

• Capabilities are evolving and focused to meet needs of armament and protection community by addressing
  – Materials technology – to achieve desired properties
  – Processing technology – to ensure effective integration in complex configurations at an affordable cost
  – Design expertise – to assist OEM’s in meeting their lightweighting goals in a cost-effective manner