Titanium Supply Chain Trends For The Aerospace Industry

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This presentation shall answer the following questions for the aerospace titanium supply chain...

What are the main capacity constraints?
How is the workload distributed globally?
What are the key global trends and structural adjustments?
Contents

Demand Overview
Supply Side Overview
Key Global Trends
Aerospace titanium is 40% of total titanium market, and represents 12% of all aeromaterial demand.
Titanium is anticipated to grow >4% per annum with strong growth by airframe

Titanium Aerospace Demand Forecast*

- Titanium growth is led by airframe/component with 6% CAGR
- Growth is driven by 787, A350 and F-35 programs
- Engine titanium is muted by increased use of composites

* 2013/2014 demand is likely closer to 130M lbs

Source: ICFI
Three largest titanium mills account for nearly 80% of production, led by VSMPO

Titanium Mill Output for Aerospace (2014)

- Global mill demand for aerospace is roughly 130M lbs annually
- Mills are assumed to currently operate between 55 to 65% utilization
- Aerospace represents 50 to 80% of mill’s portfolio

* Includes inventory overhang
Capacity for downstream value add is constrained

Simplified Titanium Supply Chain

Heat treatment and final machining lack adequate investment, and surface treatment is sub-optimized.

Key:
- limited
- adequate

Source: interviews
Imbalances within the global supply chain create inherent inefficiencies

Titanium Supply Chain Capacity*

<table>
<thead>
<tr>
<th>Region</th>
<th>Melt</th>
<th>CD Forge</th>
<th>Machine</th>
<th>Assemble</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>45%</td>
<td>50%</td>
<td>50%</td>
<td>45%</td>
</tr>
<tr>
<td>Europe</td>
<td>5%</td>
<td>30%</td>
<td>35%</td>
<td>35%</td>
</tr>
<tr>
<td>Russia/Kazstn</td>
<td>35%</td>
<td>15%</td>
<td>5%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Asia</td>
<td>15%</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Rest of World</td>
<td>0%</td>
<td>0%</td>
<td>&lt;1%</td>
<td>5%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

* For aerospace closed die forging, final machining, subassembly

There is considerable benefit to melt, forge and machine in close proximity

Source: interviews, analysis
Contents

- Demand Overview
- Supply Side Overview
- Key Global Trends
Various events have influenced supply chain over past several years

Trends for Aerospace Titanium Production*

- Global Sourcing Disruptions
- Russia As Strategic Partner
- Directed Buy Contracts
- Additive Manufacturing
- Competing Materials
- Vertical Integration
- OEM Margins

*Includes longer-term structural adjustments
Crisis in Russia has prompted Boeing and UTC to forward buy titanium stock

Trend #1: Disruption of Global Sourcing

- Boeing and UTC have started stockpiling up to 6 months of customized titanium forgings
- Many of these forgings are specialized to VSMPO
- Ukraine crisis is further complicated as Ukraine provides nearly all VSMPO’s raw inputs
- Sources speculate some lead-times have doubled

Source: WSJ, secondary research
VSMPO is a major supplier of titanium products – geopolitics are creating a real concern

Trend #2: VSMPO as Strategic Partner

- **VSMPO is responsible for 30-35% of world’s titanium, and major supplier to Boeing and Airbus**

- **VSMPO has its own 75Kt press**

- **In 2013, signed JV with Alcoa to collaborate with forgings on Alcoa’s 75Kt press**

- **In 2009, Boeing initiated JV with VSMPO (called UBM) to machine various forgings**

- **In 2013, Boeing announced second JV facility, bring total investment to $27B (1991 to 2021)**

Domestic mills – ATI, RTI, TIMET – have benefited from this conflict

Source: WSJ, secondary, interviews
OEMs transitioning from “right-to-buy” to “directed buy” contracts, restricting latitude of its suppliers

Trend #3: Directed Buy Contracts

- OEMs moving towards “directed buy” contracts, away from “right-to-buy” (typical LTAs)
- OEMs are actively managing suppliers with multi-enterprise platform systems to ensure conformity
- “Closed-loop” system is fairly standard in auto industry
- Aerospace maybe 5-10 years from wide-scale adoption of this real-time monitoring

Source: Supply Dynamics, interviews
Additive manufacturing has great potential in aerospace, yet its application needs to be clearly understood.

Trend #4: Additive Manufacturing Adoption (1/3)

Metal AM Systems by End Market

Technology Adoption for AM (Production vs Prototyping)

Aerospace constitutes 20% total AM market and its implementation in production environment is nascent.

Source: Credit Suisse (LHS), Wohlers (RHS)
AM allows for design optimization for complex parts

Trend #4 CONT: Additive Manufacturing (2/3)

AM involves “growing” parts layer-by-layer via laser melting of powder metal – technology developed in 1980s for DARPA

**Advantages:** enhance design flexibility, reduced part count and weight, reduced scrap

**Disadvantages:** limited size, small batches, unit cost, material control

- **Targets:** complex geometries (e.g. casting), metals difficult to machine
- **Adoption:** non-structural parts for production; end-of-life parts for repairs

FAA certification is a key concern!
On July 15, GE announced plans for factory in Alabama, first to mass-produce parts using AM.

Production begins in 2015 with nozzles for LEAP engine – 1000/year via 10 AM machines.

Goal is >100,000 AM parts by 2020.

GE/Avio actively exploring AM using Ti-AL for LPT blades for GE9X engine.

GE plans to invest $3.5B in AM by 2020.
Most examples of titanium displaced involve the gas turbine fan

Trend #5: Competing Materials

- CFRP fan blades for CFM LEAP
- AL-LI fan blades for P&W GTF
- Large scale test of CFRP fan with CFRP containment case for Rolls Royce
- Current testing CMC exhaust nozzle for Trent by Rolls Royce
- Ongoing trade studies for AL-LI to supplant TI in various airframe parts
- Limited application of TI + AL bonded hybrid for some structural applications
- Some examples of TI 5553 replaced with TI 6-4 due to ease of machining
Titanium mills continue to vertically integrate – Alcoa is now a contender

Trend #6: Mill Vertical Integration

Machine

CD Forge

Melt

Ladish  Japan Aeroforge  Wyman Gordon/Carlton Forge  Aubert&Duval (Internal)  Firth Rixson/(Internal)

Alcoa has moved more aggressively into gas turbine with Firth acquisition and recently announced P&W contract

Key:

- extensive
- limited

Source: Credit Suisse, secondary, interviews
OEMs have increased margins by tactics targeting supply chain

Trend #7: OEM Margins

- OEMs margins are consistently lower than its suppliers
- OEMs have shifted design authority from “build-to-print” to “risk-sharing partner” – aiding profitability
- OEMs have rationalized direct suppliers, and implemented mandatory price concessions
- Core competence maintained via strategic facilities investments (e.g. Boeing 777X wing)

### A&D Operating Margins

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEM</td>
<td>6.3%</td>
<td>6.4%</td>
<td>7.5%</td>
</tr>
<tr>
<td>Tier 1</td>
<td>13.2</td>
<td>12.8</td>
<td>12.7</td>
</tr>
<tr>
<td>Tier 2</td>
<td>15.8</td>
<td>16.2</td>
<td>17.1</td>
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<tr>
<td>Tier 3</td>
<td>11.0</td>
<td>9.6</td>
<td>2.1</td>
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<tr>
<td>Aerostructures</td>
<td>5.0</td>
<td>4.9</td>
<td>5.5</td>
</tr>
<tr>
<td>Electronics</td>
<td>11.4</td>
<td>11.9</td>
<td>12.1</td>
</tr>
<tr>
<td>Propulsion</td>
<td>11.6</td>
<td>12.2</td>
<td>13.7</td>
</tr>
<tr>
<td>Services</td>
<td>5.5</td>
<td>6.5</td>
<td>6.1</td>
</tr>
<tr>
<td><strong>TOTAL A&amp;D</strong></td>
<td><strong>8.4%</strong></td>
<td><strong>8.6%</strong></td>
<td><strong>9.4%</strong></td>
</tr>
</tbody>
</table>

Source: Deloitte, interviews
Thank you for your attention

- Aerolytics LLC -
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www.aerolyticsllc.com