Impact of Additive Manufacturing and Compaction Technologies on the Titanium Industry
“It’s tough to make predictions, especially about the future.” Yogi Berra

This presentation contains predictions, estimates and other information that may be considered forward-looking. While these forward-looking statements represent current judgment on what the future holds, they are subject to risks and uncertainties that could cause actual results to differ materially. You are cautioned not to place undue reliance on these forward-looking statements. Please keep in mind there is no obligation to revise or publicly release the results of any revision to these forward-looking statements in light of new information or future events.
Agenda

Additive Manufacturing Technologies

Compaction Technologies

Business Case

Forecast

Headwinds

Tailwinds

Impact

Buy:Fly

Conclusion
Additive Manufacturing

Prototypes, Tooling, Serial Production and Repairs

Smaller parts from spherical powder
- Laser additive manufacturing
- EB AM
- Binder jetting
- Filament AM
- Jet fusion
- Material extrusion
- Liquid metal printing (also from wire)

Larger parts from spherical powder
- Laser DED

Larger, heavier and hybrid parts from wire
- EB wire AM
- Plasma wire AM
- Electric arc wire AM

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Compaction Technologies

High volume, small production parts from powder
• MIM: ultrafine spherical powder
• CIP: non-spherical powder
• P&S: non-spherical powder

Low volume, large production parts from powder
• HIP: spherical preferred
Improved systems performance: longer life, lighter weight, design freedom

Part consolidation: lower cost, inventory, and supply chain logistics

Bespoke and custom manufacturing: built-for-you, out-of-production, etc.

On-demand, decentralized production: shorter cycle time, less inventory

Bottom line: Additive Manufacturing Does More, Cost Less
Drivers

Additive manufacturing productivity improvements

Melt-free, low-cost Ti alloy powder will be a catalyst that enables AM and compaction technologies

Collapsing Buy:Fly ratios
Its Been Done Before

History of Aluminium demand

- Transition from precious metal to commodity
- Two decades of growth stabilises real prices
- Commercial aircraft expand rapidly post 1950
- Oil price shocks lead to oversupply
- Large scale aircraft manufacture starts during 2nd world war

Virtuous Growth Cycle

Source – USGS

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Titanium Powder Forecast

History  Forecast

Demand

Aggressive
Forecast
Conservative

Today

Today
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<th>Additive Manufacturing</th>
<th>Ti Alloy Powder</th>
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<td>Qualifications for serial production</td>
<td>Finalize melt-free powder development</td>
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<td>Need to improve productivity</td>
<td>Qualify melt-free processes</td>
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<td>Competition from aluminum</td>
<td>Wire and powder technologies competing</td>
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<td>Time between new and derivative platforms</td>
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<td><strong>Compaction Technologies</strong></td>
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<td>Ultra-high volume culture</td>
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<td>Powder price</td>
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Compelling business cases

Dramatically increasing powder availability

Melt-free, low-cost powder, promise of advanced, original alloys

Highly productive compaction technologies: MIM, CIP, P&S
Impact on the Titanium Industry

Short-term  Increased bar, wire, and powder demand

Mid-term  AM begins replacing smaller castings & components from multiple parts

Long-term
  • Additively manufactured biomedical implants further reduce bar & forging demand
  • AM preforms erode billet demand for forgings
  • Longer part life results in fewer replacement and spare parts
  • Startup businesses use additive manufacturing not traditional mfg. processes
  • AM buy:fly ratios reduce mill product demand

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1 ton of powder promises to replace many tons of mill products

- AM ~2:1 3-5 fewer tons of mill products and castings
- MIM ~1.1:1 7-10 fewer tons of mill products and castings
- CIP ~1.1:1 7-10 fewer tons of mill products and castings
- P&S ~1.1:1 7-10 fewer tons of mill products and castings

Numerous are approximations, not based upon specific parts
Additive manufacturing and compaction technologies will change the titanium industry in seen and unforeseen ways for a generation to come.

**Conclusion**

**Threats**
- Powder AM reduces demand for long products and castings
- Wire AM reduce billet & forging demand

**Opportunities**
- Compaction technologies enable new applications
- Unknown unknowns

Additive Manufacturing Enabled by Titanium Powder is a Growth Opportunity

Additive Manufacturing Does More, Costs Less