Advances in PM Titanium: Reduced Cost and Improved Properties

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Demand for Titanium is Growing

- Current US & European Military Aircraft
  - F-22 Raptor ~110,250 lbs Ti/plane*
  - Ramp-up of the JSF F-35
    - Estimate 3,100 planes
    - ~45,000 lbs Ti/plane*
- Demand for Commercial Aircraft
  - Boeing 787 ~1,750 planes
  - ~250,000 lbs Ti/plane*

* Material Buy Weights
Rising Demand Pressure on the Titanium Industry

Titanium Shipments (millions of pounds)

Compiled from USGS Materials Information Titanium Statistics and Information
Military Spending & Philosophy

Recent Statements from the DOD...

“The Pentagon Is Serious About Saving Money”*

- Affordability requirements
- Incentivize productivity and innovation
- Remove obstacles to effective competition

Military Aircraft

F-22 Raptor

Will there need to be a Sacrifice in PERFORMANCE for Affordability?

Will there need to be a Sacrifice of QUANTITY for Affordability?

Joint Strike Fighter (F-35)
DoD & Commercial Customer Needs

- Affordable Materials and Products
- Stability of Costs and Material Availability
- Reduced Material Buy-to-Fly
- New Engineered Materials
- An alternative to the conventional supply chain...now.
Dynamet’s Ti PM Technology

- Provides an affordable manufacturing pathway
- Properties meet requirements for most applications
Advantages of Ti PM Processing

- Near-net shape manufacture
- Results in fine-grained microstructure
- Processing below the melting point
- Enables new alloys with tailored properties
- Bypasses traditional supply chain
- Lower cost and quicker delivery
CIP/SINTER/CHIP Process: Production Parts

Alloy: Ti-6Al-6V-2Sn, CHIP Process
Production Volume: >50,000 parts
50% Cost Savings

Alloy: Ti-6Al-4V; CIP+Sinter Process
Production Volume: >45,000 parts
70% Cost Savings
Growing Acceptance

- Dynamet Technology’s successful production supply of titanium alloy P/M product by this process began in the late 1970s.
- Success with niche products has proven the capabilities and benefits of this technology.
- This technology has recently attracted the attention of significant users of titanium product.
Quality and Consistency

- CIP-Sinter/CHIP Process is a Mature Process
- Demonstrated Consistency
  - PM Preform Size and Shape
  - Density
  - Mechanical Properties
- Very High Material Utilization and Product Yield
  - PM Processing
  - Finish Machining
Why Now? What’s Changed?

- Customers: Attitudes & Affordability
  - Cost Pressures
  - Alternative to conventional supply chain
  - Major Ti customers interest in PM technology

- Attention to Titanium PM
  - Promotion of potential new low cost Ti powders
  - Dynamet Technology’s production proven manufacturing of PM titanium parts
Size & Shape Capability
Tubular Shaped Parts

- 7.25" OD x 3/16" wall x 17" long
- 6" OD x 0.5" wall x 26" long
Ti Mill Products Forms via PM

PM Billets

Machined

Extruded

Rolled

Forged
Titanium Tubing Development

REINVENTING TITANIUM
Aerospace & Defense, Industrial and Medical

Titanium Tubing Development

0.875 “ OD x 0.145” wall x 18” long

PM Tube Hollows

Rolled Tube Sections

Tube Rolling
New Titanium Alloys by PM

- Create new alloys by powder metal with unusual alloying elements.

- Tailored Ti PM alloys that meet new design goals EXPAND the use of titanium.
Tailored Alloys for Hydraulic Tubing

PM Ti-3Al-2.5V & Modified PM Ti Alloys offer:
- Damage Resistance
- Damage Tolerance
- Higher Strength
- Affordability

Anticipated Benefits:
- Greater Safety
- Weight Savings
- Cost Savings
Tailored PM Alloys for Medical Device Applications

- Ti MMCs for Wear Resistance
  - CermeTi® MMCs
  - Replacing stainless steel in “metal-on-metal”

- High Strength & Hardness Ti-W Alloys
  - Abkolloy® Compositions
  - ~200 ksi UTS 190 ksi YS 5% -- HRC: 45-47

- Ti-Ta Alloys for a variety of medical applications
## Low Modulus PM Ti-30Ta

<table>
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<th>Alloy</th>
<th>UTS (ksi)</th>
<th>Modulus (msi)</th>
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<tr>
<td>CP Ti</td>
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<td>Ti-6Al-4V</td>
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<td>Ti-13Nb-13Zr</td>
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<td>PM Ti-30Ta</td>
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<td>10.8</td>
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</table>
Novel Ti-Ta Materials

Balloon Stents - High Ta-Ti
Low Recoil (High Modulus, Low Yield Strength)

Self-expanding Stents - Midrange Ta-Ti
Shape Memory

Orthopaedic Implants: Ti- 30%Ta
Flexibility (Low modulus, high yield)

Ni-Free Alternatives to Nitinol & Steel
Market Impact of Ti PM

- PM product will substitute for mill product
- PM will expand the use of titanium via
  - Affordability and availability
  - Increased service use
Summary/Conclusion

Affordability & Enhanced Properties by PM will Increase Titanium’s Competitive Position

Aerospace & Defense, Industrial and Medical