Titanium Powder – the Raw Material of Future Production

Introduction and Overview

Applications for Powder Metallurgy

Methods & Systems for Powder Production

Process of Atomisation

Summary and Outlook
Metal Powder the new source of Manufacturing

Additive Manufacturing with 3D Printer will be among the 10 future key technologies*1

Source: *1 Mc Kinsey Global Institute / *2 Steel and Metals Market Research GmbH
Metal Powder the new Source of Manufacturing

Development in selected Industries for additive Manufacturing

Additive Manufacturing requires Spherical Particles, with 15 – 100μm diameter

- High Grade & Stainless Steel
- Ni-Base and Ni-Co Base alloys
- Titanium alloys
- Precious Metals

Source: Ernst & Young
Advantage Powder Metallurgy

Production of complex Structures with minimum usage of Material

Yield up to 75%

Lowest energy consumption

Mechanical Properties of the work pieces produced by 3D Printing are similar to those produced by Casting and Forging

Source: EPMA “Vision 2025”, January 2015
Powder Metallurgy, some Applications

Tools
- High grade steel
- Tool & die steel

Medical
- Stainless steel
- Ni-base alloy
- Ti & Ti alloy

Aircraft Industry
- High grade, stainless Steel
- Ni-base, super alloys
- Ti & Ti alloy

Automotive Industry
- High grade steel
- Ni-base alloys
- Al alloy
- Ti & Ti alloy

Jewellery & Chemical
- Precious metal
- Special alloys
Additive Manufacturing, sample 3D Printing

Principle of 3D Printing

- Build the work piece by selectively sintering and solidification in layers of the metal powder.
- Metal powder in a powder bed is the feed-stock, which will be transferred to the sintering area.
- Selective sintering by Laser or Electron Beam.
- Typical Powder sizes are:
  - Laser System: $15 \mu m < d_{50} < 45 \mu m$
  - Electro Beam: $55 \mu m < d_{50} < 75 \mu m$
- Achievable solution:
  - $X, Y: 43 \mu m$
  - $Z: 16 \mu m$
- High flow ability is only achievable with spherical powder and narrow tolerances of the particle size.

Source of Principle: Extreme Tech Newsletter
Making of Metal Powder

Mechanically
- Crushing and Grinding of the Metal
- Irregular and edged particles shape
- Particle size < 600μm.
- Application mainly for pressing and sintering process.

Chemical
- Reduction of grinded metal oxides,
- Precipitation of metal salt solution,
- Thermal de-composition of metal.
- All processes need after treatment,
- Irregular and edged particles shape

Atomization
- Melting and atomization in a high pressure gas or in high pressure water beam.
- As powder has up 100 times higher surface the ability of oxidation through the water is very high.
  Atomization with an inert gas like Argon avoids oxidation
- The particles are spherical with <100μm diameter
Titanium and Titanium-Alloys

Sample TiAl6-4: Chemical Composition

<table>
<thead>
<tr>
<th></th>
<th>Fe</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>H</th>
<th>Al</th>
<th>V</th>
<th>Ti</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>≤ 0,25%</td>
<td>≤ 0,08%</td>
<td>≤ 0,05%</td>
<td>≤ 0,13%</td>
<td>≤ 0,012%</td>
<td>5,5% - 6,5%</td>
<td>3,5% - 4,5%</td>
<td>balance</td>
</tr>
</tbody>
</table>

The reactive behavior of Titanium allows melting only in vacuum or under pre-evacuated protective atmosphere of Argon.

The low allowed content of Graphite (800 ppm), Oxygen (1,300 ppm) and Hydrogen (120 ppm) will be exceeded by using any conventional crucible material.

Cold Wall Crucible – permanently water cooled cupper crucible - will avoid the any cross contamination. Very sophisticated and not controllable process step of pouring to the atomization nozzle. Very high energy consuming.

The best way to produce high pure Titanium alloy powder is using an Electrode Inert Gas Atomization (EIGA) system with an open high frequency induction coil for the melting.
System for Powder Production (EIGA)

Charging
Feeding Device

Melting Section
Melting Coil
Atomization Nozzle

Spray Cone
Powder Tower

Exhaust of inert Gas
Cyclone

Pneumatic Powder
Transport Tube

Powder Collection

Electrode with conical top

EIGA: ALD
Vacuum Technologies

www.ald-vt.com
Process of Powder Making

- Electrode Feedstock
  - Electrodes with 50 – 150 mm Φ and 300 – 1000 mm length
  - Round electrodes with conical tip promote reliable melting
  - Rectangular (100mm), or hexagonal electrodes
  - Pressed electrodes

- Electrode Mounting
  - Electrode mounting to electrode feeding device
  - Continuous lowering of electrode into conical induction coil

- Melting
  - Couple energy into electrode by high frequency electro-magnetic field
  - Form melt film and melt on electrode surface due to high frequency power

- Atomization
  - Continuous and steady flow of the molten metal to the atomization nozzle
  - Atomization of melt stream by high-pressured inert gas
  - Solidification by falling in the tower
Features

- Separate feeding chamber allows fast exchange of the electrode
- Melting in a high frequency open coil induction process in an Argon atmosphere
- Very clean atmosphere due to pre-evacuation of the air
- Open coil avoids any kind of cross contamination with crucible material
- Minimized pickup of non metallic elements such as H₂, N₂, O₂
- Temperatures up to 2,500°C
- Simple and robust process with short cycle times of 15 – 45 minutes
- Productivity increases with the Electrode diameter
Melting and Atomization Process

- High frequency melt power supply allows controlled melting at the surface of the electrode conical.
- Direct metal flow to the atomization nozzle system.
- Flow Rate: 0.2 – 2.5 kg/min
- Gas Pressure: 20 – 40 bar
- Gas Flow Rate: 15 - 25 m³/min
- Atomization Gas: Argon
- Particle size: 15 to 150 μm
Powder Characteristics

- Atomization is a randomize process following the Gauss normal distribution.
- Powder is free of ceramic or any other contamination.
- Typical particle size range \(50 \, \mu m \leq d_{50} \leq 120 \, \mu m\) depend on the electrode diameter and melting speed.
- Standard deviation defined as \(S = d_{84}/d_{50} = d_{50}/d_{16}\) typically is: \(1.40 \leq S \leq 2.40\)
- Sieving may be required.
- Yield up to 80%.
- The morphology of the powder produced with electrode inert gas atomization (EIGA) is spherical.
<table>
<thead>
<tr>
<th>Market</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical</td>
<td>Ti alloy body implants</td>
</tr>
<tr>
<td>Aviation</td>
<td>Ti alloys (TiAl6V4, TiAl) aircraft engine turbine blades and disks</td>
</tr>
<tr>
<td>Automotive</td>
<td>Ti alloys (TiAl6V4, TiAl) valves, charger, piston</td>
</tr>
<tr>
<td>Other Markets</td>
<td>Semiconductor – Sputtering targets Sport: golf club</td>
</tr>
</tbody>
</table>

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Summary & Outlook

- Additive Manufacturing is one of the key technologies of the future
- New and improved printing technologies will increase the productivity and reduce the costs significantly
- Complex forms could be produced without any costs for mold or tools and significantly reduced machining
- Applications and new developments in aircraft, automotive, and medical industry will be the driving forces with an enormous growth in the near future
- Only spherical powder will fulfill the demanding requirements of additive manufacturing processes
- Only the Electrode Inert Gas Atomization (EIGA) can achieve contamination-free and spherical Titanium or Titanium-Alloy powder.

There are a lot of discussions and opinions about Industry 4.0

Spherical Titanium Powder is the Raw Material for Industry 4.0
Thank You for Your Attention

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