Titanium alloy powder production and processing by MIM

Osaka Yakin Kogyou Co., Ltd.
Kenji Doi
Table of contents

1. Company profile
2. Metal injection molding
3. MIM conventional titanium
4. Talor-made titanium alloy MIM parts
5. R&D of γ-TiAl intermetallic compound with MIM
Business description of Osaka Yakin Kogyou

Heat treatment 1941~
• Vacuum heat treatment
• Vacuum brazing
• Nitriding
• High temperature nitriding

MIM (Metal Injection Molding) 1989~
• Iron-based alloy
• Stain-less steel
• Tool steel
• Active metal
• Heat-resistant alloy

AM (Additive Manufacturing) 2014~

Manufacturing based on metallurgy experience for over 75 years!
Osaka Yakin’s actions related to titanium

- R & D of MIM TiAl parts
  Powder made by Self-propagating High temperature Synthesis (SHS)
  Gas atomized powder
- Introduced Gas atomization unit
- Manufacturing MIM titanium alloy parts
- R & D of titanium medical devices with powder pressing
- Introduced additive manufacturing system
Table of contents

1. Company profile
2. Metal injection molding
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Powders for various P/M process

Particle size distribution of gas atomized powder

Particle size for P/M process
MIM process

Kneading

Injection molding

De-binding, Sintering
## Features of Osaka Yakin’s MIM

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas atomization unit</td>
<td>Active metal</td>
</tr>
<tr>
<td>Three types of binder</td>
<td>General parts, active metal, large size parts</td>
</tr>
<tr>
<td>Clamping force</td>
<td>180t&lt;br&gt;Large size parts (~400g)</td>
</tr>
<tr>
<td>Pressure-assisted sintering furnaces</td>
<td>High density, high reliability</td>
</tr>
<tr>
<td>Various apparatus for inspection and analysis</td>
<td>High reliability, R&amp;D</td>
</tr>
</tbody>
</table>

*CT system*
Table of contents

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Change in oxygen content through MIM process

- CPTi
- Ti-15Mo-5Zr-3Al
- Ti-6Al-4V
Influence of oxygen on MIM CPTi

![Graph showing the influence of oxygen content on tensile strength and elongation. Tensile strength increases with oxygen content, while elongation decreases.](image-url)
MIM Ti-6Al-4V

Sample: as MIM Ti-6Al-4V

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Mechanical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>Carbon</td>
</tr>
<tr>
<td>0.023 wt%</td>
<td>0.070 wt%</td>
</tr>
</tbody>
</table>

Tasks in order to achieve standard (AMS4928, ASTM Gr.5)

- Lower oxygen content
- Suppression of grain coarsening
- Optimal heat treatment
# Standardization of MIM titanium

<table>
<thead>
<tr>
<th>JPMA S01:2014</th>
<th>Metal injection molded materials - Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material</strong></td>
<td><strong>Standardized items</strong></td>
</tr>
<tr>
<td>MIM-Ti (High-ductility)</td>
<td>Chemical composition, yield strength, ultimate tensile strength, elongation, rotating bending fatigue</td>
</tr>
<tr>
<td>MIM-Ti (High-strength)</td>
<td></td>
</tr>
<tr>
<td>MIM-Ti6Al4V</td>
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</tbody>
</table>

## ASTM

<table>
<thead>
<tr>
<th>Standardization Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F2885:11</td>
<td>Standard specification for Metal Injection Molded Titanium-6Aluminum-4Vanadium Components for surgical implant application</td>
</tr>
<tr>
<td>F2989:13</td>
<td>Standard Specification for Metal Injection Molded Unalloyed Titanium Components for Surgical Implant Application</td>
</tr>
</tbody>
</table>
Table of contents

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Tailor-made titanium alloy for wear resistant gear

Ti-5%Fe (mass%)
Blended elemental method
Density : 4.6 g/cm³
Relative density : 98 %
Constituent phases : α+β
Surface modification : Oxy-nitriding

※ compared with plasma carburizing
Tailor-made titanium alloy for wear resistant gear

Wear test
( Ball on disk tribometer)
## Tailor-made titanium alloy for wear resistant gear

### Rotary mounting test

<table>
<thead>
<tr>
<th>Surface modification</th>
<th>as-sintered</th>
<th>Plasma carburized</th>
<th>Oxi-nitrided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of rotations</td>
<td>2,000</td>
<td>6,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Appearance</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
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Table of contents

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R&D of γ-TiAl inter metallic compound with MIM

MIM Ti-33.8Al-3.6Cr (mass%)

< Powder for MIM >

Gas atomized powder
Particle size: less than 45 µm
D_{50} = 33µm
Oxygen content : 0.11wt%

< Sintered parts >

Density : 3.8 g/cm³
Relative density : 98.5%
Oxygen content : 0.15 wt%
Carbon content : 0.04 wt%
R&D of γ-TiAl inter metallic compound with MIM

MIM Ti-33.8Al-3.6Cr (mass%)

< Tensile properties >

< Microstructure>

![Graph showing tensile strength and elongation vs. temperature](image1)

![Microstructure image showing lamellar structure, β phase, and γ phase](image2)

Scale: 50μm
Summary

• Gas atomization unit enables high quality active metal powders for MIM
• Request of active metal powders has been increasing
• It is very important to prevent oxidation in each process
• MIM Ti and Ti-6Al-4V were standardized in Japan
• Oxi-nitriding enables wear resistance on originally designed titanium alloy
• Modifying alloy by blended elemental method is applicable to MIM