Development of New Alpha+Beta Titanium Alloy of Vanadiumless

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Daido’s Titanium Alloys

**Plant**
- DT2 (CP-Ti)
- DT7 (0.15Pd)

**Sports**
- DAT5 (6Al-4V)
- DAT51 (22V-4Al)
- DAT15G (15-3-3-3)
- DAT55G (15V-6Cr-4Al)
- CA Ti
- VLTi

**Medical**
- DT2, DT4 (CP-Ti)
- DAT5E (6-4 ELI)
- DAT67 (6Al-7Nb)

**Aerospace**
- DAT5 (6Al-4V)
- DAT53 (6Al-6V-2Sn)
- DAT54 (6Al-4Sn-4Zr-3Mo-1Nb-0.4Si-0.06C)

**Automobile**
- DAT52F (3Al-2V-REM-S)
- DAT5M (6Al-4V-Fe)
- DAT62M (6-2-4-2S)
- DAT54
- γTIAI (33.5Al-4.8Nb-1Cr-0.3Si)
- VLTi

**PPC furnace**
**GFM forging machine**
**LEVICAST**
**LEVI atomization**

*Alloy developed by Daido*
To supply more economical and stable price titanium alloy, a new alloy without expensive alloying element is necessary.
Concept of New Alpha+Beta Alloy

- Requirement of cost reduction of titanium alloys
- Recent rapid price increase of raw material (Vanadium etc.)

- Application of low cost titanium raw material (Off-grade titanium sponge)
- Vanadiumless alloy

- Vanadiumless titanium alloy
  VLTi
Development Target

Daido’s approach to cost reduction of Ti alloys

DAT5: Ti-6Al-4V
DAT5M: Ti-6Al-4V
Off-Grade Titanium Sponge

Target

the same properties as Ti-6Al-4V
• Hot workability
• Strength

Production cost

low
high

Year

Off-Grade Titanium Sponge

Titanium raw materials for
- Aircraft materials
- Mill product

Off-Grade titanium sponge
(Raw material for steel making)

Example of Iron distribution in sponge masses
Alloy Design

Ti-6Al-4V (base alloy)

Alpha stabilizing element
Al = 6%
for high temperature strength

Off-Grade titanium sponge

Beta stabilizing element
V ⇄ Fe

V equivalence: 4V ⇄ 1Fe
for formability and heat treatment ability

VLTi(Ti-6Al-1Fe)
Microstructure

Annealed at 750°C

200 µm

50 µm

Ti-6Al-4V

VLTi(Ti-6Al-1Fe)
Hot Workability

Test condition:
- Cross head speed: 50.8 mm/s
- Test duration: 60 seconds

Graphs showing:
- Flow stress (MPa) vs. Temperature (°C)
- Reduction of area (%) vs. Temperature (°C)

Materials compared:
- VLTI
- Ti-6Al-4V

Graphs illustrate the workability of VLTI and Ti-6Al-4V at different temperatures.
Tensile Properties at Room Temperature

- Tensile strength, 0.2% Proof stress (MPa)
- Elongation
- Reduction of area (％)

- VLTi
- Ti-6Al-4V
Relationship Between Fatigue and Tensile Strength

$$\frac{\sigma_{wb}}{\sigma_B} = 0.6$$

$$\frac{\sigma_{wb}}{\sigma_B} = 0.5$$

10⁷ Cycles rotating bending fatigue strength (MPa)

Tensile strength (MPa)

SUH11: $1050^\circ$C/0.5h/OQ+
$720^\circ$C/1h/AC

400°C

VLTi

Ti-6Al-4V

SUH11 (JIS)
(8Cr-1.5Si-0.5C)
Balance of Density and Strength

<table>
<thead>
<tr>
<th>Composition</th>
<th>Density (g/cm³)</th>
<th>Tensile Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti-15Mo-5Zr(ST)</td>
<td>5.1</td>
<td>1300</td>
</tr>
<tr>
<td>Ti-11.5Mo-6Zr-4.5Sn(ST)</td>
<td>5.0</td>
<td>1200</td>
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<tr>
<td>Ti-3Al-8V-6Cr-4Mo-4Zr(ST)</td>
<td>4.9</td>
<td>1100</td>
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<td>Ti-13V-11Cr-3Al(ST)</td>
<td>4.8</td>
<td>1000</td>
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<tr>
<td>Ti-15V-6Cr-4Al(ST)</td>
<td>4.7</td>
<td>900</td>
</tr>
<tr>
<td>Ti-15V-3Al-3Cr-3Sn(ST)</td>
<td>4.6</td>
<td>800</td>
</tr>
<tr>
<td>Ti-22V-4Al(ST)</td>
<td>4.5</td>
<td>700</td>
</tr>
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<td>Ti-6Al-4V(A)</td>
<td>4.4</td>
<td>700</td>
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<tr>
<td>Ti-6Al-1.7Fe-0.1Si(A)</td>
<td>4.3</td>
<td>600</td>
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<tr>
<td>Ti-4.5Al-3V-2Mo-2Fe(A)</td>
<td>4.3</td>
<td>500</td>
</tr>
<tr>
<td>Ti-VL22.4Al-3Cr-2Fe-1Si(A)</td>
<td>4.2</td>
<td>400</td>
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</tbody>
</table>

ST: solution treated
A: annealed

Beta
Alpha+Beta

TITANIUM 2007
Production Process

Off-grade titanium sponge
Ti scrap
Alloying element

PPC (2ton)

VAR

Hot Rolling

Wire Rolling
Annealing
wire

Bar Rolling
Annealing
bar

PPC Process
(Plasma Progressive Casting)

TITANIUM 2007
VLTi can replace Ti-6Al-4V alloy.

Typical application of VLTi:
- Golf club heads
- Intake engine valves
- Connecting Rods
Example of Application

Golf club head

- Additional weight

- Highest moment of inertia

Released in Oct. 2007

Photo: courtesy of BRIDGESTONE SPORTS CO., LTD.
Conclusion

In order to supply more economical and stable price titanium alloy, new alpha + beta titanium alloy VLTi(Ti6Al1Fe) without vanadium was developed by employing off-grade titanium sponge and iron. VLTi has following characteristics.

◆ The same mechanical properties as Ti6Al4V

◆ The lightest alloy in conventional titanium alloys

◆ Applicable to sports gears and automobile components instead of Ti6Al4V
Thank you for your attention