HIGH-PERFORMANCE METALS AND MATERIALS by GfE

Manufacturing of TiAl Powders Based on Electrode Induction Gas Atomization

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1. Introduction

**GENx aircraft engine family (GE)**
- 2011 into commercial service
- $\gamma$-TiAl in last stage(s) of LPT
- Ti 48Al -2Cr -2Nb (at.-%)

**PurePower PW100G family (PW)**
- 2016 into commercial service
- $\gamma/\beta$-TiAl in last stage of LPT
- Ti 43,5Al -4Nb -1Mo -0,1B (at.-%)

**LEAP engine family (CFM)**
- 2016 into commercial service
- $\gamma$-TiAl in last stage of LPT
- Ti -48Al -2Cr -2Nb (at.-%)
1. Introduction

The **GE9x** aircraft engine is being equipped with **TiAl LPT blades**
produced by **Additive Manufacturing via EBM**
2. GfE TiAl materials production - virgin route -

a) VAR processing of compacted consumable electrodes to ingots

- VAR furnace
- compacted consumable electrodes
- single VAR processed ingots
2. GfE TiAl materials production - virgin route -

b) Ingot homogenization in VAR Skull Melter and subsequent centrifugal casting

Partly remelted VAR ingot as consumable electrode in the VAR Skull Melter

Crucible with skull after pouring

Demoulded casting wheel consisting of 18 moulds, diameter approximately 1.3 m
2. GfE TiAl materials production - recycling route -

funnel / tundish, water jet cut feeders, crushed casting plate, crushed casting crown, secondary revert from pre-shaping via water jet cutting.
3. GfE TiAl materials production - recycling route -

ISM
Induction Skull Melting
After the centrifugal pouring procedure:
Casting wheels of VAR SM are applicable to ISM as well

Remaining skull in the crucible after pouring (diameter 320 mm)
3. Production of TiAl powders

VIGA
Vacuum Induction Gas Atomization

PIGA
Plasma Inert Gas Atomization

EIGA
Electrode Induction Inert Gas Atomization

PREP
Plasma Rotating Electrode Process
3. Production of TiAl powders

cast EIGA electrodes

EIGA processing to powder
3. Production of TiAl powders
3. Production of TiAl powders
3. Production of TiAl powders - screening under controlled Ar atmosphere -
4. Characterization of TiAl powders - EBM powder 45 – 150 µm

Apparent density: 2.2 g/cm³
Flow test: 31 s
4. Characterization of TiAl powders
- EBM powder 45-150 µm -

**Result Statistics**

<table>
<thead>
<tr>
<th>Distribution Type: Volume</th>
<th>Concentration = 0.1596 %Vol</th>
<th>Density = 1.000 g / cub. cm</th>
<th>Specific S.A. = 0.0852 sq. m / g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Diameters:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D (v, 0.1) = 49.19 um</td>
<td></td>
<td>D (v, 0.5) = 75.56 um</td>
<td>D (v, 0.9) = 124.29 um</td>
</tr>
<tr>
<td>D [3, 2] = 70.46 um</td>
<td></td>
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</tbody>
</table>

**Graph:**

- X-axis: Particle Diameter (µm.)
- Y-axis: %

- Graph shows the particle size distribution of the TiAl powders.

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**GfE**
4. Characterization of TiAl powders - EBM powder 45-150 µm -

- no deviations in alloying element composition
- minor increase of processing related impurities: Σ 160 ppm (Cu, Si, Ni)
- determined oxygen pick-up of 20 ppm within accuracy limit of analysis

<table>
<thead>
<tr>
<th>Element</th>
<th>Feed Stock</th>
<th>Powder</th>
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</thead>
<tbody>
<tr>
<td>Ti</td>
<td>57.9</td>
<td>57.8</td>
</tr>
<tr>
<td>Al</td>
<td>34.5</td>
<td>34.5</td>
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<tr>
<td>Nb</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Cr</td>
<td>2.5</td>
<td>2.5</td>
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<tr>
<td>Fe</td>
<td>0.028</td>
<td>0.030</td>
</tr>
<tr>
<td>Co</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Cu</td>
<td>0.002</td>
<td>0.008</td>
</tr>
<tr>
<td>Hf</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Mn</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Mo</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Ni</td>
<td>0.007</td>
<td>0.011</td>
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<tr>
<td>Si</td>
<td>0.003</td>
<td>0.009</td>
</tr>
<tr>
<td>Sn</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>Ta</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>V</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>W</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Y</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Zr</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>C</td>
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<td>0.008</td>
</tr>
<tr>
<td>H</td>
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<td>0.001</td>
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<tr>
<td>N</td>
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<tr>
<td>O</td>
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<td>0.041</td>
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<td>S</td>
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<td>0.002</td>
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<tr>
<td>ToE</td>
<td>0.028</td>
<td>0.044</td>
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</table>

XRF (Borax method) all figures in wt.-%
ICP
LECO combustion

TiAl TNM powder 25 – 80 µm

Apparent density: 2.2 g/cm³
Flow test: 24.1 s
5. Summary

- The strategy of GfE in the emerging market of TiAl based components for aircraft engines and race sport engines is to stay in the technology leadership for TiAl semi-finished products and powders.

- TiAl semi-finished products of outstanding homogeneity are being produced via Vacuum Arc Remelting (VAR) of ingots and subsequent homogenization in VAR Skull Melter (VAR SM) followed by centrifugal casting in permanent moulds.

- Valuable revert is being recycled in a single step conversion process to semi-finished products based on Induction Skull Melting (ISM) and subsequent centrifugal casting.

- TiAl powder production is based on Electrode Induction Melting technology (EIGA).

- Production capacities will be adjusted to market needs.
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Thank you for your attention

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