Titanium remelting studies using a semi-industrial PAM-CHR

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Uckange, France
“Valleys of Death and Darwinian Seas”

❖ Certain innovative projects can fail during the upscaling phase
   • Technical complexity and uncertainty over extrapolation from lab-scale
   • Questions about pay-back and hypotheses for the business plan
   • Cost and financial risk for the industrial entity

❖ Pilot- or semi-industrial scale trials can help accelerate this process

❖ However, they present another set of challenges
MetaFensch

- MetaFensch is a French publicly funded R&D platform whose goal is to help industrial actors bring their innovative metallurgical products/processes to market.

- Titanium is approximately 80% of our activity.

- 3 cross-sectoral domains:
  - Melting, casting and powder metallurgy
  - Metal recycling and process energy efficiency
  - Upscaling/industrialization via semi-industrial pilot furnaces

- ...serving various customer markets:
  - Aerospace
  - Biomedical
  - Automotive
  - Other...
Melting and casting R&D platform: Uckange (F)

How can these tools accelerate the time-to-market for innovative titanium processes and products?
Semi-industrial PAM-CHR

Important process parameters

- **Influence of the PAM parameters**
  - Raw material (scrap)
  - Melt speed (feeding speed/withdrawal speed)
  - Torch pattern
  - Atmosphere (pressure, gas quality)

- **Molten pool**
  - Geometry
  - Overheating
  - Flow
  - Residence time

- **Casting**
  - Segregation

- **Ingot quality**
  - Chemical composition conformity
  - Elimination inclusions (LDI, HDI)
  - Surface aspect

Key figures at a glance

<table>
<thead>
<tr>
<th>Dimension (W x L x H)</th>
<th>11,4m x 6,4m x 9,5m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting</td>
<td>Plasma arc, cold hearth (copper cooled)</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Helium: 400-1200mbar</td>
</tr>
<tr>
<td>Power</td>
<td>Torches: 3x800kVA Peripherics: 300kVA</td>
</tr>
<tr>
<td>Ingot</td>
<td>Ø 100-150 mm x 1,5 m (≈ 120kg for TA6V)</td>
</tr>
<tr>
<td>Feedstock size</td>
<td>Ingots, scraps (massives or chips), compacts</td>
</tr>
<tr>
<td>Metal type</td>
<td>Reactive metals, including titanium and titanium intermetallics</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>Thermal camera, Thermocouples, Flowmeters, Gas analyses</td>
</tr>
</tbody>
</table>
Raw material

- Scrap type
- Heterogeneity

**Compact**
- Machining chips
- Titanium sponge
- Master alloys

**Scrap electrode / bar**

**Scrap boxes**

**Remelt ingot**
Overview

Pressure: 400 – 1200 mbar
Gas: helium
Raw material
- Scrap type
- Heterogeneity

Melting
- Melting speed
- Torch pattern
- Atmosphere

Overview
- Withdrawal crucible
- Melt hearth
- Refining hearth

Feeding
- Raw material (bar)

Pouring
- Refining hearth
Melting
- Melting speed
- Torch pattern
- Atmosphere

Ingot quality
- Microstructure
- Chemical composition
- Conformity/segregation/Al evaporation
- Defect elimination

Raw material
- Scrap type
- Heterogeneity

Segregation

⇒ B-fleck

Fe enriched region, known as bet fleck, in Ti-10V-2Fe-3Al [1].

Inclusion
⇒ High Density Inclusion (HDI)
Exogeneous defects
Ex: WC (machining tools), Mo

⇒ Low Density Inclusion (LDI) or Hard α
Enriched with α-stabilizers (O, N, C)
Ex: TiN, TiO₂

[1] R.R Boyer, Boeing
Examples of studies using the PAM-CHR

❖ Fundamentals (often coupled with numerical simulation)
  • Fluid flow/particle residence time in different hearths
  • Heat transfer
  • Impact of torch gas (He and/or Ar)

❖ Scrap remelting
  • Influence of scrap quality on final ingot quality
  • Influence of scrap geometry on melting
  • Influence of raw materials on process productivity

❖ Alloy development
  • “Exotic” reactive metals
  • Tailored alloys for atomization

❖ Powder recycling
Conclusion

❖ Pilot-scale studies:
  • can be a critical step in upscaling new processes and reducing time-to-market
  • reduce industrial risk (both financial and technical)
  • are complicated to carry-out and still require interpretation

❖ Semi-industrial PAM-CHR remelting
  • A semi-industrial scale PAM-CHR has been installed in France
  • The objective is to carry out studies on scrap melting, alloy development and powder recycling
  • The PAM-CHR is compatible with an EIGA atomizer installed in the same location

❖Acknowledgements for public financing: