Outokumpu VDM
A high-performance enterprise

Quality assured production of Ti-6Al-4V by an EB furnace

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Electron Beam Cold Hearth Remelting Furnace (EBCHR) - Facility -

Capacity:
- up to 5,000 t/year

Furnace characteristics:
- Supplier: ALD Vacuum Technology
- Furnace Type: EBCHR 6/200/3600
- 6 EB guns, max. 600 kW each
- 200,000 l/sec pumping capacity
- Cold hearth melting including melt section, refining area, crystallization in water cooled copper mould

Feeding:
- 3 drum feeder 2,500 kg each
- 1 bar feeder 3,600 kg max
Electron Beam Cold Hearth Remelting Furnace (EBCHR) - Feeding -

**Feeding material:**
- Titanium sponge
- Scrap as feedstock, chips (loose or compacted), cobbles, etc.
- Every ratio of each, sponge and scrap
- Automatic weighing and mixing systems for sponge, scrap, master alloys, micro components
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- Melting -

Process control:
- Automatic Beam Power Distribution Control (ESCOSYS)
- Process observation by 6 viewing systems

Melting rate:
- up to 1,600 kg/h
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- Skull of melting and refining -
Electron Beam Cold Hearth Remelting Furnace (EBCHR) - Products -

**Grades:**
- Grade 1s (low oxygen content)
- Grade 1, 2, 3, 4
- Ti-0.8Ni-0.3Mo (grade 12)
- Ti-6Al-4V (grade 5)
- Ti-6Al-4V ELI (grade 23)

**Product sizes:**
- Ingots: 840 mm dia x 5.5 m (13.5 t)
- Slabs: 500 x 1,300 mm x 5.5 m (16 t)
- Slabs: 500 x 1,050 mm x 5.5 m (13 t)
- Slabs: 375 x 1,345 mm x 5.5 m (12.5 t)
- Slabs: 375 x 1,100 mm x 5.5 m (10.2 t)
Electron Beam Cold Hearth Remelting Furnace (EBCHR)  
- Analysis Grade 5 slab -

Chemical composition along the slab length 611340E:
- Aluminum
- Vanadium
- Iron
- Oxygen, Carbon, Nitrogen

Ti-6Al-4V
1050 x 500 x 2700 mm
Weight: 6.2 t
Electron Beam Cold Hearth Remelting Furnace (EBCHR) - Analysis Grade 5 ingot EB + VAR -

Chemical composition along the ingot length 612183E:
- Aluminum
- Vanadium
- Iron
- Oxygen, Carbon, Nitrogen

612183E, Ø850mm, Gr.5, 12t, Melt Sampling EB, drill VAR

Ti-6Al-4V
Ø850mm x 4700mm
Weight: 12 t
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- Analysis Grade 5 Ø850-ingot EB, homogeneity in the cross section

Chemical composition along the ingot length 610573E,
Homogeneity in the cross section:
- Aluminum
- Vanadium
- Iron

Cross section

Former EB ingot bottom: C bottom
slab 160 x 1100 x length [mm]

Former EB ingot top: B top
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- Analysis Grade 5 Ø850-ingot EB, homogeneity in the cross section

Ø850mm-ingot, 6t, Melt Sampling, product analysis

Cross section

Chemical composition along the ingot length 610573E,
Homogeneity in the cross section:
- Oxygen
- Carbon
- Nitrogen

Former EB ingot top
Former EB ingot bottom

C top
C bottom

B top
B bottom

slab 160 x 1100 x length [mm]
Electron Beam Cold Hearth Remelting Furnace (EBCHR) - HDI experiment, preliminary investigations -

Estimation of the bath depth:
Skull from CP melting campaign, Skull: **8 heats Gr.1S, then 4 heats Gr. 2L**

<table>
<thead>
<tr>
<th>Skull thickness (125mm)</th>
<th>Hardness</th>
<th>Longitudinal cut</th>
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<tr>
<td>124</td>
<td>109</td>
<td>liquid</td>
</tr>
<tr>
<td>124</td>
<td>110</td>
<td>liquid-solid</td>
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<tr>
<td>108</td>
<td>102</td>
<td>solid</td>
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<td>100</td>
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</table>
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- HDI experiment, preparation -

Feeding of HDI-test ingot

Contamination: 0.6, 1, 3 and 5 mm balls, insert 4x12x12 mm

HDIs - contamination before charging

Feeding of HDIs: - in the beginning
- at the first third
- at the second third
- at the end.
Electron Beam Cold Hearth Remelting Furnace (EBCHR)  
- HDI experiment, investigation after melting -

HDI ingot 610576E

Picture with indications Nr. 7, 8, 11, 12, 13

No indications

Transition to refining

Feeding

Melting area (skull turned)

Refining channel (skull)
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- HDI experiment, contamination in melting area -

Depth of liquid ~40 mm
in agreement with the preliminary investigations

X-ray picture of the skull view from the top (0°)

X-ray picture from the skull view from the side (90°)

Melting area (skull turned)
Electron Beam Cold Hearth Remelting Furnace (EBCHR) - HDI experiment, measuring of indications -

Insert before melting

Insert in the skull (melting area)

X-ray picture

X-ray picture

Pieces of an insert after melting
Electron Beam Cold Hearth Remelting Furnace (EBCHR)  
- HDI experiment, measuring of indications -

X-ray investigation of the skull (melting area)

indications: 3 inserts, 8 balls

<table>
<thead>
<tr>
<th>Fedded HDI pieces</th>
<th>4 inserts</th>
<th>4 balls (5mm)</th>
<th>4 balls (3mm)</th>
<th>4 balls (1mm)</th>
<th>4 balls (0.6mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found pieces</td>
<td>3 inserts</td>
<td>4 balls (3.6mm, 3.6mm, 2.9mm, 2.7mm)</td>
<td>4 balls (2.2mm, 2.0mm, 2.0mm, 1.3mm)</td>
<td>0</td>
<td>0</td>
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HDI test ingot 610576E
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- HDI experiment, dissolution behavior of tungsten carbide balls in the liquid pool -

- indicated diameter of balls [mm] by X-ray
- Dissolutions trend lines for 5 and 3mm balls, linear
- theoretical dissolutions trend lines for 1 and 0.6mm balls

Time of the tungsten carbide balls in the liquid melt pool [min]

original diameter of the balls [5, 3, 1 and 0.6mm] before the melting
Electron Beam Cold Hearth Remelting Furnace (EBCHR)
- Conclusions -

- Quality assured production of Ti-6Al-4V in EB furnace was demonstrated, the desired longitudinal- and cross-homogeneity of the chemical composition was achieved.
- The refining effect of the EB furnace was proven by a complex trial.
- High density particles are already absorbed in the initial melting area and frozen in a certain depth in the skull.
- Small particles were completely dissolved after specific time, larger ones partially.
Thank you for your attention

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