The Production of Titanium and Titanium Alloys Using Electron Beam Cold Hearth Single Melt

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Introduction

Electron beam melting has been used for more than 25 years for the production of
- CP sheet and strip
- CP forgings
- Alloy electrodes for subsequent VAR melt

Most CP today is produced using EB Only melt techniques
- Economies of scale (large piece weights)
  - “Jumbo” Slabs
TIMET Morgantown EB Production History

Over 250 million lbs (113,000 MT) over the 10 year period ending December 2005
All CP used as “EB Only”
Electron Beam Melting Overview

- Spray Shield
- Electron Beams
- Feed
- Hearth
- Mold
EBSM Advantages

- **Raw Material**
  - Difficult to recycle revert materials
  - Use of elemental additions
  - Elimination of expensive master alloys

- **Near Net Shape Casting**
  - Appropriate cross section for manufacture of sheet (slab) or rod (small diameter round)

- **Yield Improvements**
  - Larger piece weights
  - Fewer operations (melt and downstream conversion)

- **Defect Removal**
  - High Density Inclusion removal
Conversion

Conventional Processing of Standard Ingot

1. Heat Ingot
2. Upset Forge
3. Forge Slab
4. Reheat Slab
5. Forge Slab
6. Crop Slab
8. Condition Slab
9. Crop Slab
10. Additional Hot Rolling, Heat Treating, Conditioning and Cold Rolling Operations

Processing of EBSM Slab

1. Heat Slab
2. Roll Intermediate Slab
3. Condition Slab
4. Crop Slab
5. Additional Hot Rolling, Heat Treating, Conditioning and Cold Rolling Operations
6. Condition Slab
7. Crop Slab
Production of TIMETAL® 64 by EBSM

- Started in December 2001
- Primarily manufacture of Ti-64 plate for land-based military vehicles
- Development of process for production of airframe quality plate
- Over 7 million lbs (3,300 MT) melted to date
- Raw materials equivalent to those used in production of EB+VAR electrodes
- Publication of AMS 6945 in summer of 2005
- TIMET material approved for use by one US based OEM
Material Characteristics

- Chemistry equivalent to EB+VAR or VAR only material
- In process sampling is representative of the product chemistry
- Static room temperature material properties are equivalent to material produced by traditional melt methods
- Dynamic material properties are equivalent

<table>
<thead>
<tr>
<th>2” Plate</th>
<th>UTS</th>
<th>YS</th>
<th>Elong.</th>
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</thead>
<tbody>
<tr>
<td>AMS 4911</td>
<td>130 (896)</td>
<td>120 (827)</td>
<td>10%</td>
</tr>
<tr>
<td>AMS 6945</td>
<td>132 (910)</td>
<td>122 (841)</td>
<td>8%</td>
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</table>
Production of TIMETAL® 54M by EBSM

TIMETAL® 54M
- Originally developed for automotive forgings and ballistic application
- Mechanical properties similar to Ti-6Al-4V
- Improved machining when compared to Ti-6Al-4V

Composition
- Ti 5Al-4V-0.5Fe-0.7Mo-0.15O

Initial production quantities melted by EBSM
- 14” diameter ingot for automotive application
- Slab for aerospace plate application
Production of TIMETAL® 21S by EBSM

- Most TIMETAL® 21S is used in a sheet or plate form.
- TIMET has manufactured 21S sheet using EBSM.
- Chemistry and mechanical properties have been shown to be equivalent to traditional manufacturing techniques.
- Manufacturing tests have been conducted and the material has performed well.
Other Alloys

- Production of TIMETAL® LCB for Automotive Application
  - 8” diameter ingot

- Production of TIMETAL® 62S for Automotive Application
  - 8” diameter ingot

- Production of TIMETAL® Ti1100 for Automotive Application
  - 8” diameter ingot

- Production of TIMETAL® 3Al-2.5V for Automotive Application
  - Slab
Other Alloys

- Production of TIMETAL® 15-3-3-3 for Aerospace application
  - 12” x 44” slab
- Production TIMETAL® Ti230 for Aerospace application
  - 12” x 44” slab
- Production TIMETAL® XT for Automotive application
  - CP with Fe & Si
  - Jumbo Slab
Concluding Remarks

Over the past five years TIMET has demonstrated EBSM for Ti-6Al-4V plate products.

TIMET has successfully produced a number of other alloys via EBSM:
- TIMETAL® 21S
- TIMETAL® 54M
- TIMETAL® 3Al-2.5V
- TIMETAL® XT

The advantages of EBSM – raw materials utilization, reduced steps, reduced cycle time, improved yield – demonstrated for Ti-6Al-4V can also be applied to other alloys.
Future Work

- TIMET sees EBSM alloy as an integral part of our ongoing business
- Continued development of various alloys and applications
- Manufacture of Ti-64 EBSM bar for Medical and Aerospace application