Master Alloys

Market Trends and Analysis
Disclaimer

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Agenda

• Overview

• Critical Raw Material Issues
  – Vanadium
  – Molybdenum

• Strategic Issues

• Summary
Overview

• Master Alloys in the titanium industry are binary, ternary or multi-component alloys used to efficiently and effectively allow the melting of titanium alloys.

• Vanadium and molybdenum master alloys account for approximately 90% of the total annual demand volume.

• More than 40 master alloys are regularly used by the titanium industry including master alloys of Co, Cu, Cr, Nb, Ni, Si, Sn and Zr.
Overview (cont.)

- Quality is an absolutely critical attribute for master alloys given their use in critical applications.
- A critical and highly variable cost component in master alloy production is the market price of raw materials.
- Assurance of supply of the broad range of master alloys necessary is an important issue.
- The ability of the master alloy supplier to design solutions for titanium alloy producers is a critical value added factor in the relationship.
Vanadium
Vanadium Consumption

• Global vanadium consumption is estimated at 93,000 metric tons vanadium (MTV) 2015
• Approximately 92% of demand is from the steel industry
• Approximately 5% of demand is from the titanium alloy industry
• Approximately 3% of demand is from the chemical and energy storage applications
V Consumption by Region 2015
Total 93,000 MTV

- China: 45%
- Europe: 19%
- North America: 11%
- Japan: 6%
- CIS: 7%
- India: 3%
- Other: 9%
- Other: 9%

Total consumption: 93,000 MTV
Vanadium Consumption 2003 to 2015

CAGR 6.7%
75% of growth from China
Vanadium Production

• Vanadium production is estimated at 82,000 metric tons vanadium in 2015, down considerably from 2014

• Two thirds of current production is based on processing of coproduct vanadium bearing slag from steel mills in China, Russia, South Africa and New Zealand (Coproduct production)

• Approximately 20% of production is based on primary vanadium bearing titaniferous magnetite ore beneficiation directly for vanadium extraction (Primary production)

• Roughly 13% of production is based on processing secondary and waste materials from the oil, petrochemical and power generating industries (Secondary production)
V Production by Country 2015

China: 54%
Russia: 10%
South Africa: 15%
North America: 7%
Europe: 6%
Japan: 2%
Korea: 1%
Taiwan: 0%
India: 0%
Australia: 1%
Brazil: 4%

Total 82,000 MTV
Vanadium Production 2003 to 2015

CAGR 5.5%
95% of growth from China
Vanadium Production and Consumption 2003 to 2015

2003-2015 CAGR:
Production 5.5%
Consumption 6.7%
Vanadium Industry Cost Curve 2014

- Traditional suppliers of V2O5 to the Ti alloy market
- V2O5 producers who can meet Ti alloy quality standards via lot selection

Current market demand
Vanadium Summary

- Prices are near historic lows and at or below the cash cost of production for a portion of the supply base.
- Global inventory levels are decreasing.
- Coproduct supply base is threatened by a downturn on the global steel industry.
- Global demand continues to expand >5% CAGR in the face of slowing global steel production.
Molybdenum
Mo Reserves

- China: 8,300,000 mt
- USA: 5,400,000 mt
- Chile: 2,500,000 mt
- Canada: 910,000 mt
- Other: 1,940,000 mt
Molybdenum Demand by Application 1Q2015

133 million pounds Mo

- Engineering steel: 43%
- Stainless Steel: 21%
- Chemicals: 13%
- Foundries: 8%
- Tool Steels: 7%
- Nickle Alloys: 5%
- Titanium Alloys: 2%
- Mo Metal: 1%

Terry Perles, President MoTiV Metals, LLC

October 4-7, 2014 • Rosen Shingle Creek Golf Resort • Orlando, FL, USA
Mo Consumption

Million Pounds Mo

- 600.0
- 500.0
- 400.0
- 300.0
- 200.0
- 100.0

2011 2012 2013 2014 1Q15 Annualized

China Europe Other USA Japan CIS
Mo Consumption

Million Pounds Mo

China | Europe | Other | Japan | USA | CIS

1Q14 | 2Q14 | 3Q14 | 4Q14 | 1Q15

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Mo Production and Consumption

2011 2012 2013 2014 1Q15 Annualized

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
<th>Consumption</th>
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<tbody>
<tr>
<td>2011</td>
<td>520</td>
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<td>2013</td>
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<td>2014</td>
<td>580</td>
<td>580</td>
</tr>
<tr>
<td>1Q15</td>
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</table>
Mo Production and Consumption

Million Pounds Mo

Production Consumption

1Q14 2Q14 3Q14 4Q14 1Q15

Terry Perles, President MoTiV Metals, LLC
BHN Special Materials, Ltd.
How well we do it: Management Systems

- Advanced ERP System
- Integrated Management System

<table>
<thead>
<tr>
<th>认证项目</th>
<th>时间表</th>
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<td>EN 9100:2009</td>
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<td>Aerospace Quality Management System</td>
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<td>Occupational Health &amp; Safety Management Systems</td>
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<td>Environmental Management System</td>
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Comparison of Melting Temperatures and Densities

VAR, standard raw material input for Ti 10-2-3, Ti-10V-2Fe-3Al:

<table>
<thead>
<tr>
<th>Material</th>
<th>Raw material input ratio (wt%)</th>
<th>Melting temperature (°C)</th>
<th>Density (kg / dm³)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA1 85:15</td>
<td>12.47</td>
<td>1,890</td>
<td>5.14</td>
<td>standard raw material input</td>
</tr>
<tr>
<td>Titanium metal</td>
<td><strong>85.26</strong></td>
<td>1,668</td>
<td><strong>4.51</strong></td>
<td>standard raw material input</td>
</tr>
<tr>
<td>Iron metal</td>
<td>1.81</td>
<td>1,538</td>
<td>7.87</td>
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<tr>
<td>Aluminum metal</td>
<td>0.79</td>
<td>660</td>
<td>2.70</td>
<td>standard raw material input</td>
</tr>
</tbody>
</table>

|            | max          | 1,890                  | 7.87               |
|            | weight average| 1,685                  | 4.63               |
|            | min          | 660                    | 2.70               |
| STDEV      |              | 539                    | 2.14               |
| Δ min-max  |              | 1,230                  | 5.17               |
Comparision of Melting Temperatures and Densities

VAR, sophisticated raw material input for Ti 10-2-3, Ti-10V-2Fe-3Al:

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</tr>
</thead>
<tbody>
<tr>
<td>VAIFe 69:19:12</td>
<td>15.00</td>
<td>1,730</td>
<td>5.03</td>
<td>sophisticated raw material input</td>
</tr>
<tr>
<td>Titanium metal</td>
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</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>max</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>weight average</td>
<td>1,677</td>
<td>4.59</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>1,668</td>
<td>4.51</td>
</tr>
</tbody>
</table>

\[
\begin{array}{cccc}
\text{STDEV} & 44 & 0.37 \\
\Delta \text{min-max} & 62 & 0.52 \\
\end{array}
\]
Advantages of VA\(\text{Fe} 69:19:12\)

- The standard recipe for Ti 10-2-3 has a delta in melting temperature of 1,230°C and a delta in density of 5.17 kg / dm\(^3\) for the raw material input.

- The characteristics of VA\(\text{Fe} 69:19:12\) is closer to denominator Titanium metal by temperature, density and morphology.

- The parameters of BHN’s ternary master alloy improve:
  - the handling of the pressed electrode [ for VAR consolidation melt ]
  - the melting and dissolution activity of alloying components in the Titanium matrix
  - homogeneity of the 1st VAR ingot [ consolidation melt ], minimize VAR defects, and may even result in saving 1 VAR melting step for industrial application.
Where to go with Titanium Master Alloys?

- The perfect Master Alloy for Titanium Alloys
  - pseudo binary alloy, *theoretical* approach: Ti-V, Ti-Mo, Ti-Nb, Ti-etc.
    - highly flexible but expensive
      - in volume utilizing the same or similar, expensive equipment, e.g. VAR, VIM, EB
    - technically tough to make
      - in quality [ homogeneity, contamination-free and size ]
  - binary alloy, *pragmatic* approach: Al-V, Al-Mo, Al-Nb, Al-etc.
    - but not all oxides can be reduced by ATR – see Mr. Ellingham
    - but not all compositions can satisfy every defined final Ti-Al alloy
  - BHN master alloys, *the solution*
    - just kindly provide your RFQ and BHN will advise the best option
Strategic Issues

• The quality of master alloys is absolutely paramount and cannot be compromised.

• The price and market risk associated with vanadium and molybdenum are key drivers to the cost of master alloys. Producers of master alloys must have secure supply of these critical raw materials with minimal market price exposure.

• Master alloy suppliers must have the experience, knowledge and desire to act as a metallurgical resource for titanium alloy producers in designing new alloys or new methods to produce existing alloys. The value contribution of this capability cannot be underestimated.
Summary

• Vanadium and molybdenum markets are experiencing ten year lows in market prices today and in both cases current prices are not sustainable in the long run

• Rationalization of vanadium production in South Africa and China could set the stage for a change in the vanadium market fundamentals in the near future

• The molybdenum market is under pressure due to inventory accumulation over the past several years combined with softening demand from the important oil and gas sector. Primary Mo mines in China and North America will be under pressure.
Summary (cont.)

- Master Alloy producers can create value for the titanium alloy producers by bringing several capabilities to the table:
  - All necessary quality certifications
  - Upstream supply of V and Mo to provide competitive prices and minimize market risk
  - The experience and ability to bring metallurgical solutions to the table to improve existing alloy production methods and develop alloy systems for new titanium alloys.
Thanks!