CRITICAL MATERIALS FOR
THE NEW
MILLENNIUM

AMG Titanium Alloys & Coatings
Capital Markets Day June 2017
TABLE OF CONTENTS

AMG Business Segments 1

AMG Titanium Alloys & Coatings:
Safety 2
Overview 3
Titanium Aluminides 4
Long Term Contracts 9
Titanium Master Alloys 13
Chemicals 14
Coating Materials 15
Strategy 16
Plant Tour 17
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AMG CRITICAL MATERIALS

- Vanadium
- Superalloys
- **Titanium Alloys & Coatings**
  - Aluminum Alloys
  - Tantalum & Niobium & Lithium
  - Antimony
  - Graphite
  - Silicon Metal

AMG ENGINEERING

- Vacuum Technology
- Metallurgy
- Heat Treatment Services
LEADING SAFETY INDICATORS

- The number of safety improvement items (based on near miss or unsafe conditions) reported in 2016 was 31% higher compared to 2015. These are essential in order to avoid potential injuries.

- Safety training hours increased 11% in 2016.

- At the end of Q1 2017, lost time incident rate was 77% lower and total incident rate and incident severity rate were down 89% and 99%, respectively, from Q1 2016.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LOST TIME INCIDENTS IN THE LAST 12 MONTHS</th>
<th>12 MONTH AVERAGE LOST TIME INCIDENT RATE</th>
<th>12 MONTH AVERAGE INCIDENT SEVERITY RATE</th>
<th>12 MONTH AVERAGE TOTAL INCIDENT RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>4</td>
<td>1.31</td>
<td>0.34</td>
<td>2.62</td>
</tr>
<tr>
<td>2017</td>
<td>1 ↓</td>
<td>0.30 ↓</td>
<td>0.01 ↓</td>
<td>0.30 ↓</td>
</tr>
</tbody>
</table>

Rigorous commitment to safety reflected in continually improving safety records
SLIDE III: OVERVIEW

AMG Titanium Alloys and Coatings

- Titanium Master Alloys: 29% of revenues
- Titanium Aluminides: 21% of revenues
- Chemicals: 17% of revenues
- Coatings: 33% of revenues

A leading manufacturer of high performance metals and materials

Note: Figures based on 2016 revenue split
<table>
<thead>
<tr>
<th>End Market</th>
<th>TRANSPORTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Products</td>
<td></td>
</tr>
<tr>
<td>Titanium Aluminides</td>
<td></td>
</tr>
<tr>
<td>• Titanium Aluminides ($\gamma$-TiAl)</td>
<td></td>
</tr>
<tr>
<td>Value Proposition</td>
<td></td>
</tr>
<tr>
<td>• The new high growth area in light-weighting aerospace engines</td>
<td></td>
</tr>
<tr>
<td>• Strong thermo-mechanical properties at lower densities</td>
<td></td>
</tr>
<tr>
<td>• Reduction of engine weight, improving fuel efficiency (CO$_2$ emissions)</td>
<td></td>
</tr>
<tr>
<td>Applications</td>
<td></td>
</tr>
<tr>
<td>• Presently, the main application in blades of the low pressure turbine (Boeing 737 max and the Airbus A320 neo)</td>
<td></td>
</tr>
</tbody>
</table>
AMG TAC produces a complete range of materials along the exhaust path

<table>
<thead>
<tr>
<th>Material</th>
<th>Ti-64</th>
<th>Ti-6246</th>
<th>Ti-834</th>
<th>Ni-based Superalloys</th>
<th>Ti Aluminides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Op temperature [°C]</td>
<td>up to 300</td>
<td>up to 450</td>
<td>up to 600</td>
<td>1,230 - 750</td>
<td>up to 750</td>
</tr>
</tbody>
</table>

**SLIDE V: MARKET – TITANIUM MASTER ALLOYS & TI ALUMINIDES**
SLIDE VI: TITANIUM ALUMINIDES – PRODUCTS, END MARKETS, AND APPLICATIONS
SLIDE VII: TITANIUM ALUMINIDES – PRODUCTS, END MARKETS, AND APPLICATIONS
SLIDE VIII: TITANIUM ALUMINIDES EXPANSION TIMELINE

July 2014
Selected by SNECMA for the LEAP engine program (value exceeds $50M)

October 2014
Maiden flight of the A320neo powered by Pratt & Whitney's PurePower® engines

May 2016
Awarded by MTU Aero Engines for the Pratt & Whitney PurePower® PW1100 engine (value exceeds $40M)

2016
Production quantity tenfold versus 2010

2017
Install and commission additional melting capacity
Titanium Aluminides Sales Visibility

- Close to 100% of sales contracted
- Average contract length: 5 years or longer
SLIDE X: MARKET – TITANIUM ALUMINIDES MID-/LONGTERM

- P&W PurePower engine
- Airbus A 320neo
- Mitsubishi Regional Jet
- CFM LEAP engine
- Airbus A 320 neo: LEAP-1A
- Boeing B737MAX: LEAP-1B
We are the world leader in Titanium Aluminides

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing 747-8</td>
<td>GE Aviation GEnx-1B</td>
</tr>
<tr>
<td>Intercontinental + Freighter</td>
<td></td>
</tr>
<tr>
<td>Boeing 787</td>
<td>GE Aviation GEnx-2B</td>
</tr>
<tr>
<td>“Dreamliner”</td>
<td></td>
</tr>
<tr>
<td>COMAC 919</td>
<td>Snecma / GE LEAP-X</td>
</tr>
<tr>
<td>Boeing 737 max</td>
<td></td>
</tr>
<tr>
<td>Airbus A320 neo</td>
<td></td>
</tr>
<tr>
<td>Bombardier CSeries</td>
<td>P&amp;W / MTU Geared Turbo Fan (GTF)</td>
</tr>
<tr>
<td>Mitsubishi Regional Jet</td>
<td>PW1524G / PW1217G / PW1400G/PW1100G</td>
</tr>
<tr>
<td>Irkut MS-21</td>
<td></td>
</tr>
<tr>
<td>Airbus A320 neo</td>
<td></td>
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</tbody>
</table>

Source: The Airline Monitor June 2016 / Customer Information
SLIDE XII: MARKET – TITANIUM ALUMINIDES SHORT-/MIDTERM

110% CAGR

Source: Ascend, Avascent Analysis
SLIDE XIII: TITANIUM MASTER ALLOYS – PRODUCTS, END MARKETS, AND APPLICATIONS

End Market

Key Products

- Titanium master alloys for aircraft engine components
  - Vanadium Aluminum (VAl)
  - Molybdenum Aluminum (MoAl)

Value Proposition

- Reduce aircraft weight, improving fuel efficiency and reducing CO₂ emissions

Applications

A Boeing 787 Dreamliner contains ~ 250k lb titanium, a 17% increase in fuel efficiency compared to an older Boeing 737

Fastener
Source: PCC website

Undercarriage
Source: Kobe website

Source: PCC website
SLIDE XIV: CHEMICALS – PRODUCTS, END MARKETS, AND APPLICATIONS

**End Markets**

**SPECIALTY METALS & CHEMICALS**

**TRANSPORTATION**

**Key Products**

- Vanadium oxides and compounds for various industries
  - $V_2O_5$, AMV, KMV, SAV

- Act as catalyst for chemical reactions

- Protect from corrosion

- Absorb UV and IR-light

**Value Proposition**

- Reduce aircraft weight, improving fuel efficiency and reducing CO$_2$ emissions

**Applications**

- Catalyst’s are used to clean exhaust gases or to produce chemical products

- Titanium master alloys to produce Titanium Alloys like Ti-6-4
SLIDE XV: COATINGS – PRODUCTS, END MARKETS, AND APPLICATIONS

**End Markets**

**SPECIALTY METALS & CHEMICALS**

**ENERGY**

**Key Products**

- Sputtering targets for various industries such as tooling, automotive and aerospace
  - AlTi, AlCr
- Sputtering targets and rotatable targets for the flat glass industry
  - AZOY® (ZnO/Al₂O₃), CROMA®

**Value Proposition**

- Improve wear resistance
- Provide protective hard coatings
- Thermal insulation
- Reflecting or transparent
- Electrically conductive

**Applications**

- Surface coatings applied to tooling to improve wear resistance and to avoid abrasion
- Coating layer applied on building glass to improve thermal insulation and reduce reflection

- Sputtering targets for TCF’s for PV thin film cells
  - AZOY® (ZnO/Al₂O₃)
  - Aluminium
  - Chromium

- Solar absorbing
- Metallization
- Anti-reflective
- Use of TCO’s

- All thin film producers apply TCO’s with the sputtering process and ~90% of thin film TCO layers are made with ZnO:Al₂O₃
Summary

• Traditional emphasis: light-weighting the engine

• Additional future emphasis: metallurgical powder products for additive manufacturing
SLIDE XVII: PLANT TOUR

- Main Entrance
- Meeting Room
- Inspection (Vanadium Aluminum)
- Titanium Aluminides

Main Entrance
Meeting Room
Inspection (Vanadium Aluminum)
Titanium Aluminides