TITANIUM POWDER BY SANDVIK
THE ADDITIVE ADVANTAGE

22 OCTOBER, 2019
SANDVIKEN, SWEDEN

80% REDUCED WEIGHT
200% INCREASED PRODUCTIVITY
# AGENDA

**TITANIUM POWDER BY SANDVIK – THE ADDITIVE ADVANTAGE**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Presenter/Speaker(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:30 - 13:45</td>
<td>SAFETY FIRST AND WELCOME!</td>
<td>Kristian Egeberg</td>
</tr>
<tr>
<td>13:45 - 14:10</td>
<td>INTRODUCTION TO SANDVIK – AND TITANIUM AS AN ELEMENT</td>
<td>Mikael Schuisky</td>
</tr>
<tr>
<td>14:10 - 14:35</td>
<td>TITANIUM AND NICKEL POWDER PRODUCTION BY SANDVIK</td>
<td>Martin Mueller</td>
</tr>
<tr>
<td>14:35 - 15:00</td>
<td>TITAINUM AND NICKEL POWDER BY SANDVIK – THE ADDITIVE ADVANTAGE</td>
<td>Keith Murray</td>
</tr>
<tr>
<td>15:00 - 15:20</td>
<td>SWEDISH &quot;FIKA&quot;</td>
<td>All</td>
</tr>
<tr>
<td>15:20 - 15:40</td>
<td>AM-PROCESSING OF TITANIUM</td>
<td>Harald Kissel</td>
</tr>
<tr>
<td>15:40 - 16:10</td>
<td>BEAMIT – EXPERIENCE FROM AM OF TITANIUM COMPONENTS</td>
<td>Michele Antolotti and Martina Riccio</td>
</tr>
<tr>
<td>16:10 - 16:25</td>
<td>TITANIUM COMPONENTS FOR GSD E-BIKES</td>
<td>Zach Krapfl</td>
</tr>
<tr>
<td>16:25 - 16:40</td>
<td>LIGHTWEIGHT COROMILL® 390</td>
<td>Matts Westin</td>
</tr>
<tr>
<td>16:40 - 16:55</td>
<td>OSSDSIGN – IMPLANTS FOR BONE REGENERATION</td>
<td>Kajsa Björklund</td>
</tr>
<tr>
<td>16:55 - 17:10</td>
<td>SWISS CENTER OF MANUF. TECHNOLOGIES FOR MEDICAL</td>
<td>Harald Kissel</td>
</tr>
<tr>
<td>17:10 - 17:30</td>
<td>SUMMARY, CONCLUSIONS AND KEY TAKE-AWAYS</td>
<td>Mikael Schuisky &amp; All</td>
</tr>
<tr>
<td>18:00</td>
<td>DINNER @ BRUKSMÄSSEN</td>
<td>All</td>
</tr>
</tbody>
</table>
INTRODUCTION TO SANDVIK
AND SANDVIK ADDITIVE MANUFACTURING
SANDVIK GROUP
WORLD LEADING POSITION IN...

- METAL CUTTING
- ADDITIVE MANUFACTURING
- ADVANCED MATERIALS TECHNOLOGY
- MINING AND ROCK TECHNOLOGY

42,000 EMPLOYEES

SALES IN OVER 160 COUNTRIES AROUND THE GLOBE

100 BILLION SEK IN REVENUES

3.5 BILLION SEK ANNUAL R&D INVESTMENT

50 R&D CENTERS GLOBALLY

5,900 ACTIVE PATENTS

Figures refer to Group total 2018
LEADING AND WELL ESTABLISHED CAPABILITIES ACROSS THE AM VALUE CHAIN

MATERIALS
- World leader in metallurgy
- Powder expert
- Leading in metal powder for AM
- Widest range of Osprey™ AM-alloys

MANUFACTURING
- 3D design
- Several AM processes
- Center of Digital Excellence

POST PROCESSING
- World leader in metal cutting
- Sintering and HIP
- Other post processing

RELATED CAPABILITIES
- Testing and characterization
- Traceability and documentation
- Component know-how
- Customer base
- Distribution network

SANDVIK
ADDITIVE BY SANDVIK
PLAN IT – PRINT IT – PERFECT IT

OUR OFFERING:

Advisory services
We take you from idea to prototype – or serial production.

Manufacturing services
From rapid prototyping to serial production, we offer full service production of your component.

Metal powder
We offer the widest range of powder alloys for additive manufacturing around and can even customize materials.
2019
SANDVIK ADDITIVE MANUFACTURING

MARCH
Launch of CoroMill® 390 in titanium, with 80% reduced weight – and increased productivity by up to 200%.

APRIL
The smash-proof guitar in Ti is launched. The film has so far been seen by 41 million people.

JUNE
ADDITIVE NEXT – a joint AM-event by Sandvik and Siemens – takes place in Högbo, Sweden.

JULY
Sandvik announces a major investment in the strategic partner BEAMIT in Italy.

SEPTEMBER
Increased AM-powder production capabilities with a new tower – and approved investment in Aluminum powder capabilities in Neath, UK.

OCTOBER
Sandvik inaugurates state-of-the-art titanium powder plant in Sandviken, Sweden.

OCTOBER
The inch assortment of the of CoroMill® 390 is launched.

NOVEMBER
BEAMIT and Sandvik will join forces and co-exhibit at Formnext in Frankfurt.
TITANIUM AS AN ELEMENT

INTRODUCTION:
80% REDUCED WEIGHT
200% INCREASED PRODUCTIVITY

MIKAEL SCHUISKY
VP AND HEAD OF R&D AND OPERATIONS
SANDVIK ADDITIVE MANUFACTURING
PHYSICAL PROPERTIES
OF TITANIUM

- Melting Point: 1668 °C
- Boiling point: 3287 °C
- Density: 4.506 g/cm³
- Heat of fusion: 14.15 kJ/mol
- Heat of Vaporization: 452 kJ/mol
- Molar heat capacity: 25.06 J/(mol*K)
ATOMIC PROPERTIES
OF TITANIUM

- Oxidation states -2, -1, +1, +2, +3, +4 (an amphoteric oxide)
- Electronegativity 1.54 (Pauling Scale)
- Atomic radius 147 pm
- Covalent radius 160±8 pm
- Natural occurring Isotopes $^{46}\text{Ti}$, $^{47}\text{Ti}$, $^{48}\text{Ti}$, $^{49}\text{Ti}$ & $^{50}\text{Ti}$

SPECTRAL LINE OF TITANIUM
OTHER PROPERTIES
TITANIUM

- Hexagonal closed packed (hcp)
- Thermal expansion 8.6 µm/(m*K)
- Thermal conductivity 21.9 W/(m*K)
- Electrical resistivity 420 nΩ*m
- Youngs modulus 116 GPa
- Shear modulus 44 GPa
- Bulk modulus 110 GPa
- Vickers hardness 830-3420 MPa
THE HISTORY OF TITANIUM
Clergymen and amateur geologist **William Gregor** successfully isolated titan oxide from the mineral Ilmenite (FeTiO3).
Discovered the same material in mineral Rutile (TiO2). He named it **Titanium** after the Titans of Greek mythology.
Metallic titanium was first produced in an un-pure form by the Swede Jöns Jacob Berzelius.

“THE FATHER OF THE SWEDISH CHEMISTRY”
Pure metallic titanium (99.9%) was first prepared in 1910 at Rensselaer Polytechnic Institute by heating TiCl₄ with sodium at 700–800 °C under great pressure in a sealed batch process today known as the Hunter Process.

\[ \text{TiCl}_4(g) + 4 \text{Na(s)} \rightarrow \text{Ti(s)} + 4 \text{NaCl(s)} \]
The Kroll process is a pyrometallurgical industrial process used to produce metallic titanium.

1) FeTiO3 + C => Fe + TiO2 + CO
2) TiO2 + 2C +2Cl2 => TiCl4 + 2CO
3) TiCl4 + 2 Mg => Ti + 2 MgCl2
AeroMet a subsidiary of MTS Systems Corp developed a process called **laser additive manufacturing (LAM)** which used a high power laser and **titanium powders**.

"We're one of the first wave of companies in the new industry of direct-metal deposition," said Frank Arcella, president of AeroMet. "The unique niche we hold is that titanium is so hard to work with."

**TITANIUM**

**USE WITHIN SANDVIK**

**1964** Sandvik starts the production alloys of reactive metals i.e. Zr and Ti.

Ti is used as a minor alloying element by Sandvik in several alloys for instance 18Ni300.

At Sandvik we since the **1980’s** produces Ti tubes for aerospace applications.

**1969** Sandvik Coromant introduced TiC coated inserts and today hard and wear resistant titanium coatings like TiAlN, Ti(C,N) and TiN are used on most inserts.

TiN
Al$_2$O$_3$
Ti (C,N)
TITANIUM ABOUNDANCE
TITANIUM ABOUNDANCE

THE 9TH MOST COMMON ELEMENT IN THE EARTH CRUST (0.57%)

• Primarily found in the minerals
  – Rutile (TiO₂)
  – Ilmenite (FeTiO₃)
  – Sphene (CaTiSiO₅).
TOP PRODUCERS OF TI MINERALS
Metallic titanium sponge is today mainly produced with the Kroll process.

1) $\text{FeTiO}_3 + \text{C} \rightarrow \text{Fe} + \text{TiO}_2 + \text{CO}$

2) $\text{TiO}_2 + 2\text{C} + 2\text{Cl}_2 \rightarrow \text{TiCl}_4 + 2\text{CO}$

3) $\text{TiCl}_4 + 2\text{Mg} \rightarrow \text{Ti} + 2\text{MgCl}_2$
TITANIUM SPONGE PRODUCTION (2018)

Titanium Sponge Capacity vs Production

CAPACITY UTILIZATION
Ukraine 50%
Kazakhstan 60%
Russia 95%
USA 79%
Japan 80%
China 75%