Additive Manufacturing of Implants
- The Path to Production

Lars Ryberg, Arcam
AM – size of the market

“*The titanium casting market is worth about 10 Billion USD*”

“The orthopaedic industry use about 1000 tons of titanium per year”

“The aerospace industry use about 75 000 tons of titanium per year”

Additive Manufacturing uses today < 50 tons of titanium per year
Mission statement

"Arcam provides cost-efficient Additive Manufacturing solutions for production of metal components"

Focusing on

- Orthopedic implants
- Aerospace components
Production focus

- Series production allows process optimization in each specific production case (application and geometry)
- Parameters such as layer thickness and build speed may for this reason be different for different production cases
Customer benefit - Performance

Arcam’s EBM technology is used to produce products with new, unique properties

- Weight reduction (aero)
- Advanced cooling (aero)
- Bone ingrowth (implant)

Our customer will increase the performance of their product, thus making their product more valuable
Customer benefit - Cost

Arcam’s EBM technology is used to replace present technology
- No tooling cost
- Shorter lead time
- Less material use, more efficient

Our customers will make their production more efficient, thus reducing their costs
EBM in the Orthopedic industry

Around 100 EBM systems are in production

Products on the market include
- Hips (Acetabular cups and Hip stems)
- Knee components
- Spinal cages
- CMF implants

Additive Manufacturing is now well established, yet << 1 % of all implants are made with AM
Success factors for production

- Economy
  - High production rate
  - Competitive powder cost

- Quality
  - Material quality
  - Geometric accuracy
  - Surface quality

- Added values with AM
  - Freedom in design
  - Cellular structures

Courtesy of NCSU

Powder metal
Production case, implants: Acetabular cups

- Produced in Ti6Al4V with EBM
- CE-certified acetabular cups since 2007
- Cups with FDA clearance since 2010
- Implants with CFDA (China) approval since 2015
- > 50,000 cups implanted
System and process stability

- The graph below shows development of system reliability for EBM systems in series production of acetabular cup implants over more than three years during production ramp-up.

Based on more than 45,000 running hours

Monthly success rate of production runs from log files from all builds
Production cost of cups

Implants built with EBM

- High productivity
- Excellent material properties
- No secondary coating operation
- No mechanical support structure (hot process)
Implant Categories

- Acetabular cups
- Revision cups
- Augments
- Femoral stems
- CMF
- Spine
- Tibial trays
- Glenoids
- Triflanges
- Wedges
- Femoral knees

In production with EBM®
DELTA TT™ Augment

CE-certified since 2007

Material: Ti6Al4V

Courtesy of Limacorporate S.p.a.
Pulchra™ Femoral Stem

CE-certified since 2011

Material: Ti6Al4V

Courtesy of Adler Ortho s.r.l.
EndoLIF® Lumbar Cage

Material: Ti6Al4V

CE-certified since 2013,
FDA-approved since 2015

Courtesy of Joimax GmbH
SMR Axioma® TT Glenoid

CE-certified since 2013

Material: Ti6Al4V

Courtesy of Limacorporate S.p.a.
**EBM® - Electron Beam Melting**

- The electron beam gun generates a high energy beam (up to 3,000 W)
- The beam melts each layer of powder metal to the desired geometry
- Extremely fast beam translation (up to 8,000 m/s) with no moving parts
- **High beam power** -> **high melt rate** (up to 100 cm³/h) and **productivity**
- **Vacuum process** (<0,001 ppm oxygen) -> eliminates impurities and yields excellent material properties
- **High process temperature** (600 ºC for titanium) -> **low residual stress** and **no need for heat treatment**
Arcam MultiBeam™

- The beam steering coils and electronics facilitate a high beam translation of up to 8,000 m/s.
- The high power electron beam jumps repeatedly between different melt pools to keep all of them active.
- This process strategy takes advantage of the high beam power and enables both higher build rate and smoother surfaces.

Fast beam jumping  Keeping multiple melt pools “alive”!

whole sequence << 1 second
Arcam MultiBeam™ process
Advantage of hot process for bulk melting

Increased bulk temperature reduces gradient, allowing for higher speed with preserved quality
Overview: Arcam machine generations

S series

EBM S12 (2003)

A series


Q series

Design for Production

• The Arcam Q systems are developed in collaboration with leading aerospace and implant manufacturers

• Arcam Q10 is the EBM system designated for volume production of orthopedic implants

• Arcam Q20 is the EBM system designated for volume production of aerospace components
Arcam Q - Highlights

- New EB gun design
- Improved resolution
- Higher productivity
- Prevention of operator mistakes
- In process quality verification
- Software adapted to volume production
New EB gun design

- Use of high brightness cathodes LaB$_6$
  - 500+ hours operating time
  - Improved beam formation

- Improved spot quality at high beam power enables faster processing of high quality surfaces
Higher productivity

Arcam A2XX
Build time, customer part

Arcam Q20
Build time, same part

~ 130 h

~ 85 h
In process quality verification

- Arcam LayerQam™

- Camera-based quality verification system
  - Additive Manufacturing provides a new melted surface for each layer
  - The melting depth is thicker than the layer of powder
  - Camera-based monitoring of each melted layer provides porosity control of the entire produced part
  - Monitoring each layer hence provides a unique capability to verify the full density of EBM-produced components
Arcam LayerQam™ - demo, sample with deliberately generated defects

Filtered camera images

Micro tomography
Long-term EBM® development

• Faster processing and Larger build envelope
  • The available beam power restricts build area and build rate
  • The need for higher electron beam current is thus twofold:
    • More power for heating to enable larger build envelope
    • More power to enable more Arcam MultiBeam™ spots
  
• An EU FP7 project, FastEBM, has developed a prototype electron gun for EBM with more than **three times higher beam power** than for current systems

• The prototype 10 kW gun is under testing on an Arcam Q platform to evaluate potential for system development
Thank you for your attention!

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