Industrialisation of Additive Manufacturing

Additive World Conference; March 23rd, Eindhoven; Netherlands
Martin Schäfer

- General remarks Siemens and AM
- AM process chain and opportunities
- Applications and Industrialisation
Customer-oriented organization
Setup as of October 1, 2014

Global presence and go-to-market of our businesses
Americas  Europe and Africa  C.I.S.¹ and Middle East  Asia and Australia

Power and Gas  Wind Power and Renewables  Energy Management  Building Technologies  Mobility  Digital Factory  Process Industries and Drives  Healthcare (separately managed with global supply chain)  Financial Services

Power Generation Services

Corporate Services  Managing Board  Corporate Core

¹ Commonwealth of Independent States.

Our global presence – Partner to customers all over the world

A worldwide presence lies at the heart of the Siemens brand – and that goes for us as well. That presence enables us to quickly offer targeted solutions that are tailored to regional requirements.
Additive Manufacturing at Siemens

1984
Stereolithographie

1989
CT Start

~ 2004
Ceramic SLA

~ 2007
Laser Melting

2002
X-ray grids
Healthcare

2010
Burner repair
Power Generation

2014
Spare parts
Different Divisions

Products

R&D

Prototyping

Manufacturing

Different requirements

Consumer

Industry

Source: makerbot.com

Source: EOS
"3D printing" versus Additive Manufacturing

Established market requirements are driving the industrialization of Additive Manufacturing

Additive Manufacturing – Process Chain

Potential for unique features are based on the mastery of knowledge intensive process chain and the interaction between manufacturing process, material condition and component properties
Applications

Additive Manufacturing for Gas Turbine Applications: Opportunities and Challenges
Power and Gas Division

**Business Fields**
- Large Gas Turbines, Generators (PG GT)
- Compressors (PG CP)
- Energy Solutions (PG ES)
- Instrumentation and Electrical (PG IE)
- Steam Turbines (PG SU)
- Compressors (PG CP)
- Energy Solutions (PG ES)
- Instrumentation and Electrical (PG IE)
- Gas turbines from 100 to 400 MW
- Electrical generators from 25 up to 2,235 MVA
- Fuel gasifiers
- System Integration
- Steam turbines from 45 kW to 1,900 MW
- Steam turbines for industrial applications & power generation
- Turbo compressors for - Oil & Gas - Industrial applications
- Compressor packages incl. drives
- Compressor automation
- 50 HZ and 60 HZ Gas turbine power plant solutions
- CHP*
- IGCC**
- Repowering
- Integrated solar combined cycle
- HRSG
- Control solutions
- Electrical solutions
- Energy management solutions
- Solutions for distributed and hybrid power generation

* Combined heat and power  ** Integrated gasification combined cycle

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AM at is PG DG and PS DG; Industrial Gas Turbine Selective Laser Melting (SLM)

Combustion chamber
Burner
Swirler / Nozzles / Filter / Mixer

*a SGT750 from Finspong (PG DG/PS DG)*

**High Tech-Components with complex design and high potential to increase the benefits of the customer (e.g. efficiency; life time)**
Main benefits:

- Faster repair
- Technology updates included

Power and Gas Division

Large Gas Turbines, Generators (PG GT)
- Gas turbines from 100 to 400 MW
- Electrical generators from 25 up to 2,235 MVA
- Fuel gasifiers
- System integration

Distributed Generation (PG DG)
- Industrial gas turbines from 5 to 50 MW
- Aero derivative gas turbines from 4 to 64 MW

Steam Turbines (PG SU)
- Steam turbines from 45 kW to 1,900 MW
- Steam turbines for industrial applications & power generation

Compressors (PG CP)
- Turbo compressors for:
  - Oil & Gas
  - Industrial applications
- Compressor packages incl. drives
- Compressor automation

Energy Solutions (PG ES)
- 50 HZ and 60 HZ Gas turbine power plant solutions
- CHP*
- IGCC**
- Repowering
- Integrated solar combined cycle
- HRSG

Instrumentation and Electrical (PG IE)
- Control solutions
- Electrical solutions
- Energy management solutions
- Solutions for distributed and hybrid power generation

* Combined heat and power  ** Integrated gasification combined cycle
### SLM Rapid Manufacturing and Rapid Repair

*Additive manufacturing has arrived in customer engines*

#### Rapid Manufacturing

<table>
<thead>
<tr>
<th>Driver</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long lead times</td>
<td>Lead time reduction by six months</td>
</tr>
<tr>
<td>Long time line for implementation of new designs</td>
<td>short term implementation of re-designs</td>
</tr>
</tbody>
</table>

#### Rapid Repair

<table>
<thead>
<tr>
<th>Driver</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long repair times</td>
<td>Significant lead time reduction</td>
</tr>
<tr>
<td>Costs for repair</td>
<td></td>
</tr>
</tbody>
</table>

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**Industrialization Line Integration**
Additive Manufacturing process overview

Additive Manufacturing summarizes various production processes.

<table>
<thead>
<tr>
<th>Production process</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder bed fusion</td>
<td>• Metal</td>
</tr>
<tr>
<td></td>
<td>• Polymer</td>
</tr>
<tr>
<td></td>
<td>• Ceramic</td>
</tr>
<tr>
<td>Vat photopolymerization</td>
<td>• Photopolymer</td>
</tr>
<tr>
<td>Directed energy deposition</td>
<td>• Metal</td>
</tr>
<tr>
<td>Material extrusion</td>
<td>• Polymer</td>
</tr>
<tr>
<td>Material jetting</td>
<td>• Photopolymer</td>
</tr>
<tr>
<td></td>
<td>• Wax</td>
</tr>
<tr>
<td></td>
<td>• Metal</td>
</tr>
<tr>
<td></td>
<td>• Polymer</td>
</tr>
<tr>
<td></td>
<td>• Ceramic</td>
</tr>
<tr>
<td>Binder jetting</td>
<td></td>
</tr>
</tbody>
</table>

1 based on ASTM F2792-08
Our Portfolio for AM covers the entire Value Chain

Additive Manufacturing is influencing high end and daily life applications

Energy, aerospace, automotive  Medical and health care  Daily life
Siemens vision of industrialized Additive Manufacturing

1. Increased part accuracy
   One seamless software platform synchronizing the entire PLM tool chain down to the machine runtime (e.g. optimized formats w/o “STL-triangles”)

2. Increased process quality
   Real time acquisition, analysis and control of the relevant process data on the machine level (= closed loop control)

3. Increased machine efficiency & flexibility
   Open CNC enables comprehensive machine data analytics for continuous improvement (e.g. condition monitoring)

4. Enhanced process stream
   Fully automated horizontal work flow integrating pre- and post- processes in one production line (strong analogies with production machines)

5. Increased production efficiency
   KPI based certificates for documented part quality of produced parts w/o inefficient workarounds (e.g. w/o computer tomography)

The Siemens portfolio along the entire value chain enables the industrialization of AM

PLM Software

Automation

Products

Material
Production

Siemens Bets Big on Metal 3D Printing with €21.4 Million Facility
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- €21.4 Million Facility
- Currently staffed with 20 employees such as operators and engineers
- Producing metal 3D printed components for Siemens’ own industrial gas turbines
- Both for prototyping, as well as for end-part production and repair.

Thorbjorn Fors, global business director for Distributed Generation at Siemens, said of the facility, “With this investment, we can develop new and improved components and repairs, for example burner tips to serve our industrial gas turbine SGT-800, significantly faster. Using this innovative approach, we will shorten repair times from months to weeks. It is an important step in our ability to respond to the needs of our customers.”

http://3dprintingindustry.com/2016/02/03/66016/?utm_source=3D+Printing+Industry+Update&utm_medium=email&utm_campaign=5ff97e5909-RSS_EMAIL_CAMPAIGN&utm_term=0_695d5c73dc-5ff97e5909-64470153

Summary and Outlook
Additive Manufacturing is a key technology to fulfill market requirements.

**Market requirements**
- Increased energy and resource efficiency
- Highly complex structures and designs
- Individualized mass production
- Shorter innovation cycles

**Levers**
- Designed-in functionality
- High end resilient materials
- Rapid prototyping
- Spare parts on demand

1) ISO/TC 261 – Additive manufacturing

**Summary**
Additive Manufacturing...
- facilitates optimization potentials.
- is on the path of industrialization.
- requires a holistic digitalized approach.
Many thanks for your attention!

Martin Schäfer  
Senior Key Expert “Additive Manufacturing”  
Corporate Technology / Germany /  
CT RTC MAT COA-DE

Siemensdamm 50  
13629 Berlin

Phone: +49 30 386 – 23087  
Fax: +49 30 386 – 25764  
Mobile: +49 173 9795263

E-mail:  
martin.schaefer@siemens.com

intranet.ct.siemens.com