Additive Manufacturing with laser melting on it’s way to series production

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Additive Manufacturing with laser melting on its way to series production

Agenda

1. Fraunhofer, facts and figures
2. New machine concepts
3. New materials
4. Cost calculation
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Facts and Figures of Fraunhofer ILT

- € 31.1 M operating budget (without investments) in 2014
- 75% contract research revenue and 25% base funding
- € 3.4 M in investments in 2014
- 405 employees in 2014, of this 152 scientists and engineers, and 178 student assistants
- DQS certified according to DIN EN ISO 9001
- One patent application per month on average
- One to two spin-offs per year on average (More than 30 ILT spin-offs in the last 25 years)
- Approx. 10-15 participations in trade fairs and more than 20 organized events (conferences, seminars) per year
- Approx. 15 Ph.D. graduates at RWTH faculties per year
- Over 70 diploma, master, bachelor degrees per year
## Products and Services

### LASER MATERIAL PROCESSING

<table>
<thead>
<tr>
<th>Products and Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Laser Cutting</td>
</tr>
<tr>
<td>- Laser Welding</td>
</tr>
<tr>
<td>- Soldering</td>
</tr>
<tr>
<td>- Heat Treatment</td>
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<tr>
<td>- Cladding</td>
</tr>
<tr>
<td>- Laser Metal Deposition</td>
</tr>
<tr>
<td>- Rapid Manufacturing</td>
</tr>
<tr>
<td>- Process and Beam Control</td>
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<tr>
<td>- Machine and Control Technology</td>
</tr>
<tr>
<td>- Plastics Cutting and Welding</td>
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<td>- Cleaning</td>
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<tr>
<td>- Marking</td>
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<tr>
<td>- Drilling</td>
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<tr>
<td>- Micro Joining</td>
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<tr>
<td>- In-Volume Structuring</td>
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<tr>
<td>- Polishing</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Thin Film Processing</td>
</tr>
<tr>
<td>- Ultrashort Pulse Processing</td>
</tr>
<tr>
<td>- Micro Structuring</td>
</tr>
<tr>
<td>- Nano Structuring</td>
</tr>
<tr>
<td>- Simulation</td>
</tr>
</tbody>
</table>

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Fraunhofer IKT
Products and Services: Rapid Manufacturing

Process
- Selective Laser Melting
- Powder bed process
- Processing of serial material
- Part density approx. 100%

Process Development
- Enlargement of processable materials
- Improvement of part quality
- Increase of productivity
- Enlargement of feasible structure sizes
- Manufacture of components with new design (e.g. hollow structures)

Application Development
- Application of SLM in different branches and for custom specific tasks
- SLM for series production
- SLM-compatible part design
- Implementation of SLM in existing process chains

Machine- and Component Development
- Special purpose machines
- Machine modification
- Integration of additional components
Selective Laser Melting
Naming and common Confusion

Direct Metal Laser Sintering (DMLS)
Selective Laser Melting (SLM®)
Laser-powder bed fusion (L-PBF)
Selecting Laser Melting (SLM®
LaserCUSING®
CONCEPTLASER
Same Process
TRUMPF
Laser Metal Fusion (LMF)
Metal Additive Manufacturing
Selective Laser Melting (SLM™)
Direct Metal Printing (DMP)
The AM (R)evolution @ ILT

SLM as one of the key enablers of AM

1996
First Tool Insert

...from
Prototyping

Basic Patent

2001
First Production

2003
First Implant

2008
First series Production

2015
...to Series Production

Laser Melting of powder material
Deposition of powder layer
Lowering of build platform

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Slide 9
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Scalability of size and build rate

Laser radiation is the energy source →
Increasing build rate needs increased laser power
New machine concepts
Increased laser power in a single laser beam

Aluminum (ALSi10Mg)

- **SLM process**
  - \( P_L = 200 \text{ W} \)

- **High Power SLM**
  - \( P_L = 1000 \text{ W} \)
New machine concepts

Skin core principle

- **SLM process**
  - $P_L = 400 \text{ W}$

- **High Power SLM process (skin-core)**
  - $P_L = 400 \text{ W (skin)}$ 1000 W (core)

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*Images show results of the SLM process and high power SLM process (skin-core) with time stamps of 00:00:00:18 and a scale of 25 mm.*
New machine concepts
Multiple laser scanner systems
New machine concepts
Expanding build envelop

Approach
- Basis: Laser cutting machine
- 1 kW laser power with variable spot size
- Movable process chamber with local shielding gas systems

Advantages
- Scalable, modular concept
- Almost unlimited part size
- Optical system independent from platform size
New machine concepts

Multi-Spot processing

Conventional SLM

New Multispot concept
New machine concepts
Multi-Spot processing

Conventional SLM

New Multispot concept
New machine concepts
Multi-Spot processing

Main advantages as a matter of principle:
- Use of diode lasers
- Easy upscaling in productivity (higher number of laser spots)
- Easy upscaling in build size (larger axes)
- Local shielding gas flow, local process control units
New machine concepts

Low Cost SLM System

- SLM fabber system:
- Single diode laser gantry system
- Component cost < 30 k€
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Material
Increasing material range – steel 16MnCr5

- Density > 99.97 %
- Crack free without preheating
- Bainitic micro structure
- Hardness > 720 HV1 after heat treatment
Material

Increasing material range – copper alloys

- High heat conductivity and reflection coefficient
- Approx. 100% density
- Mechanical properties and heat conductivity within specifications given by alloy manufacturer
Material

Increasing material range – magnesium alloys
Material
Increasing material range – shape memory alloys NiTi

- Pseudoplasticity (shape memory effect) or super elasticity adjustable by choice of process parameters
- Smallest feature size: approx. 30µm
- Surface roughness Sa: < 2µm
Material

Increasing material range – high temperature preheating

Laboratory system with platform pre-heating up to 1000°C
Material
Increasing material range – Titanium Aluminide (TNM)

- surface roughness $S_a$
  - downskin $< 45\mu m$
  - upskin $< 25\mu m$
  - side $< 10\mu m$
- dimensional deviation $< 77\mu m$
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Cost calculation

Simple: Cost calculation

Input
- Part
- Support, Orientation
- Machine
- Material
- Parameter

Output
- Job duration
- Part cost

Advanced: Production planning scenario

Job composition
(parts & arrangement)

Staff presence
(e.g. shift system, public holidays etc.)

Manufacturing
(e.g. machine, material, parameter set)

Automated modelling of series production over arbitrary evaluation period for each scenario & result comparison

Output
- No. of parts produced, part costs, cost split
- Time split & staff requirement
- Added value and machine productivity
- Optimization of job layout for maximum machine utilization*
- Recommendations for action

*) currently under development
Cost calculation

### Results (example!)

**Overview about input data, job composition and evaluation period**

**Scenario**
- Jobname: 14_01_2017_103113_JOB - subject 3
- Anlage: SLM280
- Wartung: AVG105kg
- Faktoreinsatz: Kosteneinsparung 01-03-2017
- Maschinenstundensatz: 450,00 €/h

**Output**
  - Baujob: 381
  - Bauabschnitt: 2048
  - Bauzeit (bei Baujob): 8

**Baujob**
- Dauer: 07/27/27
- Belichtung: 09.28.27: 67,22%, 09.28.30: 25,07%, 00.27.20: 7,92%
- Beschichtung: 00.32.44

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### Part costs and cost split

<table>
<thead>
<tr>
<th>Kosten</th>
<th>Value</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Anlage</td>
<td>20,04 €</td>
<td>50,04%</td>
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<tr>
<td>Service</td>
<td>0,96 €</td>
<td>2,39%</td>
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<tr>
<td>Energie</td>
<td>0,62 €</td>
<td>1,55%</td>
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<tr>
<td>Schutzg.</td>
<td>9,95 €</td>
<td>24,83%</td>
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<tr>
<td>Personal</td>
<td>5,73 €</td>
<td>1,43%</td>
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<tr>
<td>Verbrauchsmaterial</td>
<td>11,31 €</td>
<td>28,28%</td>
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<tr>
<td>Pulver Vorbereitung</td>
<td>1,22 €</td>
<td>3,06%</td>
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<td>Pulver Verkauf</td>
<td>0,12 €</td>
<td>0,03%</td>
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<tr>
<td>Fläche</td>
<td>0,01 €</td>
<td>0,00%</td>
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<tr>
<td>Gesamt</td>
<td>40,17 €</td>
<td>100,00%</td>
</tr>
</tbody>
</table>

### Machine utilization and time split

<table>
<thead>
<tr>
<th>Zeiten</th>
<th>Value</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Vorbereiten</td>
<td>22.20.00</td>
<td>2,12%</td>
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<tr>
<td>Belichtung</td>
<td>30.05.37</td>
<td>27,75%</td>
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<tr>
<td>Beschichtung</td>
<td>21.45.42</td>
<td>2,30%</td>
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<tr>
<td>Nacharbeiten</td>
<td>06.16.00</td>
<td>0,56%</td>
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<tr>
<td>Stahlsand geplant</td>
<td>19.18.01:33</td>
<td>52,46%</td>
</tr>
<tr>
<td>Stahlsand ungeplant</td>
<td>14.15.08:06</td>
<td>30,07%</td>
</tr>
<tr>
<td>Gesamt</td>
<td>364.00.00</td>
<td>100,00%</td>
</tr>
</tbody>
</table>
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