Overview of Laser Metal Deposition Applications, Trends and Products

International Conference on Additive Manufacturing, EMO Hannover | 17. September 2019

Marco Göbel | Industry Management LMD
TRUMPF is…

Family business since 1923

Technology leader in two business divisions

Close to its customers with 77 subsidiaries

Innovation promise – holistically and constantly
Facts and Figures TRUMPF

Company Figures FY 2018/19

Sales in Mio. € 3,800 +6 %

R+D expenditures in Mio. € 337 +6 %

R+D Quota 9.5 %

Employees on June 30, 2019 ~ 14,500
| 01 | Introduction TRUMPF |
| 02 | Laser Metal Deposition LMD |
| 02.1 | Process |
| 02.2 | Fields of Application |
| 03 | LMD for Part Modification |
| 04 | EHLA – Extremes Hochgeschwindigkeits - Laserauftragschweißen |
| 04.1 | Coating for Brake Discs |
| 04.2 | Further Applications |
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## Process – Differences LMD & LMF

<table>
<thead>
<tr>
<th>Laser Metal Deposition (LMD)</th>
<th>Laser Metal Fusion (LMF)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Features</strong></td>
<td></td>
</tr>
<tr>
<td>Geometrical Complexity</td>
<td>★★★★</td>
</tr>
<tr>
<td>Build-Up on existing workpiece</td>
<td>★★★★</td>
</tr>
<tr>
<td>Material Selection</td>
<td>★★</td>
</tr>
<tr>
<td>Build-Up Rate</td>
<td>★</td>
</tr>
<tr>
<td>Details / Precision</td>
<td>★★★★</td>
</tr>
<tr>
<td>Surface Quality</td>
<td>★★</td>
</tr>
</tbody>
</table>

- **Productive process for repair, surface functionalization and AM on free-form surfaces**
  - (free-form surface) ★★★★
  - (10 - 600 cm³ / h) ★★
  - (< 0.5 mm) ★
  - (Ra 10-20 µm) ★

- **Precise process for AM of complex workpieces in a powder bed**
  - (with preheating) ★★★★★
  - (flat substrate) ★★★
  - (2 - 180 cm³ / h) ★★★★
  - (< 0.1 mm) ★★★
  - (Ra 5-10 µm) ★★★

1 depending on system configuration, parameters, strategy and material
Fields of Application

**Surface Functionalization**

Enhancement of wear- & corrosion protection

**Repair**

Repair of tools:
Hybrid method → OKUMA

**Joining Technology**

Joining with powder additive:
- Gap bridging
- Joining of dissimilar materials
- 3D joining

**Additive Manufacturing**

Modification of parts and AM on 3D structures:
- Build-up of complete volumes
- Local reinforcements
Laser Metal Deposition
Equipment & Fields of Application

Laser Metal Deposition with TRUMPF
Fields of Application

Surface Functionalization
Enhancement of wear- & corrosion protection

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LMD for Part Modification

EHLA – Extremes Hochgeschwindigkeits - Laserauftragschweißen
  04.1 Coating for Brake Discs
  04.2 Further Applications

Summary & Outlook
Part Customization by LMD – Modification of Automotive Parts

LMD on Conventionally Cast Preforms

- Application oriented modification of 3D-parts for small and big parts for small – medium size production
- Economical supplement by combination of conventional and additive manufacturing
- Combination of different materials, tailored to the requirements of a given application
- Reduction of different variants → „Mass customization“
Part Customization by LMD – Modification of Automotive Parts

LMD on Conventionally Cast Preform

- Part: Suspension arm (part of a rear axle)
- Application: Local, stress optimized reinforcement of component
- Advantage: Reduction of various casting tools → reduction of costs

Scope of Production: Reduction of process time and costs by approx. 67 %
Part Customization by LMD – Modification of Automotive Parts

LMD on conventionally cast preform – 5-Axis Application

Partielles Verstärken von 3D-Strukturen
Mittels dem LMD Verfahren
EHLA – „Hochgeschwindigkeits-Laserauftragsschweißen“

Comparision: Conventional LMD – EHLA

- EHLA is a very high speed variant of the LMD process, yielding very high surface rates
- Using the EHLA-process powder particles are heated up to melting temperature before hitting the surface

Conventional LMD

- Powder particles molten on surface
- High build-up rates (volume)

EHLA

- Powder particles molten above surface
- Very high surface rates
## Comparison LMD – EHLA

<table>
<thead>
<tr>
<th>Feature</th>
<th>Conventional LMD</th>
<th>EHLA</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanning speed</td>
<td>0.5 - 2 m/min</td>
<td>&gt; 100 m/min</td>
<td>50</td>
</tr>
<tr>
<td>Surface rates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ 50 cm²/min (local build-up)</td>
<td>Up to 1000 cm²/min</td>
<td>10 – 20</td>
</tr>
<tr>
<td></td>
<td>▪ 100 cm²/min (surface)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAZ*</td>
<td>≥ 500 - 1000 µm</td>
<td>&lt; 10 µm</td>
<td>100</td>
</tr>
<tr>
<td>Layer thickness</td>
<td>≥ 500 µm</td>
<td>≥ 50 - 250 µm</td>
<td>10</td>
</tr>
<tr>
<td>Surface roughness</td>
<td>R₂ = 100 - 200 µm</td>
<td>R₂ = 10 - 20 µm</td>
<td>10</td>
</tr>
</tbody>
</table>

* Typical values. Heat input can be reduced and adapted; enabling new material combinations and properties, which are considered to be not conventionally achievable (e.g. Ti on steel, defect free coatings on cast iron).

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Significant increase in productivity for coating of rotational symmetric parts.
Fine Dust in Cities – A Very Actual Problem in Stuttgart
37% Fine Dust Originates from Abrasion of e.g. Brake Discs
EHLA for Brake Discs

New Coatings with State of the Art Coating Technology

- Coating System (corrosion- and abrasion resistant) using Cermets
- Challenge for conventional welding and LMD: cast iron. Graphite in lamellas enhance brittle phases, which can cause cracking within coating and substrate.
- By use of EHLA a minimized thermal energy input and dilution into workpiece is feasible, therefore significant reduction of brittle phases and risk of cracking

Coated Brake Disc (felt).
Quelle: TRUMPF, Fraunhofer ILT

Cross section of Cermet: WC-Carbides in Ni-Matrix. Substrate is cast iron (right).
Further Applications for EHLA

<table>
<thead>
<tr>
<th>Industry</th>
<th>Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing industry</td>
<td>Feed-, print rolls, etc.</td>
</tr>
<tr>
<td>Machine- &amp; Toolbuilder</td>
<td>Components of hydraulics; e.g. lifters, pistons, vibration dampers, etc.</td>
</tr>
<tr>
<td>Automotive</td>
<td>Brake disc, valves, piston rings, etc.</td>
</tr>
</tbody>
</table>

EHLA – Hochgeschwindigkeits-Auftragschweißen  
Beschichten mit >100m/min
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Summary & Outlook
Typical Powder Additives for LMD

Outlook – Next System Technology

**Fe-base**
- High Hardness
  - Typ. 800 – 1100 HV / 62,5-74,5 HRC

**Co-base**
- Good corrosion resistance
- High max. temperatures
  - Typ. 600°C

**Ni-base**
- Good wear properties
- High max. temperatures
  - Typ. 600°C

**Al-base**
- High thermal conductivity

**Cu-base**
- High thermal conductivity

Typ. 600°C
Outlook – LMD of Cu-Alloys

Absorption as Function of Laser Wavelength

By use of green laser radiation an >30% increase of absorption feasible

Overview:
coating of cuboid

Detail:
- Cu9.5Al (see above)
- Cu11Sn
- CuZn31Si1

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![Graph showing absorption as function of laser wavelength](image)

Legend:
- TruDisk: 515 nm
- TruDisk IR: 1030 nm
- Cu

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Green High-Power Lasers by TRUMPF
Current Laser Sources & Future Laser Sources

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pulsed</th>
<th>CW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TruDisk Pulse 421</td>
<td>TruDisk 1020</td>
</tr>
<tr>
<td>Pulse peak power</td>
<td>4 kW</td>
<td>1 kW</td>
</tr>
<tr>
<td>Average power</td>
<td>400 W</td>
<td>1000 W</td>
</tr>
<tr>
<td>Wavelength</td>
<td>515 nm</td>
<td>515 nm</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>0.3 … 50 ms</td>
<td>cw</td>
</tr>
<tr>
<td>Max. Pulse energy</td>
<td>40 J</td>
<td>---</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>&lt; 1000 Hz</td>
<td>---</td>
</tr>
<tr>
<td>LLK diameter</td>
<td>≥ 100 µm</td>
<td>≥ 50 µm</td>
</tr>
<tr>
<td>No. of outputs</td>
<td>max. 2</td>
<td>max. 2</td>
</tr>
<tr>
<td>BPP</td>
<td>4 mm·mrad</td>
<td>2 mm·mrad</td>
</tr>
</tbody>
</table>
### Summary – Trends & Challenges for LMD

#### Process Development

**EHLA**
Will become much stronger, but still new in market…

**AM by LMD**
Driven by CAD/CAM; predominantly for modification

**Continuously: Repair & Coating**
For molds, casts, aerospace and medical applications

#### Industry 4.0

Automatization and inter-machine networks
incl. a look into the overall process chain

#### Productivity

- Increase of laser power (also in “green”)
- New optics and system technology
- Automatization

#### Software

CAM-software and simulation tools for machine and part

#### Quality Assurance

- Powder: mass, flow & focus
- Laser beam properties
- Process monitoring & control
- In-situ check of quality

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**Marco Göbel | Brachenmanagement LMD | 17. September 2019**
Thank You for your kind attention
Vielen Dank für Ihre Aufmerksamkeit

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Branchenmanagement LMD