Prospects of Laser Polishing for Small and Complexly Shaped Parts

High Speed / High Precision Laser Microfabrication

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Polishing of Complexly Shaped 3D Parts

State of the art

- Many 3D parts are polished manually
- Time (1 .. 60 min/cm²) and Costs (30 .. 100 €/h)
- Lack of suitable laborers
- Roughness Ra down to 0.005 µm

High demand for automated polishing

Laser polishing

- Suitable for many 3D parts
- Time (0.01 .. 1 min/cm²) and Costs (40 .. 120 €/h)
- Fully automated polishing
- Roughness limited to Ra 0.05 .. 0.5 µm

Laser polishing has potential for many applications
Laser Polishing of Metals
Process principle

- Remelting of a thin surface layer and smoothing the surface through surface tension
- Nearly no material removal → high shape retention
- Solid state laser source: continuous wave / pulsed, laser power 40-500 W
Pulsed Laser Polishing of Guide Vane for VAD (Ti6Al4V)
AGENDA

- Introduction / Process principle
- Machine Tools for Laser Polishing
- Application Examples
- Conclusion
Machine Tools for Laser Polishing
Machine Tool for Small Parts

- **3-axis laser scanner** and **6-axis robot** with pneumatic gripper
- Suitable for complexly shaped parts up to 1 kg
- Glove box process gas chamber with airlock
- Solid state laser (continuous wave or pulsed)
- Optional: triangulation sensor; inner processing optics for bore or tube polishing
Machine Tools for Laser Polishing
Machine Tool for Small Parts by Unitechnologies

- 2 or 3-axis laser scanner and XYZ - delta robot with 2 rotational axes BC
- Flexible process gas chamber for complex shaped parts
- Different machine platforms:
  Standalone cell or integrated in automatic production lines
- Suitable for laser polishing, structuring and welding
  (depending on selected laser source)
- CAM-NC data chain for laser polishing by Fraunhofer ILT
Machine Tools for Laser Polishing
Machine Tool for Medium-large Parts

- 3-axis laser scanner and 5-axis portal machine with XYZ-AC kinematics
- Designed for parts with up to 100 kg (crane loading is possible)
- Ergonomic process chamber
- Solid state laser source (continuous wave or pulsed)
- Optional: Tactile probe for determination of part orientation
  Process gas system with more than one inert gas
Machine Tools for Laser Polishing
Polishing of a Mold for Glass Forming
AGENDA

- Introduction / Process principle
- Machine Tools for Laser Polishing
- Application Examples
- Conclusion
Application Examples

Blow mold
Stavax, 1.4021

Guide Vane, Titanium (Berlin Heart)

Embossing tool
1.2379 plus (Bosch)

Dental implant
Titanium Grade 4

laser polished tool

laser polished area
Application Examples
Overview of Investigated Materials

46-98% Roughness Reduction @ <1 min/cm²
**Application Examples**

**Ti6Al4V**

- Initial state (milled)
- Laser polished

Ra-Reduction: 1.1 µm → 0.12 µm @ 3.3 s/cm²

**1.1221**

- Initial state (milled)
- Laser polished

Ra-Reduction: 1.26 µm → 0.17 µm @ 20 s/cm²

**Inconel 718**

- Initial state (SLM)
- Laser polished

Ra-Reduction: 12-20 µm → 0.19 µm @ 27 s/cm²
Application Examples
Grinding vs. Laser Polishing – Tribological Surfaces

- Low macro roughness, spikes and scratches
- Higher macro roughness, no spikes, no scratches

Potential for peaks to get caught in each other

Ground

50 μm
no scratches

Laser polished

50 μm
Application Examples
Edge Polishing and Rounding / Deburring

- Rounding of steel-pins
- Processing time 0.2 s

- Polishing or rounding of the cutting edge of sheet metal

- Rounding of steel-pins
- Processing time 0.2 s

\[ r \approx 500 \mu m \]
\[ d = 1 \text{ mm} \]
Tooling Industry
Polishing of Micro-Lens Arrays

- Light scattering surfaces by
  - 1. laser ablation (ps-Laser) and
  - 2. laser polishing (ns-Laser)
- Tool steel 1.2343
- Structure depth 35 µm
- Structure width 120 µm
Application Examples
Increasing the Gloss Level
Application Examples
Two-Gloss-Level Design by Selective Laser Polishing

- Selective laser polishing of matt surfaces
- Circle pattern

- Selective laser polishing of photo chemical etched surfaces
- Polishing only of the pits in the tool

![Image of selective laser polishing example](image-url)

- Initial surface
- Ridges not polished
- Laserpolished pits

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Application Examples
Glass Polishing – Ground Spherical Lens, Fused Silica, Ø25 mm
AGENDA

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**Conclusion**

- Laser polishing is
  - feasible for **3D** geometries,
  - **automated** and
  - **fast** (almost independent of complexity).

- Offers **new possibilities** for
  - functional and tribological surfaces,
  - medical applications,
  - design surfaces
  - and many more…
Save the Date

2nd Conference on Laser Polishing - LaP 2016
April 26 to 27, 2016 in Aachen, Germany

Thank you for your attention!
Questions?

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CAM-NC Process Chain
Fully Integrated Process Chain

CAM software
Tool path calculation

Technology Processor (ILT)
Adaption of tool path to LP

6-axis robot laser polishing machine
Automated polishing

Application database

CAD Model ➔ APT File ➔ NC + Scanner ➔ Part

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# Laser Polishing of Metals

## Process variants

<table>
<thead>
<tr>
<th></th>
<th>Macro polishing</th>
<th>Micro polishing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser radiation</td>
<td>continuous wave (cw)</td>
<td>pulsed (100 - 1000 ns)</td>
</tr>
</tbody>
</table>

### Schematic drawing

- **Remelting depth:**
  - 20 - 100 µm
  - < 5 µm

### Processing time

- 7 - 60 s/cm²
- 1 - 10 s/cm²

### Initial surface roughness

<table>
<thead>
<tr>
<th>Method</th>
<th>Ra (µm)</th>
<th>Rz (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>milled, turned, EDM</td>
<td>0.4 - 10</td>
<td>0.4 - 3</td>
</tr>
<tr>
<td>ground and fine-milled</td>
<td>0.2 - 0.8</td>
<td></td>
</tr>
</tbody>
</table>

### Achievable surface roughness

- Depending on material, quality of material and initial roughness
- Ra = 0.05 - 0.50 µm / Rz = 0.4 - 3 µm

### Notes

- Adjusting the gloss level
Polishing of the entire surface except the exterior of the wings
- Manual polishing: 3h
- Laser polishing: ca. 5min