Lasers in Automotive Lightweighting

- Basics of laser cutting
- Hotforming in automotive
  - Process overview
  - Lightweighting with hotformed parts
  - Laser cutting of hotformed parts
- Additive Manufacturing – potential for weight reduction
  - Laser Metal Fusion
  - Laser Metal Deposition
Laser Cutting – Basics

Laser cutting – Hollywood style
Laser Cutting – Basics

Principle of laser cutting (elements)

1. Process gas
2. Cutting nozzle
3. Nozzle offset
4. Cutting speed
5. Molten material
6. Dross
7. Cutting roughness
8. Heat affected zone
9. Kerf width
Laser Cutting – Basics

Principle of laser cutting (process)

- Focused laser beam and cutting gas exit concentrically out of the nozzle
- Protective glass in front of the lens
- Cutting (assist) gases: Air, O₂, N₂, Ar
- Laser beam generates molten and vaporized material and determines the kerf geometry
- Cutting gas expels the molten material from the kerf
- Cutting process:
  - Drilling the starting hole (piercing)
  - Cutting the programmed contour
Laser Cutting – Basics

Initiating the cut

- Blow piercing (standard piercing)
  - Larger kerf
  - High spatter
  - Fast
  - Larger holes & closed features
- Controlled pulse piercing (soft piercing)
  - Smaller kerf
  - Low spatter
  - Slow
  - Smaller holes & closed features
- Piercing on the fly
  - Smaller kerf
  - Medium spatter off-set by motion
  - Fastest
  - Smaller holes & closed features

Heat dissipation
Expulsion of molten material
Cutting gas nozzle
Focused laser beam
Current drilling depth
Cutting gas
Expulsion of molten material
Heat dissipation
Expulsion of molten material

2mm

2mm
Different laser cutting methods

• Fusion Cutting (N₂ high pressure cutting):
  – Gas: N₂ (8-22 bar typical)
  – Stainless steel, aluminum, galvanized steel
  – Mild steel for welding application
  – Oxide free cutting edge

• Flame Cutting (oxygen / exothermic cutting):
  – Gas: O₂ (0.5 – 6 bar typical)
  – Mild steel
  – High productivity
  – Oxidized cutting edge

• Sublimation Cutting:
  – Laser vaporizes and burns the material
  – Vapor pressure expels the slag from the kerf
# Laser Cutting – Basics

## Materials for laser cutting

<table>
<thead>
<tr>
<th>Material</th>
<th>CO₂ Laser</th>
<th>SSL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild Steel</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Alloy Steel</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Tool Steel</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Aluminum &amp; Aluminum Alloys [up to 6 mm (0.24 inch)]</td>
<td>fair-good</td>
<td>fair-good</td>
</tr>
<tr>
<td>Copper &amp; Copper Alloys</td>
<td>difficult</td>
<td>fair</td>
</tr>
<tr>
<td>Titanium</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Gold &amp; Silver</td>
<td>poor</td>
<td>fair</td>
</tr>
<tr>
<td><strong>Non-Metals, Organics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastics (Polymers)</td>
<td>good-excellent</td>
<td>poor [³]</td>
</tr>
<tr>
<td>Composites</td>
<td>fair-good</td>
<td>fair-good</td>
</tr>
<tr>
<td>Rubber</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Wood</td>
<td>excellent</td>
<td>poor</td>
</tr>
<tr>
<td>Paper and Cardboard</td>
<td>excellent</td>
<td>poor-good</td>
</tr>
<tr>
<td>Leather</td>
<td>excellent</td>
<td>poor-good</td>
</tr>
<tr>
<td>Synthetic Textiles</td>
<td>excellent</td>
<td>poor-good</td>
</tr>
<tr>
<td><strong>Non-Metals, Inorganics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>good-excellent</td>
<td>not possible</td>
</tr>
<tr>
<td>Glass</td>
<td>difficult</td>
<td>not possible</td>
</tr>
<tr>
<td>Ceramics</td>
<td>fair-good</td>
<td>fair</td>
</tr>
<tr>
<td>Stone and Rock</td>
<td>poor</td>
<td>poor</td>
</tr>
</tbody>
</table>
# Laser Cutting – Basics

## Assist gas types and common uses

<table>
<thead>
<tr>
<th>Assist Gas</th>
<th>Common Applications</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oxygen</strong></td>
<td>mild steel (comments 1 &amp; 2),</td>
<td>(1) $O_2$ increases cut speed,</td>
</tr>
<tr>
<td></td>
<td>stainless steel &amp; copper (comment 2),</td>
<td>$O_2$ burning possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) oxide layer on cut edge</td>
</tr>
<tr>
<td><strong>Nitrogen</strong></td>
<td>stainless steel,</td>
<td>slower cut speeds,</td>
</tr>
<tr>
<td></td>
<td>aluminum,</td>
<td>clean cuts (no oxide layer,</td>
</tr>
<tr>
<td></td>
<td>nickel base alloys,</td>
<td>suitable for welding)</td>
</tr>
<tr>
<td></td>
<td>mild steel (clean cut)</td>
<td></td>
</tr>
<tr>
<td><strong>Air</strong></td>
<td>thin mild steel, thin aluminum (air reactive),</td>
<td>inexpensive when applicable</td>
</tr>
<tr>
<td></td>
<td>alumina (air inert),</td>
<td></td>
</tr>
<tr>
<td></td>
<td>plastics, wood composites,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>glass, quartz</td>
<td></td>
</tr>
<tr>
<td><strong>Argon/Helium</strong></td>
<td>titanium</td>
<td>argon relatively expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>($oxygen$ reacts violently &amp; $nitrogen$ yields imbrittlement)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>helium or helium/argon mix minimizes HAZ &amp; reduces argon plume problems</td>
</tr>
</tbody>
</table>
Material is de-coiled and cut into blanks with either a blanking press, or a flatsheet laser cutter.
Blanks are then heated up to approx. 950 C in the oven.
Blanks are formed in the press while hot and quenched very quickly down to approx. 200°C to achieve a martensite structure.
Hotforming in Automotive

Process overview

Blanking | Oven | Press hardening | Laser cutting

Platine erwärmen

Formed parts are then trimmed / cut in a 3D laser cutting system as the material is too hard for any mechanical trimming.
The tensile strength of 22MnB5 before processing is comparable to mild steel. When the material is heated it is very ductile, which allows great freedom of formability. After quenching the hot steel in the stamping press it changes its properties and becomes very hard with a high tensile strength.
Hotforming in Automotive

Lightweighting with hotformed parts

Part 2
ZSte260
(1.5 mm)

Part 3
TRIP700
(1.75 mm)

Part 1
ZSte260
(1.5 mm)

Part 2
CPW800
(2.25 mm)

mod345

mod354

AUDI A4:
11kg weight reduction

Good crash performance
with reduced weight
Lesser parts
Increased gas mileage
(reduced carbon footprint)
Laser Cutting of Hotformed Parts

Processing equipment
Laser Cutting of Hotformed Parts

• Trends / Developments
  – Complex patchwork parts
  – Full body sides
  – Variable thickness
  – Automation
  – Spot / area softening
Additive Manufacturing – Potential for Weight Reduction

Additive Manufacturing – Definition

Additive Manufacturing (AM) is a process in which a three-dimensional metal object is created out of a digital model. The additive process builds up metal parts layer by layer.
# Additive Manufacturing – Potential for Weight Reduction

**Overview on Production Methods**

Additive Manufacturing as an extension of the portfolio

## Production methods

<table>
<thead>
<tr>
<th></th>
<th>Subtractive manufacturing</th>
<th>Forming production methods</th>
<th>Generative / additive manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Form alteration through material removal</td>
<td>Form alteration through heating or mechanical force</td>
<td>Building of materials layer-by-layer</td>
</tr>
<tr>
<td></td>
<td>E.g.: grinding turning milling</td>
<td>E.g.: forging bending</td>
<td>E.g.: Laser Additive Manufacturing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electron Beam Melting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Laser Metal Deposition</td>
</tr>
</tbody>
</table>

![Subtractive manufacturing](image1.png)

![Forming production methods](image2.png)

![Generative / additive manufacturing](image3.png)
Additive Manufacturing – Potential for Weight Reduction

Additive Manufacturing Technologies
Laser Metal Fusion – Laser Metal Deposition

<table>
<thead>
<tr>
<th></th>
<th>Laser Metal Fusion (LMF)</th>
<th>Laser Metal Deposition (LMD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometrical complexity</td>
<td>★★★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>Build rate</td>
<td>★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Accuracy</td>
<td>★★★★</td>
<td>★★</td>
</tr>
<tr>
<td>Surface quality</td>
<td>★★★</td>
<td>★</td>
</tr>
</tbody>
</table>

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Additive Manufacturing – Potential for Weight Reduction

Benefits of LMF Technology offers many opportunities

- **Complex parts**: Maximum geometric freedom of design.
- **Weight**: Lightweight construction through grid structures or bionic design.
- **Speed**: Reduction of manufacturing steps. (e.g., tool-free production).
- **Costs**: Economical production of small, complex parts starting with a quantity of 1 ("complexity for free").
- **Sustainability**: Saving resources through low material and energy consumption.
Additive Manufacturing – Potential for Weight Reduction

Laser Metal Fusion (LMF) Process
Layer-by-layer creation of complex parts from 3D data

1. Digital model

2. LMF process

3. Final product

Process description:
- Layer-by-layer creation of parts in a powder bed
- Tool-free manufacturing directly from 3D CAD data

Advantages:
AM complements conventional production technologies and is already beneficial for:
- Individual products
- Small quantities
- Complex parts
Additive Manufacturing – Potential for Weight Reduction

AM Advantage: complexity for free
Complex geometries without higher costs

**Comparison - AM vs. conventional manufacturing**

- **Cost**
  - Conventional manufacturing
  - Additive Manufacturing

- **Complexity**
  - AM Advantage: Complexity for free

**Implications**

- AM facilitates the creation of new geometric forms, which are not feasible with conventional production methods.
- With the help of AM, complex geometric forms with an improved functionality and performance can be produced without additional costs.

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Additive Manufacturing – Potential for Weight Reduction

Production of complex geometries by LMF
Flowing media and heat management

<table>
<thead>
<tr>
<th>Conventional technology:</th>
<th>Assemblies of structures for flowing media / heat management (i.e. Hydraulics, heat exchanger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New concept:</td>
<td>Required geometry printed by LMF process</td>
</tr>
<tr>
<td>Advantages:</td>
<td>Reduction of weight and package size</td>
</tr>
<tr>
<td></td>
<td>High complexity</td>
</tr>
<tr>
<td></td>
<td>Increased freedom of packaging</td>
</tr>
<tr>
<td></td>
<td>Fast turn around time during product development</td>
</tr>
</tbody>
</table>
## Additive Manufacturing – Potential for Weight Reduction

### Joining of components by Laser Metal Deposition (LMD)

<table>
<thead>
<tr>
<th>Conventional technology:</th>
<th>Component made of 1 material required for specific performance in one or more areas of its geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New concept:</strong></td>
<td>Joining of components made from different materials to achieve location specific performance</td>
</tr>
<tr>
<td><strong>Advantages:</strong></td>
<td>Reduction of weight</td>
</tr>
<tr>
<td></td>
<td>Joining of dissimilar materials (i.e. Cast iron to sheet metal)</td>
</tr>
<tr>
<td></td>
<td>Ability to bridge gaps</td>
</tr>
</tbody>
</table>
Additive Manufacturing – Potential for Weight Reduction

Feature generation as needed by Laser Metal Deposition (LMD)

<table>
<thead>
<tr>
<th>Component &amp; process examples for weight reduction:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle components shared over several platforms</td>
</tr>
<tr>
<td><strong>Situation:</strong></td>
</tr>
<tr>
<td>Various load and/or feature requirements for different models</td>
</tr>
<tr>
<td>Various volumes amongst vehicles with low volumes for high load/feature models</td>
</tr>
<tr>
<td><strong>Common solution:</strong></td>
</tr>
<tr>
<td>One part based on max. load/features used across all platforms</td>
</tr>
<tr>
<td><strong>Issue:</strong></td>
</tr>
<tr>
<td>Part overbuild/too heavy for majority of applications</td>
</tr>
</tbody>
</table>
Additive Manufacturing – Potential for Weight Reduction

Feature generation as needed by Laser Metal Deposition (LMD)

Component & process examples for weight reduction:
Vehicle components shared over several platforms

Solution:
- Common base part produced conventionally: casting, forging, forming...
- Only one forming/casting tool needed (for the base part)
- Generation of reinforcements or functional structures by LMD
- High flexibility regarding location, geometry and dimensions of reinforcements / structures

=> Material is deposited only where and for the vehicles needed
Q&A

And now I am looking forward to your questions!

Frank Geyer
Product Manager
Additive Manufacturing & Laser Systems
Celebrating 15 Years

Great Designs in STEEL

Presentations will be available May 16 at www.autosteel.org