Lasers – Efficiency and Strength for Lightweighting

Laser Processing of Steel

Rahul Patwa, Thomas Kretzchmar, Arkan Abdulkadir, Brian Della Mora and Craig Bratt

Fraunhofer USA
Center for Laser Applications
Fraunhofer USA – Center for Laser Applications

- 23 years in USA (2017)
- Laser Applications Center located in Plymouth MI (+ 6 other Centers in USA)
- Provide Contract Applications Research and Development for industry
- Laser Applications
  - Welding / Cutting / Drilling
  - Cladding / Hardening/ Surface Treatment
  - Macro / Micro processing
- 2007 Received Henry Ford Technology Award for Development of F150 Roof Welding Process
Outline - Laser Processing of Steel

- Laser Joining
  - Laser Welding
  - Laser Welding with Filler Wire
  - Remote Laser Welding
  - Laser Brazing
- Laser Hardening
- Laser Softening
- Laser Surface Treatment
- Laser Drilling
Laser Welding

Basic Principle

- Laser beam provides a highly concentrated heat source
- Melts metal and even produces vapor (plasma)
- As the laser beam moves along the joint, weld is created upon solidification
Laser Welding – High Speed Process Video
Laser Welding – Automotive Applications

- Body in White
- Tubes and Closures
- Powertrain
- Tailor Welded Blanks

- Eliminates bolted assembly for weight reduction and material cost saving!
- Less assembly steps, remove the need for machining holes and bolting assembly!
- Minimal heat input and distortion
- Proven performance and durability
Types of Laser Joining Processes

1. Filler Wire
2. Beam delivery

Laser welding with wire

Laser brazing

Laser remote welding
## Limitations of Autogenous Laser Welding

<table>
<thead>
<tr>
<th>Limitations</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Weld defects due to</td>
<td>Laser Welding with filler wire</td>
</tr>
<tr>
<td>• alloy metallurgical incompatibility</td>
<td></td>
</tr>
<tr>
<td>• dissimilar material</td>
<td></td>
</tr>
<tr>
<td>• Weld geometry not meeting specifications</td>
<td></td>
</tr>
<tr>
<td>• Welded surface not aesthetically smooth</td>
<td>Laser Brazing</td>
</tr>
<tr>
<td>• High power melts the zinc coating</td>
<td></td>
</tr>
<tr>
<td>• No fast movement between the welds</td>
<td>Laser Remote Welding</td>
</tr>
</tbody>
</table>
Laser Welding with Filler Wire

Basic Principle
- During laser welding, external wire is fed into the melt pool
- As the laser beam and wire moves along the joint, the weld is created upon solidification
- Filler material
  - Metal cold/hot wire

Applicability
- Otherwise not laser weldable materials
- Overcome poor weld geometry or fit up
- Change weld chemistry and properties
Laser Welding with Filler Wire – High Speed Video
Laser Welding with Filler Wire - Application

- Welding of Dissimilar Materials
  
  Steel 4320 – Steel 8620 using Ni-based filler wire

- Laser welding can weld conventionally un-weldable materials such as higher carbon steels and cast irons using filler wire or pre heat techniques
Outline - Laser Processing of Steel

- Laser Joining
  - Laser Welding
  - Laser Welding with Filler Wire
    - Remote Laser Welding
    - Laser Brazing
- Laser Hardening
- Laser Softening
- Laser Surface Treatment
- Laser Drilling
Remote Laser Welding

Basic Principle
- Uses a relatively long focusing optic (hence "remote")
- Highly dynamic scanning mirrors enable extremely fast indexing in-between welds
- Therefore laser is spending more time joining parts and much less time waiting

Applicability
- Fast and Flexible
- No limitation of weld geometry and speed
Remote Laser Welding – Application Video

**Spot weld - production**

34  + mech. shift code
4 robots, 5 welding guns
Welding time: 34.7s

**Laser remote weld - production**

34  + shift code
1 robot, 1 scanner optic
Welding time: 13s (4kW), <10s (6kW)
Remote Laser Welding – Application Video

Source: Volkswagen AG

Courtesy of Trumpf

Source: Volkswagen AG
Remote Laser Welding – Weight Saving

Reduction of flange width

- Additional potential for mass reduction
- High beam-to-seam accuracy is required
- Seam tracking with remote welding head can be utilized

Courtesy of Trumpf
Remote Welding of Fillet Joints

Video by courtesy of Blackbird/BMW
Laser Brazing – Applications

- Nearly all of the latest generation of German automobiles use one or more laser brazed seams to connect sheet metal in the car’s body
  - Tailgate / Liftgate (License plate) / Roof

Has been Implemented by:
- BMW (various models inc Liftgate)
- Chrysler Sebring (Liftgate)
- Ford (Mondeo – Roof development)
- GM – Cadillac CTS (Roof and Liftgate)
- Mercedes (Liftgate)
- VW / Audi / SEAT (various)
- Renault (Roof)

Source: Audi / Laserline
Laser Brazing – Application Video

Fraunhofer USA
Center for Coatings and Laser Applications

Trunk Lid Brazing
High Speed Camera Monitoring

- Turn-key integrated laser in-process monitoring system for laser welding
- High speed camera with illumination
- Robust industrial system can be integrated in existing laser welding setup
- Defect detection operator feedback (OK/NOK)
Outline - Laser Processing of Steel

- Laser Joining
  - Laser Welding
  - Laser Welding with Filler Wire
  - Remote Laser Welding
  - Laser Brazing
- Laser Hardening
- Laser Softening
- Laser Surface Treatment
- Laser Drilling
Laser Hardening

Basic Principle
- Laser beam heats the surface just below the melting point
- Very high cooling rate is obtained by moving the beam
- High hardness is achieved

Applications
- Trim Dies and Tools
- Engine Components
Laser Softening

Basic Principle
- Laser beam heats steel sheet above transition temperature
- By moving the beam, a larger area is treated and cooling rate is controlled
- Suitable microstructures are formed by rearrangement and softening is achieved

Applications
- Selective softening for easier formability or mechanical fastening
- High speed process compared to conventional heat treatments
- Tailored microstructures
Laser Treatment - Enhanced Crash Performance

- Locally modify material properties to optimize collapse and energy absorption during crash
- Crash performance of steel parts can be modified

*Results courtesy and copyright Fraunhofer IWS, Dresden.*
Laser Surface Treatment

- Laser surface texturing
- Laser coating removal
  - Phosphorous coating removal for clean welding surface
  - Paint removal
- Laser color marking

Surface Texturing

Color Marking

Phosphate Coating Removal

Paint Removal
Laser Drilling

- High aspect ratio – 40:1
- High speed drilling – 15,000 holes/sec
- Fuel injector drilling

High Aspect Ratio Holes
Summary and Conclusion

- Laser applications employed by automotive industry for steel
  - Welding
  - Hardening
  - Surface treatment
  - Drilling

- The automotive industry has incorporated laser processing in virtually every sub-system of the automobile

- Ongoing laser innovations will continue to make laser implementation more and more affordable

- Lasers are a key technology enabler for mass reduction in steel vehicles!
Contact:

Rahul Patwa
Fraunhofer USA, Center for Laser Applications (CLA)
46025 Port Street, Plymouth, Michigan 48170
rpatwa@fraunhofer.org
Phone +1 (734) 738 0505
www.cla.fraunhofer.org

Thank you for your attention!