Lasers – Efficiency and Strength for Lightweighting

Laser Joining of Steel

Rahul Patwa and Craig Bratt
Fraunhofer

- 66 Research Institutes in Germany
- 7 Centers in USA
- 24,000 Staff
- 3000 Customers Worldwide (EU / USA / Asia)
- $2.5 Billion Research Budget

Research Fields
- Materials, IT, microelectronics, sensors
- Energy, environment, molecular biology
- Production and process technology, Laser Process Technology

Focus on applied research activities
Fraunhofer USA – Center for Laser Applications

- 22 years in USA (2016)
- Laser Applications Center located in Plymouth MI (+ 6 other Centers in USA)
- Provide Contract Applications Research and Development for local 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 Joining of Steel

- Laser Welding

- Different Types of Laser Joining Processes
  - Laser Welding with Filler Wire
  - Remote Laser Welding
  - Laser Brazing

- Process Monitoring
Laser Welding – Car Roof Welding Video
Laser Welding

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

<table>
<thead>
<tr>
<th>Common Concerns</th>
<th>Opportunity</th>
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<tbody>
<tr>
<td>Relatively Higher Capital Equipment cost</td>
<td>• Laser costs → Laser prices are reducing all the time now</td>
</tr>
<tr>
<td></td>
<td>• Cost savings → high productivity → reduction of scrap and re-work</td>
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<tr>
<td>Good part fit-up required</td>
<td>• New processing techniques (twin spot, wobble) to bridge gaps</td>
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<tr>
<td></td>
<td>• Laser welding with filler material, hybrid techniques</td>
</tr>
<tr>
<td>Precision alignment required</td>
<td>• Automatic control with seam tracking and height sensing</td>
</tr>
<tr>
<td></td>
<td>• State-of-the-art closed loop process monitoring systems</td>
</tr>
<tr>
<td>Laser champion required</td>
<td>• More laser training programs are available</td>
</tr>
<tr>
<td></td>
<td>• Laser applications are growing very fast</td>
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</tbody>
</table>

- High quality parts with minimal distortion and narrow weld bead
- Easily automated with consistent weld quality
- Ability to weld in difficult to reach areas with single sided access
- High strength welds with improved stiffness and crash performance
- Reduced flange widths with reduction of component size / weight
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

Bolted Design vs Laser Welded Design
Laser Welding - 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.*
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Types of Laser Joining Processes

1. Filler Wire
2. Beam delivery

(Autogenous) Laser welding

Laser welding with wire

Laser brazing

Laser remote welding
### Limitations of Autogenous Laser Welding

<table>
<thead>
<tr>
<th>Limitations</th>
<th>Solutions</th>
</tr>
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<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 – Application Video
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 Material

  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
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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
- Sheet metal welding
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)

Source: Volkswagen AG

Courtesy of Trumpf
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
Remote Laser Welding – Seam Tracking

- High speed camera with on-axis illumination
- Auto-focus of camera along z-axis
- Edge detection with a resolution of ~ 0.1 mm
- Omni-directional 3D on-the-fly welding with tracking

Courtesy of Blackbird
Remote Welding of Fillet Joints

Video by courtesy of Blackbird/BMW
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Laser Brazing – Application Video

Fraunhofer USA
Center for Coatings and Laser Applications
Trunk Lid Brazing
Laser Brazing

Basic Principle
- Laser beam heats filler metal (braze) above melting point
- Filler material flows between two close-fitting parts by capillary action.
- Braze material
  - Bronze wire

Applicability
- Smooth surfaces, no finishing required
- Ability to avoid melting the zinc coating
- Joining of dissimilar metals
Laser Brazing – Applications

- Latest generation of 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
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- Process Monitoring
Still Defects are Inevitable...

- Process Monitoring
- Pre, inline, Post weld
High Speed Camera System

- Turn-key integrated laser in-process monitoring system for laser welding.
High Speed Camera System – Defect Detection
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
Summary and Conclusion

- Laser joining applications employed by automotive industry for steel
  - Laser Welding
  - Laser Welding with Filler Wire
  - Remote Laser Welding
  - Laser Brazing

- 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!
Thank you for your attention!

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