LASER WELDING 101

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Contents

- Introduction
- Why employ laser welding?
- Fit-up & basic joint configuration
- Joint bridging techniques
- Joint design & feature considerations
- Summary
A vast array of applications
Laser applications - Automotive Industry

- Passenger-safety
- Interior
- Electronic
- Chassis/BIW
- Components
- Exhaust systems
- Engine
- Powertrain
- Suspension

www.autosteel.org
Minimum heat input and high aspect ratio resulting in …
- minimal shrinkage & distortion of the workpiece
- small heat affected zone
- narrow weld bead with good appearance

High strength welds often resulting in …
- improved component stiffness / fatigue strength
- reduction of component size / weight  Design Optimization

Ability to weld in areas difficult to reach with other techniques
- non-contact, narrow access, single sided process

Flexibility …
- beam manipulation (beam switching and sharing)
- variety of part & weld geometries and materials
Why employ laser welding?

- **Cost savings ...**
  - high productivity $\Rightarrow$ faster cycle time = less stations & **less floor space**
  - reduction of manual labor, scrap & re-work
  - reduction of component material and weight
  - can eliminate secondary processes

*Laser Welding vs. Resistance Spot Welding*

- **Reduction or elimination of flanges**
  - reduction of component size / weight
  - reduced cost
  - greater visibility / accessibility

- **Increased strength / stiffness**
  - localized increase of component strength / stiffness / fatigue strength
  - weld shape optimization for component loading / stresses
  - elimination of lower electrode access holes
Laser – The Universal Tool for Welding

- Narrow weld seam
- Min. heat affected zone
- Little metallurgic effects on the material

- Little distortion
- No filler material required
- High process speed
- Non-contact
- No wear

Laser welding
Laser as a tool

- relatively wide / narrow
- continuous / stitch / spot
- through / partial
- line / optimized shape
- conventional / remote
- multiple layers

*When would you want wide? When narrow?*

*What benefits does partial penetration have?*

*Why would you want a shape that is not a straight line?*
Material selection

1. Causes of porosity, underfill, undercut:
   - Volatile constituents (e.g. S, P)
   - Volatile coatings/surface contaminants (e.g. Zn, oil based lubricants)

Notes for welding of Zn coated steels in overlap configuration

a. Increased weld length may compensate for porosity in non-critical components

b. Electro-galvanized & electro-galvanneal are better than hot dipped galvanized

c. Bare to Zn is often okay (especially electro plated)

d. Zn to Zn configurations usually require a gap and/or Zn exhaust path for reasonable results (e.g. dimples, shims, knurling, fixture/tooling, leading pressure finger, part design, joint design)

e. Watch out for patent infringements!
2. Britteness & cracking:
   - Can occur in steels when >0.3%C (>0.4%C equivalent)
   - 6000 series aluminum

3. Reflectivity
   With high reflective materials (e.g. Al, Cu) – 1 micron wavelength has greater absorption than 10.6 microns
Seam and joint types

Lap weld on lap joint

Seam weld on butt joint
## Seam and joint types

<table>
<thead>
<tr>
<th>Name</th>
<th>Example</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| Seam weld on butt joint     | ![Example](#) | + Weld Fusion Area  
  • less material = weight & cost savings  
  • faster or less power  
  • less HAZ / distortion  
  • no issues w/ Zn  
  • no step  
- Positioning Tolerance  
  • edge requirements  
  • fit up can be more difficult to obtain  
| Lap weld on lap joint       | ![Example](#) | + Positioning Tolerance  
  • larger process window  
  • can have aesthetic underside  
- Weld Fusion Area  
  • more energy required = slower or higher power & more distortion / HAZ  
  • inefficient process |

Think about a positive & negative characteristic of both the butt & lap weld configurations.
## Seam and joint types

<table>
<thead>
<tr>
<th>Name</th>
<th>Example</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| Seam weld on stepped lap joint      | ![Diagram](image1) | + weld fusion area  
- positioning tolerance |
| Seam weld on T-joint                | ![Diagram](image2) | + weld fusion area  
- positioning tolerance |
## Seam and joint types

<table>
<thead>
<tr>
<th>Name</th>
<th>Example</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lap weld on T / border joint</td>
<td><img src="lap_weld_t_border.png" alt="Diagram" /></td>
<td>+ positioning tolerance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- weld fusion area</td>
</tr>
<tr>
<td>Seam weld on flange</td>
<td><img src="seam_weld_flange.png" alt="Diagram" /></td>
<td>+ weld fusion area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- positioning tolerance</td>
</tr>
<tr>
<td>Lap weld on formed seam</td>
<td><img src="lap_weld_formed_seam.png" alt="Diagram" /></td>
<td>+ positioning tolerance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- weld fusion area</td>
</tr>
</tbody>
</table>
Fit-up requirements

Butt joint configuration:
- Gap: 3-10% thickness of thinnest sheet
- Offset: 5-12% thickness of thinnest sheet

Overlap joint configuration:
- Gap: 5-10% thickness of top sheet

Why is this general guideline not absolute?
(What influences the amount of gap that can be bridged?)
- Focus spot size
- Edge geometry for butt weld
- Strength requirements
How can we estimate the weld length of a laser “stitch” to give the same strength as a resistance spot weld?

1. Determine average RSW nugget diameter
2. Calculate nugget area
3. Determine the average weld width at interface of the laser welded component
4. Set nugget area (A) equal to the weld length (L) x the weld width at interface (w)

\[ A = L \times w \]

\[ L = \frac{A}{w} \]

Typical values of \( w \) are 0.8-1.0 mm
Typical values of \( L \) are 18-25 mm
Tolerance compensation
Joint bridging techniques

**Autogenous**
- **Larger focus spot**
  - slower, more heat input
- **Twin spot**
  - 2x higher power density
  - Less wasted energy
  - **faster!!**
  - Directionality

**Non-autogenous**
- **Hybrid (laser + MIG + wire feed)**
  - cost, complexity, may require vision system
- **Wire feed**
  - gap & metallurgical bridging
Design features

K-Joint in Application / Flange-reduced Design
Design features

Specialized cutting & bending of tubes w/ positioning aids

Special bent tubes techniques create connections with the need of only a few welds.
Design features

More Tube Interfaces

Coding system to avoid possible assembly mistakes, accurate position.
Design features

Interlocking tabs for tubes
Design features

Integrating locating & interlocking features
Design features

Concept for an Underbody design with K-Joint & Interlocked Joints
Design for laser welding summary (pt. 1)

- Design & re-design components for laser welding
  - Reduce component weight & cost by reducing or eliminating flange widths (*enabled by single sided, narrow beam access*)
  - Increase vehicle accessibility & driver visibility by reducing or eliminating flange widths (*enabled by single sided, narrow beam access*)
  - Reduce component weight and cost by reducing gage thickness (*enabled by increasing strength through optimized weld shapes and/or continuous weld seams in high stress locations*)
  - Reduce component weight and cost, and increase strength (*enabled by elimination of RSW lower electrode access holes in structural reinforcements*)
Know & employ the strengths of the full variety of weld joint styles

Realize there are several ways to bridge the gap, … but don’t start there

Consider the variety of design features when designing for laser welding (e.g. K-Joint, positioning aids, tabs, bayonets, interlocking joints, tolerance compensation planes, etc.)
Continuous Education / Improvement

Laser Welding
Christopher Dawes
Abington Publishing (1992)

Laser Welding
Walter W. Duley
John Wiley & Sons (1999)

Laser Material Processing – Fourth Edition
William M. Steen / Jyoti Mazumder
Springer (2010)

AWS Welding Handbook
Welding Processes, Part 2
Ninth Edition, Volume 3

LIA Handbook of Laser Material Processing
John F. Ready – Editor in Chief
Laser Institute of America (2001)
Please join TRUMPF for their Open House

Open House Schedule
5:30 pm – 9:00 pm

Join us at TRUMPF’s Laser Technology Center for an evening of technical discussion, machine demonstrations, tabletop displays and refreshments.

The Power of Choice
There is no “one size fits all” in industrial lasers. Optimization of diverse applications requires different laser technologies. TRUMPF offers the largest application and service network in the world as well as the broadest industrial laser portfolio of any manufacturer, including CO₂, Nd:YAG, disk, fiber coupled direct diode and more.

May 2, 2013 – 5:30 p.m.
TRUMPF Laser Technology Center
47711 Clipper Street
Plymouth Township, MI 48170

Featured Equipment
• High speed 3D cutting (CO₂ and disk laser)
• Robotic remote welding (disk laser)
• High precision cutting (fiber laser)
• Automated pulsed welding (pulsed laser)
• Precision laser marking (marking laser)
• Short pulse applications in automotive (disk laser)
You are invited to attend ALAW

- Welcome Reception tonight: The Inn at St. John’s in Plymouth at 5 p.m.
- ALAW presentations here on Thursday & Friday
- TRUMPF Open House and Reception in Plymouth Thurs. 5:30-9 p.m.
- Fraunhofer CCL Open House and Lunch in Plymouth Fri. 12:30-4 p.m.
- Questions? Stop by the FMA/ALAW booth.
Thank you

TRUMPF Laser Technology Center
Plymouth, MI
(734) 454-7200
Design optimization

- Laser welding
- Resistance spot welding
- Laser welding

- Flange Reduction or Elimination (flangeless design)
- Better Accessibility
- Less Interference
Principle of time sharing

Throughput maximization & manufacturing flexibility
Principle of energy sharing

➔ Reduced distortion
Continuous weld & strength optimization
Advantage: Programmable Weld Shapes

Customized weld patterns for optimal joint strength:

- Distribution
- Orientation
- Shape
Elimination of lower electrode
Summary: Golf IV / Golf V

Goals reached:
- Increased process speed (joining)
- Increased productivity
- Increased strength compared to alternative joining methods
- Reduced heat distortion
- Narrow or no flange => Weight reduction
- High flexibility via sharing & back-up of lasers into different work cells
- Reduced floor space

<table>
<thead>
<tr>
<th></th>
<th>Golf IV</th>
<th>Golf V</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor space Side panel</td>
<td>2816 m²</td>
<td>1472 m²</td>
<td>(-50%)</td>
</tr>
<tr>
<td>Floor space Underbody</td>
<td>480 m²</td>
<td>320 m²</td>
<td>(-33%)</td>
</tr>
<tr>
<td># of Weld spots</td>
<td>4608</td>
<td>1400</td>
<td></td>
</tr>
<tr>
<td>Length of laser weld</td>
<td>1.4 m</td>
<td>70 m</td>
<td></td>
</tr>
</tbody>
</table>
Wide vs. narrow

**Wide**
- Overlap welding
- Poor edges
- Poor fit-up
- Poor beam to seam location tolerance

**Narrow**
- Low distortion, high speed welding w/ minimum power for butt welding configurations
- ... but, good edges, excellent fit-up, & good beam to seam location tolerance required
**Partial penetration vs. full penetration**

**Partial**
- Aesthetics on back side of component
- Mating part considerations (fit-up & friction)
- Thickness of lower part (through penetration may be impractical or impossible)
- Protection of heat or spatter sensitive components
- Higher speeds (or lower laser power) w/ less HAZ & distortion

**Full**
- Visual weld verification possible
- Larger fusion area for butt weld configuration

Compared to through penetration weld …

Compared to partial penetration weld …
Advantage: Programmable Weld Shapes

Stress = \( \frac{F}{A} \)
Advantage: Programmable Weld Shapes

Peel

Peel
Zn coated material: Gap for out gassing

- Evaporating temperature of zinc < melting temperature of steel
- Vapor pressure causes expulsion of molten steel in upper sheet
- Result: Welding seam becomes highly porous and weak
Gap for outgassing: Laser dimpling

- Pre-treatment of one sheet to generate 0.1-0.2mm standoff between sheets
- Use of same laser equipment and optics
Gap for out gassing: Laser dimpling

- Constant dimple height (depending on zinc layer approximately 0.15 mm)
- Dimple height adjustable via laser parameter
Gap for out gassing: Laser dimpling

**Step 1:**
Laser Dimpling

**Step 2:**
Placement of upper sheet

**Step 3:**
Scanner Welding

Feed rate

BEO or PFO

BEO or PFO
PRESENTATIONS WILL BE AVAILABLE MAY 3

Use your web-enabled device to download the presentations from today’s event

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