LASER GUIDED AND STABILIZED GAS METAL ARC WELDING PROCESSES (LGS-GMA)

Jörg Hermsdorf
Laser Zentrum Hannover, Germany
OUTLINE

- Motivation
- Innovation Technology
- Project Concept
- Welding and Cladding Results
- Summary
MOTIVATION

Trailer and automotive industry

Reduce energy costs → Lightweight construction → Aluminium and high strength steels → New and flexible joining technologies

Railway industry

Source: Alstom

Ship building industry

Source: Meyer Werft

Source: Schmitz Cargobull
COMMON JOINING TECHNOLOGIES

Laser welding
- Expensive
- High demands on work piece preparation / narrow tolerances
- **Deep welding effect**
- Narrow weld seams possible

Arc welding
- Most common, cost-effective
- High thermal energy deposit
- **Distortion of work piece**
- Alteration of material properties
- Arc root point may move uncontrollably on the work piece, particularly on oxidized surfaces

Hybrid welding
- Expensive laser systems
- High laser intensities ($I > 10^6 \, \text{W/cm}^2$)
- **Deep welding effect**
- Good gap bridging ability and high penetration depths

Laser guided and stabilized the welding process
LASER-GUIDED AND STABILIZED WELDING

Properties

- Low laser intensities (~10^4 W*cm^2)
- ~10-20% contribution to total power
- Only usage of the laser for guidance and stabilization
- Cost-effective laser systems
- Increased conductivity in the electric arc

Possibilities

- No keyhole, no deep welding effect
- Different seam geometries may be welded
- Higher feed rates possible
- Active positioning of the electrical arc, oscillation
- Decrease of thermally induced distortion
INTERACTION BETWEEN LASER RADIATION AND ELECTRIC ARC
INTERACTION BETWEEN LASER RADIATION AND ELECTRIC ARC
LASER GUIDED AND STABILIZED GAS METAL ARC WELDING PROCESSES (LGS-GMA)

PROJECT-CONCEPT

Concept

Fiber guided laser
GMA-head
Scanner-mirror
CMOS camera
Electric arc
Laser beam
Workpiece

Test Setup

Laser fibre
Laser head
GMA-head
sample
Head from Fa. Precitec
WELDING RESULTS

- Bead on plate welds
- Butt welds
- Different plate thicknesses
- Guiding of the electric arc
- Industrial validation
LASER GUIDED OF GMA WELDING PROCESS

A: Various welding directions and change of direction in process possible
B: Short distances can be bridged
C: Existing weld seams can be welded over again

Result: Laser beam with low intensity is stabilizing and guiding a GMA-welding process
STABILISATION OF GMA PROCESS

GMA reference weld

GMA+Nd:YAG-Laser

GMA+Diode-laser 808nm

GMA+Diode-laser 811nm

Process parameters:

- Wavelengths: 1064 / 808 / 811nm (cw)
- Beam diameters: 0.9mm / 2 mm / 1.3mm
- Focus positions: +4mm / +7mm / +3mm
- Laser power: 400 / 360 / 250W
- Welding power: 1600 W
- Material: Steel
- Gas: Corgon

Result: 120% increase of the welding speed because of laser stabilisation
LASER STABILIZED GMA BUTT WELDS

Laser stabilized butt weld:

Wavelength: 811 nm (cw)  
Beam diameter: 1.3 mm  
Focus position: +3mm  
Laser power: 380 W

Welding power: 3690 W  
Material: Steel  
Speed: 1.7 m/min  
Gas: Corgon

Result: Higher welding speed and deeper penetrations by butt welds due to laser stabilization.
LASER STABILIZED WELDING OF PLATES WITH DIFFERENT THICKNESSES

Problem: Self positioning of the electric arc on the thicker plate

No contact to the thinner plate

Wavelength: 811 nm (cw)  
Beam diameter: 1.3 mm  
Focus position: +3mm  
Laser power: 380 W  
Welding power: 2790 W  
Material: Steel  
Speed: 1.9 m/min  
Gas: Corgon

Result: Laser beam with low intensity is stabilizing and guiding a GMA-welding process
GUIDING OF A TIG ELECTRIC ARC

Setup:

Process parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength:</td>
<td>811 nm (cw)</td>
</tr>
<tr>
<td>Beam diameter:</td>
<td>ca.1.2 mm</td>
</tr>
<tr>
<td>Focus position:</td>
<td>+3mm</td>
</tr>
<tr>
<td>Laser power:</td>
<td>280 W</td>
</tr>
<tr>
<td>Welding power:</td>
<td>1050 W</td>
</tr>
<tr>
<td>Material:</td>
<td>Aluminium</td>
</tr>
</tbody>
</table>

3 Hz; 1.5m/min

Result: Guiding of a TIG electric arc with low laser power is possible

3 Hz; 5 Hz; 0.5m/min
LASER GUIDED ELECTRIC ARC

Laser führt den Lichtbogen

Jörg Hermsdorf
Laser Zentrum Hannover e.V.
CONTROLLING OF A GMA ELECTRIC ARC

Wavelength: 811 nm (cw)  
Beam diameter: 1.3 mm  
Focus position: +3  
Laser power: 280 W  
Welding Power: 1600 W  
Material: Steel  
Feed Rate: 1.0 m/min  
Gas: Corgon

Result: Controlling of a GMA electric arc with low laser power is possible
INDUSTRIAL VALIDATION

Reference weld GMA
- Material: DC01
- Material thickness: 2x 0.8 mm
- Gas: Cargon
- Speed: 1.3 m/min

GMA+diode laser 811nm
- Laser power: 320 W
- Fokus diameter: 2.4 mm
- Wavelength: 811 nm
- Speed: 2 m/min

Material: DP 800 zinc coated
- Speed without laser: 0.8 m/min
- Speed with laser: 1.6 m/min
- reduced distortion
INDUSTRIAL VALIDATION

Weld quality (T-joint)

Without laser radiation
Rework needed

With laser radiation
No rework needed

Reinforcement at the back

<table>
<thead>
<tr>
<th>Without laser radiation</th>
<th>With laser radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength: 811 nm</td>
<td>Welding Power: 5500 W</td>
</tr>
<tr>
<td>Beam diameter: 2.4 mm</td>
<td>Material: Aluminium</td>
</tr>
<tr>
<td>Focus position: +3 mm</td>
<td>Feed Rate: 3.0 m/min</td>
</tr>
<tr>
<td>Laser power: 380 W</td>
<td>Gas: Argon</td>
</tr>
</tbody>
</table>
CLADDING RESULTS

- Single platform
- Raising surface quality
- Structure with high hardness material
- Multiple platform
Problem: Self positioning of the electric arc on the highest position
No contact to both layers

Result: Placing a middle layer in between two weld clads is possible.

Beam diameter: 1 mm
Focus position: +3mm
Process speed: 900/800 mm/min
LASER STABILIZED CLADDING

- Cladding of different materials
- High process speed
- High surface quality
- Low dilution
- Application: protection layers against wear

Manganese-Chromium layers on mild steel

Hardness >350 HB

Hardness 250 HB

Cladding area 100mm x 50mm
**GENERATING A 6×6 CLAD MATRIX**

<table>
<thead>
<tr>
<th>Clad matrix:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed: 900 mm/min</td>
</tr>
<tr>
<td>6 platforms</td>
</tr>
<tr>
<td>36 Layers</td>
</tr>
<tr>
<td>Height: 8 mm</td>
</tr>
<tr>
<td>Width: 12 mm</td>
</tr>
<tr>
<td>Length: 200 mm</td>
</tr>
<tr>
<td>No cracks</td>
</tr>
<tr>
<td>Good accuracy</td>
</tr>
<tr>
<td>Deposition rate 1.25 kg/h</td>
</tr>
</tbody>
</table>

Result: Generating a clad matrix consisting of 6×6 clads is possible.
ADDITIVE LAYER MANUFACTURING WITH LASER SUPPORTED ARC PROCESS

Generation of structures
Possibility for building up geometric structures through:

- Guiding of the electrical arc energy
- Reducing of the heat input

Cost reduction through decrease in post-processing
SUMMARY

- Stabilisation of the electric arc with low power laser
- In bead on plate welding 120% increase of the welding speed is possible
- Higher welding speed and deeper penetration with laser stabilisation on butt welds
- Guiding of the electric arc welding
- Industrial validation

- Increasing the surface quality with new cladding process
- Structural build-up with material higher hardness
THANK YOU FOR YOUR ATTENTION