VERTICAL-DOWN HYBRID WELDING IN SHIP BUILDING
- THE NEXT INNOVATION STEP -

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Dr.-Ing. S. Olschok
Dipl.-Ing. C. Turner
1979 First mention in literature

1994 – 1999 Work at ISF with CO₂ lasers with different laser power

Till 1999 development of possible fields of application for shipbuilding (butt joint, fillet joint)

Certification of hybrid welding by DNV for plates till 12 mm thickness

2000 Installation and bringing into service of first panel line world wide (20 m)

2000 – 2012 Development with solid state lasers

2009 First panel line with 30 m width with solid state laser

2011 Formulation of three ISO standards for hybrid welding
ISO-TC44-SC10-WG9 „HYBRID WELDING“

Secretariat: Torsten Diether, Deutsches Institut für Normung e.V. (DIN)
Convenor: Simon Olschok, RWTH Aachen University (ISF)

ISO/DIS 12932: Welding — Laser-arc hybrid welding of steels, nickel and nickel alloys — Quality levels for imperfections


<table>
<thead>
<tr>
<th>GMA</th>
<th>Laser</th>
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<tbody>
<tr>
<td>- cheap, conventional power source</td>
<td>- high welding speed</td>
</tr>
<tr>
<td>- directed influence of the thermal cycle</td>
<td>- high welding in depth</td>
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<tr>
<td>- Addition of filler material &gt; good gap bridging ability</td>
<td>- deep small weld seam</td>
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<tr>
<td>&gt; metallurgical influence of the grain structure</td>
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</table>

**Hybrid process**

- stabilisation of the process by interaction between the single processes
- increase of the thermal efficiency
- extended welding possibilities

**Hybrid - Advantages**
1. Forming Panels
2. Adding longitudinal stiffeners (bulb flats)
3. Adding transversal stiffeners (bulb flats)

Starting Situation 1995
First Three Welds of a Ship

Source: FORCE Institute, Denmark
CO$_2$-Laser (TLF12000 turbo)
Material: AH36; $t = 12$ mm
Edge preparation: Plasmacut
Filler wire: G3Si1; $d_{FW} = 1.2$ mm

$P_L = 12$ kW
$v_w = 2$ m/min
$V_{FW} = 12$ m/min

Pictures: MEYER WERFT, Papenburg
CO₂-Laser-GMA Hybrid Welding – Fillet Weld Application at a Shipyard (10 m length)

Welding parameters:

- \( t_{\text{Web}} \) = 7 mm
- \( t_{\text{Flange}} \) = 6 mm
- \( P_L \) = 6 kW
- \( v_W \) = 1.25 m/min
- \( v_{FW} \) = 12.5 m/min
900 km Weld Seam Length

450 km Hybrid Welds

Pictures: MEYER WERFT, Papenburg

CO$_2$-Laser-GMA Hybrid Welding
Panel Production
Solid State Laser – Next Generation Welding Task
Fiber Laser IPG

Nominal output power: 10.0 kW (at the workpiece)
Wavelength: 1070 nm
Fibre optics core: \(\varnothing 200 \mu m\)
BPP: < 12 mm x mrad
Foot Print: 800 x 1.460 mm
Height: 1.500 mm
Cooling capacity: 31 kW
WPE (wt cooler): > 27%

Scanner Mirror ILV

KuKa Robot, Cloos Control

KuKa KR 60 Jet
Cloos Robot Control
Cloos GMA Machine
Cloos Hybrid Head

60 kG
Rotrol II
Quinto

Welding Equipment
9 mm Web
6 mm Belt
\( v_W = 1.5 \text{ m/min} \)
GMA Leading

6 mm Web
6 mm Belt
\( v_W = 2.2 \text{ m/min} \)
GMA Leading

9 mm Web
6 mm Belt
\( v_W = 1.5 \text{ m/min} \)
GMA Trailing

Fillet Weld PB
For welding as far in the corner as possible (floor plate), the GMA torch is set in neutral position, the laser beam irradiates at an angle of 13° from the top in leading direction. Biggest problem: molten pool is running ahead. Through adaptation of the GMA process during welding operation, the molten pool is retained.

9 mm Web
6 mm Belt
\(v_w = 1.2 \text{ m/min}\)
GMA Leading

6 mm Web
6 mm Belt
\(v_w = 2.2 \text{ m/min}\)
GMA Leading

9 mm Web
8 mm Belt
\(v_w = 1.2 \text{ m/min}\)
GMA Leading
Adjustment of \(t_p\)

Fillet Weld PG (falling down)
<table>
<thead>
<tr>
<th>Gap</th>
<th>v_W (1,5 m/min)</th>
<th>P_L (8 kW)</th>
<th>v_f (11,5 m/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Gap</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Gap 0,5 mm</td>
<td></td>
<td></td>
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<tr>
<td>Gap 1 mm</td>
<td></td>
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</table>

**Gap Bridging Ability with Scanner Mirror**
GMA Sensoring
- Problem -

side control
\[ \Delta I = 0 \]

hide control
\[ \sum I = 2 \times I_{\text{Soll}} \]
GMA Sensoring
- Problem -
Synchronous Displacement of Robot and Scan Mirror
Current-/Mirror (Rob) Signal in Case of Position Misalignment – Part 1
Position Misalignment, Not Readjusted

Position Misalignment, Readjusted

Current-/Mirror (Rob) Signal in Case of Position Misalignment – Part 2
Video: MEYER WERFT, Papenburg

Testing on Shipyard
Video: MEYER WERFT, Papenburg

Testing on Shipyard
**Welding Task Third Generation**
- **In Future Possible?**

- Wall Thickness: 4 – 12 mm
- Seam length: up to 5 m
- Type of weld: Fillet- and Buttm Weld
- Joint gap: 0 – 3 mm
- Clamping: Teckwelding

**GMA (3Gd):**
- Lack of Penetration
- Incomplete Fusion

**GMA (3Gu):**
- Thermal Load

Diagram:
- Welding Task
- Panel
- Supporting Beam Structures
- Holland Profiles
2 process variants for vertical down welding
Both sided, simultaneous GMA welding
Laser-GMA Hybrid Welding with GMA process opposite

- High welding speed compared to the commonly used vertical uphill welding
- High degree of mechanisation
- Welding in one molten pool -> reduction of distortion
- Automatic seam tracing and measurement of the joint gap
- Automatic selection of the welding parameters dependent on the joint gap
Concept Laser-GMA Hybrid

Laser Optics with Scanning Mirror

Workpiece

ILV Scanning Mirror

Schematic Drawing

Laser Beam

GMA front

GMA back

x-, y-, z- Adjustment

MSG Torch

200 mm
Effect – Integration of the laser welding process

Base Material: Grade A (5 mm)
Consumable: G4Si1 (Ø 1,2 mm)
No joint gap
Base Material: Grade A (5 mm)  
Consumable: G4Si1 (Ø 1,2 mm)

<table>
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<tr>
<th></th>
<th>$v_S$ [m/min]</th>
<th>SG M21 [l/min]</th>
<th>$v_{\text{Wire}}$ [m/min]</th>
<th>$f_p$ [Hz]</th>
<th>$I_G$ [A]</th>
<th>$I_P$ [A]</th>
<th>$t_P$ [ms]</th>
<th>$P_L$ [kW]</th>
<th>$A_S$ [%]</th>
<th>$f_S$ [Hz]</th>
<th>$x_P$ [mm]</th>
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<tr>
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<td>1,5</td>
<td>15</td>
<td>3,5</td>
<td>96</td>
<td>39</td>
<td>390</td>
<td>1,9</td>
<td>6</td>
<td>15</td>
<td>100</td>
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<tr>
<td>back</td>
<td>15</td>
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2 mm Joint Gap; Plasma Cut Edges
- Wall Thickness 7 mm
- No Joint Gap

Minimal Distortion
### Base Material: Grade A (5 mm)
### Consumable: G4Si1 (Ø 1,2 mm)

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Fully mechanized, sensor based vertical down welding for the section fabrication

1. LPF-camera detects the vertical and lateral position of the joint
2. Axis to adjust the focal position
3. Axis to adjust the lateral position
4. Laser-Hybrid Welding Head YH50

Outlook – Sensor Integration

Quelle: Precitec Group
- Implementation of a high power solid state laser and different welding power sources
- Usage of metal cored wire
- Further welding trials to determine parameters and to increase the robustness of the processes using DoE
- Field Trial Shipyard -> Comparison of „FaSek“ with the conventionally used processes
- Preparation of concepts for the workplace safety based on current regulations, state of scientific research and firing test in the laboratory
Vielen Dank für ihr Aufmerksamkeit!

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