LASER WELDING OF 2000 MPa PRESS HARDENED STEEL

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AGENDA

• Joint Definition
• First Trials
• Laser Welding Development & Optimization
  • Linear Weld
  • Circular Weld
• Weld Strength Overview
• Prototype Insights
• Conclusions
JOINT DEFINITION

Material
• 1.2 mm DP600 UN (Top)
• 1.8 mm 2000 MPa PHS AS150 (Bottom)

Joint Configuration
• Lap shear
  • Coupon size: 45x105mm
  • Overlap: 16mm
• 25mm Linear welds
• Ø10mm Circular welds
FIRST TRIALS

Preliminary welding trials performed with standard laser equipment revealed cracks in circular laser welds.

Benefits of circular welds:

- Weld geometry can fit in constraint/narrow areas
- Circular welds can take higher external loads than linear welds

These conditions and weld geometry benefits encouraged the team to seek weld optimization with advanced laser equipment.
LASER WELDING SETUP

Laser
- Coherent ARM Fiber Laser
  - Coaxial Fiber - Core 100μm / Ring 290μm

Optic
- II-VI HIGHYAG RLSK scanner – 3X magnification

Plume Suppression
- Squirrel cage blower
LINEAR WELD OVERVIEW

- Standard (hot start/cold end) linear power decrease at weld termination
- No cracking observed in linear welds
- Consistent depth to width ratio from start to end
WELD TERMINATION

Approach to mitigate centerline cracking in the weld termination
• Defocus = Increase the focal length which results in wider weld width at the surface with less penetration through the joint thickness.
• Lower Power Reverse = Secondary weld pass with minor laser energy.
• Independent power ramp = Decrease power for the ring while simultaneously increasing power to the core.
CIRCULAR WELD

Baseline

Defocus

✓ Independent power ramp and low power reverse
Independent power ramp and low power reverse mitigated the centerline cracking.
CIRCULAR WELD - INTERMEDIATE RESOLUTION

- Centerline crack
- Through crack

✓ Independent power ramp and low power reverse
CIRCULAR WELD - THROUGH CRACKS

- Through cracks were still present in circular welds
- Cracks occurred on the outer diameter of the circular weld in PHS2000

Theory:
- Inside cools down and shrinks slower than the outer weld boundary
- High energy stored in the center of the weld causing thermal stresses
CIRCULAR WELD - CRACK MITIGATION

Introduced laser beam oscillation to:
• Control the Heat Affected Zone (HAZ) on the outer boundary
• Increase the weld width (+48%)
• Reduce thermal stresses in the weld

No wobble

With wobble
CIRCULAR WELD - CRACK MITIGATION

In addition, independent power modulation synchronized with oscillation was included to control the stored energy within the C-weld.
Independent power modulation synchronized with oscillation

The beam traces a sinusoidal pattern along the arc. Laser power in ring and core are adjusted continuously from peak to peak to help minimize heating of the area inside the weld zone and eliminate cracking.
CIRCULAR WELD- POWER MODULATION

Independent power ramp synchronized with oscillation and low power reverse

High Speed Camera of Synchronized Power Modulation
CIRCULAR WELD- FINAL RESOLUTION

Centerline crack

Through crack

✓ Low power reverse + Independent power modulation + beam oscillation
Tensile testing was performed for samples with and without oscillation for linear and circular welds.

Observations:
• The weld width increase from beam oscillation improves tensile strength performance (Linear +30%, Circular +16%)
• Fracture mode mainly occurred on top sheet base metal (DP600)
PROTOTYPE INSIGHT

Coupon weld development was proven in prototype parts. Different thicknesses were welded with same welding parameters.

- 1.6mm DP600
- 1.2mm DP600 - baseline
- 1.0mm DP600

Identical weld parameters for all conditions
SUMMARY

• A mode shaping laser was used to successfully weld 600 MPa Dual Phase steel to 2000 MPa press hardened steel on coupons and prototype parts.

• Linear welds and circular welds had different crack behavior and required different welding strategies.

• Gap variation can influence the crack behavior.

• Low Power Reverse was used to avoid cracks in the weld termination.

• Laser beam oscillation combined with power modulation was used to avoid through cracking in the weld.
FOR MORE INFORMATION

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