On-line Laser Weld Monitoring

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Why On-Line Weld Monitoring?

Reliable on-line monitoring of the laser welding process is necessary, because:

- Efforts for lightweight construction will increase the introduction of more "difficult-to-weld"-materials such as different grades of high strength steels and aluminium alloys.
- There will always be a demand for robust joining processes and short cycle times.
- The welding process will present a larger solidification interval due to a higher amount of alloying elements.
- New materials will increase the risk of formation of weld seam defects, such as hot cracks and porosity.
- Less scrap rate compared to post checking of weld quality.
- Off-line testing adds manual labour and cost.
- Automatic generation of data for interconnected processes in line with Industry 4.0.
A Variety of Different Methods

- High speed videography
- Plasma monitoring
- Thermography by pyrometric technology
- Thermographic detection by thermo camera
- Infrared radiation
- Hyperspectral monitoring
- Acoustic emission
- Low coherence interferometry
- Optical coherence tomography
- Oscillations from induced vibrations
High Speed Videography [1]

What can be observed?

- Velocity and angle of the vapour plume
- Velocity of the melt waves at the keyhole front wall
- Area of the keyhole opening

- Vapour plume monitoring is less suitable due to very dynamic movement and delay time
- Meltflow monitoring inside the keyhole is feasible as it has low dynamic but low sensitivity
- Monitoring the keyhole opening is well suited as an input signal due to low dynamic and high sensitivity

Ref. Michael Schmidt, Friedrich-Alexander Universität
High Speed Videography [2]

- WeldEye® from Lessmüller

Alignment of laser beam / wire position

⇒ Laser weld O.K.

Mismatch of laser beam / wire position

⇒ Laser weld on the upper sheet

Ref. Christian Truckenbrodt, Lessmüller Lasertechnik GmbH
High Speed Videography [3]

- SCeye® from Scansonic / ILT
- Illumination by 4 VCSELs
  4 x 100 diodes / 4 x 10 W
  and 4 LEDs (λ = 850 nm)
- Picture frequency 350 fps
- Resolution 40 µm
- Visualization through FPGA

Ref. Christoph Franz, Scansonic AG
Plasma Monitoring [1]

- Measures plasma radiation intensity over time

Ref. Thomas Grünberger, Plasmo AG
Plasma Monitoring [2]

- Measures weld pool eigenfrequencies
- Visualization by waterfall analysis

Ref. Libor Mrna, Czech Academy of Sciences
Thermography by Pyrometric Technology

- Measures melt pool temperatures

Ref. Friedhelm Dorsch, Trumpf Laser- und Systemtechnik GmbH
Thermographic Detection by Thermo Camera

- Thermographic on-line process monitoring
- Off-axis monitoring of cooling zone behind the melt pool
- Difference in temperature fields and gradients of defective and accurate weld seams
- Higher emission coefficient for surface defects (e.g. cracks and pores)
- Observation of melt pool geometry possible
- Observation of solidification cracks along the center line of the weld seam is possible

Ref. Michael Schmidt, Friedrich-Alexander Universität
Infrared Radiation

- Measures melt pool infrared radiation

Welding profile

Contamination of grease and dirt

Lack of penetration

Ref. Rodrigo Linares, *New Infrared Technologies* [NIT]
Hyperspectral Monitoring

- Use of temperature dependent spectral information
- Planck’s radiation law can be assumed for metals: Spectral emission (colour) is temperature dependent (Black/grey-body radiation)
- Spectrum can be visualized using diffractive methods and computationally reconstructed
- No knowledge of emission coefficient needed to estimate absolute temperature
- Acquisition of radiation spectra using hyperspectral imaging enables absolute temperature monitoring
- Monitoring the temperature of the melting process of steel during laser irradiation
- Indicator for hot crack formation

Prototype setup

High-speed camera with an additional diffractive element to record the original image as well as its diffraction

Original image (middle) and diffraction pattern (± 1st order)

Ref. Michael Schmidt, Friedrich-Alexander Universität
Acoustic Emission

- Structural borne noise signal 400-1.200 kHz
  Best correlation with penetration depth
- Air borne noise signal 700-1.000 kHz
  Best correlation with vapourization of melted material

Ref. Matthias Bastuck, Fraunhofer IZFP
Low Coherence Interferometry

- Measures the weld depth
- IDM [In Depth Monitoring] from Precitec, measures along the weld seam
- ICI [Inline Coherent Imaging] from Laser Depth Dynamics Inc., measures along and transverse to the weld seam

Ref. Marcus Kogel-Hollacher, Precitec GmbH / Paul Webster, Laser Depth Dynamics Inc.
Optical Coherence Tomography

- Interference between impinging and reflected laser beam
- Measures weld profile

Ref. Nataliya Deynea-Dupriez, Lessmüller Lasertechnik GmbH
Monitoring Oscillations from Induced Vibrations

- Visualization by Speckle technique
- Preferably used for laser brazing

Ref. Felix Tanner, Friedrich-Alexander Universität
Project Plan

- Inventory of different systems [commercial or close to commercialization]
- What type(s) of defect detection is of prime interest to the industrial partners
- Deeper analysis of the systems selected, establish contact with supplying companies
- Investigate the potential to integrate adaptive regulation of welding parameters to these systems
- Laboratory testing of systems and devices
- Pilot installation of at least one system integrated in a production laser welding cell
- Overall evaluation and report
- Result dissemination
Project Members

- Volvo Cars
- CEVT
- GKN Aerospace
- Siemens Turbomachinery
- AlfaLaval
- TetraPak
- Wugang Tailored Blanks
- Gestamp
- SAPA
- TeknikCentrum i Gnosjö

- Brogrens
- Husqvarna Construction Products
- Permanova Lasersystem
- Stjernberg Automation
- SwereaKIMAB
- Precitec [Levitronics]
- University West
- Luleå Technical University
- Svetskommissionens Lasergrupp