plasmo 2011:

Quality assurance systems for remote laser welding processes

In recent years, laser technology has become one of the joining technologies of the future for automotive companies and their suppliers. The development of remote laser welding technology has created a process which stands in direct competition to spot welding. The welding speed 10-15 times higher than that of spot welding, the freely-programmable seam geometry and the need for access to just one side of the joint are characteristics which make remote welding attractive. The use of lightweight structural designs based on high-strength steels in particular make the future prospects of remote welding even more attractive.

1. Quality requirements

The ever-increasing demands placed on the quality of series-produced components in many branches of industry are usually only achieved by means of a 100% final inspection. The question of production process validity is also becoming more prevalent. This is particularly apparent in the electronics and automotive industries where remote welding processes are also being used on a more regular basis.

Behind every quality inspection lies the question whether the workpiece will be able to reliably fulfil its purpose. In welding, the quality criteria relate to the seam properties and the effect of the manufacturing process on the workpiece. Weld seams are subject to two basic requirements:

2. Basic requirements for welds

- The **width and depth** of the seam must meet the specified values as these determine the joint cross-section and therefore the strength of the welded joint.
- The **metallurgical qualities**: the microstructure of the seam should be as even and fine-grained as possible.

Technical standards list many other criteria and different types of seam defects. They differentiate between external and internal seam defects. Figure 1 illustrates some of these.

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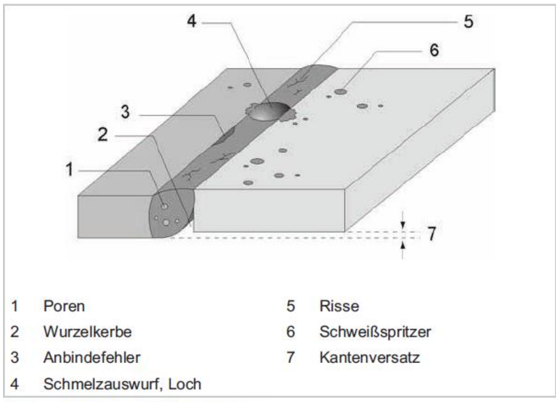


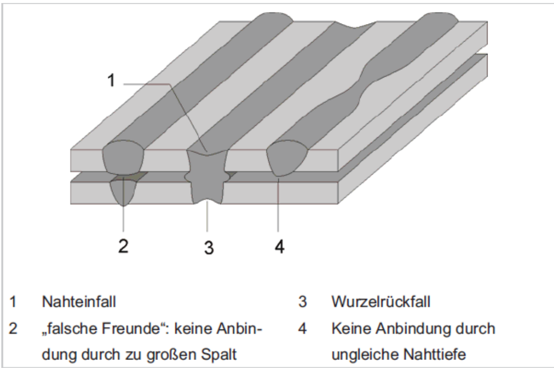
Qualitätsmängel von Schweißnähten

[Figure 1: Weld seam quality defects]

3. Internal seam defects in weld seams

Typical inner seam defects include:

- **Lack of joint fusion**: The joining gap is insufficiently filled.
- **Pores:** The seam contains small air or gas pockets.
- **Cracks** in the seam surface or in the workpiece.



Qualitätsmängel in Überlappverbindungen

[Figure 2: Quality defects in overlap joints]

4. External seam defects

External seam defects and their effects:

- **Seam geometry defects** such as weld penetration and root notches are weak points at which the seam may tear.
- **Melt protrusions**: Holes form when melt is expelled rapidly from the seam. These reduce strength and may make the seam permeable.
- **Weld sink and weld seam collapse** reduce the seam cross-section and therefore its strength.

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- **Linear misalignment** of scarf joints reduces the seam cross-section.
- **Pool craters** at the end of the seam, so-called end craters, reduce the seam cross-section.
- **Oxidation** of the seam surface reduces the corrosion resistance of stainless steels.
- **Spatter** on the workpiece or the seam surface may interfere and require post-processing.

5. Heat input and warping

During welding, the melt gives off heat into the surrounding material. High quality means heating the workpiece as little as possible to ensure that the heat is able to dissipate easily.
This can be achieved in three ways:

- Stepped seams instead of continuous weld lines.
- Welding in pulsed mode.
- If the assembly contains many weld points or seams, select a welding sequence which heats the component evenly.

Form	Grafik	Bewertung
Durchgezogene Linie		Die Standardnaht im cw-Betrieb; am Anfang und Ende der Naht ist die mechanische Spannung bei Belastung am höchsten und die Einschweißtiefe geringer. Die Naht ist gas- und flüssigkeitsdicht.
Gesteppte Linie		Wärmeeintrag geringer als bei der durchgezogenen Linie; geringere Einschweißtiefe am Anfang und Ende jedes Nahtabschnitts.
Linie aus Einzelpunkten		Die Standardnaht für gepulste Laser. Geringere Erwärmung durch Pulsen; das Werkstück kühlt in den Pausen zwischen den Pulsen ab; gas- und flüssigkeitsdicht – abhängig vom Überlappungsgrad der Schweißpunkte.
Einzelne Schweißpunkte		Typische Verbindung für Pulslaser. Anwendung meist im Elektronik-Bereich; durchlässige Verbindung.
Freie Formen		Möglich mit Scannerschweißen; die Nahtform wird für die Belastung optimiert; Wärmeeinbringung wird optimiert.

Nahtarten im Überblick

[Figure 3: Overview of seam types]

6. Parameters

Laser welding requires that the welder is able to deal correctly with the following laser parameters:

- Laser output depends on the material, process and seam geometry. Joining high-grade steel edges by heat-conduction welding requires less power than generating seams in structural steel by deep welding.
- In cw-mode, the welding speed determines how much energy the material absorbs along the weld seam (energy per unit length). It affects both the depth and the geometry of the seam.
- In pulsed mode, the welding speed is determined by the pulse frequency and the overlapping of the weld points. Pulse output and pulse duration determine how much energy enters the material.
- The focal diameter and focal position determine the beam diameter on the workpiece and therefore affect the width and depth of the seam.
- The power density must be high enough to counteract the process swell of the respective method. Deep welding requires higher power densities than heat-conduction welding.
- A double focus may improve the welding result in some applications, for example: welding aluminium or seams in lap joints.

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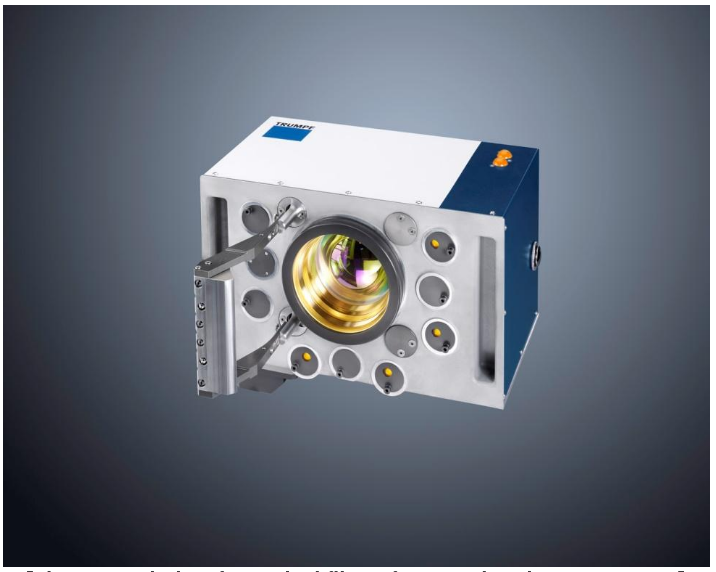
7. Structure and mode of operation of inline remote welding test devices

The process**observer** series is based on the evaluation of the visible and infra red light emissions, which differ for OK and NOK welds. The process light leads to a sensor via six optical fibres



[Figure 4: Window for optical fibres for covering the remote area]

integrated in the welding optics, where it is evaluated. The emission values of an OK weld must lie within a predetermined scatter band. Various algorithms developed over the years reliably identify relevant process fluctuations which occur during remote welding. It is therefore possible to check every seam according to the given quality criteria and effect a system-side OK/NOK decision regarding whether post-processing is required and if the component should be removed from the process. With complex components, such as seating assemblies and car doors with up to 1000 seams, all seams are evaluated after component machining. Seam-to-seam times of up to 10 ms are easily possible by covering the remote welding space.

8. Parameters and evaluation algorithms

Laser welding generally requires that the welder is able to deal correctly with the following laser parameters in order to draw the correct conclusions regarding the process. The plasmo process**observer** with its modular software has proven itself as very advantageous time and time again in practice in terms of the monitoring and detection of welding defects. One considerable advantage is the use of various evaluation algorithms.

- Absolute limits / long-term defect
- Relative limits / short-term defect
- Minimum weld time / seam too short, change the welding speed
- Signal dynamics / defective joint, false friend

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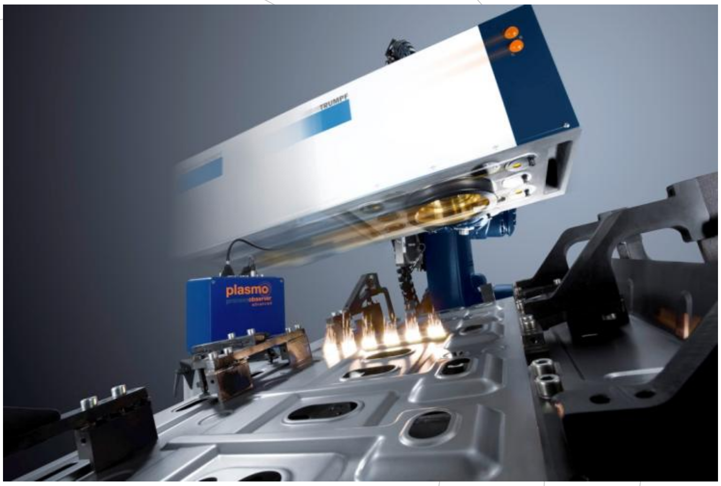
- Pulse frequency, pulse duration and number of pulses

Every one of these mathematical algorithms has been developed according to years of experience of different welding processes in different series production processes and laboratory tests and implemented in the system for the detection of specific types of defects. Experience has shown that the types of defects apparent in a wide range of different applications usually behave similarly with regards to signal behaviour and the change in light intensity.

Parameters	Description	Evaluation
Laser output	Laser output depends on the material, process and seam geometry. Joining high-grade steel edges by heat-conduction welding requires less power than generating seams in structural steel by deep welding.	The signal intensity increases or decreases in line with the changing process parameters over a longer period and exceeds the “absolute limits”.
Speed	In cw-mode, the speed determines how much energy the material absorbs along the weld seam (energy per unit length). It affects both the depth and the geometry of the seam.	If signal behaviour is set to be shorter than this value, the plasmo process**observer** rates the weld seam as NOK.
Pulsed mode	In pulsed mode, the welding speed is determined by the pulse frequency and the overlapping of the weld points. Pulse output and pulse duration determine how much energy enters the material.	The central monitoring of the signal energy for each seam is determined by the number of pulses, pulse frequency and the pulse duration.
Power density	The power density must be high enough to counteract the process swell of the respective method. Deep welding requires higher power densities than heat-conduction welding.	The signal intensity increases or decreases in line with the changing process parameters over a longer period and exceeds the “absolute limits”.



[Figure 5: Inline proccessobserver advanced monitoring in use with a Trumpf PFO 3D]

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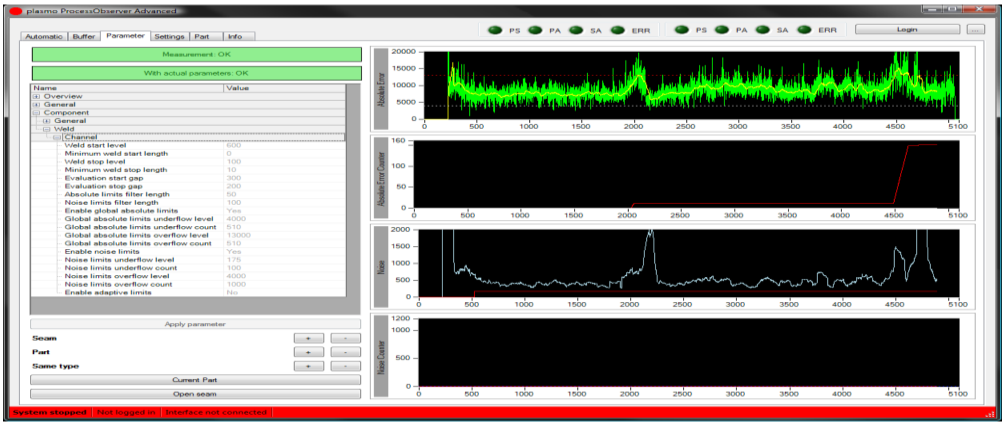
9. Documentation of the inspection results

In order to fully document all weld seams on the manufactured component, all inspection results are stored in a database. In addition to the information regarding the component number, detailed information (see Figure 6) regarding the individual weld seams relating to both the seam and the component are saved and documented.



[Figure 6: Advanced evaluation of an individual seam by the processobserver software]

This enables consistent documentation and forms the basis of the visualisation and continued continuous improvement of the production process and quality of the welding process using statistical methods.

10. Visualisation

All inspection results may be displayed at a workstation or an off-line workstation to quickly optimise the seam. For example, the position of the automatic inspection of the weld seams are presented to the machine operator directly on the screen in red or green. Comprehensive detailed information is also available as statistical evaluations over several layers directly on the production lines or is saved in a higher level system.The machine operator is able to view another external screen-based visualisation of the weld seams later during production and post-process them as required.

plasmo Industrietechnik GmbH

plasmo is an innovative, global technology company for automated quality assurance systems in the production industry. Founded in 2003, plasmo is a leader in real-time quality controls for welding processes. Its diverse quality assurance portfolio includes laser power measurement, welding process checks, monitoring of welded seams, geometric shapes and surfaces, customised solutions in the area of industrial image processing, analysis software, as well as a wide range of services. The expert team assists its customers from the moment the test task is defined until implementation of the test system. Reputable customers from ABB, Benteler, BorgWarner, Faurecia, INA, SMS Simag, Hettich, Magna, Valeo to Webast and numerous automobile manufacturers such as Audi, BMW, Daimler, PSA, Suzuki, Volvo, and various steel manufacturers: all place their trust in plasmo's quality and quality assurance. In 2010, the Vienna-based company with 20 staff and sales partners in Europe and Oversee earned a sales turnover of 2,0 million Euros.

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