Non Destructive Testing of Laser Welded Lap Seams by Eddy Current Technique

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Abstract. Eddy current method has been tested for detection and classification of defects in laser welded seams. Influence of disturbance effects was investigated systematically. Before analysis data have been processed for consideration of changes in material properties. It can be shown that seam different defects lead to different characteristic indication ranges in the impedance plane. By investigation of samples with known defects a basis of valuation has been created. The application of this basis allows an experimental validation of industrial samples. The poster shows that by the help of eddy current technique detection and classification of defects in laser welded seams are possible. The results are in good agreement with reference methods such as radiography and metallography.

1. Introduction

Laser welding has become standard technique in the automotive industry. The use of laser welding can shorten lap widths because of the smaller seam width, reduce the number of reinforcing parts, as well as decrease the volume of the structural parts of the car chassis by increasing the rigidity and crash safety simultaneously. Power and size of laser beam can be adjusted dynamically according to processing requirements [1]. But its higher complexity in comparison with conventional welding methods and increasing quality demands have made a reliable quality control getting more and more important for manufacturing and processing industries.

Evaluation of the laser welds is based on DIN EN ISO 13919-1 according to acceptance level B ("high") [4,5,6]. Requirements on position and geometry are specified to guarantee a satisfying weld quality in laser welded multi plate joints. Destructive tests (e.g. chisel and peel test) are very expensive. So a non destructive method for testing of laser welding seams for automotive applications should be developed, which is able to detect the relevant flaws and suitable for integration into production process without any negative influences on the process.

The advantages of the eddy current technique are used by a wide range of applications to ensure a constant quality: eddy current measurements require a minimal testing time, offer the possibility to measure without human intervention and are non destructive. The method is very sensitive to small cracks and other defects, gives immediate results, minimum part preparation is required and test probe does not need to contact the sample. Limitation of eddy current inspection includes, that only conductive materials can be inspected, surface must be accessible to the probe, surface finish and roughness may interfere, reference standards are needed for set up, depth of penetration is limited [2,3].

Eddy current inspection is one of several NDT methods that use the principal of electromagnetism as the basis for conducting examinations. When an alternating current is applied to a coil, a magnetic field develops in and around it. If an electrically conductive material is placed in the coils dynamic magnetic field electromagnetic induction will occur and eddy currents will be induced in the material. Eddy currents generate a secondary magnetic field, which will oppose the coils primary magnetic field.

The eddy current instruments measure the electrical impedance of the coil including resistance and inductive reactance. If a flaw is introduced in the tested material, eddy currents are disrupted and the impedance of the system will change [2,3].

Eddy current method has been tested and improved for detection and classification of defects in laser welded seams. For a successful application the dependence of measurement results on nature of defects must be investigated. Probe design and test parameters must be established with a good understanding of the flaw that is trying to be detected [7].

2. Experimental

2.1 Laser welding seams

For test and improvement of eddy current technique laser welding seams of different quality were produced by the help of a laser type Haas HL 4006D on different materials used in car bodies. Two plate joints have been prepared at power of 4 kW and a process velocity varying between 30 mms^{-1} and 60 mms^{-1}, respectively.

Laser welding depends on the influence of a number of different factors. The gap size between the welded parts is a very important parameter. It has been used to define the produced flaws in the laser welded seam. The gap size was varied between zero and 0.8 mm.

For zinc coated sheet steel the implementation of a gas release between the sheets during the laser welding process is recommended. Best quality results were reached with gap of 0.1 mm to 0.2 mm, respectively. With increasing gap sizes first weld concavity and/or root concavity and than single-sided connection or lack of connection occur.

2.2 Eddy current measurements

Fig. 1: Eddy current probe on laser welding seam

Eddy current measurements have been carried out by the help of an ELOTEST B320 by Rohmann GmbH, Germany. The eddy current probes was made as reflection (“transformer”) style devices (PLR Linke&Rühe GmbH, Germany). Reflection probes utilize a driver coil and a sensor coil. The primary advantages of reflection probes are good signal-to-noise ratio and a wide band of operating frequency. The probes have been used as absolute probes, which can detect both gradual and sharp changes. Physical size and shape of the eddy current probes were adapted for testing short lap widths.

Selection of frequency depends on material and subsurface depth of inspection interest. Lower frequencies are used for greater subsurface depths and higher frequencies are used for detection of flaws near the surface. For investigation of laser welding seams frequencies of 70 kHz and 140 kHz have been used.

During measurements samples were moved laterally by the help of a linear unit using a linear stepping motor with repeatability of ± 0.02 mm. Eddy current probe was assembled into a resilient mount which ensured a constant gap between probe and surface of 0.2 mm.

Analog output signals of eddy current instrument have been recorded by PC simultaneously. For data processing special software was developed which allows using the lift off signal as reference phase direction automatically and independent of balance. Eddy currents are affected by the electrical conductivity and magnetic permeability of materials. Changes in the plate's material properties may lead to an additional modification of eddy current signals. Therefore by help of the software calculate a background for consideration of material properties. Eddy current data were displayed on impedance plane and signal amplitude versus time.

3. Results and discussion

3.1 Investigation of reference samples

In current standard the most critical irregularities in laser welding seams are defined:

- General irregularities: variations in the weld width, surface pores, excess material, localized porosity, weld concavity, root side suck back,
- Through holes in the weld and pores in upper sheet (including end craters),
- Non-continuous weld (evaluation of upper bead),
- Partially melted weld spatter,
- Melting of edges, edge burn-through,
- No connection: joining planes are not connected.

Assessment of irregularities depends on quality requirements such as demanded strength of laser welds, but also corrosion and leak tightness, depending on their positions and on the painting methods applied.

Eddy currents are affected by the electrical conductivity and magnetic permeability of materials. Defects and changes in material properties result in changing eddy current signals. For the interpretation of measurement results investigation of samples with known properties are necessary. Therefore eddy currents measurements at reference samples have been carried out. Flaws have been detected by measuring the surface profile of welding seams and X-ray investigations.

Eddy current data have been displayed in the impedance plane diagram. It can be shown that similar laser weld quality lead to similar eddy current signals. For the relevant irregularities characteristic areas can be found in the impedance plane diagram.

The example shows evaluation of two plate lap seams of TRIP 700 (thickness 1.5 mm) and H260 PD Z 100 (thickness 1.6 mm) produced with laser power of 4 kW and process velocity of 40 mms^{-1}, respectively. Reference samples were produced and investigated. After data pre-processing in the impedance diagram characteristic areas for the states "weld quality OK", "surface pores", "no connection between joining plates" and "no welding seam" were defined by averaging eddy current data of corresponding weld parts (Fig. 2-4). It can be shown that there are differences between these states.

Changes of the signals into the lift off direction indicate the existence of partially melted weld spatter (Fig. 2). Eddy current probe is shifted and the lift off effect occurs. The effect can be identified because it is characterized by large changes in x-direction and small changes in y-direction.

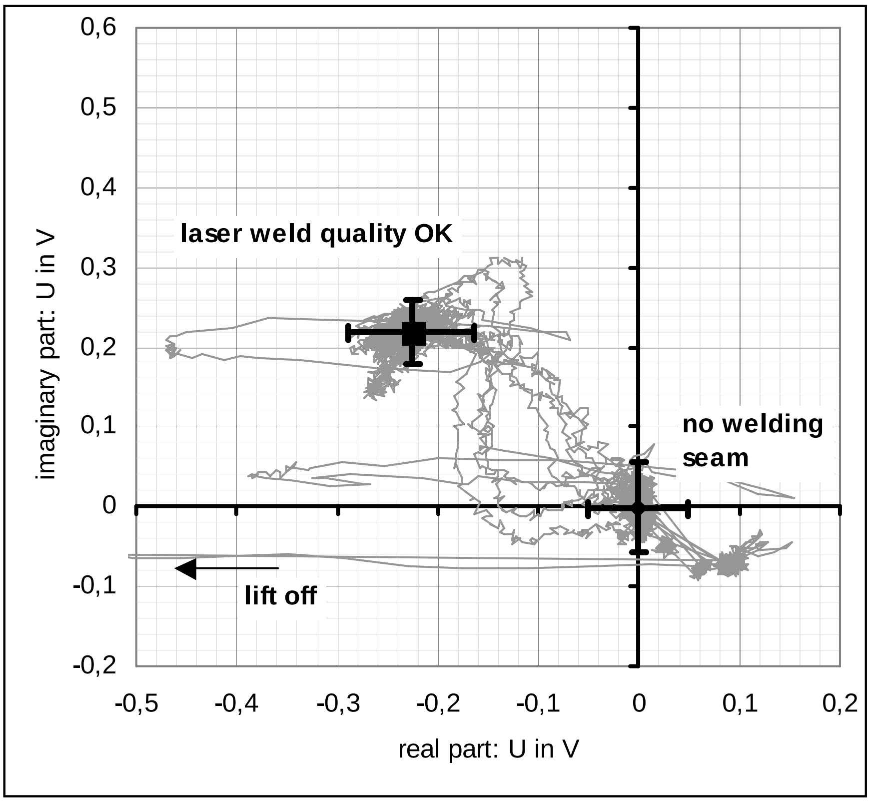

Fig. 2: Impedance plane: characteristic area for “laser weld quality OK”

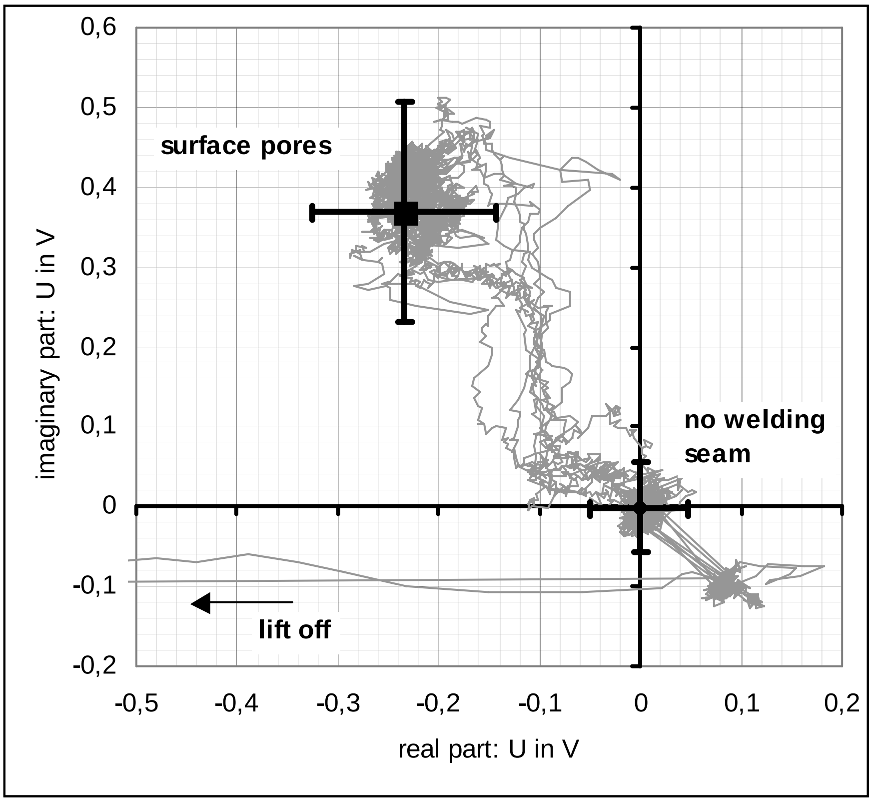

Fig. 3: Impedance plane: characteristic area for surface pores

[4] DIN EN ISO 13919-1, Ausgabe:1996-09:
Schweißen - Elektronen- und Laserstrahl-Schweißverbindungen; Leitfaden für Bewertungsgruppen für Unregelmäßigkeiten - Teil 1: Stahl (ISO 13919-1:1996); Deutsche Fassung EN ISO 13919-1:1996
[5] Norm VW 01141-1: Laserstrahlschweißen; Stahlblechverbindungen; Teil 1: Konstruktion, Ausführung,, Qualitätssicherung. Ausgabe Juni 1999
[6] Prüfvorschrift PV 6719: Laserstrahlschweißen an Stählen; I-Naht am Überlappstoß; Mehrblechschweißen. VW AG, Feb. 2003
[7] MAINE project, co-financed by SAB bank Saxony

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