

## **IN-LINE QUALITY CONTROL OF LASER WELDS OF TAILORED BLANKS BY COUPLANT FREE ULTRASONIC INSPECTION**

**H. J. Salzburger**

Fraunhofer-Institut zerstörungsfreie Prüfverfahren  
Universität Geb. 37  
66123 Saarbrücken  
Germany

**H. Mohrbacher**

SIDMAR N.V.  
Tailor Steel Technology Center  
John Kennedylaan 51  
9040 Genk  
Belgium

**Laser welding, Tailored Blanks, Nondestructive Testing, on-line, Process Control,  
Ultrasound, EMAT, on-line**

### **Abstract:**

In modern design of automobile car bodies reduction in weight and maximization of the structural stiffness and passive safety are the main challenge. The 'Tailored Blank' has contributed to achieve a significant weight reduction in recent years. The single flat sheets are joined by Laser Welding in butt configuration without filler wire. Usually the quality of the welds is assured by precise preparation of the plate edges as well by the suitable selection of process parameters. However due to unforeseen deviations typical defects occur, which make NDT necessary to detect defects as incomplete welding, lack of fusion, misalignment, pinholes, porosity etc.

The contribution presents a new UT inspection technique designed for the in-line inspection of the laser welds of Tailored Blanks. Conventional UT is ruled out because of the necessary liquid coupling medium. The inspection is based on the application of guided ultrasonic (plate) waves with shear horizontal polarization excited and detected by couplant free Electromagnetic Acoustic Transducers (EMAT's).

## 1.INTRODUCTION

In modern design of automobile bodies, reduction in weight and maximization of the structural stiffness and passive safety are the main challenges. In general, by using high strength steel sheet with high deformability, the weight can be reduced by reducing the thickness. For a further essential reduction in weight the 'Tailored Blank' has contributed [1, 2]. Depending on the requirements of the individual components of a car body, different steel grades and thicknesses are used for a tailored blank, which uses single flat sheets to join by laser welding (butt weld)

Usually the quality of the welds is assured by precise preparation of the plate edges to be welded and by setting a couple of process parameters (laser power, focal spot of the laser beam, inert gas atmosphere). However, if there are undue deviations in the weld preparation as well in the process parameters typical defects occur, which result in scrapping the welded blank. Therefore process-integrated nondestructive testing is necessary to detect defects which include incomplete welding, lack of fusion, misalignment of the weld, holes and porosity. Conventional ultrasonic technique is ruled out because of the necessary coupling medium, eddy current (EC) is not suitable because of the thickness step within the weld region and X-ray because it requires high investment costs and unacceptably long inspection time.

## 2.LASER WELDING

For laser welding two blanks to be welded are placed side by side and mechanically fixed. The welding is done without any welding flux. This results in a very narrow heat affected zone (HAZ), which does not significantly change the mechanical and compositional properties of the welded blank (deep drawing property, corrosion resistance). However butt welding by lasers requires a very precise edge preparation of the sheet to achieve a good weld quality. The jointing gap has to be less than 0.1 mm; furthermore a precise positioning of the two blanks and a sufficiently strong clamping of the sheets are necessary. During welding any opening of the jointing gap due to thermal deformation and lateral displacements of the laser spot from the weld position have to be avoided.

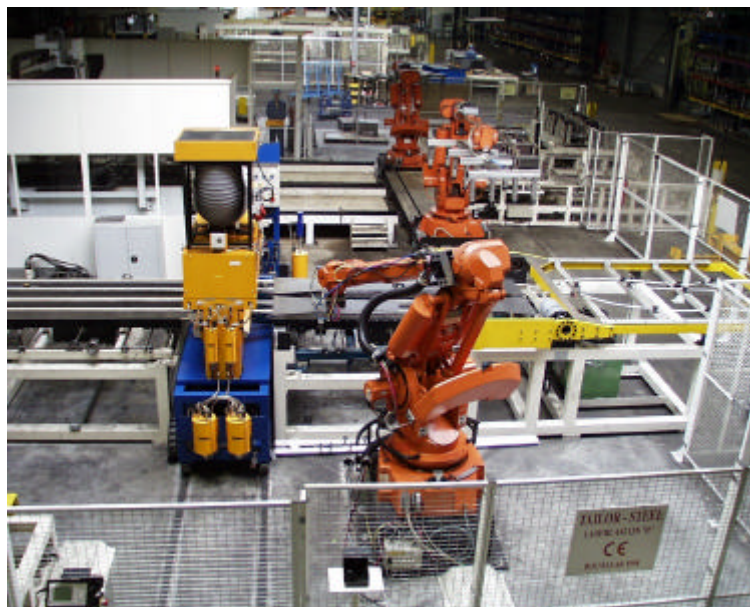


Fig.1: Laser welding line at Tailor Steel, Genk(B) –Inspection Robot in the front-

The process parameters (laser power, welding speed, focal spot of the laser beam, inert gas atmosphere) must be held constant within an optimized process window. By these means butt welding by lasers is a very reproducible technique. However, if any deviations in the preparation of the weld or in the process parameters occur, then typical defects as listed in Table I are the unavoidable results. These defects cannot be repaired and the welded blank has to be scrapped.

### 3.State of the Art of Quality Assurance

Besides statistical destructive examinations (deep drawing test) methods to monitor the welding process and optical inspections of the laser weld are the state of the art in quality assurance (Table I).

Inspection Technique	Information
Visual inspection	Lack of fusion, holes, geometry, mismatch
Video-camera and image processing	holes, seam width, (incomplete fusion)
Light intersection sensors	weld profile, mismatch
light barriers	Holes
Infrared	lack of fusion, holes
x-ray	pores, incomplete fusion, holes

Table I - Inspection techniques for different types of defects in laser welds

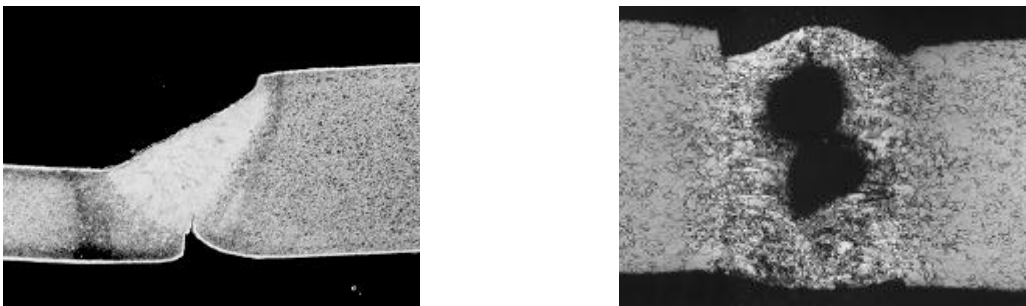


Fig.2: Micrographs of seam cross-sections  
incompletely welded through                      weld with internal pore

Optical techniques cover only one surface (adjacent to the laser beam) and are not capable of detecting internal defects nor defects at the opposite surface. X-ray techniques are very expensive (manipulation of the parts, radiation protection) and cannot be applied at typical production cycles of a weld machine.

### 4.NEW INSPECTION TECHNIQUE AND SYSTEM

Safety requirements of specific components and the required zero-defect in production, necessitate the use of NDT of all welds for surface and internal defects. The technique to be applied must detect the different defect types in circumstances, where a thickness gradient (up to 50%) may be present.

Due to large production-volumes the inspection technique has to be integrated into the production process to directly separate defective blanks. The process integration requires an inspection speed of about 10 m/min, a signal processing technique that can easily be automated at moderate costs.

The geometry of the blanks favours the application of guided waves (plate waves) [3]. These waves are most suited because the whole plate thickness is under vibration detecting surface and internal defects. Furthermore guided waves allow the inspection at large distances between probe (several 100 mm) and weld and at much lower frequencies than bulk waves.

Most of guided waves are dispersiv, i.e. their propagation velocity (phase and group velocity) depends on frequency and thickness of the component. Tailored blanks are usually composed of sheets of different thickness. Hence within the butt joint, there is a thickness step which can cause additional echoes masking the echoes from defects in the weld. To overcome this problem a non-dispersiv mode is used. The only mode of plate waves without dispersion is the lowest mode of guided Shear Horizontal (SH) plate waves. Its sound velocity is independent from frequency and thickness of the waveguide. For applications of SH-modes in the field, the only

way to excite and detect them is by Electromagnetic Acoustic Transducers (EMATs) [4], which provide a couplant free, rapid and reproducible inspection of the weld. Fig. 3 shows the EMAT together with a holder moving on a blank.

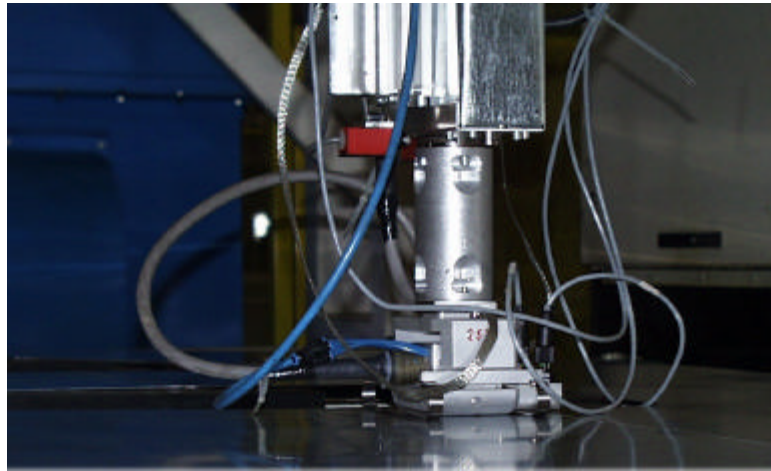


Fig. 3: EMAT with Probe Holder scanning a weld

The inspection by the SH-plate wave is performed in the pulse echo technique using specular reflected and diffracted signals. According to fig. 4 the probe is placed on one of the surfaces of the thinner sheet and radiates the ultrasonic pulse under an angle of  $\pm 15^\circ$  to the direction of the weld.

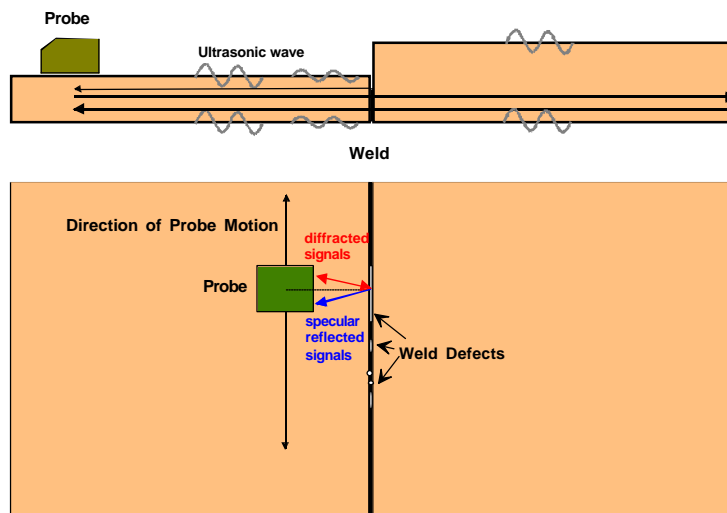


Fig. 4: Inspection principle

Back coming signals from the weld are simultaneously detected by two separate receivers as diffracted and specular reflected signals; these are recorded and displayed on separate scans, so that a discrimination of the two major defect classes is possible. Specular type defects are lack of penetration, lack of fusion, mismatch... . Non-specular type defects include porosity, pin holes ... .

Fig. 5 shows how the results of an inspection are displayed. In two display frames the maximum of the ultrasonic echo signal from the weld are displayed as Amplitude-Locus Curve (ALC) (echo maximum vs. probe position) for each of the two receivers (diffraction and specular reflection). The upper ALC displays the diffracted signals, the lower the specular reflected signals.

Fig.5 also demonstrates the unique feature of this technique in detecting internal defects. A sample of 300 mm in length contained major internal porosity in the second half of the weld (from 150 mm till 300mm). As expected strong diffracted signals are displayed in this region, whereas in the first half the signal level is very low except in the first 30 mm. Also the specular reflected signals show a high level of amplitudes between 150-280 mm; this results from a contiguous conglomeration of single pores.

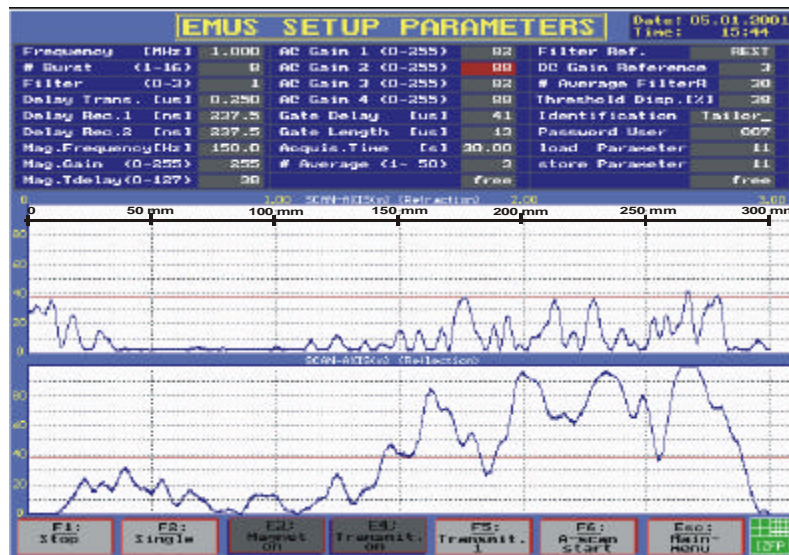


Fig. 5: Display software window

On the basis of the technique described above, industrial systems for in-line quality control of the laserwelds were designed, constructed and put into operation at the manufacturing plants of Tailor Steel, Genk, Belgium and Tailor Steel America.

Fig.6 shows the inspection cabinet which contains the electronics for the operation of the probes and the data preprocessing, an industrial PC for the control of the electronics and for the display and evaluation of the inspection data.



Fig.6: Inspection cabinet with Monitor

The inspection is performed by moving the probe parallel to the weld seam. During the scan the system automatically acquires and analyzes the weld quality in real time. Immediately after each scan an ok/nok disposition based on preset acceptance criteria is provided. Via serial and parallel digital communication with the controllers of the production line all necessary commands for the start and the stop of the inspection system and the identification codes of the



welded blanks are transferred. The disposition information are sent back from the inspection system to the controllers which reject blanks with defective welds. The raw data, traceable to the product, are saved for each inspection and are available for later analysis, documentation and process monitoring.

The systems are either operating with fixed probes and robot guided positioning of the welds along the probe (fig. 7) or with a robot as positioner (fig. 8).

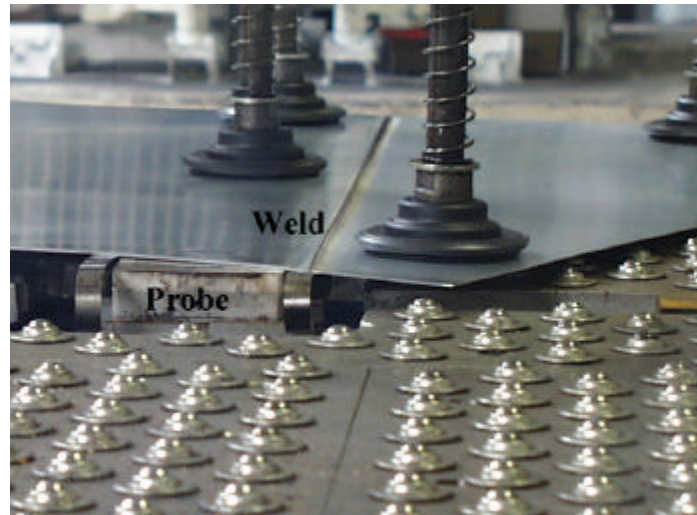


Fig. 7: Probe in a fixed position under the welded blank

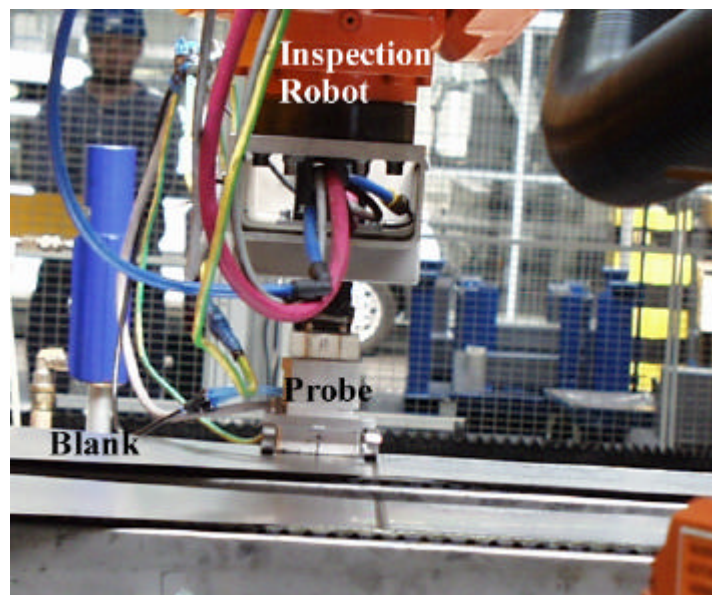


Fig. 8: Probe is moved by a robot

## 5. Literature

- [1] 'ULSAB Ultra Light Steel Auto Body-Project'. Porsche Engineering Services, Projektphase 1, 1995.
- [2] MOHRBACHER, H., RUBBEN, K., VAN DER HOEVEN, J.-M. and LEIRMAN, E.: 'Tailored Blanks - Mit gekrümmten Nähten in die Zukunft?' EFB Tagungsband T17, Leichtbau durch intelligente Blechbearbeitung, Stuttgart, 1977
- [3] SALZBURGER, H.-J.: Trockene Ultraschallprüfung der Laserschweißnähte von Tailored Blanks In: Stahl und Eisen 119 (1999), Nr.1, S.51-53
- [4] SALZBURGER, H.-J.: Guided Shear Horizontal (SH-) Waves - Examples of the Practical Use of Their Benefits for New NDE-Applications In: Chimenti, D.E. ; Thompson, D.O.:Review of Progress in Quantitative Nondestructive Evaluation. 18A New York, London : Plenum Press, 1999, S.269-276