State Of Art in Ultrasonic Spotweld Testing – Offline & Inline – New Materials and Coatings

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Abstract: The utilisability of ultrasonic testing particularly for new materials and coating in automotive industry is a major point of interest for improved quality management of car bodies. The ultrasonic testing instruments swi-100x and UT Mate SW for the manual inspection of resistant welded spots provide highest reliability of test results in a dimension of more than 350 devices in the market at DaimlerChrysler, BMW, VW, AUDI, PORSCHE and many suppliers. The further development of the new evaluation algorithm controls the optimised position of the probe and monitors the best incidence of sound in the material. The spotweld software permits temporarily storage of all Ascans for evaluation of the best A-scan within an adjustable time period – online and enables explicit evaluation of intermediate echos with tunable evaluation thresholds. Therefore the newest version of the spotweld software provides ideal condition for testing of unequal and 3 plate combinations as well as high strength steels. The evaluation algorithm provides the ability for manual testing of high strength steels and new coatings e.g. TRIP; USIBOR. The self-developed inline ultrasonic testing system SPOTline is used for inspection and process control of resistant spot weldings. SPOTline provides with directly into the welding tong integrated ultrasonic sensors a 100% inspection during the welding process. The through transmission and pulse echo signals will be collected, stored and evaluated by means of fuzzy-logic and neuronal network technic. The results will be transmitted online from the spotline-client in the sql-data-base of the server for processing. World-wide SPOTline is the only ultrasonic inspection system, which is working under real production conditions in a network of welding robots. Test with 2 and 3 plates, high strength steels and all coatings demonstrate the accurately identification of discrepant welds.

Spotweld – Offline Testing of Resistant Spotwelds

The Spotweld Inspector series provides the automotive industry with an easy-to-use, reliable means of inspecting and evaluation of spot welds during production. The main features are virtually unlimited hard-disk storage capacity of ultrasonic set-up files for different material and welding parameters; instantaneous recall of any set-up file; intuitive screen dialog boxes for entry of part data, operator information and parameters for spot weld evaluation and classification. The Spotweld Software includes tools for interactive preparation of inspection set-up files for different parts and spot welds as well as the inspection plans includes reference
waveforms and part image. The evaluation is available with GO/NOGO decision making with automatic A-scan signal capture display and optional defect classification. The spotweld series ultrasonic system creates, controls, and direct the ultrasonic sound beam into the Spot Weld. Upon signal return from the weld, signal processing is performed and a digital signature is created for system use:

- Comparison to known signal characteristics indicating weld conditions.
- To Limitations programmed to reflect user programmed specifications and tolerances.
- For the creation of a visual indication of the returned ultrasonic signal (A-scan) for use by operator and programmer personnel.

New materials effectively make the inspection of some resistance spot welds impossible, using conventional analog equipment. Computer based ultrasonic testing has allowed advanced analysis to resolve problems in process of production. Advanced algorithms greatly assist operators in performing inspections. Manufacturing facilities worldwide have correlated and implemented this technology very effective for inspection and process control with resistance spot welds.

For new materials and coatings the operational experience in automotive industry requires the necessity to establish a reliable process. This means to set the production process of spot welding in a way to get testable and evaluable spots.

For the testing of high strength steels for example it is a indispensable requirement to get a minimum tip impression. This avoid the problem of cladding on the one side and the problem with porosities on the other side. Only a specification for the minimum wall thickness of the welded materials allows a reliable test with the settings of the spotweld software. So the main important criterium for manual testing of resistance spots is the minimum wall thickness to get the verifiability with ultrasound. For this reason the ultrasonic testing has to established in a process circuit to fix the varieties of defects in spot welds and find out with correlation the specifiable differences.

Ultrasonic testing can substantially reduce the need for destructive verification for resistance welds. Ultrasonic testing is a potential cost reduction opportunity for current and future resistance spotweld applications.

Figure 1: swi-100x Spotweld Inspector
Spotline –

**Inline Process control of Resistance Spot welding of car body frames**

The self-developed inline ultrasonic testing system SPOTline is used for inspection and process control of resistant spot weldings. SPOTline provides a 100 % inspection during the welding process by ultrasonic sensors which are integrated directly into the welding tong. SPOTline provides with directly into the welding.

During the welding process ultrasonic pulses are conducted with 500 Hz from the SPOTLINE - client through the weld nugget. The through-transmission and reflection signals are recorded, stored and evaluated. Immediately after completion of the spot weld a result value is available which correlates to the quality (diameter) of the spot weld. This value is assigned according to quality characteristics by two limit values into three classes: good spot, average spot or discrepant spot (figure 1). Therefore the inspection result is not a diameter value but one of the classes mentioned correlated to the quality of the spot weld. In production stick welds, discrepant and small nuggets are recognized during welding.
The basic testing system consists of four components (figure 2): SPOTLINE client, SPOTLINE communication unit, ultrasonic sensors and optional SPOTLINE information terminal.

The SPOTLINE client (figure 3) is the very heart of the testing system, required for each welding unit. The Client consists of the ultrasonic card, the embedded PC, the main adaptor and, if required, interfaces (i.e. interbus card) for communication with peripheral equipment.
The evaluated data of the individual clients are gathered and stored in the client and transferred to the SPOTLINE communication unit for statistical process control. The system (all interlaced clients) can be configured and maintained from the communication unit.

The ultrasonic sensors produce the required ultrasonic pulses for testing which run through the weld during the welding procedure. Therefore ultrasonic transducers are positioned at both sides of the welding tongs. The accurate classification of spot welds depends on reliable basic measurements which only can be obtained by optimal positioning of the sensors in the tongs. Due to the big variety of tongs and electrode shaft forms, different sensor types, and resulting from this, different sensor positions have been developed. But there are hardware requirements for the tips (figure 4).

The sensors are producing a longitudinal wave, which usually is located on the tip base and transmits directly and vertically through the electrode tip into the spot weld which is to be tested.
The SPOTLINE information terminal is an industrial or office computer with monitor where the SPOTLINE - visualizing-software is installed. Test data recorded at the attached welding stations can be visualized by means of the display of the information terminal. So the spot quality is displayed and checked directly at the production site or at any other chosen workstation involved (in the network).

The ultrasonic signals of both UT sensors are recorded in order to generate the raw data. The test range (spot weld) is right between the two sensors implemented in the shafts. Data acquisition starts with the end of the squeeze time and continues during the entire welding-time lasting into the hold time. During this period the sensors are operating alternating in through transmission and in pulse/echo mode with a pulse rate of 500 Hz each. (each 2 ms one measurement). The amplitude and time-of-flight data resulting from this are continuously recorded and analysed thereafter.

Not the absolute values of amplitudes and time-of-flights are evaluated, but the relative values to the ones at the beginning of the welding phase. Evaluation of absolute values especially regarding the amplitudes turned out to be impractical due to the rough conditions in production. The benefit of the differentiation measurement is the compensation of external influences, for example the varying electrode pressing force or temperature differences.

After entering two limit values into the system the algorithm does the classification of the welding spots into three categories. The evaluation is executed on the basis of trace slopes, which are considered individually or in relation against each other. Judging the spot weld quality requires the complete set of ultrasonic signals per spot weld.

The ultrasonic signals are recorded separately by a timeline with respect to its relative amplitude and time-of-flight, this during squeeze time, welding time and hold time. For the calculation of the quality value of the weld, the changes of the ultrasonic signals occurring in the “sonic time-of-flight window” (sonic distance area) will be evaluated separately from each other concerning amplitude height (sound energy) and time-of-flight (sonic time-of-flight from the transmitter- to the receiver-ultrasonic sensor).

The basic principle of the ultrasonic testing are structural changes in the material welded under the influence of dissipated energy. These changes are displayed as so called raw curves of difference value measurements of amplitudes and time-of-flights depending on time. The changes in time-of-flight within the transition from solid to plastified respectively
from plastified-to-solid, are characteristic for every good weld. If not enough energy is used, the heat which is needed to smelt the spot is not sufficient. A significant characteristic is missing in the time-of-flight difference curve; giving clear evidence of a “bad” spot (discrepant spot), i.e. dry joint. By means of the transmitted longitudinal wave, which runs through the spot weld, the reflectivity and the height of the weld pool are measured and indirectly, later on, the welded surface resulting thereof. The structural changes during cooling-down depend on temperature gradient and alloy components are identified when interpreting the recorded data. Temperature changes of the tips may influence the results, but these distortions can be compensated by evaluating the pulse-echo-data. Dissipating excess energy (heat) will evaporate the nugget and cause weld spatters. Spots with spatters are counted and evaluated for statistical process control for the correction of weld current. For online control of the welding process it is possible to judge a quality trend already after the first welding periods has been carried out. This information may be used for the interactive control of the welding process. To do so, the SPOTLINE testing system may communicate with the weld control for appropriate adjustment of the welding current. The precondition is an interface between the weld control and the SPOTLINE client (not yet realized with a welding machine manufacturer).

Results are transferred by bus connection and via network. Interactive controls of status are interchanged and statistical process control is displayed. The testing of conventional steel materials up to high-strength steel like USIBOR as well as Aluminium and Stainless Steel with all kind of thicknesses up to Three plate welds is possible. Test results of different materials and the integrated functionality with the welding machines or robotics are shown.