Automation of Resistance Spot Weld Inspection

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Spot Welding

Spot welding involves:

- electrode forces: 500..2200 lb
- electric currents: 5000..13000 A
- temperatures: 70..3000 F

Some means of quality control are required to ensure uninterrupted automatic production.
Resistance Spot Welding in Industry

Regular vehicle contains 4000-6000 spot welds.

Spot welding is highly automated today.
So has to be inspection.
Testing Spot Weld Using 2D Ultrasonic Matrix
2D Matrix Array Technology

Resistance Spot Weld Analyzer (RSWA)

- A portable, easy in operation ultrasonic device for assessing the quality of resistance spot welds
- Ultrasonic sensor is the latest generation of matrix transducer technology
- Provides internal image of the weld
- Automatically estimates the nugget diameter and surface indentation

Features automatic setup and calibration
The RSWA’s sensor is a unique matrix transducer designed specifically for spot weld testing.

Unlike phased arrays, commonly used in medical ultrasonic devices, this probe has 52 channels that work independent from each other.

Parameters:
- 8×8 matrix
- 52 independent elements
- 1.25 mm element size
- 15 MHz central frequency
- 2 m cable with 52 coaxes
- Replaceable delay line
Matrix transducer

uses electronic scanning to obtain the 3D image

- Pros: No moving parts, real-time imaging and nugget size estimation, hand-held, simple in operation
- Cons: Low resolution, probe is larger than that in single-transducer devices

From Single-Element Probes to 2D Matrix Transducers
Matrix transducer
unique design provides five measurements for every weld

1. Image
2. Diameter
3. Indentation
4. Front Plate Thickness
5. Stack Thickness
• Instant visual feedback greatly simplifies the interpretation of measurement data

smaller than minimum size

minimum size

larger than nominal size

2.1 mm

4.5 mm

6.1 mm
• The ultrasonic representation of a weld’s internal structure is conveniently displayed on the screen as a color coded image

• The software displays the estimation for nugget diameter, surface indentation, and other parameters

• The automatic setup procedure simplifies RSWA operation
Motivation for further automation

- Eliminate human error factor
- Improve repeatability and consistency
- Speed up inspection process
- Automate reporting and decision making

**Handling of components**
- Universal Robots: UR 10
  - Handling of optical measurement system and ultrasonic probe

**Camera and image processing**
- IDS Imaging: Camera
  - Detection of spot welds
  - Automated visual inspection
  - Determination of coordinates

**Automatic nugget size estimation**
- Tessonics: RSWA
  - Non-destructive testing of spot welds

**Fully automated non-destructive inspection system**
schematic representation

definitions:

- **first step**
  - optical camera system
  - robot and ultrasonic probe

- **second step**
  - RSWA (Resistance Spot Weld Analyzer)
  - test specimen
1...optical camera system
2...flexible probe holder
3...couplant application
4...couplant extraction
5...RSWA probe
6...robot
example of the new Porsche Panamera
concept realization

• **correlation of test results**

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<tr>
<th>manual examination</th>
<th>automated testing</th>
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<td>uneven point orientation</td>
<td>consistent point orientation</td>
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<tr>
<td>deviated point contours</td>
<td>comparable point contours</td>
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<tr>
<td>multiple measurements of the spot weld</td>
<td>single measurement of the spot weld</td>
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<td>different weld diameters (± 0.5mm)</td>
<td>high repeatability of measurements (± 0.2mm)</td>
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<table>
<thead>
<tr>
<th>spot weld</th>
<th>1</th>
<th>2</th>
<th>7</th>
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Testing Spot Welds at the Moment of Their Production
Welding Application with Ultrasonic Monitoring Station

- Quality monitoring system
- Robot controller
- Weld controller
- Weld gun with ultrasonic probe
- Remote Workstation (optional)
Ultrasonic wave is sent by the ultrasonic transducer submerged into the cooling water stream. Reflections from the stack boundaries and nugget tell whether the base metal is melted or not.
From here (RegDelay) software starts to look for water-copper and copper-steel.

Water-copper: 26 us

Copper-steel: 31 us

Water-copper secondary: 34 us

Copper-steel secondary: 38 us
Physical Principles of Real-time Ultrasonic Testing of Spot Welds

Ultrasonic probe built into electrode*

Incident wave

Copper Electrode

Steel Plate 1

Steel Plate 2

Copper Electrode

*Transducer built into an electrode by Maev et al. US Patent 6297467

Physical Principles of Real-time Ultrasonic Testing of Spot Welds

Ultrasonic probe built into electrode*

Incident wave

1. Copper Electrode
2. Steel Plate 1
3. Steel Plate 2
4. Copper Electrode

Amplitude

Arrival Time

Welding time

Current ON

1. 5
2. 2
3. 3
4. 4


*Transducer built into an electrode by Maev et al. US Patent 6297467
Geometry Matching

Real Acoustic Image

Pattern

Weld geometry
Transducer Built into Customer’s Electrode

Flex coaxial cable is installed outside

Water enters center channel and returns on the outer

Cap can be replaced in the usual manner

Water flow is maintained in the proper way to cool electrode cap
Probe Designs
Each weld is ultrasonically scanned during formation. Special software analyzes the image (signature). Based on calibration data, it makes a decision about weld quality.
At 11:43:44 part was intentionally built with three undersize welds.
RSWA Measurements Validated the RIWA readings

Performance example

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Communication Between Units
Both systems provide quality evaluation to most of the welds being produced by the robot.

Since the quality of the weld is determined at the spot, feedback provided by the system can be used to prevent producing more bad welds (send alerts, send notifications to maintenance personnel, stop the production line, etc.).

Communication between systems and a main server makes the remote monitoring of the whole production floor accessible from a single PC. Special software performs analysis and creates customized reports from the collected data.
Conclusions

Automation of inspection in body-in-white is a:
- Necessity
- Cost saver
- Time saver
- Ambassador of reliability and repeatability