Ultrasonic Spot Weld inspection system based on Industrial Robotic, Artificial Intelligence and Artificial Vision

Montserrat Acebes Mainauthor[1], Iñaki Gauna Coauthor[1], Héctor de Matías Coauthor[1]
Rafael Delgado Coauthor and Alberto Álvarez Coauthor[1]
1 Tecnitest Ingenieros, C/ Ciudad de Frías, 1. 28021 Madrid. Spain
macebes@tecnitest.com; comercial@tecnitest.com

Abstract

Nowadays, spot welding is still one of the most frequently used techniques for bonding metal plates, for example, in an automotive chassis between 3000 and 4000 spot welds can be found. Using this technique is possible to obtain at a low cost, easily automated and versatile welds with high quality and speed of operation but, the inspection and quality control process needs to be improved so that it is possible to reach automatic systems that allow maximizing the speed of inspection and guarantee, in turn, the repeatability and accuracy of the results, eliminating possible deviations introduced by the operator.

In this paper an inspection system, based on the ultrasonic propagation, is described. The main challenges faced are presented, such as the location of the spot weld, using artificial vision, the definition and positioning of the probes until a reliable signal, and the final analysis through a development based on artificial intelligence.

The results achieved in real parts, have shown that this robotic system, has a better defect detection capacity than the systems currently on the market, and is applicable to the inspection on assembly lines, optimizing not only the inspection times but also improving the results and therefore the quality of the process.

KEYWORDS: Ultrasounds, Spot welds, Artificial Intelligence, Artificial Vision, Industrial robots, NDE 4.0

1. Introduction

In this paper are presented the results achieved by Tecnitest within the project titled: “Robotic Ultrasonic spot welding testing and control system” (no. EXP 00113921 / IDI-20181298), which was partially funded by the Centre for Industrial Technological Development - CDTI.

This project was launched as a response to the need in the market for a device for spot weld inspection in real time, which enables a rapid and reliable determination of their quality, without using complicated ultrasonic setups or complex human interpretations.

The work carried out during that time showed that it was possible to reach a system with the required characteristics, integrating different technologies, in the field of NDE 4.0.

Manually or using industrial robots, the solution applies the latest artificial intelligence and artificial vision technologies that allows to maximize the speed, repeatability, and accuracy of the results.

2. Main elements of the inspection system

The in-line inspection of spot welds, is an issue that is still unsolved [1][2].

In the last few years Tecnitest has been working in a fully automatic system for inspection, evaluation, and monitoring of quality in spot welds, for which developed a prototype [3] that used artificial vision for position control and included a dry coupling technology and a signal processing software, in order to improve the reliability of the inspection, minimize human intervention in the evaluation of the results and facilitate the automation to allow the system to be used in line production.

Although this system allowed a great advance with respect to the manual inspections carried out up to that moment, it presented limitations derived from the state of the surface, when it was significantly deformed or inaccessible, and it was not possible to determine the centre of the weld and what the orientation of the probe should be to have a perpendicular incidence. In order to solve these problems, Tecnitest has developed a new robotic prototype for the inspection of spot welds in assembly lines, optimizing the takt time of the line.

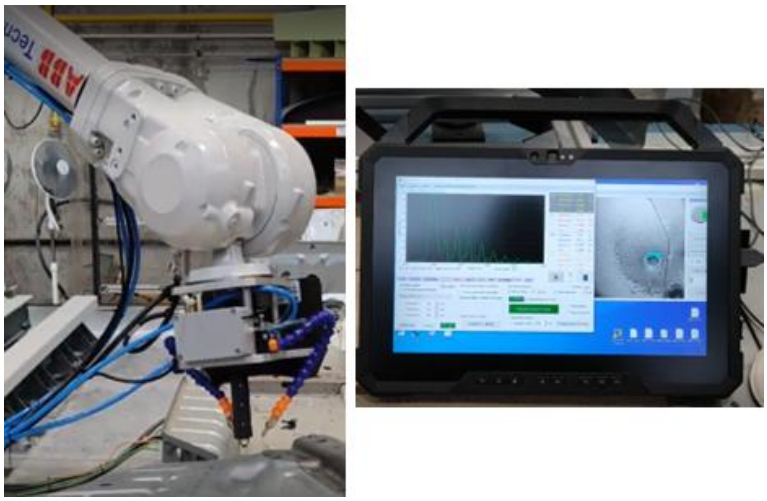

Figure 1. (a) Automatic system for spot weld inspection. (b) Evaluation of results.

This automatic inspection and evaluation system has been tested at the Tecnitest facilities on a car chassis with up to 200 different welds.

Figure 2. Different spot welds tested.

The inspection system uses an industrial robot, which allows the displacement of the probe with great accuracy, and comprises the key elements described below

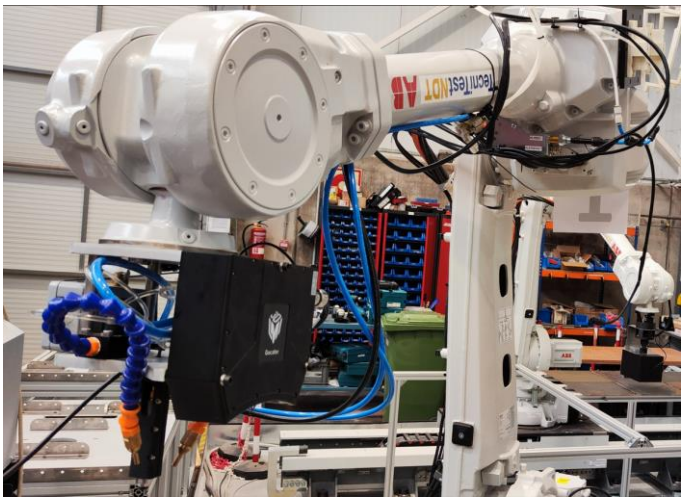

Figure 3. Key elements

2.1. Set of probes and mechanical integration elements

Throughout the project different probes and frequencies have been used, but in all case, commercial ones (15MHz- 20MHz). For those that presented a better behaviour, an ad-hoc support was designed and developed, as well as the adjustment elements and the delay coupling.

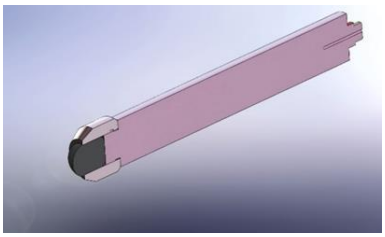

Figure 4. Diagram of the delay element used.

This delay is a flexible rubber element that adapts to the geometry of the surface and has good ultrasonic behaviour, with an acoustic impedance similar to the water one, that allows an adequate transmission without significant signal loss.

2.2. Artificial vision camera

A new 3D artificial vision camera, that once the robot approaches, takes a picture and the software can locate the centre of the spot weld and send to the robot, in real time, their exact X Y Z coordinates and the inclination to make the final focus and carry out the measurement without human intervention or predefined position.

Figure 5. Spot weld detection by AV camera.

2.3. Artificial Intelligence system

An artificial Intelligence (AI) system for automatic evaluation, also in real time and without human intervention, based on the ultrasonic indications obtained from the spot weld. It also adapts easily to new test conditions, learning different results for different types of materials and thicknesses.

Its main advantages include maximum simplicity, classification in real time, the possibility to learn one time and repeat always, being applied to two or three sheets of different types, materials, and spot diameters, and allowing optimization of inspection times up to 3 seconds per spot weld, without requiring intervention by an expert operator.

2. Evaluation and control

The software developed for evaluation is very friendly, being only necessary to have the input data of the sheets to be inspected.

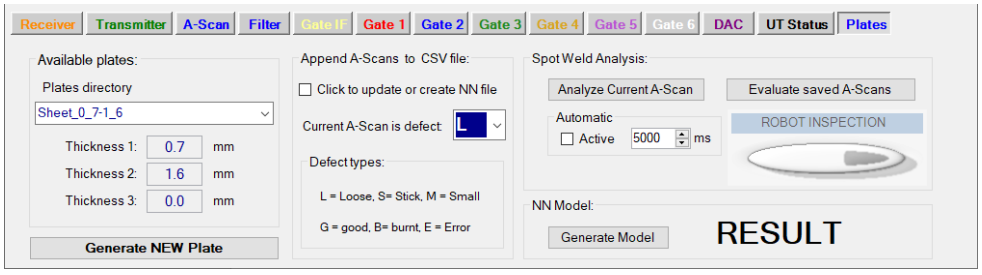

Figure 6. Input data corresponding to the characteristics of the sheets.

Each set of sheets has a different setup, being the system able to recognize patterns for classification only through training.

In turn, the system is controlled by an easy-to-use software interface, which allows to control the ultrasonic system and perform spot weld evaluation, all in the same interface window.

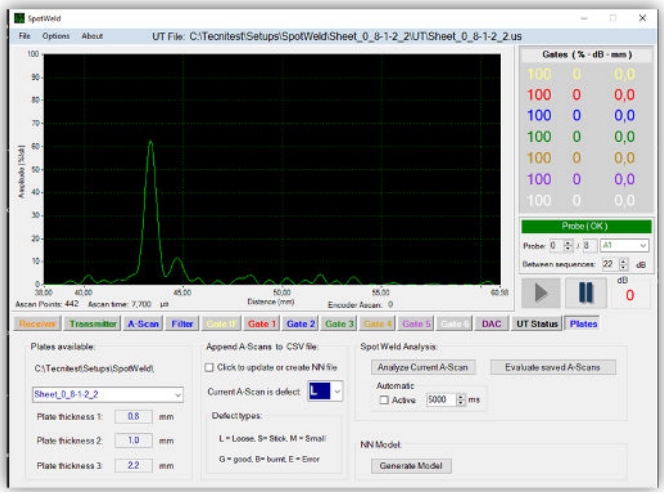

Figure 7. Software interface.

In this way, to inspect a spot weld, it is only needed to select its geometry in the list of configurations that is available for the user. The system automatically loads the designated ultrasonic calibration to obtain the best signal and controls the movements of the robot to place the probe in the correct position for each weld. When the centre and the inclination is determined, the system automatically checks the current signal of the A-Scan obtaining the result.

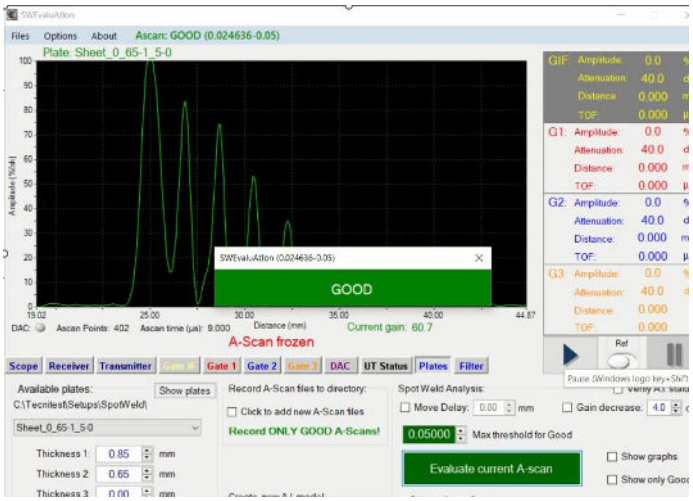

Figure 8. A-Scan and evaluation.

According to the requirements, the system can generate a complete report with all the analysed data.

3. Conclusions

The system, that has been presented in this paper, was developed by Tecnitest, and validated with real samples in a production plant in which all possible types of defects were analysed.

The first results showed an in-line detection capacity of 85%. This figure may be greater, improving the training of the system and optimizing the determination of the inclination of the spots, mainly the most deformed by the weld. For those inspections in which it was only necessary to discriminate between OK/not OK, the probability of detection was close to 100%.

More results in: https://www.tecnitestndt.net/spot-weld/

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