Easy to go and innovative validation process using the spot weld inspection system PHAsis and related software

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Abstract

In the industry 4.0 the need for a cost-saving and efficient production process is of high significance. This includes every area of the production processes and leads to appropriate testing procedures by means of the quality management. A combination of ultrasonic inspection devices and software tools for result post processing reduces the need of several cost-intensive validation circles with destructive testing to a very low level. This can be shown for example with the imaging phased array spot weld inspection system PHAsis in combination with a software app for post processing. This is including the software part for the data and result management as well as a device software for the ultrasonic inspection of the spot welds. In combination with the usage of an automation interface for robotic usage, even more cost reduction is possible.

Several validation processes on typical resistance spot welding applications with plate pairings of two or three plates (aluminium as well as steel combinations) by the use of PHAsis and the connected PostProcessor will be exemplified. The general procedure of the validation process will be accentuated step by step. Therefore, the original data of phased array testing and a comparative method in the shape of a destructive testing (hammer & chisel test or horizontal respectively vertical cross section) will be presented. Furthermore, the steps of the post processing procedure to define the ultrasound system parameters for a best fit will be described. During these steps, the influence of the different sensitivity and system parameters on the spot weld size will be explained. Also, the measurement uncertainties given by the destructive testing that have an influence to the comparison with ultrasonic testing in general will be addressed. The efficiency of the post processing software tool due to reaching a high match between PHAsis and the comparative destructive method will be illustrated.

KEYWORDS: spot weld; inspection; validation process; cost-reduction; efficiency

1. Introduction

Industrial production and especially the industry 4.0 are representing the need for efficient and fully integrable processes. This is including the complete production process but also the accompanying quality process to control the production. Therefore, often non-destructive testing methods are used as this doesn’t lead to the loss of material or parts in comparison to the destructive testing (and the quasi-non-destructive testing). This can include ultrasonic testing, X-ray inspection by means of CT, Dye Penetrant testing and further inspection methods.
During the manufacturing of the car-body-structure especially the resistance spot welding is of high importance as the leading joining technology. As quality methods, the destructive testing with for example cross sections or the chisel-test as well as the non-destructive ultrasonic testing can be used. Imaging ultrasonic inspection methods with the PHAsis ultrasonic instruments are used, which considerably drops down training costs with simultaneous improvement of the test quality and which are fully integrable in automatic robot production processes as well as in the quality system.

2. Validation process

2.1 System overview

2.1.1 PHAsis

The PHAsis system consists of different parts – mainly the software components are the PHAsisManager as front-end for the administration of the complete data management, the PHAsisDevice as inspection software, the database and a PHAsisService for the communication between the software components. It can be used as a single user all-in-one solution or as a distributed system to create a multi-user solution (see Figure 1).

![Figure 1. System overview](image)

![Figure 2. Device overview](image)
As inspection solution, two different products are available – PHAsisNEO as an easy-to-use hand-held inspection solution or PHAsisBLU as a solution fully integrable in automatic processes (see Figure 2). For the complete range of inspection tasks, phased array probes with 20 MHz and 12 MHz (both as versions with a pitch of 1.0 mm and 1.3 mm) as well as different wedges (water wedges with several footprints and a fix Rexolite® wedge) are available and usable with both PHAsis devices. Additionally, customized probes with all kind of frequencies as well as ultrasonic element numbers and pitch sizes dedicated to any application are available.

2.1.2 PostProcessor
An important element of spot weld inspection software and the quality process is the validation of the non-destructive results with a comparing inspection method (e.g., cross sections). Therefore, the additional software component PHAsis PostProcessor (see Figure 3) is a useful opportunity. With this software, it is possible to correlate data between the ultrasonic inspection and the comparing method. Existing offline stored ultrasonic data files can be uploaded in the software, and it is possible to modify all evaluation parameters to get a best fit without the need of a new ultrasonic inspection. This saves time and money in the qualification process of ultrasonic inspection method.

Figure 3. Software interface PHAsis PostProcessor

2.2 Validation process
The validation process with the PHAsis PostProcessor is an iterative process, where in several steps the ultrasonic evaluation parameters were optimized to get the optimal correspondence between ultrasonic inspection results and the measurement during destructive testing.

2.2.1 Standard parameters
During the initial phase of a validation process and for a greater range of plate combinations with spot welds, standard parameters are the basic starting point. This includes the automatically defined reporting level as well as a standard cladding threshold to detect echoes in the welded range as the most recent parameters (see Figure 4). Besides these standard settings, also advanced settings exist for further parametrization and special applications.
2.2.2 Sample parts
For the validation/parametrization outside the production process, it is recommended to use at least three analogue welded validation parts with a minimum of seven spot welds with a welding quality from worse to good. These validation parts should be inspected with the standard parameter set (optional for a higher confidence level: procedure of an uneven number of inspections higher than one of each part and averaging the ultrasonic result). Afterwards the sample part with the supposed worst ultrasonic results respectively highest deviations should be destroyed (optimal: cross section). Alternatively, all parts can be destroyed at this step which is followed by the adjustment of the parameters by using the PostProcessor if needed. With the new parameter set, all parts should be re-evaluated. The new settings also should be controlled with the destructive testing of a further part. In the end the identified best-fit parameter set refers to one defined thickness-material-combination.

2.2.3 Production part
For a production part, the general procedure is analogue to the one for sample parts, but without the first step of welding parts as they already exist. Also, these parts usually consist of several plate combinations with (mainly) good spot welds and not only of one defined thickness-material-combination like during the validation of sample parts.

2.2.4 Examples

Figure 4. Standard basic parameters

Figure 5. Diagram – steel 1.20 mm on 2.00 mm (left side) and steel 1.00 mm on 1.00 mm (right side)
Typically, the standard parameter set leads to a good first indication of the spot weld quality like it is visible in Figure 5 on the left side. For the two-plate-combination with 1.20 mm on 2.00 mm the original value as well as the comparative destructive test indicate two spots with a worse quality and then a constant diameter increase. Also, for the right side of Figure 5 the standard settings enable a first indication with constant deviations to the destructive testing up to spot 12 and with an analogous trend for the last spots. But in both cases, adjustments are necessary consisting of a more insensitive setting for 1.20 mm on 2.00 mm and for the combination of 1.00 mm on 1.00 mm the parameters have to be more sensitive.

During the evaluation it is visible that thinner plate combinations require more sensitive settings to minimize the deviation between the ultrasonic results and the destructive testing (Figure 6).

For the longer conical water wedge with smaller footprint the necessary parameter optimizations are analogous to the standard water wedge. For a combination of two plates with thicknesses of 1.00 mm a more sensitive setting in contrast to the standard parameters is necessary as it is visible in the lower diameters in Figure 7.

![Figure 6. Diagram - steel 0.60 mm on 0.60 mm](image)

![Figure 7. Diagram - steel 1.00 mm on 1.00 mm (conical wedge)](image)
Also, for typical aluminium plate combinations (e.g., 1.50 mm on 3.00 mm, see Figure 8), standard parameters lead to a good correlation between the destructive testing and the ultrasonic inspections. For thicker plate combinations analogues more insensitive settings have to be used.

![Figure 8. Diagram - aluminium 1.50 mm on 3.00 mm](image)

### 2.2.5 Measurement uncertainties

As both, the destructive testing and the ultrasonic inspection, have deviations related to method and material, leading to differences in the results. The deviation of the destructive testing depends on the method used for destruction. The chisel-test has a minimum standard deviation of 0.25 mm up to 0.5 mm. For cross sections (vertical or horizontal) the deviations are lower in case of the correct execution where the welded area is used for the cross section.

The ultrasonic inspection system has an ultrasound related standard deviation of approx. 0.1 mm (determined on non-welded reference parts). Depending on the material and the welding process the standard deviation for real spot welds has a minimum value of approx. 0.1 mm up to 0.2 mm. One essential factor for the standard deviation and the differences between the ultrasonic inspection and the destructive testing is caused by the fact, that the ultrasonic inspection is not a measurement method but a comparing method.

### 3. Conclusions

By using a standard parameter set during the validation procedure, a first indication is reachable between the ultrasonic inspection and the destructive testing which possibly can be improved offline by the PHAsis PostProcessor. Therefore, for both, steel and aluminium, more sensitive settings for thinner plates and more insensitive settings for thicker plate combinations have to be used to reach a good fit between the PHAsis results and the destructive testing. For all cases, the uncertainties for both systems (destructive measurement and PHAsis inspection) have to be considered to identify deviations and differences between the results. Nevertheless, it is possible to may reach an even better correspondence during the continuous improvement process of the ultrasonic evaluation algorithm.