Thermografische Prüfung von Fügeverbindungen im Karosseriebau

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Summary. In the automotive industry, non-destructive testing (NDT) has a great capability to improve the part quality and to make production processes more efficient. Non-destructive testing techniques that are suitable for the inline quality control of conventional joining techniques (e.g. spot or laser welding) in body-in-white structures are presented.

The ultrasound excited thermography has proved its general feasibility for the evaluation of adhesive bonded joints. This application is currently under investigation at Volkswagen. Current results of ongoing tests with scopes and constraints of the technique are shown. Furthermore, an outlook to new applications developed for future body structure concepts will be given. Challenges for testing new materials and joining technologies will be discussed.

Another important aspect of this paper is the need to qualify non-destructive testing procedures for the implementation in automotive production processes. An approach how to prove their feasibility is presented.

Introduction

To assure the quality of joints in automotive body structures there are still many destructive testing procedures like chisel testing or metallographic examinations in use. Production costs could be reduced enormously by establishing reliable non-destructive testing techniques for the process control when we just focus on the discarded body structures scrapped after destructive tests and mostly high personal costs.

An approved and state-of-the-art technique to control the quality of resistance spot welds is the manual ultrasonic test [1]. For laser welded car bodies, thermographic pulse techniques with flashlight excitation are successfully established [2]. This represents a reliable testing method for a half automated sampling inspection, sufficiently robust for the use under production line conditions. (Fig. 1)

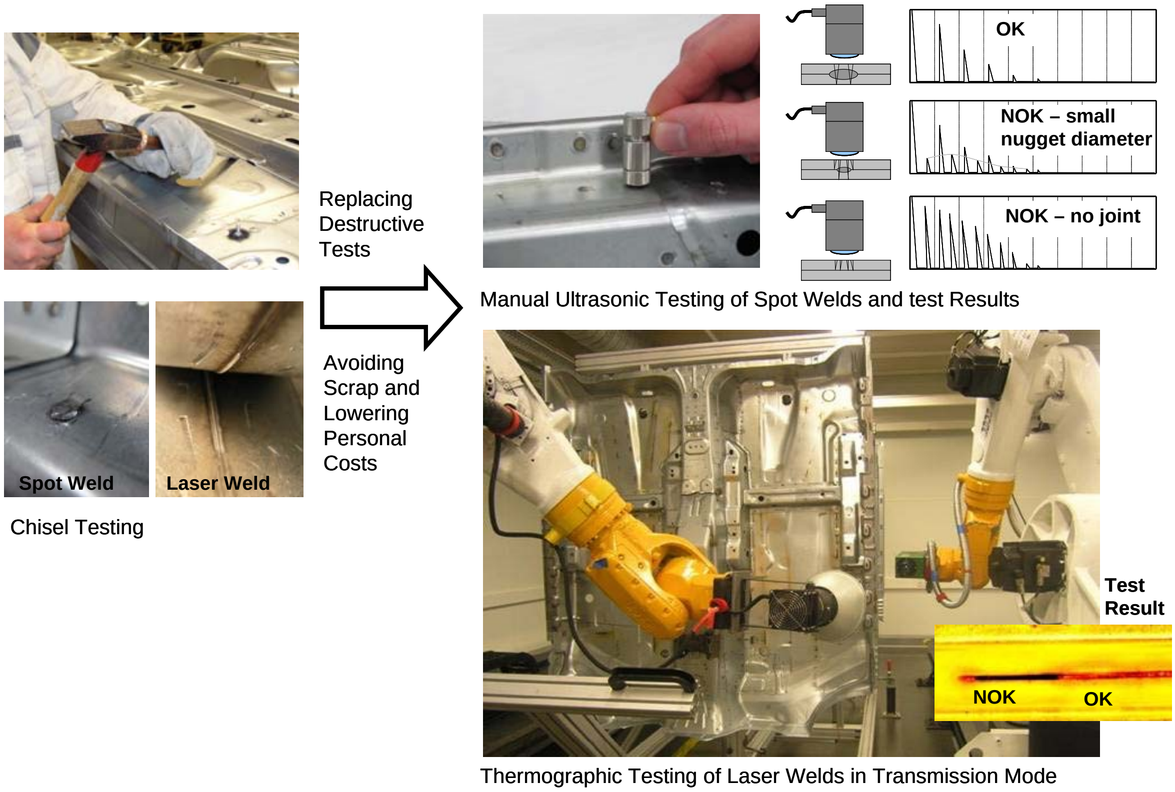


Figure 1: Reducing production costs by replacing destructive tests (left: chisel testing) with non-destructive tests (right: manual ultrasonic check and half-automated thermographic testing)

Recent developments in the field of non-destructive testing offer great opportunities to enhance the advantages to new types of applications. How to implement a non-destructive testing technique in the automotive industry, particularly with regards to the development of a testing method for adhesive joints, will be the main part of the following content.

1. Ways to implement a Non-destructive Testing Technique

The industrial use of non-destructive testing techniques is generally motivated by different aspects:

1. Replacing costly destructive or less efficient non-destructive testing procedures that are currently used in series production (examples are shown in figure 1).
2. Establish non-destructive testing procedures in new car projects or production concepts with
    a) state of the art methods or
    b) innovative methods.

2. How to Qualify a Non-destructive Testing Technique

Regardless of the motivation that pushes the application of a non-destructive testing method, its feasibility to control the required quality has to be proved [3]. At Volkswagen, a comprehensive qualification process is developed in order to assure the implementation of non-destructive testing techniques in production processes. The approach in figure 2 defines necessary steps that are including the requirements of normative regulations in the automotive industry. In connection with these steps, a more detailed checklist is available at the Volkswagen Group supporting the qualification. [4]

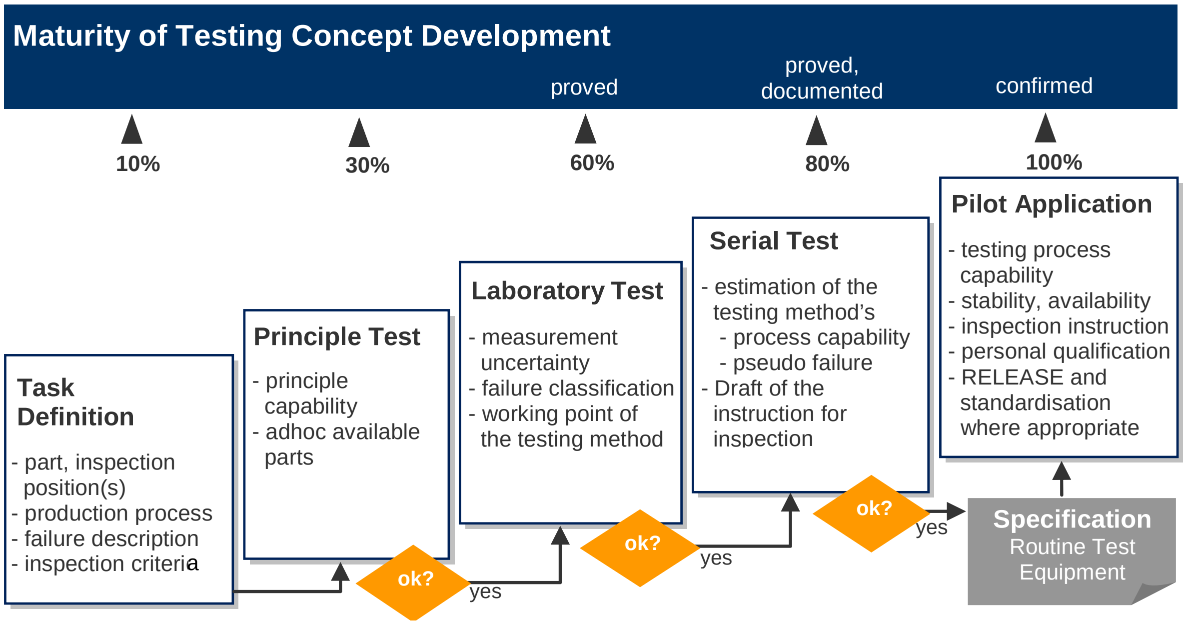


Figure 2: Qualification steps for the implementation of non-destructive testing techniques

The definition of all important qualification steps – for example how to check the reliability of the non-destructive test method – results into an internal Volkswagen Group standard [5].

3. Advances in Thermographic Testing of Adhesive Joints

Because of the growing number of adhesive joints in automotive body structures, the demand for testing techniques to control the quality is obvious. Especially ultrasonic testing and thermography seem to have adequate chances to replace the costly destructive methods currently in use. For adhesive bonded hem-flanges, the ultrasound excited thermography is recently under examination at the Volkswagen Group. Some first results according to the qualification steps from the recommended approach (figure 2) are presented below.

3.1 Task Definition

An important quality criterion is the resistance against corrosion, generally caused by porosity of the adhesive bond. Figure 3 (left) illustrates the required tolerances of the adhesive in hem-flange joints in steel or aluminum body constructions, e.g. in a car front door. In the further investigations the outer panel side will be called “a”-flange, the inner panel side “b”-flange. Small pores in the hem-flange loop are allowed, but the loop must be sufficiently filled so that no humidity can penetrate from one side to the other.

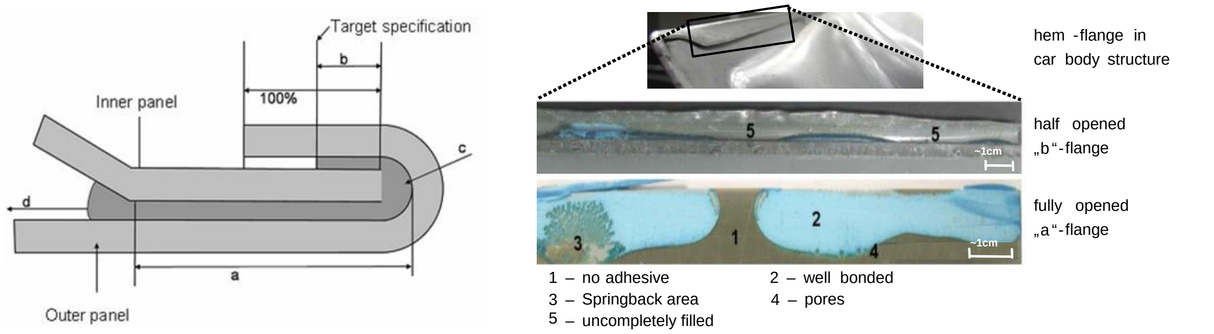


Figure 3: Left – Cross section of a hem-flange bonded joint according to PV2047 [7]
Right – Irregularities seen in visual tests after opening the hem flange joint (chisel test)

Typical irregularities of adhesive bonds are shown in figure 3 (right). The capability of the testing technique will be initially evaluated based on these properties.

3.2 Principle Test

As earlier examinations show, the ultrasound excited thermography is a promising way to visualize properties of hem-flange joints [8]. The general principle of this technique is the dissipation of elastic wave energy into heat that primarily occurs in areas filled with adhesives. The generated thermal radiation is recorded by an infrared camera and the signal can be evaluated in different manners [9]. Figure 4 gives an impression of the test equipment and the position of the ultrasound sonotrode and the infrared camera. Possible configurations are illustrated.

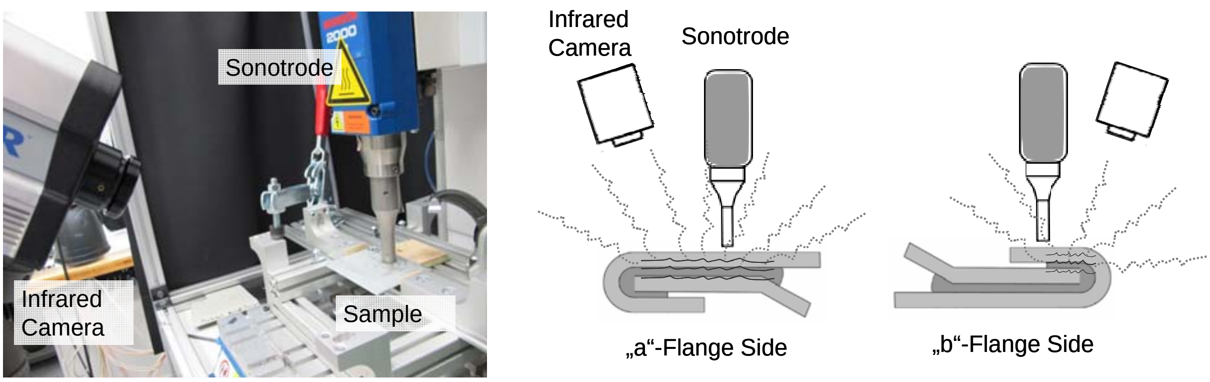


Figure 4: Ultrasound excited thermography test configuration

By testing geometrically simple and planar samples, pulse phase evaluations of the thermal sequences result to significant images. Principally defects in hem-flange bonds can be visualized as it can be seen for the pore marked in figure 5. For a secure interpretation of springback defects the test parameters still need to be optimized in future examinations.

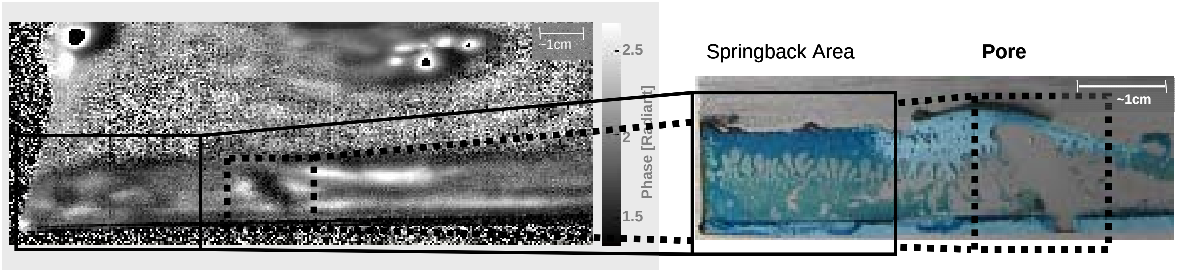


Figure 5: Thermal testing with ultrasound excitation of geometrically simple and planar samples – thermographic result image (left) and destructive opened “a”-flange (right)

3.3 Laboratory Test

In laboratory tests the best conditions to evaluate hem-flange bonds were figured out. Multiple influence parameters were analyzed so that uncertainties were thoroughly defined. One special action while adopting the test procedure to whole car front doors was to place a special buffering material between the ultrasound sonotrode and the part. In this way the ultrasound energy could be increased in the part and surface damages were successfully avoided. Figure 6 (left) shows an adhesive trace at a car door outer panel, especially prepared with deviations in form and position. The thermographic test result on the right side represents together with the opened “a”-flange how precisely defects can be visualized.

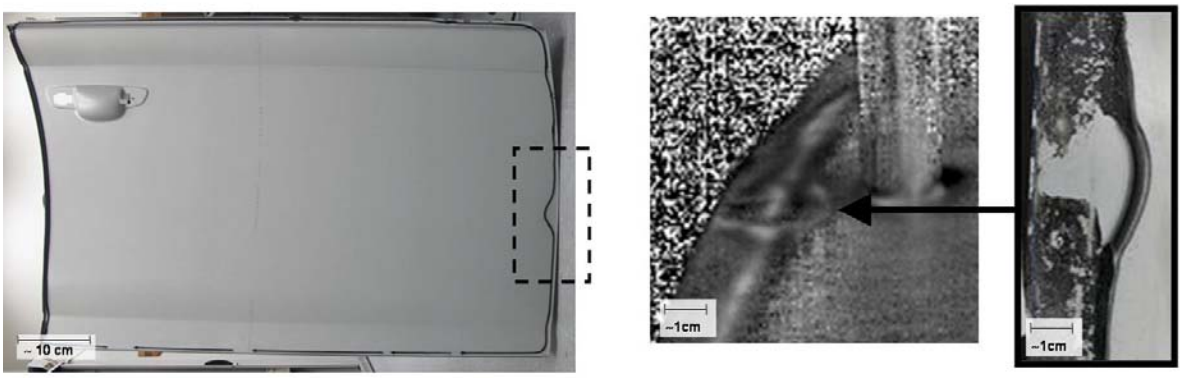


Figure 6: Left – Adhesive trace at a specially prepared car door outer panel
Right – Thermographic test result image and opened “a”-flange with the intended defect

The general test ability at samples could be successfully transferred to complete parts, in this case a car front door. Irregularities were detected, but only from the outer side (“a”-flange). Scopes and constraints of the thermographic evaluation for adhesive fillings in hem-flanges are summarized in table 1.

Table 1: Scopes and constraints of thermographic evaluation of hem-flange bonded joints in “a”-flanges

Samples 	• Cleary observable contour of the adhesive and wetted area • Inner structures (like pores, springback / meander areas or no adhesive) are recognizable down to > 2 mm extension
Car Front Door 	• Contour of the adhesive and wetted area is recognizable (with little less quality) • Only larger inner structures > 5 mm can be observed

3.4 Serial Test and Pilot Application

Before the non-destructive testing technique is ready for serial inspections, a lot more influences must be taken into account. Many of them can be simulated in the laboratory, as it can be seen in the foregoing results. But finally the serial test under production conditions must prove that the whole test procedure is sufficiently robust against all relevant noise sources. Figure 7 shows the main influence parameters and sources of error for the ultrasound excited thermography.

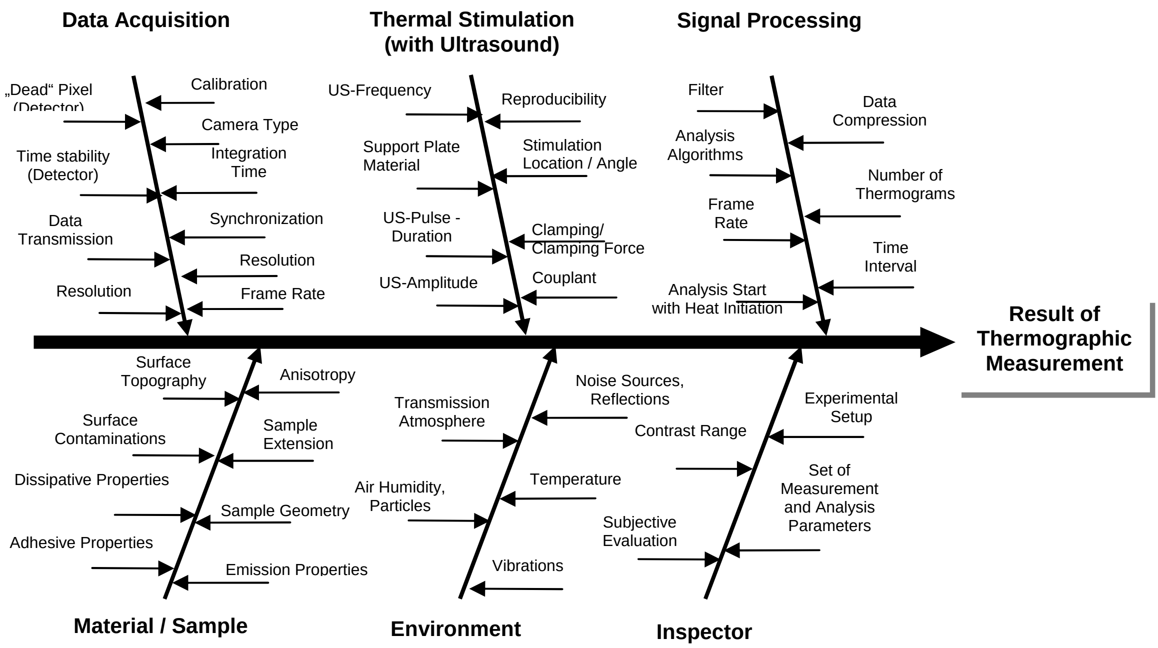


Figure 7: Influence parameter and sources of error in thermographic measurements

During the pilot application also organization tasks have to be assured. These are for example providing the inspection instruction or arranging the personal qualification concept.

4. Challenges for Non-destructive Testing with New Car Concepts

The development of new car concepts are often connected with the introduction of new materials or production processes. That means also a great challenge for the automotive industry to provide suitable non-destructive testing procedures.

In the last years materials like carbon fiber reinforced plastics (CRFP) for example became more interesting for the automotive industry. For life cycle checks of airplanes, the thermography is already well known. The adoption to automotive applications should be realizable without a huge effort. On the other hand, mixture constructions like steel-polymer or steel-aluminum combinations, are also gaining importance in car bodies. Knowledge about several testing opportunities is available for these applications, too. The contour control of adhesive in a steel-polymer construction is possible with the optical excited thermography (fig. 8).

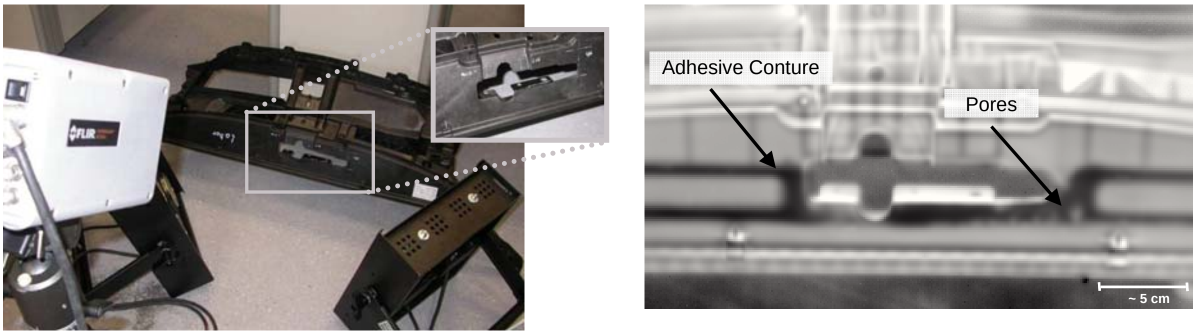


Figure 8: Left – Optical excited thermography with halogen lamps at a cross member (glass fiber reinforced polymer bonded on a steel construction)
Right – Thermographic test result image: adhesive contour, partially with pores

A stud welding technology will be installed to connect sheet structures (fig. 9).

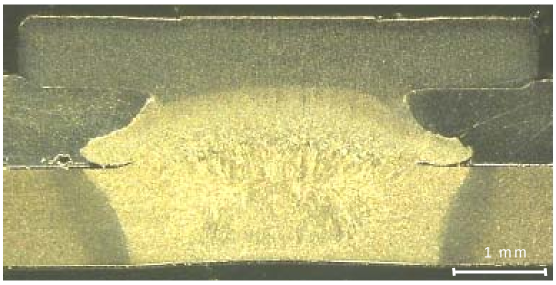
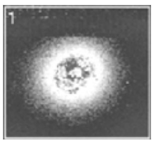
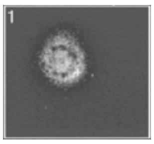
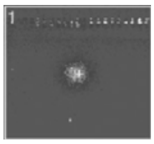
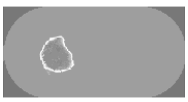
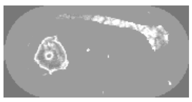


Figure 9: Cross section of a stud weld

Typical defects, that will be the relevant quality criteria for a non-destructive check of these welds, are shown in table 2. Initial results from a thermographic quick check and also from a test with an ultrasonic miniscanner are added to give an impulse for possible future investigations.

Table 2: Metallographic cross sections of welds followed by initial result images of innovative NDT-examinations with thermography and an ultrasonic miniscanner

	OK	Pore	NOK - not bonded
Metallographic Cross Section			
Thermographic Result Image			
Ultrasonic Miniscanner Result Image			

Conclusion

The implementation of non-destructive testing techniques for the quality control of production processes offers great opportunities to reduce costs. On the other hand, a comprehensive qualification must be conducted to prove the suitability of the test methods. A new adoption must be thoroughly chosen to ensure an adequate effort. At the end, robust production processes with a better quality as well as lower costs can be achieved.

For the non-destructive test of adhesive bonds in car body structures, several techniques are under investigation. Some capabilities of the ultrasound excited thermography to check hem-flange bonded joints were presented. In general, a relatively facile thermographic application is to visualize the contour of thick adhesive traces behind planar and thin sheets. The thinner the adhesive layer and the more complex the geometry is, the more difficult is the test.

Referenzen

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