Lock-In Thermography Based NDT of Parts for the Automotive Industry

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Abstract: The successful use of adhesively bonded parts depends on the defect-free bond of the components. Therefore it is necessary to detect relevant faults and defects in an early state of the production. A 100% test should be pursued, but especially at complicated structures the detection of defects is not easy. Possible testing methods, which show a high potential for the NDT of adhesively bonded parts, are thermography based NDT methods. At present mainly two different procedures of active thermography are being used: Pulse and Lock-In Thermography. With pulse thermography the examined material is warmed up with a short energy pulse (light, eddy current or ultrasonic pulse) and the heat response is recorded after a certain time. The result is an infrared image which indicates material defects in different depths. This paper presents a variety of images showing the capability of Lock-In Thermography to image subsurface defects. Several examples of adhesives joints qualify the ultrasonic Lock-In-Thermography for the in-process quality control for adhesive bonded components.

Keywords: *NDT, Lock-In-Thermography, adhesively bonding, 100% testing*

1. Introduction

Defects in adhesively bonded parts possess other physical properties as the bond area in which are no defects. This local inhomogeneities and the resulting stress concentration influence the expansion of elastic waves. These are damped in areas of defects due to the hysteresis loss caused by the friction at the border of the defects. The loss energy guides to a local increase of temperature, which can be measured by thermography, Figure 1.

2. Optical Excited Lock-In Thermography

The optical excited Lock-In Thermography is based on IR radiation which is coupled onto the surface of a component. The stimulation take place by spotlight or laser and the modulation is sinusoidal.

The surface of the component is warmed up and the heat is conducted into the component. The heat conduction is now disturbed by above described defects. Either the heat is reflected or the heat is scattered. Comparing the phases shift between stimulation and the resulting temperature course (measuring the temperature course and using the Fourier transformation to get the phases shift) measured by a powerful IR camera system (resolution 20 mK at 30°C) it is possible to detect (location, depth and kind of failures) existing defects.

A schematic diagram of the experimental set-up of the optical excited Lock-In Thermography is shown in Figure 2.

The optical excited Lock-In Thermography enables the contact less NDT at materials and components with dimensions of 3 m^2. The reachable depth of failure detection is about 3 mm in plastics, 6 mm in fiber reinforced plastics and 12 mm in metals.

3. Ultrasonic Excited Lock-In Thermography

With optical activating, failures are only detectable comparing the measured signal with a (good) reference signal. With ultrasonic activating, areas of changed materials properties are stimulated and due to the increased mechanical lost angle (hysteresis) heat is dissipated.

With ultrasonic waves the defects in material and joint are excited into oscillation and the absorbed energy by

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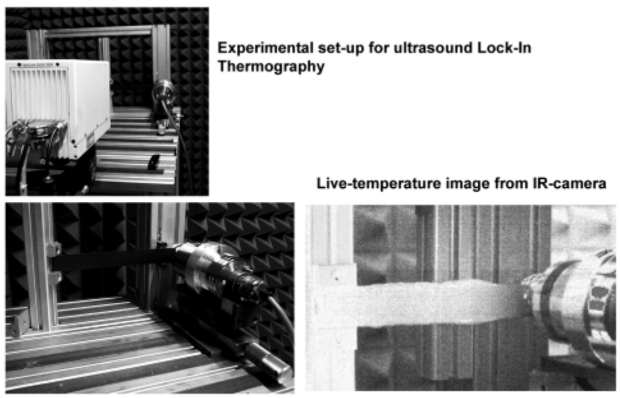

Figure 1. Ultrasound lock-In thermography.

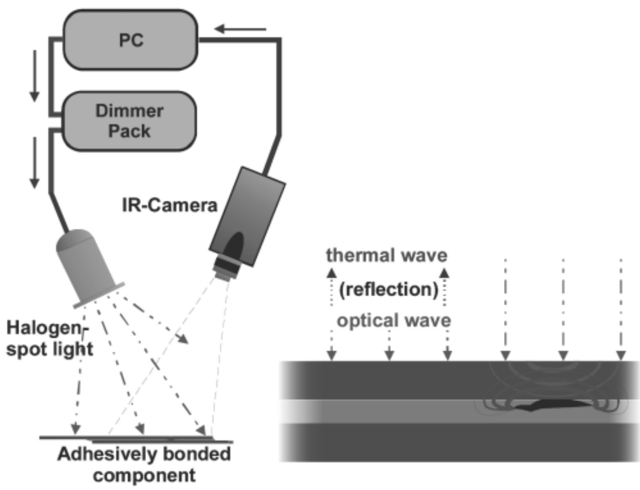

Figure 2. Optical excited lock-In thermography.

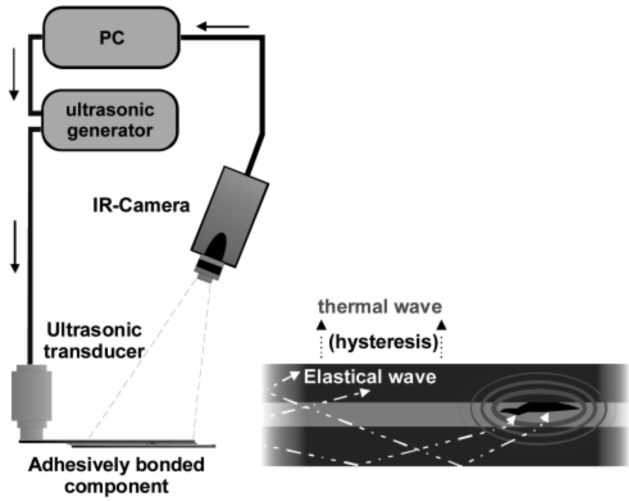

Figure 3. Ultrasonic excited Lock-in Thermography.

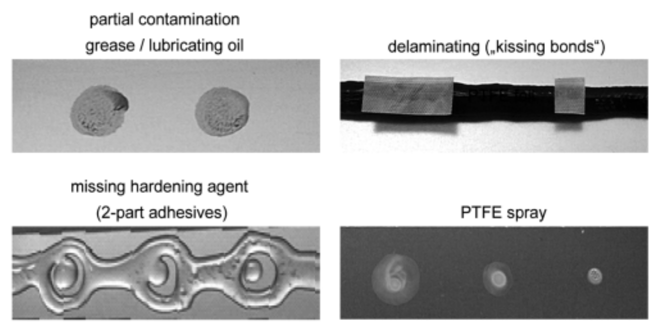

Figure 4. Fingerprint contamination with lubricating oil and simulation of defects with thin PTFE-layers.

plastic deformation or friction is transformed into heat energy. The two surfaces of the defect do not move in unison when ultrasound penetrates into the sample. A defective joint differs from an intact one by its reduced loading capacity. Defective joints show for example voids, delaminating, porosity or cracks in the joint. The result is an infrared image which indicates material defects in different depths.

A schematic diagram of the experimental set-up of the ultrasonic Lock-In Thermography is shown in Figure 3.

4. Ultrasonic and Optical Excited Pulse Thermography

Compared to the Lock-in Thermography with the sinusoidal modulated activation the Pulse Thermography uses short optical or ultrasonic pulses (burst signals). The biggest advantage is an explicit reduction of the time of measurement. A further advantage is the broader temperature answer signal, because the used burst signal consists of a lot of different frequencies in comparison to the single-frequent sinusoidal signal of the Lock-In signal. So it is possible with only one measurement to use a wide range of activating frequencies. The ablating behaviour and so the range of the thermal wave is directly dependent on the activating frequency.

5. Experimental Results

For the determination of the boundary conditions and the limits of the above mentioned NDT methods, a lot of different materials were used for the experiments. These materials are stainless steel (0.6 mm and 1 mm), mild steel (1 mm and 1.5 mm), aluminium (1 mm), PA66 and various FRP's. The used adhesives were 1p PUR adhesives and 1p and 2p EP adhesives.

In cooperation with the industry some groups of fail-

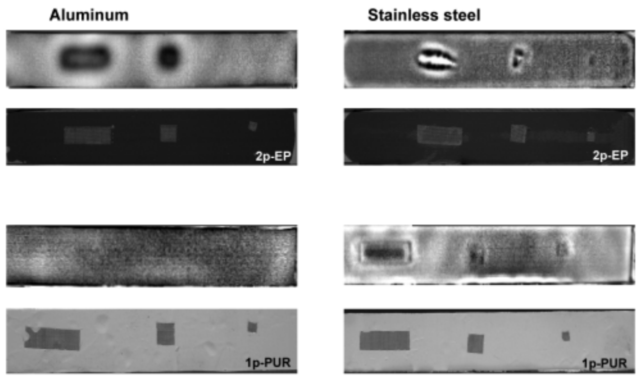

Figure 5. Detect ability of adhesive bond failures at aluminium and stainless steel with Ultrasonic excited Pulse Thermography.

ures are determined which are prior be examined for their detect ability. These failures are in-homogeneities due to the presence of spurious materials, delaminating, porosity, localized lack of or excess of resin and debonding.

The failures were generated artificial using PTFE foil and spray, grease or lubricating oil or using only one part of a two part adhesives, Figure 4.

At Figure 5, the results of the NDT are in good accordance with prepared failures. It is visible, that for aluminium adherents and PUR adhesives with higher elasticity the detect ability is less than for steel adherents and EP adhesives with lower elasticity. The reasons for this are for the one hand the higher lost angle for adhesives with higher elasticity and so the damping of the thermal wave. And on the other hand the higher heat conductivity of aluminium in comparison to stainless steel which guides to smaller temperature difference and imagine sharpness.

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