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Infrared thermography as a new method for quality control of sheet metal parts in the press shop

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ABSTRACT

Active dynamic thermography was proved to be a new alternative for crack detection. To achieve zero failure sheet metal production in the press shop, this method was investigated for different steel components, which were directly collected from series production. And the cracks in the presented specimens differ in length and in depth, and a series study on these surface cracks is executed. The crack detection capabilities of active thermography with two different excitation sources were compared: optical and inductive excited thermography. Results of experiments obtained by these two techniques are showed and compared with each other. Opportunities of applying these methods in press shop are discussed.

1. Introduction

Infrared thermography (IRT) was at first an invention for military applications. However, due to the rapid development of thermal cameras since the 1970s, this technology has been increasingly used in civilian areas. Because of its several advantages, such as non-contacts with the inspected object and detection capability of subsurface failure [7], IRT is widely applied for nondestructive testing (NDT). Furthermore, materials with either low or high thermal conductivity are able to be detected using IRT with proper mathematical evaluations [7,11]. For example, cracks or impact of lamination. Furthermore, IRT system requires very short testing time, which enable its application on automatic quantitative material defects detection [1,2,7]. These properties of IRT also match the requirements of quality control systems for sheet metal parts, and it can be a solution for an automated defects detection system in the press shop.

In this paper, two of the most common IRT techniques will be introduced, which are the optical and inductive excited pulsed-phase thermography (PPT). Specimens for the experiments are collected and cut off from the series production of luggage trunk door. Detection results of defects with these two IR techniques were compared, in order to approach a better suitable method for quality controlling of specific sheet metal parts.

2. Material and methods

Under the definition of IRT, a distinction is made between passive and active thermography. In passive thermography, measurements of temperature decreases provide temperature profiles, and an abnormal temperature profile indicates a problem in the specimen. In the active thermography, extra energy is brought onto the specimen, so that there would be a significant temperature difference [1,7].

2.1. *Active thermography*

The fundamental of NDT procedures nowadays is mainly based on the active thermography, because of its many advantages, such as more reliable information in its results,

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and insensibility of influence from environments [1]. Fig. 1 exhibits a typical classification of all common IRT methods.

Among all these active thermography techniques, pulsed-phase thermography (PPT) and lock-in thermography (LIT) are mostly applied [4,5]. Thus, the methods for detects defection in sheet metal parts were focused on PPT and LIT techniques.

According to [3,8,9,12], main advantages and disadvantages of these two techniques are listed in Table 1.

As described in [6,7], PPT combines promising features from two older thermographic techniques. It is as rapid and easy as pulsed thermography to develop and requires a shorter evaluation time. Moreover PPT provides phase delay images as Lock-in thermography. Accordingly, PPT is safe and easy to deploy NDT technique, giving the possibility to rapidly inspect large and complex surfaces. So it is more applicable for defect detection in sheet metal parts, and was therefore discussed in this paper, covering two exitation techniques.

2.2. *Pulsed-phase-thermography*

In PPT, a short burst of excitation is applied to the specimen, and the heating pulse occurs in milliseconds with its shape being approximately rectangular. This is very important, because this pulse includes in the frequency speckle a high lobe near zero frequency and smaller lobes in low frequencies, which improve entirely the signal–noise-ratio [9,10]. Temperature history of one pixel is normally pattered into two sections: heating and cooling. A strong contribution is however included in the cooling period, so the result evaluation is applied to this area with a Fast Fourier Transform (FFT) algorithm. As it is known, FFT can calculate a time domain into a frequency domain, which exhibits enhanced thermographic results in phase and amplitude images [10,11].

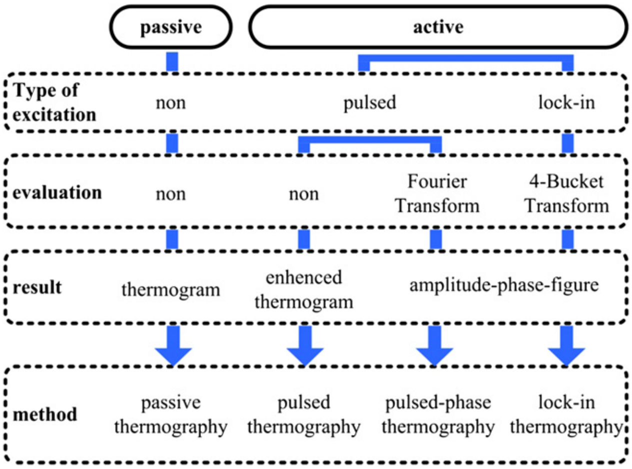

Fig. 1 – Classification of active thermography methods.

Table 1 – Advantages and disadvantages comparison of the pulsed-phase and lock-in thermography.

Method	Advantages	Disadvantages
Pulsed-phase thermography (PPT)	• Rapid testing time • Suitable for unknown defects • Relative easy excitation's control	• Low detectable depth • Relative high heating volume
Lock-in thermography (LIT)	• Advanced detection depth • Relative low heating volume	• Longer testing time • Necessity of finding optical lock-in by unknown defects • Complex testing equipments

Fig. 2 shows a graphical explanation of data acquisition and processing by PPT, and it is based on [7,9,13]. Only the phase image processing is showed, and the amplitude image processing follows the same principle.

The temperature of pixel (*i*,*j*) is T_{ij}, which decreases after impulse excitation till $T_{ij}(N)$. *N* is the sum of sampling images, Δt is the sampling interval, so $N\Delta t$ is the whole measure time. When the themogram sequence is processed using FFT, the real and imaginary transform will be [7]

$$F_n = \Delta t \sum_{k=0}^{N-1} (k\Delta t) e^{-j2mk/N} = \mathrm{Re}_n + \mathrm{Im}_n \tag{1}$$

where *n* designates the frequency increment ($n=0.1\ldots.N$). Re and Im are the real and imaginary parts of transform. The FFT algorithm is used in each pixel for the whole image sequence, and then thermograms will be transformed into phase and amplitude images, by using ([7]) the following equation:

$$\emptyset_n = \tan^{-1}\left(\frac{\mathrm{Im}_n}{\mathrm{Re}_n}\right) \tag{2}$$

$$A_n = \sqrt{{\mathrm{Re}_n}^2 + {\mathrm{Im}_n}^2} \tag{3}$$

The calculation with FFT is finished with software packages such as MatLab®.

When the pulsed heating reaches the specimen, thermo-energy expands into its surrounding area. And the thermo-energy intensity increases sharply where the crack is located, because cracks present a barrier for the heat transmission. Correspondingly, the crack temperature increases more rapidly than the sound area, this change can be measured with an IR camera. Even more, after the evaluation with FFT, cracks present a more characterized pattern in the phase or amplitude image. Also, phase is less affected than thermal date by problems such as non-uniform heating, surface emissivity variations and non-planar surfaces [7,10,12,13].

2.3. *Specimens*

In order to prove the PPT's availability for defects on sheet metal parts, two specimens are selected from the press shop. They represent the very typical defect of this sheet metal part. However cracks on the two specimens have different lengths and depths. Like in practice, it is difficult to characterize defects that existed in the serial production. As described in Section 2, experiments in this paper are based on the PPT technique. There are two most commonly used excitation resources in the PPT technique: the optical