Automatic data processing based on the skewness statistic parameter for subsurface defect detection by active infrared thermography

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Abstract

Non-destructive testing (NDT) by active infrared thermography requires of data processing techniques in order to: *i.* improve the thermal contrast between defective and non-defective areas, and *ii.* reduce the large quantity of images recorded during the inspection without losing relevant information. In this paper, the use of the skewness statistic parameter is proposed for the automatic processing of thermographic sequences obtained by active thermography. The main interest is to compress data from a 3D thermogram sequence to a unique skewness parameter image containing all the relevant information about the subsurface defects. Experimental thermographic data from three CFRP specimens with different surface shape (planar, curved and trapezoidal), containing 25 defects (Teflon® inserts) at different depths and having several sizes, have been processed using the skewness parameter. The results presented herein demonstrate the potential of this technique for automatic defect detection by active thermography.

1. Introduction

Active infrared thermography applied to the non-destructive testing (NDT) of materials offers a reliable, straightforward and fast means for retrieving structural information from a specimen. The technique is based on the detection of surface temperature anomalies that appear in response to the application of a thermal pulse to the specimen surface. However, active thermography presents some limitations fundamentally due to an exponential rate of attenuation of the defect signature with its depth — a consequence of the dependence of thermography on the heat conduction processes to convey information about internal structural anomalies. Defect enhancement techniques must be applied in order to produce a successful thermal inspection. Conventional image processing techniques such as [1]: the time-derivative approach by thermographic signal reconstruction (TSR) [2], the automatic algorithm based on differential absolute contrast (DAC) [3], and the application of the Fourier transform, known as pulsed phase thermography (PPT) [4], have been applied to pulsed thermographic inspection showing both advantages and disadvantages. Recently, principal component analysis (PCA), based on the second order statistic of data, was introduced in thermal NDT. This technique called principal component thermography (PCT) [5], besides of showing some potentialities for defect detection, it compresses the information contained in the sequence to a fewer number of PCs, the number of components being dependent on the number and type of defects and the experimental conditions and requiring an operator's decision. The present work describes an alternative method based on the third order statistic of data called *skewness*, which can be used to compress the information contained in the 3D sequence into a single image. The performance of the proposed method has been evaluated for depth characterization on three carbon fibre reinforced plastic (CFRP) specimens containing several defects, having different surface geometries, and being subjected to uniform and non-uniform excitation.

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2. Basic principles of skewness.

Skewness, or the third standardized moment, is a measure of the asymmetry of the probability distribution of a real-valued random variable and it is defined as [6]:

$$k_3(x) = \frac{E\left[[x-\mu]^3\right]}{\sigma^3} \tag{1}$$

where μ and σ are the mean and standard deviation of random variable *x*, respectively and *E* [] is the mathematic expectancy defined as

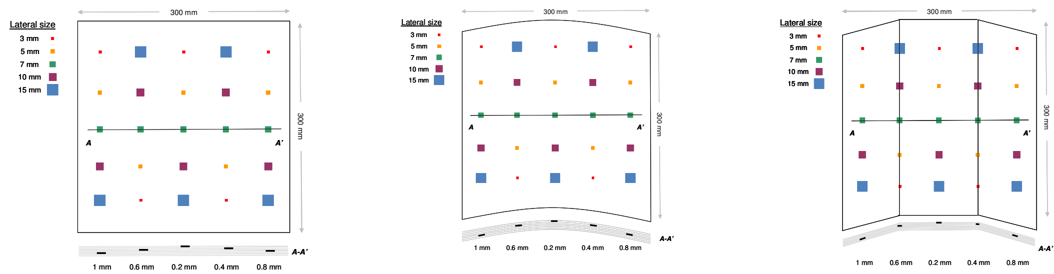
$$E[X] = \frac{1}{P}\sum_{n=1}^{P} x_n \tag{2}$$

where $X=[x_1\ x_2\ x_3 \ldots x_P]$ is a TxP dimensional matrix and *P* point x_n are the *T*-dimension.

In the case of typical pulsed thermographic data, the observation of temperature surface after a heat excitation is recorded into *T* images (n_x x n_y pixels), resulting on a 3D matrix. In order to apply Eq. (1), a pre-processing step is needed to convert the acquired three dimensional data into a two dimensional *T* x *P* data.

3. Experimental setup and data acquisition

Three CFRP specimens were tested in reflection mode using two high-power photographic flashes (6.4 kJ for 5 ms). The surface cooling down process was recorded with a medium wave IR camera (3 to 5 µm) at a frequency of 157 Hz. The thermogram matrices included cold and saturated thermograms was of 1896. Each specimen contained a total of 25 Teflon® square inclusions of 5 lateral sizes (3, 5, 7, 10 and 15 mm) grouped into 5 depths (0.2, 0.4, 0.6, 0.8 and 1 mm). Figure 1 presents the geometry and defect distribution on the (a) planar, (b) curved and (c) trapezoidal plates. Each specimen was excited using either 1 flash or 2 flashes, in order to determinate the performance of method when non-uniform heating is applied.

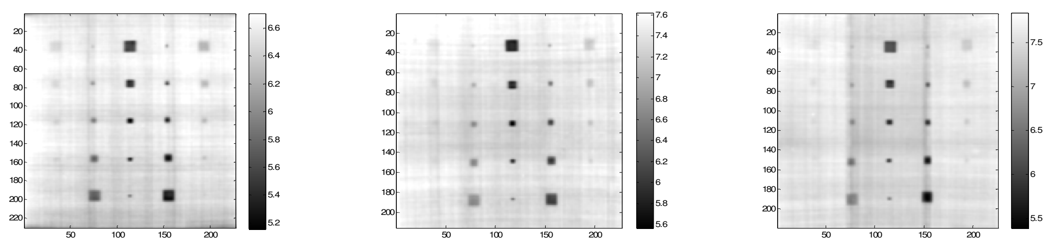


(a) **(b)** **(c)**

Figure 1. Schematic representation and defect location for specimen a) CFRP006, b) CFRP007, and c) CFRP008.

4. Results

The skewness parameter images obtained from the three measured specimens (Figure 2) show that 23 of 25 defects have been detected on a unique image. As can be seen, results are independent of the specimen's shape.



(a) **(b)** **(c)**

Figure 2. Unique skewness parameter image (a) CFRP006, (b) CFRP007, and (c) CFRP008

The influence of non homogeneity excitation in the processing method can be evaluated in Figure 3. This result shows that, even though defects are detected with practically no difference in contrast compared to Figure 2a, the impact of non-uniform heating is obvious in the lower part of the image center in Figure 3..

The proposed method based on skewness parameter statistic promises to be a powerful tool for detecting subsurface defect by active thermography. It is characterized by being an automatic process and reaching a high data compression.

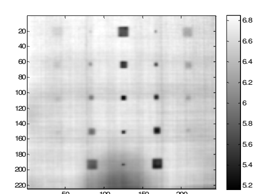


Figure 3. Unique skewness parameter image for CFRP006 using one flash excitation focused at a point (bottom-center)

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