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Quantitative analysis of thermographic data through different algorithms

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Abstract

Pulsed thermography is commonly used as non-destructive technique for evaluating defects within materials and components. However, raw thermal imaging data are usually not suitable for quantitative evaluation of defects. It was necessary to process the raw thermal data acquired to obtain a series of satisfactory results for a correct and quantitative material evaluation. In the last years, many data processing algorithms have been developed and each of them provide enhanced detection and sizing of flaws.

In this work, starting from the same brief pulsed thermographic test carried out on an aluminium specimen with twenty flat bottom holes of known nominal size, different algorithms have been compared. The algorithms used have been: Pulsed Phase Thermography (PPT), Slope, Correlation Coefficient (R^2), Thermal Signal Reconstruction (TSR), Principal Component Analysis (PCT). By analysing the results obtained using different approaches, it was possible to focus on the advantages, disadvantages and sensitivity of the various thermographic algorithms implemented.

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Keywords: Pulsed thermography; Algorithm; PPT; PCT; TSR; R^2; Slope.

1. Introduction.

In the aeronautics field, during manufacturing process, random porosity or several defects may appear in mechanical structures. These undesirable defects affect the structure and its mechanical properties. In this regard, it is very important to check the integrity of the components to reveal these defects.

Several non-destructive techniques can be used to detect such defects.

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In the last period, the thermographic technique is becoming more and more established for detecting the integrity of a structure and can be considered one of the most innovative, fast and non-contact investigation techniques to detect defects and anomalies in mechanical materials, Maldague X. P. V. (2001), Palumbo D. et all (2016), Tamborrino R. et all (2016), Palumbo D. et all (2016), Palumbo D. et all (2017), Palumbo D. et all (2017), Galietti U. et all (2012), Galietti U. et all (2012)

However, in literature, it lacks a quantitative analysis of the acquired thermal data with the aim to determine the dimension, depth and shape of defects. Raw thermal imaging thermographic data are usually not suitable for a direct quantitative material evaluation and the development of data processing methods to detect defects features as well as to determine the defect sizes and material parameters is essential for the correct application of the thermographic technique, Sun J. (2013), Balageas D.L. (2012), Junyan L. (2016).

In this work, the attention has been focused on the Pulsed Thermography (PT) technique applied on an aluminium specimen with flat bottom holes to simulate the presence defects. PT employs a short thermal stimulation to produce a thermal perturbation within the material. The presence of a defect can be revealed by monitoring the surface temperature decay of the specimen. In fact, the defect appears as an area of different temperature with respect to a surrounding sound area and it produces an abnormal behaviour of the temperature decay curve, Maldague X. P. V. (2001). It should also be pointed out that aluminium is a particular material, because of its thermal diffusivity, therefore it is difficult to apply thermographic techniques on it.

Several algorithms have been implemented to elaborate raw thermal data and to characterize the defects, such as Pulsed Phase Thermography (PPT), Principal Component Thermography (PCT), Thermal Signal Reconstruction (TSR), Slope, Correlation coefficient (R^2), in order to compare the same. The algorithms were compared in terms of the number of detected defects, the contrast between the defect and the sound area and data processing speed, to establish which applied algorithms returns the best quantitative results, Sun J. (2013), Hidalgo-Gato R. et all (2013), Hidalgo-Gato R. et all (2013), Bendada A. et all (2007), Ibarra-Castanedo C. et all (2005), Shepard S. M. (2001).

In this work, it wants to propose a semi-automatic approach to analyse the thermographic maps obtained with the various proposed algorithms to derive quantitative information from the acquired data in order to characterize the researched defects. In particular, a procedure has been developed in order to determine whether a defect is detected or not by a calculator.

2. Pulsed infrared thermography and algorithms used to elaborate the acquired data.

2.1. Pulsed infrared thermography

The pulsed thermography consists of a short heating of the sample, followed by recording temperature decay curve Maldague X. P. V. (2001).

Immediately after the heat pulse deposition stops, it is possible to consider that the cooling behavior of tested sample is the same of a semi-infinite homogeneous sample characterized by an effusivity in the *z* direction e_z. Then the surface temperature time evolution follows law:

$$\Delta T_{xy}(t) = \frac{Q_{xy}}{e_z\sqrt{\pi t}} \tag{1}$$

Where ΔT_{xy} is the increasing of temperature (in *x* and *y* directions), Q_{xy} is the energy absorbed by the surface and *t* is the time.

The presence of a defect, because of the reduction of the diffusivity of the material near it, influences the surface temperature evolution, so that in the defected area the temperature is higher than in the sound area. Besides deeper defects are observed after a longer time and with a reduced thermal contrast.

The evolution of the thermal contrast on the defect and the equations resulting from the thermal wave theory allow to characterize the defect in terms of depth and diameter. The definition of the thermal contrast is: