metals

MDPI

Editorial

Thermal Methods for Damage Evaluation of Metallic Materials

Umberto Galietti * and Davide Palumbo *

Department of Mechanics, Mathematics and Management (DMMM), Politecnico di Bari, Viale Japigia, 182–70126 Bari, Italy

* Correspondence: umberto.galietti@poliba.it (U.G.); davide.palumbo@poliba.it (D.P.)

Received: 29 October 2019; Accepted: 7 November 2019; Published: 8 November 2019

1. Introduction

Thermal methods represent a set of techniques and procedures based on the investigation of the thermal phenomena related to damage during static or fatigue stresses, or more in general, to the behaviour of damaged and defected areas. In the last years, these methods were used in many applications regarding metallic materials, such as fatigue damage, crack detection and crack growth monitoring, as well as defect detection with non-destructive testing. In particular, the use of focal plane array detectors (FPA) allowed the development of new infrared thermography techniques and new methods for data analysis.

The increasing use of thermography in industrial applications was principally due to its peculiarities that combine the full-field information of data with a relatively simple experimental set-up, consequently reducing time and costs.

The literature presents two different approaches to infrared thermography: active and passive thermography. The first one does not require an external heat source and is based on the measurement of heat source variations generated by thermoelastic coupling and damage phenomena when the material is subjected to dynamic stresses. The second approach requires external heat sources, such as halogen lamps, flash lamps, laser source, etc. The latter is used for detecting surface or sub-surface defects in metals and composites. In this regard, in the literature there are two main techniques, pulsed (PT) and lock-in thermography (LT), and several algorithms for data processing capable to provide quantitative information about defects.

In this Special Issue, both these approaches are presented. The passive one for investigating the residual stresses in aluminium and titanium with TSA (thermoelastic stress analysis), and for studying the fatigue behaviour of stainless steels and for crack monitoring in aerospace materials with TSA. The active approach has been used for quantitative defect detection in aluminium and for assessing the microstructure degradation of blades with the PT technique. Finally, eddy current pulsed thermography was used for precise crack detection and localization in ferromagnetic and non-ferromagnetic steels.

2. Contributions

In the work of Middleton et al. [1], TSA and acoustic emission (AE) were used for detecting and monitoring cracks in aerospace materials. Experimental investigations were carried out on a sheet of aluminium alloy 2024-T3 of thickness 1.6 mm and with a central hole of 6 mm in diameter. Four sensors were used for AE acquisitions, while the Delta-T Mapping method has been used for the event location. A DeltaTherm 1780 system has been used for acquiring TSA data and the optical flow method for the crack location and monitoring. Results show that AE indicates, slightly early in time, the presence of a crack, whereas TSA is more precise in crack location.

A comparison among experimental methods for the fatigue limit evaluation of stainless steel has been presented in the work of Ricotta et al. [2]. In particular, different approaches, temperature-based and energy-based, were used for evaluating the fatigue limit of cold-drawn AISI 304L bars. Results show all the analysed approaches agreed with the short staircase procedure at 10 million cycles. Maximum errors of about 11% and 4% were found for the temperature-based and the energy-based methods, respectively.

Di Carolo et al. [3] proposed a general model for studying the influence of biaxial residual stress on aluminium and titanium alloys by means of TSA. Through a statistical analysis, the minimum value of residual stresses, which lead to significant and measurable variations in the TSA signal, was estimated. Moreover, the error in stress amplitude evaluation was assessed if the residual stresses are neglected. This error depends on the modulus, direction and angle of the principal residual stresses with respect to the applied stresses.

The condition of gas turbine rotor blades was assessed with the optoelectronic and thermographic methods in the work of Bogdan et al. [4]. Metallographic investigations were carried out to verify the degradation of the microstructure. The proposed approach allows for detecting and assessing the blade conditions by means of a non-destructive analysis in various electromagnetic wave ranges (visible range, infrared).

In the work of D'Accardi et al. [5] several algorithms for defect detection with the pulsed thermography technique were compared in a quantitative way. Experimental tests were carried out on an aluminium specimen with 20 flat bottom holes with different aspect ratios. The results were compared in terms of signal-to-background contrast and number of detected defects. The strengths and the weakness of each algorithm were highlighted, and the influence of the observed time window was underlined.

Finally, Hu et al. [6] proposed an end-to-end pattern deep region learning structure to achieve precise crack detection and localization with the eddy current pulsed thermography technique. The proposed approach was tested with experimental tests on artificial and natural cracks derived from industry. Results shows a probability of detection (POD) higher than the state-of-the-art of detection methods.

3. Conclusions and Outlook

Contributions show that thermal methods can be applied on metals for different applications, from fatigue to residual stresses to defect and damage detection. All the proposed applications are related by common aims, such as the cost and time reduction during the manufacturing process or maintenance. Many algorithms and data processing procedure were presented for obtaining information about location, size and depth of damage.

All the presented works focused their attention on the quantitative analysis of thermographic data. In this regard, this Special Issue pushes the thermal methods from in-lab experiments to industrial applications.

Finally, the editors would like to thank all the reviewers for their time spent in reviewing the manuscripts, giving valuable opinion and suggestions. The editors also want to thank Ms. Harley Wang and the editorial staff for the support in the peer review and publication process.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Middleton, C.A.; McCrory, J.P.; Greene, R.J.; Holford, K.; Patterson, E.A. Detecting and Monitoring Cracks in Aerospace Materials Using Post-Processing of TSA and AE Data. *Metals* **2019**, *9*, 748. [CrossRef]
2. Ricotta, M.; Meneghetti, G.; Atzori, B.; Risitano, G.; Risitano, A. Comparison of Experimental Thermal Methods for the Fatigue Limit Evaluation of a Stainless Steel. *Metals* **2019**, *9*, 677. [CrossRef]

3. Di Carolo, F.; De Finis, R.; Palumbo, D.; Galietti, U. A Thermoelastic Stress Analysis General Model: Study of the Influence of Biaxial Residual Stress on Aluminium and Titanium. *Metals* **2019**, *9*, 671. [CrossRef]
4. Bogdan, M.; Blachnio, J.; Kulaszka, A.; Derlatka, M. Assessing the condition of Gas Turbine Rotor Blades with the Optoelectronic and Thermographic Methods. *Metals* **2019**, *9*, 31. [CrossRef]
5. D'Accardi, E.; Palumbo, D.; Tamborrino, R.; Galietti, U. A Quantitative Comparison among Different Algorithms for Defects Detection on Aluminum with the Pulsed Thermography Technique. *Metals* **2019**, *8*, 859. [CrossRef]
6. Hu, J.; Xu, W.; Gao, B.; Tian, G.T.; Wang, Y.; Wu, Y.; Yin, Y.; Chen, J. Pattern Deep Region Learning for Crack Detection in Thermography Diagnosis System. *Metals* **2019**, *8*, 612. [CrossRef]