



HAL
open science

Study of an optimal heating duration indicator for square pulsed thermography applied to CFRP gluing quality control

Antoine Crinière, Jean Dumoulin, Laetitia Perez, Frédéric Bourquin

► To cite this version:

Antoine Crinière, Jean Dumoulin, Laetitia Perez, Frédéric Bourquin. Study of an optimal heating duration indicator for square pulsed thermography applied to CFRP gluing quality control. QIRT ASIA 2015, Jul 2015, Mahabalipuram, India. hal-01230596

HAL Id: hal-01230596

<https://inria.hal.science/hal-01230596v1>

Submitted on 18 Nov 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Study of an optimal heating duration indicator for square pulsed thermography applied to CFRP gluing quality control

A. Crinière^{1,2}, J. Dumoulin^{1,2}, L. Perez³, F. Bourquin²

¹ INRIA/IRISA, I4S Team, Campus de Beaulieu, 35042 Rennes, France

² Université Paris-Est, IFSTTAR, COSYS, F-77447, Marne-La-Vallée, France

³ LUNAM Université, LTN, UMR-CNRS 6607, Rue Christian Pauc, 44306 Nantes France

During previous works, square pulsed thermography was used to carry out non destructive testing of bonding quality of CFRP glued on civil engineering structures during reinforcement operations [1,2]. The use of such wave form excitation was motivated by “on-site” requirements, but also by measurements duration, number of composite layers to test, depth of possible faulting areas versus temperature elevation allowed at composite level according to inner heat diffusion.

Nevertheless, square pulsed excitation implies to choose an adapted heat duration. This duration is directly linked to the reliability of the parameter estimator [3]. In fact, after a certain duration the standard deviation of the estimation procedure stagnates.

According to these observations, an indicator able to predict the sufficient heating time when the reliability of the parameter estimator reached an asymptotic evolution behavior was studied. Based on the absolute thermal contrast, the proposed indicator I_{ph} is defined with the maximum thermal contrast ΔT_{max} and the time delay (t_{ph}) between the heating time t_c and the appearance of the maximum contrast, as shown in figure 1 (left). A typical evolution of the I_{ph} indicator is proposed in figure 1 (right).

This indicator allows to take into account the detectability as well as the induced flaw temporal effect on the thermal contrast shape evolution. It has been observed that the maximum of I_{ph} is connected with the sufficient heating time when the standard deviation of the estimation procedure tends to be minimized.

This paper will present the establishment of this indicator for optimal square heating time and present an analysis of results obtained with numerical simulations and laboratory experiments.

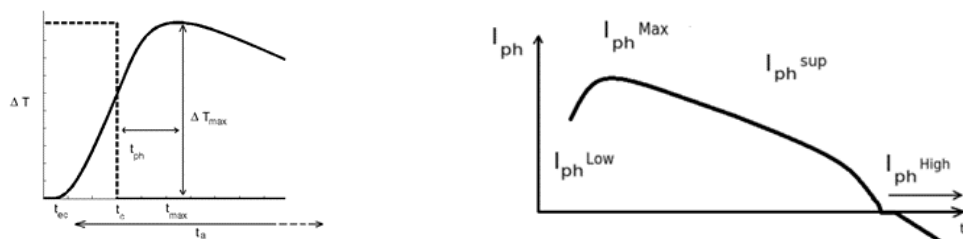


Figure 1 Absolute thermal contrast characteristics (left) and indicator I_{ph} evolution with heating time duration

Keywords: NDT, Square pulse heating, Optimal Design, Civil engineering, Parameter estimation

References

- [1] A. Crinière, J. Dumoulin, C. Ibarra-Castanedo and X. Maldague, "Inverse model for defect characterization of externally glued CFRP on reinforced concrete structures: Comparative study of square pulsed and pulsed thermography", Quantitative InfraRed Thermography Journal, Taylor & Francis Editor, vol 11, pp 84-114, 2014. DOI: [10.1080/17686733.2014.897512](https://doi.org/10.1080/17686733.2014.897512).
- [2] L-D. Théroux, J. Dumoulin and X. Maldague, "Square heating applied to shearography and active infrared thermography measurements coupling: from feasibility test in laboratory to numerical study of pultruded CFRP plates glued on concrete specimen", Strain journal, Wiley editor, 2014. doi:[10.1111/str.12086](https://doi.org/10.1111/str.12086).
- [3] V. Feuillet, L. Ibos, M. Fois, J. Dumoulin, Y. Candau, "Defect detection and characterization in composite materials using Square Pulse Thermography coupled with Singular Value Decomposition analysis and thermal quadrupole modeling", NDT&E International, Volume 51, Octobre 2012, pp 58-67, Elsevier, <http://dx.doi.org/10.1016/j.ndteint.2012.06.003>.