Optik 163 (2018) 43–48

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Improvement of crack detection on rough materials by digital holographic interferometry in combination with non-uniform thermal loads

F. Vincitorio [a,*], L. Bahuer [a], M.P. Fiorucci [a,b], A.J. López [b], A. Ramil [b]

[a] *GIF-FRP, Universidad Tecnológica Nacional, Almafuerte 1033, CP3100, Paraná, Entre Ríos, Argentina*
[b] *Laboratorio de Aplicacións Industriais do láser, Centro de Investigacións Tecnolóxicas, Universidade da Coruña, Campus de Ferrol, 15471 Ferrol, Spain*

A R T I C L E I N F O

Article history:
Received 19 May 2017
Accepted 20 February 2018

Keywords:
Digital holography
DHI
Crack investigation
Rough surfaces
Non-uniform heating
Unwrapping phase maps

A B S T R A C T

The aim of this work is to present an experimental procedure to improve crack detection in rough surfaces by means of lensless Fourier digital holographic interferometry (DHI). To overcome the problem of analyzing high speckle interferograms that blurs phase maps and hinders, or even prevents, crack detection, it is proposed the application of a non-uniform thermal load to the object under study, as excitation source, instead of the most common uniform heating. Different tests with mock ups of cracks of controlled width allowed us to demonstrate the effect of a non-uniform thermal load, and confirmed the enhancement in DHI information, especially in unwrapping phase maps. Finally, DHI was applied to the detection of a crack in a cast iron sample and the results obtained with both uniform and non-uniform heating procedures were compared and the improvement attained by means of non-uniform heating was confirmed.

© 2018 Published by Elsevier GmbH.

1. Introduction

Fracture detection is an important issue in different engineering fields, from aeronautics to civil engineering [1–3]. Up to 90% of failures of in-service metallic structures can be attributed to fatigue cracks [4]. The fatigue crack can grow rapidly and lead to a sudden catastrophic failure of the entire system; therefore, it is of vital importance to detect it, as early as possible.

Different methods for crack detection have been reported (see e.g., Yao et al. [2]); however, optical methods have gained more and more attention, mainly because of their non-destructive character, high precision and sensitivity [5,6]. In this sense, digital holographic interferometry (DHI) has been used in different fields for the detection of cracks, flaws, failure of paint/coating, etc. [8–13].

In digital holographic interferometry (DHI) two holograms are captured in different states of the object and the fringe pattern is reconstructed by the digital combination of the individual phase holograms. Any localized defect in the surface of the object can provoke discontinuities in the interference fringe pattern and, from the shifts in the phase map, these defects or flaws can be detected and characterized. Temporal and spatial phase shifts techniques for analyzing fringe patterns usually result in wrapped phase maps, i.e., phase values Φ which lie in the range $(-\pi, \pi)$. There are different phase unwrapping

* Corresponding author at: Grupo de Física Aplicada a la Ingeniería, Facultad Regional Paraná, Universidad Tecnológica Nacional, Almafuerte 1033, CP3100 Paraná, Entre Ríos, Argentina.
E-mail address: fisicaelectronica@frp.utn.edu.ar (F. Vincitorio).

https://doi.org/10.1016/j.ijleo.2018.02.068
0030-4026/© 2018 Published by Elsevier GmbH.

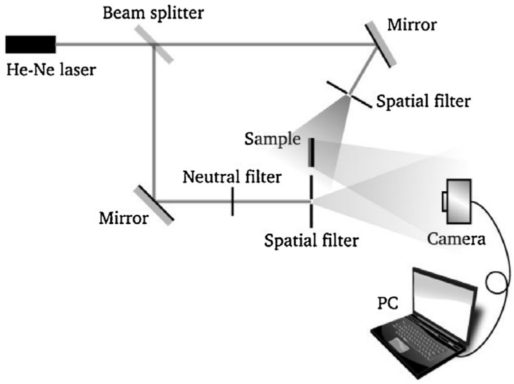

Fig. 1. Scheme of a double way holographic recording setup.

approaches; among them, phase quality guided path following, and Goldstein's brunch-cut methods are the most common. Description of both approaches can be found elsewhere [15]; and for a recent review, with a detailed accuracy comparison, see [16]. In general terms, the branch-cut approach uses to be more effective to detect cracks than the quality-guided, which always generates unwrapping phase maps without discontinuities.

One of the most frequent error sources that arise in the analysis of fringe patterns, especially in the case of rough surfaces, is the speckle noise which, in addition to the low resolution of the CCD camera, results in blurred interference patterns that lead to fuzzy phase maps and, consequently, poor performance in the detection of cracks or flaws [14]. On the other hand, when a DHI system is implement in laboratory or in field conditions it is usual the application of a uniform thermal load as excitation source. In such cases, the lack of residual stress increases the difficulty of crack recognition.

The aim of this work is to present an alternative excitation procedure based on the application of a directional, non-uniform, thermal load to the test sample. Our premise is that in the case of isotropic materials, the process of dilatation under a uniform thermal load is the same in any direction, regardless of the existence of cracks or fissures; however, when the thermal excitation is directional, non-uniform, the dilation processes give rise to different elongation at both sides of the fissure, and crack detection by DHI could be improved.

The work is structured as follows: firstly the experimental set up for DHI and the sample to be analyzed are described; secondly different tests on simulated cracks of controlled width are presented to show the effect of a non-uniform thermal load in the interference patterns. Finally, the proposed experimental procedure was applied to the sample to confirm the improvement in DHI results.

2. Experimental

2.1. Experimental set up

A scheme of the experimental arrangement for the lensless Fourier holographic recording used in this work is shown in Fig. 1. The light emitted by a 30 mW, 632.8 nm, He-Ne laser was divided by a beam splitter; one of the beams illuminated the object and the other was directed to a reference mirror. The object beam was arranged with a 15 μm spatial filter to illuminate a region of around 10 cm^2, and the reference beam was conducted to the CMOS camera using a 5 μm spatial filter. The distance camera-object, less than 40 cm, was adjusted according to the size of the object. A variable neutral filter consisting in two polarizers was used to equalize the intensity of both reference and object beams.

To reduce the spatial harmonic content and the superposition of different orders on the resulting digital image, the value of the gamma correction and the position of the object relative to the reference beam were properly chosen (to separate the first-order terms in the DC light and to lead higher order terms outside the dimensions of the matrix image) [21].

The hologram was recorded by a 5 Mpx (2592 × 1944 pixel) CMOS camera without objective lens connected to a computer via USB II port without frame grabber. The pixel size of the camera sensor was 2.2 μm × 2.2 μm. The computer with I5 microprocessor and 4 GB RAM memory processed the captured image and reconstructed the DHI through MATLAB® environment (R2012). The script reconstructed all images, both the fundamental and higher spatial orders. The user selected the region of interest in the fundamental image (real or virtual) and entered the values of the parameters required for the reconstruction of the phase map, the filtered image and the unwrapping map.

With regards to the reconstruction of phase images, in order to reduce the speckle noise and maximize the phase jump, a filtering was performed. The algorithm used was sine-cosine type, available as m-function of Matlab®, and the optimization of the filtering process was made by an interactive method.

Download English Version:

https://daneshyari.com/en/article/7223974

Download Persian Version:

https://daneshyari.com/article/7223974

Daneshyari.com