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Optics and Lasers in Engineering 44 (2006) 1336–1347
OPTICS and LASERS in ENGINEERING

A least-squares method to cancel rigid body displacements in a hole drilling and DSPI system for measuring residual stresses

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Received 13 October 2005; accepted 22 December 2005
Available online 23 February 2006

Abstract

This paper presents the evaluation of a method to cancel rigid body displacements that can be introduced when a hole drilling and digital speckle pattern interferometry (DSPI) combined system is used to measure residual stresses. The proposed method is based on a least-square calculation of three correction parameters determined from two evaluation lines located near the edge of the phase map where the displacement field generated by the drilling process is supposed to be negligible. The errors introduced by the method for different residual stress levels and rigid body displacements are analysed using a numerical simulation. An application of the method to experimental data is also presented.

Keywords: Digital speckle pattern interferometry; Residual stresses; Hole drilling; Displacement measurement

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0143-8166/$ - see front matter
doi:10.1016/j.optlaseng.2005.12.003

1. Introduction

The application of digital speckle pattern interferometry (DSPI) to evaluate the displacement field relieved by the introduction of a small hole in a mechanical component subjected to residual stresses has several advantages over the conventional measurement technique based on the use of strain gauges rosettes [1,2]. Recent efforts in this field were mainly directed to automate the determination of residual stresses by means of the application of digital data analysis techniques, usually by extracting the optical phase distribution encoded by the generated correlation fringes [3,4].

When a hole drilling and DSPI combined system is used to determine residual stresses, two sets of four speckle interferograms corresponding to the state of the specimen that had before and after the introduction of the hole are usually acquired. However, undesirable small rigid body displacements can be introduced quite frequently due to the drilling process used to relieve the residual stress field. Unfortunately, these spurious displacements can only be detected after the acquisition procedure is finished and the speckle interferograms are processed. Moreover, depending on the magnitude of the unwanted displacements, they could introduce quite important errors in the determination of the residual stresses.

Recently, Bruno and Sciumè [5] reported on the measurement of the displacement field produced by a spherical indentation using a DSPI system. In that paper, the mentioned authors presented a least-squares processing method to correct the phase values that are produced by rigid body displacements introduced during the measurement process. The purpose of the present paper is to show the application of an approach based on a similar idea to cancel the rigid body displacements that are introduced when a hole drilling and DSPI combined system is used to measure residual stresses. Our approach is based on the use of data associated to pixels near the edge of the phase map, where the displacement field relieved by the hole drilling process is very small in comparison to the one introduced by spurious rigid body motion. Since phase maps produced in hole drilling tests are quite different from the ones generated in indentation experiments, the shape of the region containing the data points to be used by the proposed method has to be selected according to their characteristics.

In order to evaluate the error produced by the least-squares method, phase maps containing rigid body displacements that were processed by the proposed algorithm were compared with those free of spurious translations. These phase maps were generated by computer simulation, since this approach enables us to control the magnitude of the rigid body displacement we want to introduce into a given phase distribution and at the same time to know the original phase map containing no movement. Finally, an application of the least-squares method to experimental data is also presented.

2. The least-squares method

As it is described in Ref. [5], the estimated phase ϕ free of rigid body motion is given by

$$\phi = \phi' - \delta, \tag{1}$$