Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Optics and Lasers in Engineering 43 (2005) 836–846
OPTICS and LASERS in ENGINEERING

Two-step digital image correlation for micro-region measurement

Jinlong Chen*, Ganmin Xia, Kebin Zhou, Guisuo Xia, Yuwen Qin

Department of Mechanics, Tianjin University, Tianjin 300072, P.R. China

Received 24 December 2003; received in revised form 9 March 2004

Abstract

A method of two-step digital image correlation is well developed with more stable and reliable calculating technology, which consists of a simple searching method and an iterative correlation method. This new method can not only improve the calculating speed and the measuring accuracy, but also simplify the process of the experiment. In order to further increase the sensitivity of the technique, the sub-pixel reconstruction is performed in sub-image by utilizing the higher precision calculation of bicubic spline interpolation value method, and the accuracy of displacement is extended to better than 0.01 pixel; the strain resolution is limited to less than 0.0002 in micro-region. The above method is applied to quantify the micro-deformation of bimaterial sample and coating sample. The experimental results show that the method of two-step digital image correlation is a potential boon to investigations at extremely small-size scales.

Keywords: Two-step digital image correlation; Micro-region; Sub-pixel rebuilt; Displacement; Strain; Coating

*Corresponding author. Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong, Tat chee Avenue, Kowloon, Hong Kong. Fax: +86 22 2335 8329.
E-mail address: jlchen@eyou.com (J. Chen).

0143-8166/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.optlaseng.2004.09.002

1. Introduction

Digital image correlation is an appealing optical method to measure deformation on an object surface based on the modern digital image processing technology and optical measurement. However, the traditional optical measurements, such as photoelasticity, moire, holography, speckle interferometrgy, shearography, etc., which need to pretreat the surface of object with spraying paint, coating and reproducing grid, and even more to make model, may give full-field information of object deformation from the interferometric fringe. Such techniques suffer from characteristic limitations and are commonly performed in the laboratory. In fact, the natural texture or the random artificial speckle on the object surface is the carrier of deformed information, and they keep one-to-one in accordance with the object's transformation. The method of digital image correlation can directly measure the transformation by tracking the gray value pattern in small local neighborhoods commonly referred to as subsets.

In the early eighties of the 20th century, digital image correlation was first used by Yamaguchi [1], Peter and Ranson [2] to focus on the determination of surface displacements. It was later formulated to improve the correlation algorithms [3-5] with simple search method, coarse-fine grid method, optimum-seeking method, and Newton–Raphson iterative method, and enable displacement measurement to sub-pixel accuracy. One common drawback among these techniques is that they, in general measure the displacement field, rather than the often more interesting strain field. The general, procedure has then been to differentiate the displacement field to obtain the strain field. The approach is not as straightforward as it first appears to be because random errors in the displacement field are magnified, they will disturb the shape of the underlying strain field and lower the precision of strain. Though some researchers [6-9,11] attempted to reduce the error of strain by eliminating the noise of displacement field firstly and then calculating the gradient of displacement, adopting the natural B-sample smooth method, or using the multi-displacement fields average method as well as exploiting the self-compensation technology, other researchers [10,12] tried to extend the method to measure the specimen's mechanical strain and thermal strain in high-temperature situation, and to determinate micro-parameters of rock; only a little progress has been made to advance the strains precision at the micro-region. At the same time, low strain precision hinders the method application in the micro-region measurement.

In this paper, a method of two-step digital image correlation is developed to measure the displacement field and strain field in micro-region. Firstly, the simple search method is applied to provide an estimate of displacement field to sub-pixel accuracy, then the displacement value is used as the initial value for the iterative method. Because we assumed that the subset deformation field is heterogeneous and 12 parameters are independent variables, and introduced the bicubic spline interpolation value to perform sub-pixel rebuilt, the accuracy of displacement and strain are improved appropriately. The method is suitable to measure the deformation in micro-region and gradually expanded from conventional material to new type of material, from elastic problem to viscoelastic problem, from the