Available online at www.sciencedirect.com

ScienceDirect

Composite Structures 76 (2006) 272–281

COMPOSITE STRUCTURES

www.elsevier.com/locate/compstruct

Damage localization in laminated composite plates using mode shapes measured by pulsed TV holography

J.V. Araújo dos Santos [a], H.M.R. Lopes [b], M. Vaz [c], C.M. Mota Soares [a,*], C.A. Mota Soares [a], M.J.M. de Freitas [d]

[a] *IDMEC/IST, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisboa, Portugal*
[b] *ESTIG – Instituto Politécnico de Bragança, Campus de Sta Apolónia, Apartado 134, 5301-857 Bragança, Portugal*
[c] *DEMEGI – Faculdade de Engenharia do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal*
[d] *ICEMS/UME, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisboa, Portugal*

Available online 26 July 2006

Abstract

Three methods for the damage localization of impact damage in laminated composite plates, based on their vibrational characteristics, are presented in this paper. These methods use double pulse TV holography with acoustic excitation for mode shapes acquisition and the differences in translations, rotations and curvatures. The rotations and curvatures are obtained by numerical differentiation of mode shapes translations using a differentiation/smoothing technique. The methods are applied to a carbon fiber reinforced epoxy rectangular plate, free in space, subjected to two cases of impact damage. It is shown that the method based on curvatures allows the localization of both cases of damage, which can be undetected by visual, X-ray or C-scan inspections. The best localizations are achieved by selecting and applying the method to the most changed mode.

Keywords: Damage localization; Laminated plate; Mode shape; Pulsed TV holography; Acoustic excitation; Non-destructive inspection

1. Introduction

In recent years the use of laminated composite materials in many mechanical and aerospace engineering structures has seen a huge increase, due, among other factors, to their specific stiffness and strength. However, because of these materials characteristics, damage can be produced during fabrication or by inappropriate or hazardous service loads. Delamination is one the most common and dangerous damages, caused by internal failure of the laminas interface. These internal damages can be undetected by visual inspection. Therefore, in order to assess the structure integrity, non-destructive inspection methods are needed for damage localization. The most used non-destructive inspection methods are either visual or localized experimental methods such as acoustic or ultrasonic methods, magnet field methods, radiographs, eddy-current methods and thermal field methods [1]. These experimental methods can detect damage on or near the surface of the structure [1], therefore not allowing the detection of delaminations.

The use of vibration based delamination identification and health monitoring techniques for composite structures have been surveyed by Zou et al. [2]. The level of success in identifying damage is directly related to the sensitivity of the applied measurement technique and the parameters used in the identification methodology. Abdo and Hori [3], showed numerically that damage localization by mode shapes can be more easily accomplished if rotation differences are involved. However, in the presence of small defects with noisy data, obtained from experimental measurement, the use of rotations can mislead the damage localization. In these cases, a higher sensitivity parameter, like the curvature or strain energy, could be used instead [4,5].

* Corresponding author. Tel.: +351 21841 7455; fax: +351 21841 7915.
E-mail address: cmmsoares@alfa.ist.utl.pt (C.M. Mota Soares).

0263-8223/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compstruct.2006.06.034