RECENT ADVANCES IN INTEGRITY-RELIABILITY-FAILURE

J.F. Silva Gomes, Shaker A. Meguid
Editors

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EDITORS PREFACE

As the engineering community continues to cross the boundaries of known practices, materials and manufacturing techniques into the frontiers of new functional materials, environments and applications, the opportunities for catastrophic failures will inevitably increase. If our knowledge of how to engineer systems, structures and components to minimize or prevent catastrophic failure is to keep pace with modern manufacturing technologies, the demanding applications, and the intolerance of a safety conscious society, we must continue our efforts to develop and use superior materials, apply reliable analytical techniques and validate these with sound experimental tools. It is with this in mind that this series of conferences was organised.

The objectives of this gathering are to provide a forum for the discussion and dissemination of recent advances in assessing the integrity, reliability and failure of engineering structures, components, and assemblies, foster research in these areas, and promote international co-operation among scientists and engineers in the field. The goal is to enable concerned researchers and scientists from all over the world to exchange ideas on mechanics, materials and design as they relate to system integrity and reliability.

This fourth international conference, which is sponsored by the University of Porto, the University of Toronto and the University of Madeira, is part of a prestigious series of Integrity Reliability and Failure conferences coordinated by the International Scientific Committee on Mechanics and Materials in Design. The conference attracted over 300 participants with 380 accepted submissions from 45 different countries around the world. These papers were presented in June 23-27, 2013 in the magnificent city of Funchal, Madeira. The conference themes which address integrity, reliability and failure focused on Analytical and Numerical tools, Testing and Diagnostics, Surface and Interface Engineering, Sensors and Instrumentation, Tribology, Mechanical Design and Prototyping, Modes of Failure, Composite Materials, Nanotechnologies and Nanomaterials, Biomechanics, Energy and Thermo-Fluid Systems, Impact and Crashworthiness and Case Studies.

We are particularly indebted to the authors and special guests for their plenary lectures and presentations. Each of the more than 380 contributions offered opportunities for thorough discussions with the authors. We acknowledge all of the participants, who contributed with innovations, new research approaches, novel modeling and simulation efforts, and invaluable critical comments. We are also indebted to the outstanding plenary lecturers who highlighted the conference themes with their contributions: Professor Xiong Zhang (Tsinghua University, P. R. China), Professor E.A. Elsayed (Rutgers University, USA) and Professor Noritsugu Umehra (Nagoya University, Japan). We also take this opportunity to thank the members of the International Scientific Committee and reviewers for their time and effort.

Last but by no means least, we offer our sincere gratitude to the symposia organisers for their contribution to the success of the event and the local organising committee for attending to many aspects of the conference demands. For all of them, we are truly very grateful.

Shaker A. Meguid and J.F. Silva Gomes
Funchal / Madeira, June 2013

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PAPER REF: 4712

REAL-TIME DAMAGE IDENTIFICATION USING ROTATING FIELD ANALYSIS

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ABSTRACT

This paper proposes a real-time damage identification method based on the disturbance of the rotation field, which are measured using shearography technique. A particular case of phase modulation method is applied to the interference pattern in order to improve the spatial resolution of the rotation field. A program was developed in Matlab® platform for digital recording the information capture by CCD camera and post-processing the data using dedicated image techniques. The phase filter and unwrapping algorithms were optimized to allow the visualization at video rate the full-field rotations fields. For small internal damages in laminated composite plates, the results show a superior performance of the proposed technique when compared with the classical raw fringe analysis.

Keywords: multi-damage localisation, laminated plate, rotation field, speckle shearography.

INTRODUCTION

The low damage tolerance of laminated composite structures and the lack of effective and global non-destructive inspection techniques have recently motivated the development of new methodologies. The perturbation or discontinuity analysis of the rotation field and their spatial derivatives has been referred in literatures as the most promising techniques for damage localisation (Pandey, 1991; Abdo, 2002). Moreover, the accurate measurement of full-field rotation fields is required to identify small internal damages. On the other hand, the speckle interferometry techniques, such as Electronic Speckle Pattern Interferometry (ESPI) and the shearography prove to be the most suitable techniques for damage localisation (Seinchen, 2003). In particular, the shearography technique allows full-field, non-contact and high resolution measurement of the rotation field. Their low sensitivity to external perturbations makes this technique suitable to industrial applications and being the rotation measurement unaffected by rigid body movements, the discontinuities and perturbations in the rotation field, associated to the internal damages, can be rapidly identify. The classical approach for internal damage localization is based on the detection of anomalies in the raw fringe spatial distribution. Since damage localisation is supported recognition and classification of fringe patterns, the identification process fails when there aren't enough fringes produced by the external loads. This scenario can occur for small internal damages or when they are located deeply inside of the structure. Instead of the fringes pattern disturbances recognition, this paper proposes the real time analysis of local perturbation or discontinuities of rotation field for damage localisation. The rotation field is obtained by filtering and unwrapping the phase map. The phase map is obtained by the correlation of light phase from a reference and deformation states. Generally for static deformations, the determination of the light phase

requires the digital recording of four intensity interferograms with different phase step (Kreis, 2005). In our case, the phase map is obtained by recording the four intensities at the reference stated, with constant phase step of $\pi/2$, being intensity interfererogram of deformation subtract to each of reference intensity. A program was developed in Matlab® platform to digitally acquire the intensity pattern created optical interferometer and post-processing the phase maps. The phase filter and unwrapping algorithms were optimized to allow at video rate the visualization of the rotation field.

RESULTS AND CONCLUSIONS

The rotation field was measured in a carbon fibre laminated plate with two different size damages, using speckle shearography technique. The plate is fixed in one edge to a high rigidity support and mounted on an optical table, in order to impart greater stability to the assembly and experimental measurement.The thermal load was applied on one side of the plate, by heating surface during 5 seconds with a 100 W halogen lamp, rising the surface temperature in 2 ºC. The reference state was recoded after the thermal load was applied and the rotation field was monitored during the cooling process. The figure 1 shows the rotation field obtained 10 seconds after removing the thermal load. The two damages location and their difference in size can be identify through the perturbation analysis of the rotation field.

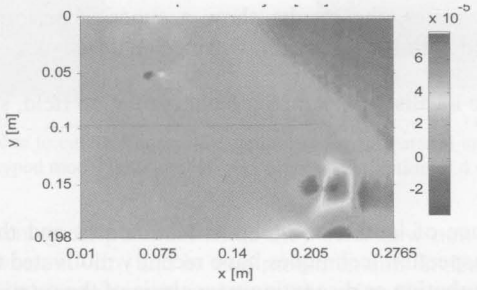

Fig. 1 - The rotation field measured during the cooling process (10 s).

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REFERENCES

[1]-Pandey A. K., Biswas M., Samman M. M., "Damage Detection from Changes in Curvature Mode Shapes", Journal of Sound and Vibration, 145(2), 321-332, 1991.

[2]-Abdo M. A.-B., Hori M., "A numerical study of structural damage detection using changes in the rotation of mode shapes", Journal of Sound and Vibration 251(2), 227-239, 2002.

[3]-Seinchen Wolfgang, Lianxiang Yang, Digital Shearography -Theory and Application of Digital Speckle Pattern Shearing Interferometry, 2003, SPIE Press.

[4]-Kreis T., Handbook of holographic interferometry: optical and digital methods, Weinheim: Wiley-VCH, 2005.