

IRF'2013

Funchal/Portugal
2013



4th International Conference on
INTEGRITY, RELIABILITY & FAILURE
(Funchal, 23-27 June 2013)

IRF2013

PROGRAM



University of Porto
University of Toronto
University of Madeira

Institutional Sponsors

FEUP
*University of Porto
Portugal*

MADL
*University of Toronto
Canada*

CCEE
*University of Madeira
Portugal*

Co-Chairs

J.F. Silva Gomes (*U. Porto*)
Shaker A. Meguid (*U. Toronto*)

Organizing Committee

Carlos C. António, Clito F. Afonso, José M. Cirne
Lino Maia, Mário A.P. Vaz, Paulo G. Piloto, Pedro M.G.P. Moreira

International Scientific Committee

Aben, H. (Estonia)	Dourado, N. (Portugal)	Masato, Y. (Japan)	Sainov, V. (Bulgaria)
Abreu, M.J. (Portugal)	Eberhardsteiner, J. (Austria)	Meda, A. (Italy)	Santos, J.M. (Portugal)
Adali, S. (S. Africa)	Esteves, J.L. (Portugal)	Meguid, S.A. (Canada)	Santos, Telmo (Portugal)
Afonso, C.F. (Portugal)	Fangueiro, R. (Portugal)	Melo, F.Q. (Portugal)	Semenski, D. (Croatia)
Alexopoulos, N. (Greece)	Fernandes, A.A. (Portugal)	Mileiko, S.T. (Russia)	Silva, A.J. (Portugal)
Alves, A. (Portugal)	Ferreira, D. (Portugal)	Miller, R.E. (Canada)	Silva, Lucas (Portugal)
António, C.C. (Portugal)	Ferreira, J.G. (Portugal)	Mines, R. (UK)	Silva Gomes, J.F. (Portugal)
Banks-Sills, L. (Israel)	Fiúza, A. (Portugal)	Miranda, R. (Portugal)	Sjödahl, M. (Sweden)
Baptista, J.S. (Portugal)	Fonseca E. (Portugal)	Moreira, F. (Portugal)	Soares, C.M. (Portugal)
Barros, R.C. (Portugal)	Gdoutos, E. (Greece)	Moreira, P. (Portugal)	Sousa, L.C. (Portugal)
Bathe, K.J. (USA)	Geraldes, M. (Portugal)	Morimoto, Y. (Japan)	Sousa, R. (Portugal)
Botsis, J. (Switzerland)	Guedes, R.M. (Portugal)	Moura, M.F. (Portugal)	Suleman, Afzal (Portugal)
Bremand, F. (France)	Hejum, Du (Singapore)	Muc, Aleksander (Poland)	Takagi, T. (Japan)
Caetano, E. (Portugal)	Igartua, A. (Spain)	Navarro, C. (Spain)	Talaia, M. (Portugal)
Camanho, P. (Portugal)	Ignaszak, Z. (Poland)	Navas, H. (Portugal)	Tamalsky, E. (Brazil)
Campos, J.R. (Portugal)	Iliescu, N. (Romania)	Pappalettere, C. (Italy)	Tamuzs, V. (Latvia)
Castro, C.F. (Portugal)	Jones, N. (UK)	Pieczyska, E. (Poland)	Tavares, J.M. (Portugal)
Castro, P.T. (Portugal)	Jorge, R.N. (Portugal)	Piloto, P. (Portugal)	Tavares, P. (Portugal)
Catarino, A. (Portugal)	Kahlen, F.-J. (S. Africa)	Pindera, M.J. (USA)	Thomsen, O.T. (Denmark)
Cavalcante, M. (Brazil)	Klein, W. (Germany)	Prime, M. (USA)	Tooren, M.J. (Netherlands)
Chen, T. (Taiwan)	Kourkoulis, S. (Greece)	Quelhas, O. (Brazil)	Truman, C.E. (UK)
Chenot, J.-L. (France)	Laermann, K. (Germany)	Ramesh, K. (India)	VanHemelrijck, D. (Belgium)
Cirne, J. (Portugal)	Langseth, M. (Norway)	Reddy, J.N. (USA)	Varum, H. (Portugal)
Correia, A. (Portugal)	Lima, G. (Brazil)	Restivo, M.T. (Portugal)	Vasques, C. (Portugal)
Croccolo, D. (Italy)	Lino, J. (Portugal)	Ribeiro, J.E. (Portugal)	Vaz, Mário P. (Portugal)
Cunha, A. (Portugal)	Lopes, H. (Portugal)	Robinson, J. (Ireland)	Vilas-Boas, J. (Portugal)
Datta, S. (USA)	Lu, Jian (Hong Kong)	Rocha, A.B. (Portugal)	Wang, Wei-Chung (Taiwan)
Degrieck, J. (Belgium)	Madureira, L. (Portugal)	Rodrigues, H. (Portugal)	Weng, G. (USA)
Dias, G. (Portugal)	Maia, Lino (Portugal)	Rodrigues, J.D. (Portugal)	Yoneyama, Satoru (Japan)
Dietrich, L. (Poland)	Mal, A. (USA)	Ruiz, G. (Spain)	Yoon, Y.C. (Singapore)
Diogo, M.T. (Portugal)	Marques, A.T. (Portugal)	Ruzicka, M. (Czech R.)	Zhang, Z. (China)

Conference Secretariat

Nuno Pinto, Lurdes Catalino, Carla Gonçalves
M.F. Silva Gomes,

with the support of

ABREU-PCO, Professional Congress Organizer (<http://pco.abreu.pt>)
Mercatura Conference System (<http://www.mercatura.pt>)

4622	STIFFENER LAYOUT OPTIMIZATION OF THE OVERALL BUCKLING OF THIN-WALLED STIFFENED PLATE. Lianchun Long, Yang Li .	517
4012	ADDRESSING GEOMETRICAL NONLINEARITY CONSIDERING PROBABLISTIC MATERIAL NONLINEARITY. Iffat Siddique.	521
4659	APPLICATION OF ANALYTICAL TARGET CASCADING TO THE DESIGN OF A RAILWAY VEHICLE SUSPENSION SYSTEM. Dário Silva, Hugo Policarpo, Miguel M. Neves, Virgínia Infante.	519

TUE, 16:00-17:30		SESSION 6G	Room G
Symp_12: VIBRATION AND STRUCTURAL ACOUSTICS ANALYSIS			
Chair: César Vasques (INEGI, Portugal)			
REF:	Title and Author(s):	Page:	
4658	A METHODOLOGY FOR THE PERFORMANCE EVALUATION OF DIFFERENT SURFACE DAMPING TREATMENTS. Márcio Furukava, Hugo Policarpo, Miguel M. Neves, Nuno M.M. Maia, Olavo M. Silva, Dário Silva, Samir N.Y. Gerges.	553	
4691	ON EFFECT OF MECHANICAL PROPERTIES OF POROUS MATERIALS ON THE TRANSFER OF ACOUSTIC VIBRATIONS. Elena Prokofieva, Mike Barker, Minsung Cho.	557	
4733	NEW VIBRODYNAMIC PHENOMENA RELATIVE TO THE SPECIFIC VOLUME FORMS OF LOOSE/GRANULAR MATTER. Yuri Makov.	559	
4746	SOUND AND VIBRATION IN AN INTERDISCIPLINARY CONTEXT; SOME EXAMPLES FROM THE LAB. Jan Tro, Ulf Kristiansen.	561	
6001	SPACE QUALIFICATION OF AN ULTRA LOW-SHOCK NON-EXPLOSIVE ACTUATOR FOR HOLD-DOWN AND RELEASE MECHANISMS: INITIAL TESTS. O.M.F. Morais, C.M.A. Vasques, L.M.S. Guimarães, P.M.G. Salvado, C. Perestrelo, V. Pimenta, G. Baldesi.	NA	

TUE, 17:30 - 18:30		POSTER SESSION III	Lounge
Symposia: 1 to 15			
REF:	Title and Author(s):	Page:	
3993	POWER HARVESTING APLICATION. Carlos A. Gallo, Roberto M.F. Neto, Amanda M. Souza, Leonardo R.O. Condor, Roberta C.S. Moreira.	427	
4687	REVIEW OF POSSIBILITY APPLICATION SHAPE MEMORY ALLOY IN KINETIC ENERGY RECOVERY SYSTEMS. Wojciech Klein, Arkadiusz Mężyk.	425	
4750	X-RAYS TOMOGRAPHIC RECONSTRUCTION IMAGES OF MATERIALS USING INVERSE PROBLEM RESOLUTION BASED ON SPARSE REGULARIZATION METHOD. Aicha Allag, Redouane Draï.	439	
4634	DISPLACEMENT AND STRAIN FIELDS ASSESSMENT OF PDMS USING DIGITAL IMAGE CORRELATION. Bebiana Mendonça, João Ribeiro, Hernani Lopes, Pedro Martins, Mário A.P. Vaz, J.F. Silva Gomes.	447	
4712	REAL-TIME DAMAGE IDENTIFICATION USING ROTATING FIELD ANALYSIS. Hernani Lopes, João Ribeiro, J.V. Araújo Santos, Mário A.P. Vaz, J.F. Silva Gomes.	451	
4654	ON THE MECHANICAL FAILURE OF ARTERIAL PROSTHESES. Catarina F. Castro, Carlos C. António, Luísa C. Sousa.	465	
4045	MOUTHGUARD FOR ORTHODONTIC PATIENT TRUMPET PLAYER. Maria João Ponces, Saúl Castro, Maria Cristina Pollmann, Paula Vaz, Jorge Dias Lopes.	487	
4014	CONE BEAM COMPUTED TOMOGRAPHY AND PROSTHODONTIC REHABILITATION OF CLEIDOCRANIAL DYSOSTOSIS. Paula Vaz, Maria Ponces, Inês Corte-Real, Afonso Ferreira, José R. Campos.	491	
4306	PRENATAL ULTRASOUND SCREENING, TOOTH GERMS HISTOLOGY AND HYPODONTIA. Mariana Seabra, António Felino, Francisco Valente, Rosete Nogueira, Paula Vaz.	495	
4682	INOVATIVE HYBRID JOINT TECHNIQUE THROUGH FRICTION STIR WELDING AND ADHESIVE BONDING. Daniel F.O. Braga, Ana Silva, Miguel A.V. Figueiredo, L.F.M. Silva, Pedro M.G.P. Moreira.	533	
4715	STUDY OF ALTERNATIVE MANUFACTURING PROCEDURES FOR AN ALUMINIUM RAILWAY CAR PASSENGER UNDERFRAME. João P.A. Dias, Daniel F.O. Braga, Sérgio M.O. Tavares, Pedro M.G.P. Moreira, Paulo M.S.T. Castro.	535	
3952	A PARAMETRIC STUDY ON THE INFLUENCE OF VARIOUS PARAMETERS ON THE UNDERWATER NOISE LEVELS GENERATED BY OFFSHORE PILE DRIVING. Gargi Kaushik, Apostolos Tsouvalas, Andrei Metrikine.	541	
4092	MECHANICAL CONTROL OF INELASTIC CHARACTERISTICS, DEFECT NANOSTRUCTURE CHANGING OF SiO ₂ + Si WAFER-PLATE, GeSi. A.P. Onanko, S.A. Vyzhva, Y.A. Onanko.	547	
4684	DYNAMIC RESPONSE OF LAYERED SATURATED SOIL SUBJECT TO SUBWAY TRAIN LOADS. Ding YuQin, Chen ChunLai, Gao ShuWei, Tao Rong.	555	

1- 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. Therefore, the discontinuities and perturbations in the rotation field, associated to the internal delaminations, 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 based on the recognition and classification of fringe patterns, the identification process fails when there isn't enough fringes produced by the external loads, due to small damage size or when they are located deeply inside of the structure.

2- OBJECTIVES

Instead of the fringes pattern disturbances recognition, this paper proposes the real-time analysis of local perturbation or discontinuities in the rotation field for multi-damages localisation in a laminate composite plate. The rotation field is measured by using speckle shearography interferometric system. The time phase modulation technique is applied for the quantification and to increase the spatial resolution of the interference phase. The phase map of the surface rotation is evaluated a real-time by correlating the interferogram phase between two loading states. The rotation fields are computed by filtering and unwrapping the phase maps, through the used of dedicate image processing techniques. The acquisition and the post-processing algorithms are optimized to allow the visualization at video rate the rotation field. The real-time analysis of rotation fields perturbations allows to improve damage localisation, through the elimination the need for interpretation of the fringes pattern and by improving the spatial resolution of the measurements.

3- METHODOLOGY

The multi-damage analysis is performed in a carbon laminated composite plate with 276.5 mm long, 198 mm wide and 1.825mm thick. The two internal damages were created by two different low-speed impacts, through the free fall of a steel sphere, being the energy 13.5 J and 26.2 J of the first and second impact, respectively. After the impacts, no damage could be seen on the plate surface, Figure 1.

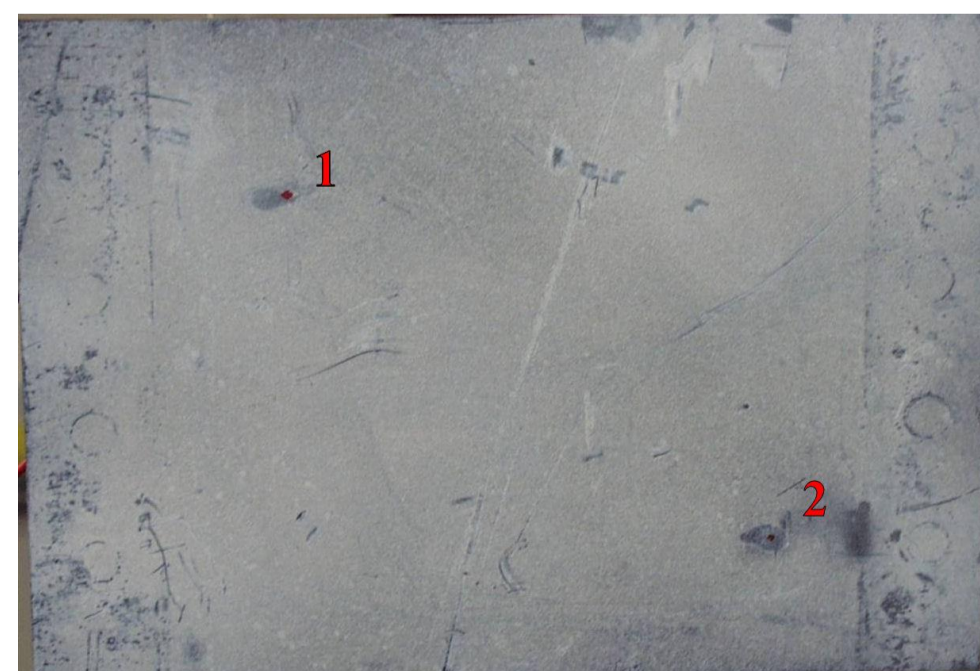


Figure 1: The damage location on the plate created by two low-speed impacts

The rotation field on the plate was measure using speckle shearography system, which were developed based on the optical Michelson interferometer. This use 4 Megapixel CMOS sensor of Dalsa camera model Falcon 4M30 to capture the interference speckle pattern, allowing a high spatial resolution with 2352x1728 measurement points in horizontal and vertical direction, respectively. The time modulation technique with constant phase-step is applied for the interference phase evaluation. This is accomplish through the translation one of the Michelson interferometer mirrors, by the actuation of a piezoelectric. A He-Ne continues-wave laser of 30 mW with a wavelength of $\lambda=694$ nm is used to illuminate the measurement surface. This was cover with a thin layer of white powder to produce a uniform light reflection. In order to impart greater stability to the assembly and experimental measurement, the plate was fixed in one edge to a high rigidity support and mounted on an optical table. The general view of the experimental set-up is shown in Figure 2.

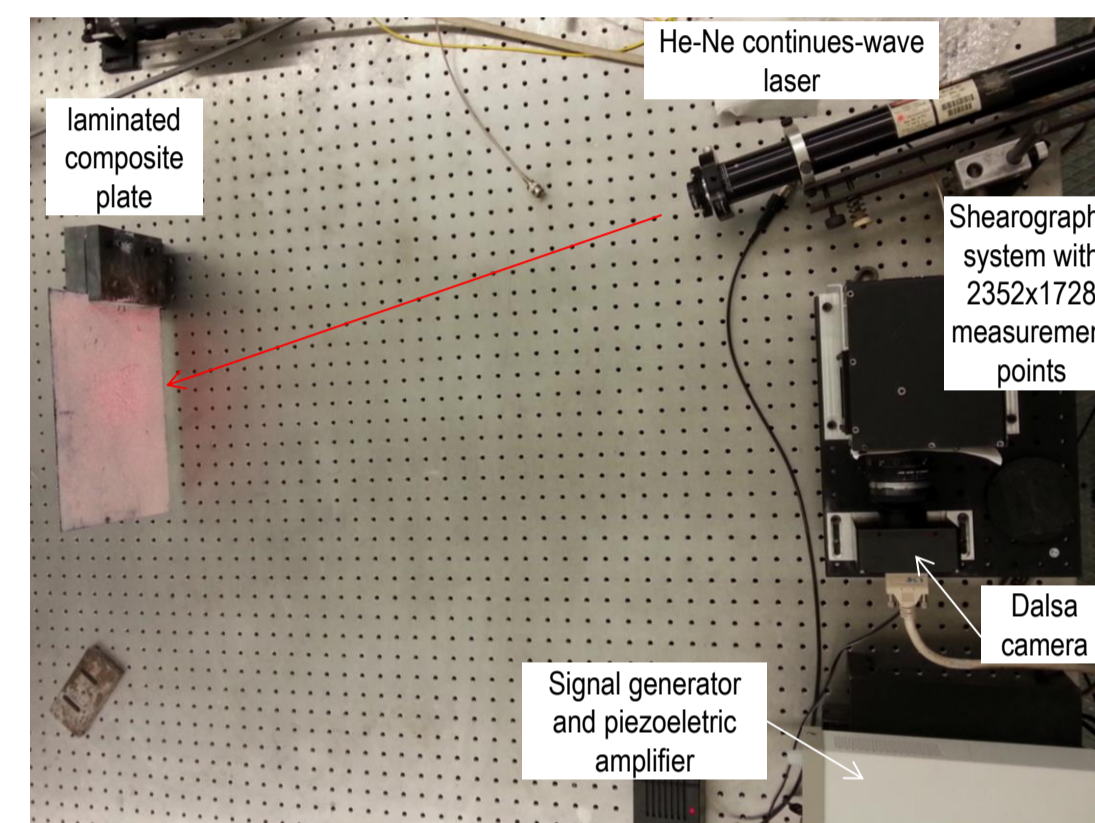


Figure 2 – General view of experimental setup.

The thermal load is 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 °C. The phase map produced by the thermal load 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 $\Delta\phi(x, y)$ is computed by recording the four intensities at the reference position or unloading state with constant phase step of $\pi/2$ ($I_R^0, I_R^{\pi/2}, I_R^\pi, I_R^{3\pi/2}$), being intensity interferogram (I_D) acquired after the thermal load subtract to each of reference intensity, and is defined by:

$$\Delta\phi(x, y) = \arctan \frac{|I_D - I_R^{3\pi/2}| - |I_D - I_R^{\pi/2}|}{|I_D - I_R^0| - |I_D - I_R^\pi|}$$

where x and y are, respectively, the horizontal and vertical plate coordinates. The rotation fields are computed by filtering and unwrapping the phase maps. The high frequency noise in the phase maps is partially remove by applying average filter through image convolution technique and the phase discontinuities are removed using Goldstein unwrapping method (Ghiglia, 1998). A relation between of the rotation field along x-axis $\Theta_x(x, y)$ and the measurement phase map can be established:

$$\Theta_x(x, y) = \frac{\lambda}{2\pi\Delta x} \Delta\phi(x, y)$$

being Δx the shearing value in horizontal direction. This can be control by adjusting the rotation of one of mirrors of Michelson interterferometer.

A program was developed in Matlab® platform to digitally acquire the intensity pattern created optical interferometer and post-processing the phase maps. The algorithms were optimized to allow at video rate the visualization of the rotation field. Thus, the damage localisation can be performed at real-time by identifying local perturbations or discontinuities in the rotation field during the heating and cooling process.

4- RESULTS

The rotation field was monitored real-time during the cooling process after applying the thermal load. The Figure 3 shows the raw fringes map, the filtered phase map and the corresponding rotation field at 10 seconds after removing the thermal load, using a shearing value of $\Delta x=10$ mm, .

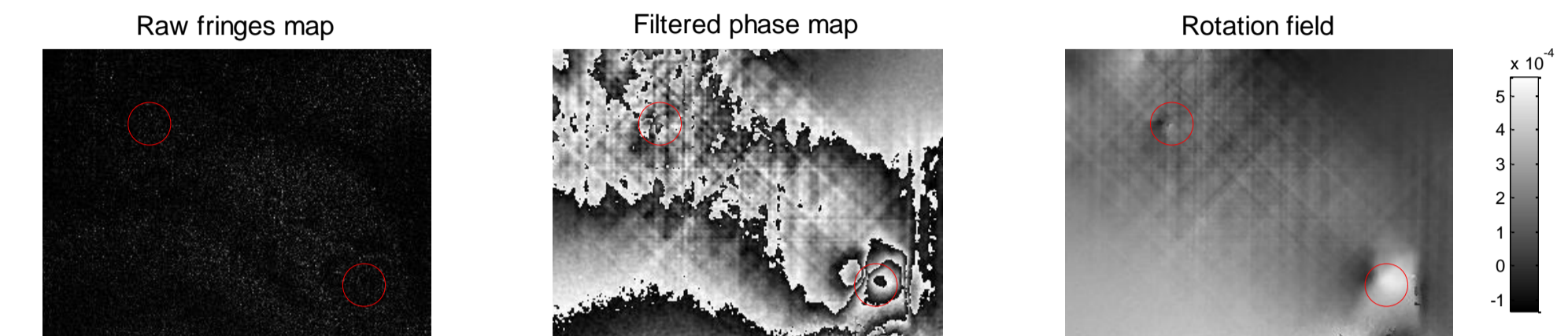


Figure 3– The raw fringes map, the filtered phase map and the rotation field obtained by speckle shearography system, being the positions of the two impacts identify by red circles.

The identification of structural damage is performed by analyzing the disturbances and discontinuities on the fringes map or in the rotation field. The raw fringes concentration near the low right edge, close to where the second impact was made, reveal the localisation of second damage (highest energy impact). This is seen more clearly by analyzing the filtered phase map, but the location first impact isn't reveal due to the presence of phase perturbations in this region. However, the analysis of the rotation field distribution presents two perturbations near to regions where the two impacts were made, allowing to correctly identify the two internal damages. This result shows a better performance of the proposed methodology for the damage localisation, which is based on the real-time analysis of the rotation field.

5- CONCLUSIONS

The proposed methodology for identification of structural damage is based on the perturbation or discontinuities analysis of the rotation fields. The high spatial resolution of the rotation field is measured at video rate by the speckle shearography system, using the time phase modulation technique. The analysis of the rotation field instead of the raw fringes or the phase maps, eliminates the need for the interpretation of the fringes pattern and increases the spatial resolution of the measurements. The comparative analysis among the application of raw fringes, phase map and rotation field for the localisation of two damages in a laminated composite plate are presented. The results show that real-time analysis of rotation field is more effective for damage localisation relatively to the raw fringe analysis. However, this methodology is much more computationally demanding.

REFERENCES

- 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.
- 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.
- Seinchen Wolfgang, Lianxiang Yang, Digital Shearography –Theory and Application of Digital Speckle Pattern Shearing Interferometry, 2003, SPIE Press.
- Kreis T., Handbook of holographic interferometry: optical and digital methods, Weinheim: Wiley-VCH, 2005.
- D.C. Ghiglia and M.D. Pritt, *Two-dimensional phase unwrapping : theory, algorithms, and software*, New York: Wiley, 1998.

ACKNOWLEDGEMENT

The authors greatly appreciate the financial support of FCOMP-01-0124-FEDER- 010236 through Project Ref. FCT PTDC/EME-PME/102095/2008..