On the detection of defects employing High Resolution Digital Image Correlation

A.J. Molina-Viedma[1], L. Felipe-Sesé[1a,] J.A. Almazán-Lázaro[1], C. Huertas-Charriel[1], E. López-Alba[2] and F.A. Díaz[2]

[1]Departamento de Ingeniería Mecánica y Minera, Campus Científico Tecnológico de Linares, Universidad de Jaén, 23700 Linares, Spain, [2]Departamento de Ingeniería Mecánica y Minera, Campus Las Lagunillas, Universidad de Jaén, 23071 Jaén, Spain

[a]lfelipe@ujaen.es

Abstract.

The detection of defects concerns many fields of engineering and it is fundamental in the weight and behaviour optimization using new additive and composite materials. Especially when discontinuities associated with the manufacturing processes or after being mechanically loaded are likely to occur.
The present work investigates the potential of Digital Image Correlation (DIC) technique to detect defects. These techniques could present an interesting alternative to traditional techniques such as ultrasound inspection or Laser Scanning Vibrometry (SLDV). DIC is based on measuring displacement and a-priori is less effective for damage detection procedures but recent advances in camera resolution allows a high sensitivity, which could compensate some aspects.
In this study, a cantilever-beam specimen with an internal discontinuity is analysed.. Mode shapes, especially that of the actual defect, are explored with 3D-DIC employing high-resolution cameras and a subsampling procedure to capture images. This procedure presents a high special resolution, unlike other approaches such as high-speed cameras. Results are compared with those obtained by SLDV.
This preliminary analysis shows the potential of full filed optical techniques in the determination of behaviours that indicates the presence of a defect.

Possible Sessions

19. Optical and DIC Techniques, 16. Novel Experimental Techniques, 5. Condition Monitoring

Introduction

The optimization in the sustainability and performance of new machines and parts usually is based on the use of new materials whose manufacturing processes or mechanical behaviour could generate inner defects or discontinuities such as composites or additive materials. Non-destructive testing and evaluation (NDT) and structural health monitoring techniques (SHM) encompass a broad set of techniques capable of evaluating the integrity of those parts [1]. SHM usually allow in-service inspection, thus, the evaluation of structural integrity can be carried out continuously. This allows identifying specific events, such as impacts, as well as monitoring the progression of possible damage. NDT allows the evaluation of the integrity of a structure without altering its behaviour or causing any damage, so that it can continue its function after the evaluation. This kind of assessment is performed when the component is not on service because it requires more manipulation, allowing more comprehensive results.
Most traditional SHM methods require the use of multiple sensors to locate the damage, which could alter it. NDT usually requires the scan of the element, which also is time consuming. There are different alternatives to perform fast scans with full-field methods based on images of different nature. Techniques based on high-frequency X-rays, thermography, or laser shearography are common [2,3]. These methods allow large surfaces to be evaluated quickly, but their cost may be higher than other techniques and some of them may be less sensitive to defects.
Due to the continuous advances in optical devices and computation, full-field optical techniques based on the visible spectrum for displacement maps or strain maps measurement represent a valuable alternative. Among others, it is worth highlighting Digital Image Correlation (DIC) which measures 2D or 3D displacements (2D-DIC and 3D-DIC respectively) [4]. Although systems based on visible spectrum range provide a global perception of the behaviour of a structure with simpler instrumentation, their sensitivity is usually lower than contact sensors, interferometry or other non-visible spectrum ranges [5]. However, the high spatial resolution that the technique is currently achieving will undoubtedly make it possible to compensate certain aspects. In fact, these optical measurement techniques are in the ascendant in mechanical engineering, particularly in dynamic testing such as vibration analysis. In this way, studies related to SHM have been carried out by subjecting components to relatively low-frequency mechanical vibrations [5], which usually result in larger displacement compare to higher frequencies. However, the use of optical techniques with high-speed cameras leads usually to lower resolution due to technical limitations. This aspect can be solved in periodical vibration tests using high-resolution cameras and developing an image capture methodology based on an adequate sub-sampling strategy. This will increase the resolution of the images and, logically, the resolution of

displacement maps obtained from them. This aspect could make it possible to detect local displacement behaviour or anomalies and, hence, it will improve its capacity for SHM and defect detection. Accordingly, the present work investigates the potential of DIC 3D to detect defects employing high-resolution cameras. Specifically, it is intended to detect specific mode shapes of defects.

Experimental Methodology and results

The experimental work intended to reveal defects in specimens by exciting at natural frequencies at which defect is excited and measured the displacement maps associated to that Operational Deflection Shape by means of Digital Image Correlation 3D. In a first step, the specimen was manufactured in natural fibre (jute-polyester) laminate (size 210x20x3 mm) with a rectangular defect (delamination) of size 50 mm starting at 5 mm of the short edge, in the middle of the thickness, as presented in Fig. 1 A).
Then, experimental natural frequencies and operational deflection shapes were accomplished using Scaning Laser Doppler Vibrometry (SLDV), Polytec PSV 400, and random excitation to detect a natural frequency on which the only the defect is excited and shows its modal shape. That frequency was 702 Hz and its modal shape observed by SLDV is shown in Fig. 1 B). Subsequently, tests employing 3D DIC were carried out on the beam. This test involved on harmonically excite the frequency of the defect obtained in previous step and record the test with a stereoscopic camera system. The image capturing of the event, using 2 AVT Alvium 12Mpx cameras, was performed at 6.1 Hz following a subsampling procedure at which the modal shape of the defect is observed at a alias frequency of 0.5 Hz. Finally, images were processed using VIC software by Correlated Solutions and result of the modal shape obtained is similar as that obtained by SLDV but, additionally, strain map could be obtained (Fig. 1 C).

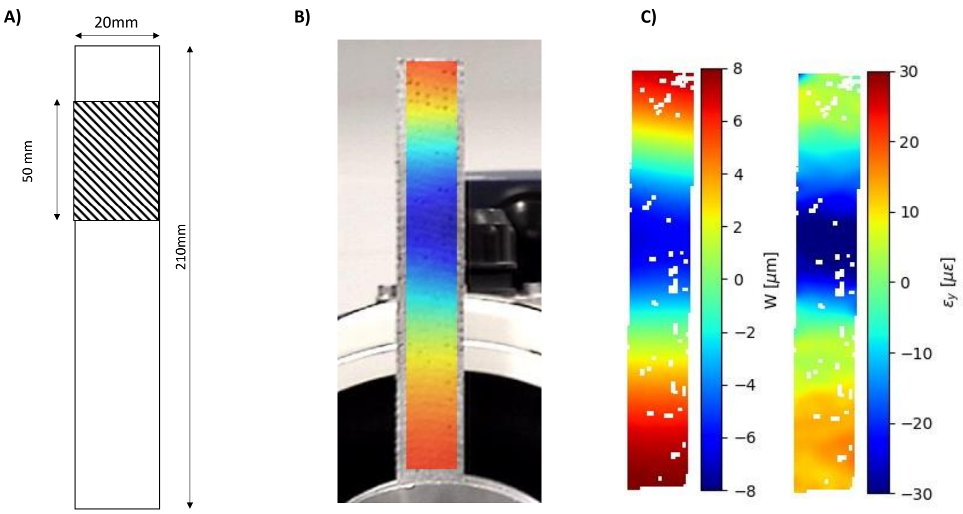

Fig. 1 A) Schematic illustration of the composite specimen evaluated where the shading area represent the defect. B) Modal shape obtained by SLDV. C) Modal shape and vertical strain map obtained employing 3D-DIC.

Conclusion

This work presents the high potential of high resolution of DIC for the detection of defects. In fact, modal shape of defects on composite material was obtained following a subsampling capture resulting in similar results as those obtained by SLDV. Compare to that technique, higher resolution and strain maps are possible, which could facilitate the definition of defect detection protocols. Further research could be performed in the detection of the objective frequencies.

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