Dynamic Analysis using Fringe Projection and Digital Image Correlation

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1. INTRODUCTION

A combination of Fringe Projection (FP) [1] and 2D Digital Image Correlation (2D DIC) [2] using a single camera has been employed to simultaneously measure in-plane and out-of-plane displacements during different dynamic events such an impact and a vibration analysis. This approach has been adopted in the past by several authors, including Mares et al. [3] who highlighted that if a telecentric lens is not employed the combination of both techniques is not straightforward since the in–plane displacements measured with 2D DIC are sensitive to the out-of-plane displacements experienced by the object during deformation. Thus, in-plane displacements measured using 2D DIC should be corrected using the out-of-plane displacements inferred using the FP technique. In the current work, an easy method for in-plane displacement correction [4] using Fringe Projection is adopted when measuring the 3D displacements during an impact on an aluminum plate and the vibration of a glass fiber composite cantilever beam.

2. METHODOLOGY

In order to be able to perform Digital Image Correlation processing, red speckle pattern was applied to the surface of the specimens. In addition, during the experiments blue fringes (RGB code 0, 0, 255) were projected over the specimen surface and a single image was recorded at each loading state. A Bayer filter was employed to separate the speckle and fringes patterns which were contained in two different images [4][5]. Speckle images were processed using the commercial software VIC 2D, while fringe images were processed using a phase stepping algorithm [6] with a quality guided unwrapping process [7].

As mentioned previously, in-plane displacements must be corrected using the out-of-plane information. The correction method is based on a pin-hole model (Figure 1) [4], which relates the virtual in-plane displacement ($\Delta y_{\Delta z}$) measured by 2D DIC with the out-of-plane distance (Δz) from a reference plane. Thus, to perform the correction, the distance between reference and lens planes (Δz) and the distance between the optical axis and a pixel position at the CCD plane are only required [5].

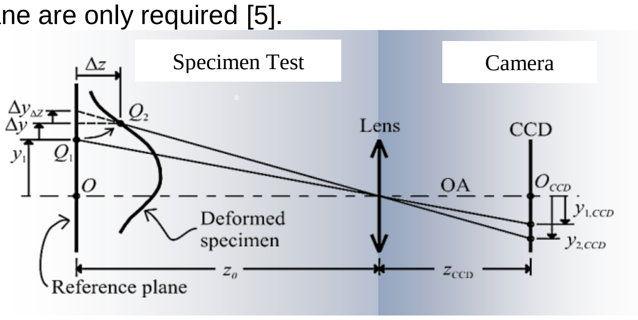

Fig. 1 Pin-hole model of FP+DIC technique

Moreover, the experimental set-up employed for impact test (Fig.2 A and B) and for vibration analysis (Fig.2 C and D) are very similar. In both cases consisted of a high-speed colour RGB camera (Photron FASTCAM SA3) with a frame rate of 3000 and 5000 fps for impact and vibration tests respectively. The camera was placed perpendicular to the specimen and a LCD projector (Epson EB-x11 and W-32 for impact and vibration test respectively) was located obliquely relative to the specimen.

Specifically, the impact test was conducted on a 150 × 150 ×3 mm^3 aluminum 1050 plate. The plate was completely clamped in its four edges having a free area of 120 × 120 mm^2. The test consisted of a drop-weight test, where a 4 mm radius hemispheric indenter impacted the specimen. A mass of 7.21 kg was positioned at a 141.4 mm height and released to generate an impact energy of 10 J. For measurement purposes, the camera observes the rear part of the specimen by the use of a 45-deg mirror, as shown in Fig. 2 A.

The vibration test was conducted on a 1,88x250x25mm composite specimen (according to ASTM-D-3039) composed by 0º unidirectional glass fiber embedded in polyester resin. It was manufactured by hand lay-up method with additional mechanical pressure in order to achieve a higher fiber volumetric rate. The specimen was clamped on a V20 Data Physics shaker which excited the cantilever beam system at 33Hz (first resonance frequency Fig. 2 C) and D)).

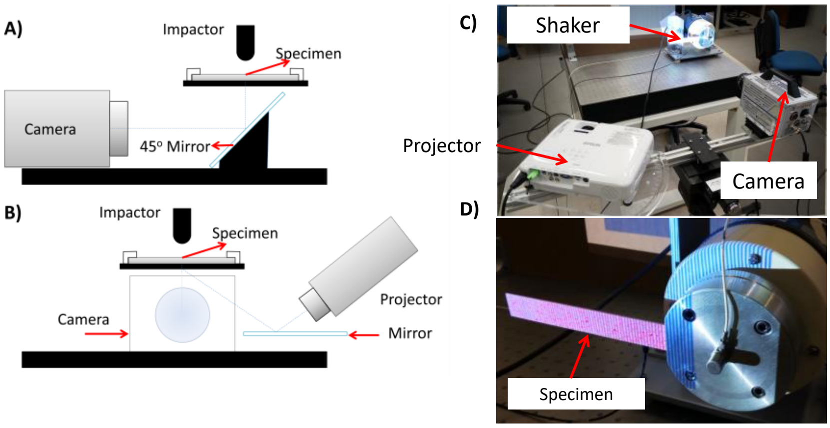

Fig. 2 A) and B) Scheme of the experimental set-up for impact test. C) and D) Illustrations of the vibration test

3. RESULTS

Maximum displacements maps obtained during the impact test are presented in Fig. 3 A) and B). Additionally, maximum and minimum displacements maps obtained during the vibration test at the first resonance frequency are presented in Fig.3 C) and D).

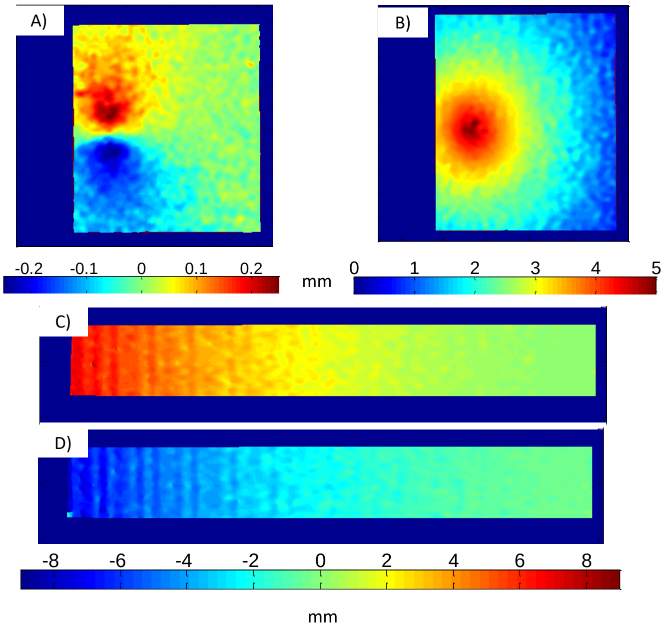

Fig. 3 Illustration showing maximum displacement results in y- (A) and z- (B) directions during impact test and maximum positive displacement (C) and minimum displacement (D) during vibration test.

3. CONCLUSION

A recent methodology for simultaneous three-dimensional displacement measurements has been presented for dynamic tests. The approach is based on a combination of fringe projection and two-dimensional digital image correlation and its applicability to dynamic testing has been demonstrated by an impact and a vibrational test. Results are comparable in quality to those obtained using three-dimensional digital image correlation with a simpler and cheaper experimental set-up.

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