Digital generation of phase-shifting fringes to provide an alternative to shearography

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The aim of this work was to create digitally phase-shift images avoiding the mechanical adjustments of the PZT, testing them with the digital shearography method. It was tested using a well-known object, a cantilever beam of aluminium under deformation, and a tooth. The results presented the ability to create the deformation map and curves with reliability and sensitivity, reducing the cost, and improving the robustness.

1 Introduction

One way to improve the quality of the images that come from the interference of the speckle patterns in digital applications, such as in digital speckle pattern shearing interferometry, is the adoption of the phase-shifting process [1, 2, 3, 4]. However, it means that one need to use an analog device, the piezoelectric actuator, to shift one of the mirrors of the interference setup. Thus, when we adopt this traditional configuration using the conventional PZT actuator we can face the nonlinearity [6] problems during the curse of the PZT, as well as an increasing of the costs. Therefore, the challenge of the viability of the new material to substitute the PZT in phase shifting and, additionally, the challenge of bias and compensation for the PZT nonlinearities create some issues of repeatability and uncertainty, which can compromise the results, or even increase the costs, complexity and number of procedures needed to overcome the issue. Additionally, the limitation presented by the pulsed laser applications to record more than one image with known phase differences boosts the search for alternatives to the techniques using a spatial carrier based on Fast Fourier Transform (FFT) calculations [5]. The limitation of using the mechanical displacement of the mirror can be also observed when the measurement needs to be conducted in an object under movement. Thus, the aim of this work was to present a protocol to create digitally the phase-shift images avoiding the mechanical action of the PZT and other new materials. The proposed protocol based on image processing from just one image was tested with a digital shearography method.

2 Methods

The configuration of a digital shearography system can be seen in Fig. 1 where the mirror linked to the PZT is expressed by an arrow regarding the shifting.

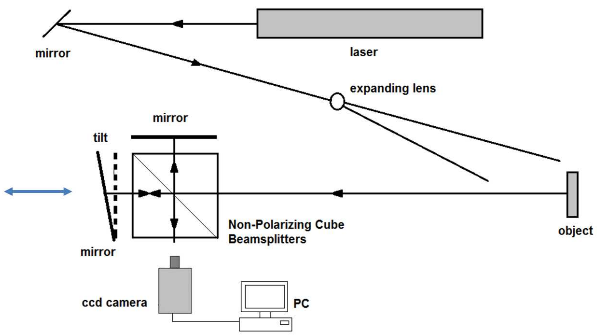

Fig. 1 *Experimental configuration of a digital shearography method with the indication of one of the mirrors being shifted.)*

The samples were placed in the object place, as presented in Fig. 1, and both, the cantilever beam and the tooth, can be seen in Fig. 2.

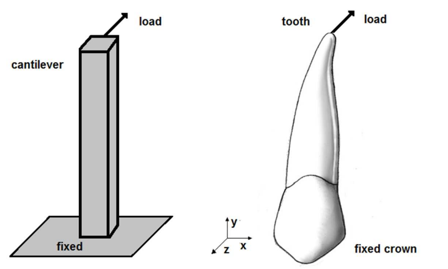

Fig. 2 *Cantilever beam and a tooth exposed to deformation and shearography.)*

The cantilever beam and the tooth was deformed using different loads, and also doing three replications of each load.

The generation of fringes shifted were done by

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means of identification of the crests and throughs in the original images with the fringes. Once the crests and throughs were identified, the next step was the interpolation of 3 new crests and throughs within each period. The interpolation respected the different period of the fringes along the sample, i.e. the distances were different to each period, since the fringes change their distance in the illuminated object. The interpolation adopted was linear.

3 Results and Discussions

In Fig. 3, the fringes generated by traditional method using the PZT and the proposed digital shifting can be seen. Visually, they present the same pattern with some differences in the edges and by the absence of filtering of noise in the outcomes of the traditional method.

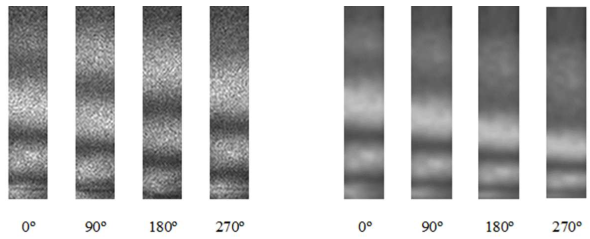

Fig. 3 *Fringes with their phase-shifting related to the traditional method using the PZT and the digital generation of the shifted fringes.*

In Figure 4 the results represent the cantilever beam during deformation related to the load 35g with the profile of the center line expressed by the simulation using the Finite Element Method, the traditional and the proposed method.

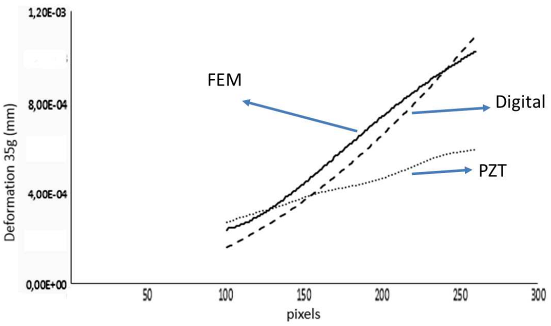

Fig. 4 *Profiles of a cantilever beam during deformation caused by a load of 30g related to the center line expressed by the simulation using the Finite Element Method, the traditional and the proposed method.*

In Figure 5 the results represent the profile of the center line of a tooth deformed by a load of 250g addressed by the traditional and the proposed method.

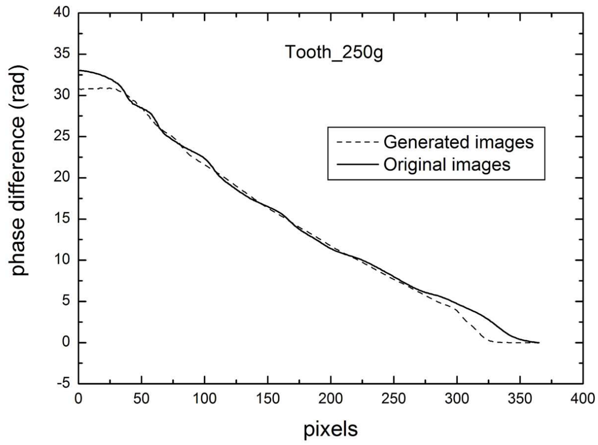

Fig. 5 *The profile of the center line of a tooth deformed by a load of 250g addressed by the traditional and the proposed method.*

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