Implementation of a novel apparatus to perform a Photoelastic Tomography analysis

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Abstract. Photoelasticity is a well-known experimental stress analysis technique based on the study of the light polarization when a light ray is passed through a birefringent material under load. This paper aims to address the drawbacks of the destructive and time consuming nature of 3D photoelasticity. A critique of current methodology of photoelastic tomography is made and a new automated design is proposed for the apparatus in order to create an efficient and accurate technique to determine internal stresses in 3D photoelastic models.

Introduction

One of the branches of photoelasticity is 3D photoelasticity, where internal stress measurements may be made by stress freezing a polymer model of an engineering component under a thermal cycle, followed by sectioning the sample in thin slices to perform a 2D photoelastic analysis [1]. However this procedure is time consuming, destroys the specimen and if the experiment intends to measure the internal stress in more than one axis, it has to be repeated [2]. Many industries such as telecommunications, automotive, aerospace and architecture are interested in internal and residual stresses but these destructive drawbacks of the technique are very limiting [3]. In order to overcome these drawbacks of 3D photoelasticity, an alternative technique has been proposed. Integrated photoelasticity or photoelastic tomography, is a technique that allows internal stress analysis without destroying the specimen [4]. Photoelastic tomography can be taken as an optical tomography, however it is not possible to apply directly the equations used in conventional tomography since the mathematical approach of the Radon equation is just for scalar fields but photoelastic tomography intends to obtain a tensor stress field. The fact that the directions and values of the principal stresses vary through the thickness of the material makes data difficult to process and to relate the measured data with the non-linear stress distribution. In order to resolve this, an optical equivalence was proposed, where three characteristic parameters (axis of the retarder ''θr'', the retardation of the retarder ''2Δ'' and the rotatory power of the rotator ''γ'') are analysed with a digital photoelasticity method (Phase stepping or Fourier analysis) [5].

Methodology

The procedure to get the raw data for the reconstruction starts with the collection of the intensity images, where the experimental setup needed to perform this is shown in Figure 1 [6].

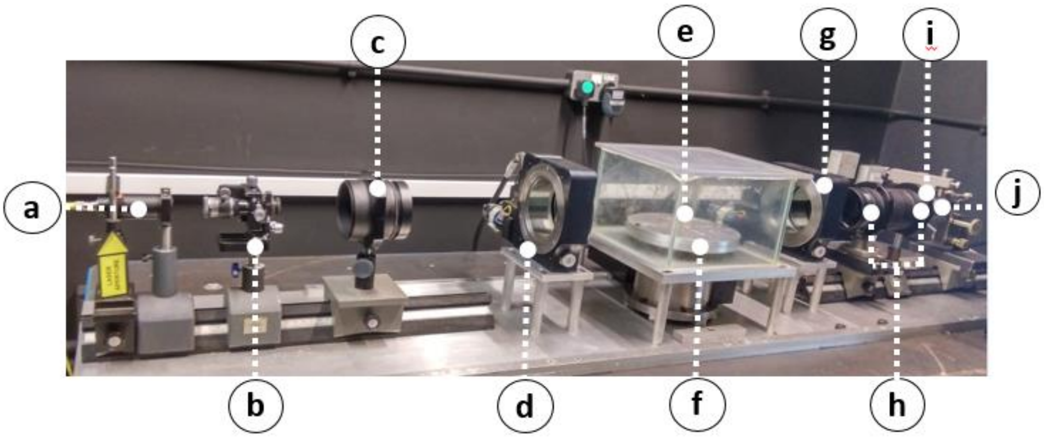

Figure 1-. Photoelastic tomography experiment: a) Laser, b) Spatial filter, c) Plano-convex aspherical lens, d)Polarizer, e) Immersion tank, f) Motorized rotation stage, g) Analyser, h) Plano-convex aspherical lens , i) Iris diaphragm, j) CMOS camera.

Then a processing treatment of the images acquired is applied, in order to eliminate the areas where the specimen is not involved and to reduce the amount of data for the reconstruction. Finally, the processed images are used in the programs that obtains the characteristic parameters, calculates the internal stresses reconstruction and displays the results.

This procedure has to be repeated for the 3 axis of the specimen, where the specimen is flipped manually. The implementation of a new positioning system within the tank in order to flip the sample automatically is proposed to avoid manual interventions, contamination of the immersion fluid and more importantly to cut down the data acquisition time. The conceptual design consists of seven motors in different positions on circular plates as shown in Figure 2. Each servomotor has a specific task to accomplish within the sequence to re-position the specimen. For example, motor 1 rotates all the repositioning system in order to select the face to be rotated. Motors 2 and 3 varies the height of the system to avoid interferences when the specimen is being rotated by motors 4 and 5, whereas the motors 6 and 7 open and close the grips that grab or release the specimen. Further designs will be explored to enable multiple shapes of components to be analysed.

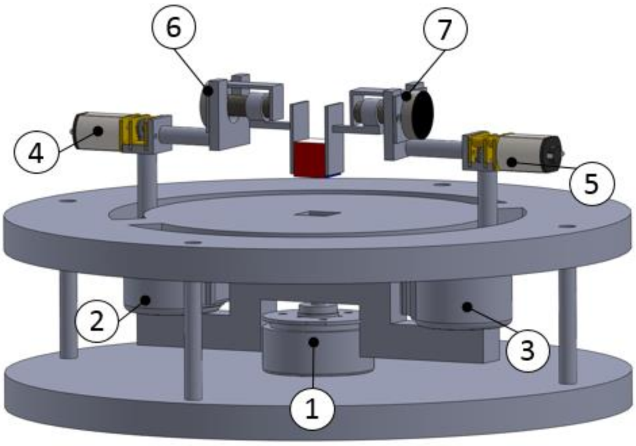

Figure 2. Locations of motors within the conceptual re-positioning system design.

Results and conclusion

Current results of the reconstructions do not yet show a defined tendency or measurement scale that can be correlated with the stresses; some drawbacks such as noise in the light system , the refractive index mismatching with the sample could be affecting these results [7]. Further investigation and improved experimentation has to be performed to achieve a full reconstruction of the internal stresses under general conditions.

References

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