AUTOMATIC PHOTOELASTIC METHODS FOR THE ANALYSIS OF MEMBRANE RESIDUAL STRESSES IN GLASS

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1. INTRODUCTION

It is well known that photoelasticity is used for the analysis of residual stresses of glass [1,2]. The determination of residual stresses in glass, using classical transmission photoelasticity, has been the subject of several contributions based on: Babinet and Babinet-Soleil compensators [3-6], Sénarmont compensation [6-10], white light photoelasticity also using the *tint plate* [6,7] and the standard strain discs [1,2,8,9].
This work concerns the determination of membrane residual stresses in glass plates; for techniques concerning the analysis of thickness stresses in glass plates and for ax-symmetric or of any shape components reference can be made to the literature [1,11,12].
The development of digital photoelasticity [13-15] allows the user to automate the analysis of residual stresses in the glass. Specifically, the automatic photoelastic analysis of membrane residual stresses was done using: GFP - Gray Field Polariscope [16-18], SCA - Spectral Content Analysis [4,19-22], PST - phase shifting photoelasticity [23-25], RGB photoelasticity [25,26], *test fringes* method [27,28], ATPM – Automated tint plate method [29,30].
The first two methods require specific equipment; while the remaining methods are based on the use of a classical transmission polariscope interfaced with an image acquisition system. In this work a comparison of the six methods above cited is presented. In the comparison the following aspects have been especially considered: availability of commercial systems, restrictions concerning the parameter of the isoclines, acquisition system, additional equipment, system calibration, number of acquisitions and external information needed.

2. EXPERIMENTS

In the analysis of the methods various experimental tests were performed. The experiments were carried out using a polariscope with quarter-wave plates matched to the reference wavelength
λ_0 = 589 nm (monochromatic yellow light) using:

1. monochromatic sodium vapour lamps that emit at the reference wavelength (λ_0=589 nm), for the experiments in monochromatic light;
2. energy saving fluorescent lamps (Philips Master 7L-D Super 80 18 watt/827) with discrete spectral emission having three main narrow band peaks at the following wavelengths: λ_R = 612 nm (red), λ_G = 546 nm (green), λ_B = 436 nm (blue), for the experiments in white light;
3. an RGB camera, model JVC KY-F30 3CCD, with three independent CCD sensors and a Matrox-Meteor 2 digital board having a spatial resolution of 768x576 pixels and a quantization of 256 RGB levels;
4. a polycarbonate (MM PSM1) specimen, used both as calibration beam and as carrier in the *test fringes* methods, and a tempered glass plate , used for the analysis of residual stresses,
5. a full wave plate (*tint plate*), used in the automated tint plate method, having a retardation δ_0^c=1.0 fringe orders at the reference wavelength λ_0=589 nm.

3. DISCUSSION

Comparing the methods, an estimation of the errors committed has been done. As a general rule, the phase shifting methods are preferable. In fact, these methods do not require calibration procedures and carrier fringes. Moreover, the relative low retardation allows the user to operate the unwrapping procedure with limited difficulties.
In cases in which multiple acquisitions are not allowable, the following methods, based on a single acquisition, can be taken into account, in particular:

1. RGB photoelasticity (without reference fringes) has the advantage of being independent of the isoclinic parameter, but may give inaccurate results in the range between 0 and 0.5 fringe orders,
2. in the range between 0 and 0.5 fringe orders, the *test fringes* method used by the RGB photoelasticity and the *automated tint plate method* (ATPM) can noticeably mitigate such disadvantage;

3. the *test fringes* method (used by the centre fringe method) is easy to apply since the calibration procedure is not required, although the presence of a carrier is needed; this method, where applicable, proves to be very effective.

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