# Stress state of a glass qt the limit crack

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If the exact knowledge of the stresses distribution permits to do some modifications of the piece shape in order to tend to optimum mechanical stability; the knowledge of the crack stress for any material with any loads permits to ovoid any defects for different systems. This, can be done by adopting a simple supervising method. This observation can be done automatically using imaging means developed by the actual technology.

If this knowledge can result from a theoretical study in case of simple loads and simple geometrical shapes, for the current loading cases, we usually use performed experimental and theoretical methods.

Photoelasticimetry witch is an optical method permitting to know quickly the spatial stresses distribution and their values of some piece in order to perform its mechanical state.

In this work, we associate the numerical storage and processing equipment for dynamical image to photoelasticimetry for studying the crack stress in glass bars submitted to four points flexion.

## INTRODUCTION

When one piece is submitted to a force, stresses appear. Their distribution isn't necessarily uniform, usually there are areas of stresses concentration. There are weak points in the piece. The knowledge of regions witch are more stressed permits to know the piece shape modifications, in order to get the more uniform distribution.

If the visualisation of the stress distribution in the structure and the access to principal stresses can be done easily by photoelasticimetry; the crack stress value can be obtained only by calculation for only one point using the crack moment.

In the present work, we associate a quickly storage method to the photoelasticimetry for following the stress distribution in a glass sample loaded at its limit crack. We determine by replaying the experimental stored film, the image just before the crack.

## PHOTOELASTICIMETRY PRINCIPLE

The knowledge of the mechanical stress at any point of one structure permits to know its stability and rigidity state in the constructed mechanism for witch it is established.

Let $\sigma_x$, $\sigma_y$ and $\tau_{xy}$ be the stresses in a point of the studied structure on (x,y) axes; the third axes (z) is the optical axes (fig. 1). $\sigma_x$ and $\sigma_y$ are the normal stresses and $\tau_{xy} = \tau_{yx}$ the shear stress.

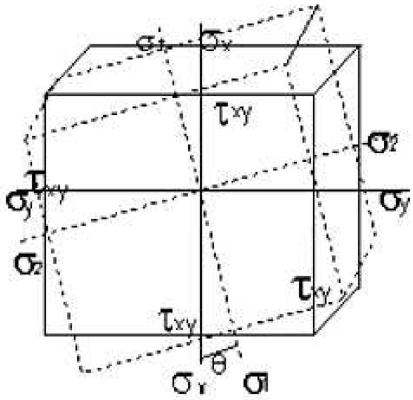


Figure 1 : State of stresses in the plane of a cutted element.

For a certain cutting direction, shear stresses become nill, in this case, one of the two normal tresses gets its maximum value and the other the minimal one. The new stresses directions are said principal stresses directions $\sigma_1$, $\sigma_2$. Knowing $\sigma_x$, $\sigma_y$ and $\tau_{xy}$, we can calculate $\sigma_1$ and $\sigma_2$ [1-2]:

$$\sigma_{1/2} = \frac{\sigma_X + \sigma_Y}{2} \pm \left[\frac{\sigma_X + \sigma_Y}{2}\right]^2 + \tau_{XY}^2 \qquad (1)$$

In the same manner, we can calculate the angle between the cutting direction and the principal direction:

$$\tan(2\theta) = \frac{2\tau_{XY}}{\sigma_X - \sigma_Y} \qquad (2)$$

According BREWSTER, the light speeds and the stresses are connected by photoelastic constants:

$$\begin{aligned} V_1 &= V_0 + C_1\sigma_1 + C_2\sigma_2 \\ V_2 &= V_0 + C_1\sigma_2 + C_2\sigma_1 \end{aligned} \qquad (3)$$

Vo is the light speed in the isotropic material.
$V_1$ and $V_2$ the speeds following the principal directions, so that the indexes $n_1$ and $n_2$.

The absolute delay introduced between the waves following the two indexes is expressed by:

$$t = d\left[\frac{1}{V_1} - \frac{1}{V_2}\right] = d(n_1 - n_2) \qquad (4)$$

(d) is the sample thickness and ($n_1$, $n_2$) the refraction indexes following the two polarisation directions.

The walk difference of polarised lights following the two directions can be expressed by:

$$\delta = (n_1 - n_2)d = C(\sigma_1 - \sigma_2)d \tag{5}$$

This equation is a fundamental in photoelasticimetry. For any wave length λ an expressing the walk difference in wave length number, the equation (5) becomes :

$$\sigma_1 - \sigma_2 = \frac{\delta\lambda}{Cd} \tag{6}$$

For a loaded photoelastic material, hence birefringent, we can at any point, look for the principal directions by studying the polarisation axes of the light and we can know the difference of principal stresses by measuring the phase difference between the two emergent rays (2)[3-4].

## MEASURING AND VISUALISATION APPARATUS

The experimental set-up used is made of (fig. 2):

- A light source with linear polarising filter;
- A sample with its four points bending devise;
- A second polarising filter which is used as an analyser;
- A video CCCD camera as a receptor.

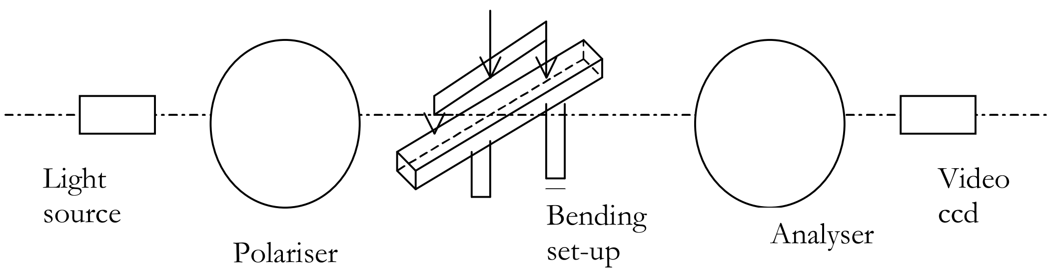


Figure 2 : Experimental set-up device.

In our case the sample is a glass which has a bar shape with 6x6 mm². This sample is introduced in the experimental device and loaded until it cracks. The result is a succession of many images stored as a film.

The processing is done on the last image before the crack. The image numerical processing permits to separate monochromatic images and using their wave lengths values to determine the corresponding stresses values.

Results are presented in figure (3) were we show in the first column the basic image and in the others the monochromatic images filtered from the basic one using numerical filters and there corresponding stresses values.

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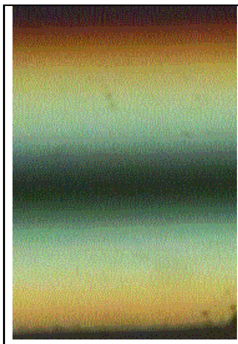
|---|---|---|---|
|  |  |  |  |
| Field stress fringes at the limit crack state | Colour red (680 nm) $(\sigma_1 - \sigma_2) = 28.33$ N/mm$^2$ | Colour orange (620 nm) $(\sigma_1 - \sigma_2) = 25.83$ N/mm$^2$ | Colour bleu green (580 nm) $(\sigma_1 - \sigma_2)=$ 24.16 N/mm$^2$ |

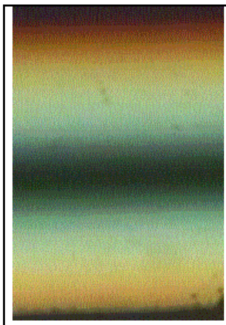
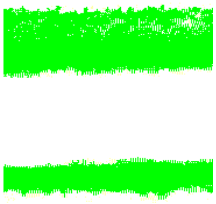
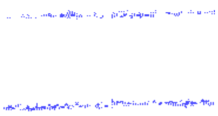
| | | |
|---|---|---|
|  |  |  |
| Field stress fringes at the limit crack state | Colour green( 530 nm) $(\sigma_1 - \sigma_2)=$ 22.08 N/mm$^2$ | Colour bleu ( 470 nm) $(\sigma_1 - \sigma_2)=$ 19.58 N/mm$^2$ |

Figure 3 : Crack and filtered images.

**CONCLUSION**

It appears clearly from these results that the combination between high speed detection device and the numerical processing methods and the optical techniques permits to solve some important mechanical problems. The quick detection of stress distribution and their determined values, particularly crack state become easy with the presented technique.

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