POLARIZED SHEARING HOLOGRAPHIC-MOIRÈ INTERFEROMETRY*

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ABSTRACT: A new holographic-moirè method is presented to obtain the in-plane strain fringe patterns. During the recording, double object beams and dual reference beams of orthogonally polarized state are used to illuminate the object and the holographic plate, respectively. Two carriers modulated by deformation are obtained through double-exposure or in real time. Pure in-plane displacement derivative patterns are then obtained through twice filtering.

KEY WORDS: orthogonal polarization, in-plane strain patterns, optical filtering.

I. INTRODUCTION

Among the interferometric methods in optical mechanics, some shearing techniques were developed to obtain the displacement derivative patterns of deformed object. For example, the speckle-shearing camera, developed by Hung[1], is a useful tool to acquire the derivative patterns of displacements on rough surface. With moirè interferometry, Weissman[2] obtained the strain fields by mechanical shifting of the recording plate. Among our newly developed methods of the polarized interferometry[3], the polarization of laser beams was used by authors[4] in moirè interferometry and the in-plane strain fringe patterns were achieved in real time. However, up to now, the application of shearing techniques to holographic interferometry has not been successful though the formation of holographic-moirè made the shearing of the separated displacement fields valuable. For the purpose of differentiation, Gilbert[5] proposed two shifting methods. In one method, multiplexing techniques were used to incorporate an initial pattern into the shifting processing, but the results of the method were a coupling of the in-plane and the out-of-plane displacement derivatives. In another method, a holographic-moirè pattern was shifted on itself to produce the derivative pattern directly. In this case, however, the strain fringes were not distinct because the frequency of the in-plane displacement fringes was usually not high enough and it is nearly impossible to separate the subtractive second-order moirè from the additive ones.

In this paper, a polarized holographic-moirè method is proposed to acquire the in-plane displacement derivative fringe patterns. Illuminating the object with double beams of orthogonally polarized axes, and by changing the directions of dual reference beams to obtain carriers, the necessary information can be recorded by double exposures or in real time as in common holographic recording. After the recording plate is filtered twice, not only the out-of-plane displacements are canceled, but also pure and clear strain patterns can be observed directly.

II. PRINCIPLES

To eliminate the influence of the out-of-plane deformation, double beams $E_1$ and $E_2$ are used to illuminate symmetrically the object (Fig.1). They are linearly polarized beams with perpendicular
axes, and at an angle of $\alpha$ with the normal to the surface of the object. Assuming the rough surface is of the property of non-depolarization, reflective diffused rays $O_1$ and $O_2$ will have the same polarization state as the incident light. When they reach the recording plane, the complex amplitudes can be expressed in Jones vectors as

$$
O_1 = \begin{bmatrix} e^{i\varphi_1(x,y)} \\ 0 \end{bmatrix}, \quad O_2 = \begin{bmatrix} 0 \\ e^{i\varphi_2(x,y)} \end{bmatrix}
$$

where $\varphi_1(x,y), \varphi_2(x,y)$ are random phases.

Figure 1: Schematic of holographic recording with orthogonally polarized beams

Moreover, collimated reference beams $R_1$ and $R_2$ are also in an orthogonal form of linear polarization. Before the object is loaded, they are symmetrical to the normal to the holographic plate at an angle of $\theta_x$, and can be written as

$$
R_1 = \begin{bmatrix} e^{i2\pi f_0 x} \\ 0 \end{bmatrix}, \quad R_2 = \begin{bmatrix} 0 \\ e^{-i2\pi f_0 x} \end{bmatrix}
$$

where $f_0$ is spatial frequency of two plane waves and equal to $\sin(\theta_x)/\lambda$. Therefore, in the first exposure, these four beams are recorded:

$$
I_1 = (O_1 + O_2 + R_1 + R_2)^+ (O_1 + O_2 + R_1 + R_2)
$$

where $'$ means the conjugation and transposition of the matrix.

When the object is loaded, the phases $\varphi_1$ and $\varphi_2$ will become $\varphi_1'$ and $\varphi_2'$ respectively, and object beams will be $O_1'$ and $O_2'$. At the same time, we change the directions of $R_1$ in plane $x-z$ by $\Delta\theta_x$, and $R_2$ both in plane $x-z$ by $\Delta\theta_y$ and in its perpendicular plane by $\Delta\theta_x$. Hence, the new reference beams are:

$$
R_1' = \begin{bmatrix} e^{i2\pi f_1 x} \\ 0 \end{bmatrix}, \quad R_2' = \begin{bmatrix} 0 \\ e^{-i2\pi f_1 x + f_2 y} \end{bmatrix}
$$

where $f_1 = \sin(\theta + \Delta\theta_x)/\lambda$ and $f_2 = \sin(\Delta\theta_y)/\lambda$.

The second exposure records the intensity distribution of

$$
I_2 = (O_1' + O_2' + R_1' + R_2')^+ (O_1' + O_2' + R_1' + R_2')
$$

and the total intensity recorded by hologram is $I = I_1 + I_2$.

After the holographic plate is developed, it is reconstructed under the illumination of both $R_1$ and $R_2$. In the condition of linear recording, the amplitude transmissivity is proportional to the intensity. Neglecting the constants, the transmissive light will be given by