

DIRECT MEASUREMENT OF THE PLATE BENDING STRESSES USING MICHELSON SHEAROGRAPHY INTERFEROMETER

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ABSTRACT: This work presents a new approach to achieve the third order spatial derivatives of out-of-plane displacements using a full field technique. The Michelson Shearography technique is used to obtain the first order derivatives. The second and third orders are computed using multiple exposed Shearography with digital superposed method. An experimental procedure is proposed for the measurement of the first order derivatives. A steel clamped plate loaded with a uniform pressure was tested for internal stresses calculation. A good agreement between the experimental results and analytical solution is presented.

1. INTRODUCTION

The second and third order spatial derivatives are needed for full stresses characterization on the bending thin beams and plates [1]. Due to there higher sensitivity in presence of the damage, these derivatives is also used in non - destructive - inspection of laminated structures. The Shearography based on Michelson interferometer setup is a full-field technique that allow a non-contact measurement of spatial gradient of the out-of-plane displacements [2, 3]. This high resolution technique show low sensitivity to external perturbations. Also, the common path interferometer allows the use of cheap Lasers, with low coherence length.

For low amplitude displacements, the rotation field can be approximate to the spatial gradient of out-of-plane displacement and the same is true for the high order derivatives. These important relationships allow the measurement of spatial derivatives using experimental displacement gradient techniques, as Shearography. In recent years, several techniques were proposed for the direct measurement of the curvature or the second order derivative [4-6]. They are based on the interference of three or four wave-fronts with phase shifting technique to obtain the curvature phase maps. However, the curvature fringes show a very pour contrast due to the superpose rotation fringes. To avoid this problem, is proposed the measurement of first order derivative phase maps with several lateral shears. The multiple exposed Shearography technique is used to accuracy produce the different lateral shift of wave fronts. Finally, the different phase maps are digitally superposed to compute the second and third spatial derivatives.

2. EXPERIMENTAL SET-UP

A thin steel clamped plate was tested for the determination of internal stresses due to a uniform pressure load. a Shearography setup with phase shifting technique was build to measure the first order spatial derivatives Fig. 1. The image shear phenomena are produced when the lateral shift of two wave's fronts is created. There value can vary continuously by adjusting the angle of one Michelson interferometer mirrors, by using two precision screws. A computer controlled phase shifting device using a moving mirror attached to PZT produces four fringe patterns with the phase step $-\pi/2$; 0 ; $\pi/2$ and $3\pi/2$. From each set of these images the fringe pattern phase map can be computed.

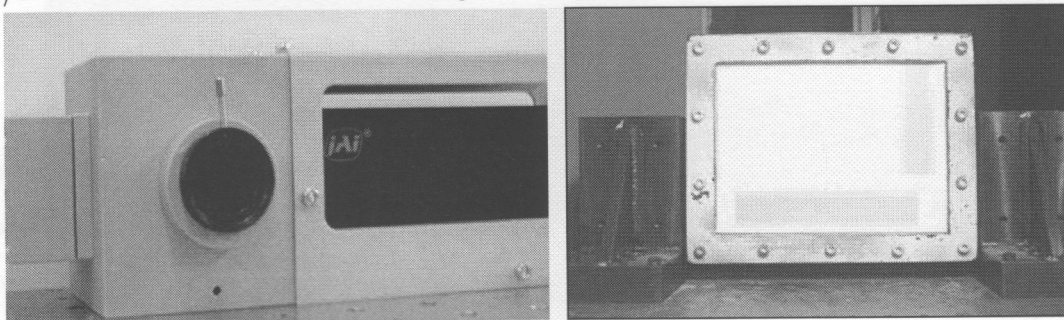


Fig. 1 - General view of experimental set-up: Michelson Shearography interferometer (left); Clamped plate (right).

For each load state, four images were recorded to create the interferogram of the first spatial derivative of the out-of-plane displacement. The first order phase maps are superposed to obtain second and third order derivatives, according to the finite central differences method. The computation of all stresses, moments and forces, involves the recording a total of eleven different phase maps of first order spatial derivatives, Table 1. For each load several images were obtained by applying shear in two directions (x , y) with amplitudes multiples of 10 mm, each one is designated by a two digit code on table 1. The phase filtering and unwrapping routines were developed by the author on MATLAB code to enhance signal/noise ratio and improve the quality of the final results.

Table 1 –Shear values of first order spatial derivatives for plate stresses computation.

Stresses	Bending moments		Twisting moments (M_{xy})	Shear forces	
	M_{xx}	M_{yy}		Q_{xx}	Q_{yy}
Shear ($\Delta x, \Delta y$) cm	(-1,0); (1,0); (0,-1); (0,1)	(-1,0); (1,0); (0,-1); (0,1)	(0,1); (1,1)	(0,-2); (0,-1); (0,1); (0,2); (0,1); (1,1); (1,-1);	(-2,0); (-1,0); (1,0); (2,0); (1,0); (1,1); (-1,1)

3. RESULTS

The plate bending stresses obtained by experimental procedure and analytical solution [7] are depicted in Fig. 2. Due to the superposition a border effect is obtained. The non-valid boarder regions of the experimental results were omitted in this representation. In general, the results show a very good agreement. Although, the shear forces present slight differences in the plate's edges, probably due to boarder effect propagation. This effect is associated to the digital computation of high order spatial derivatives.

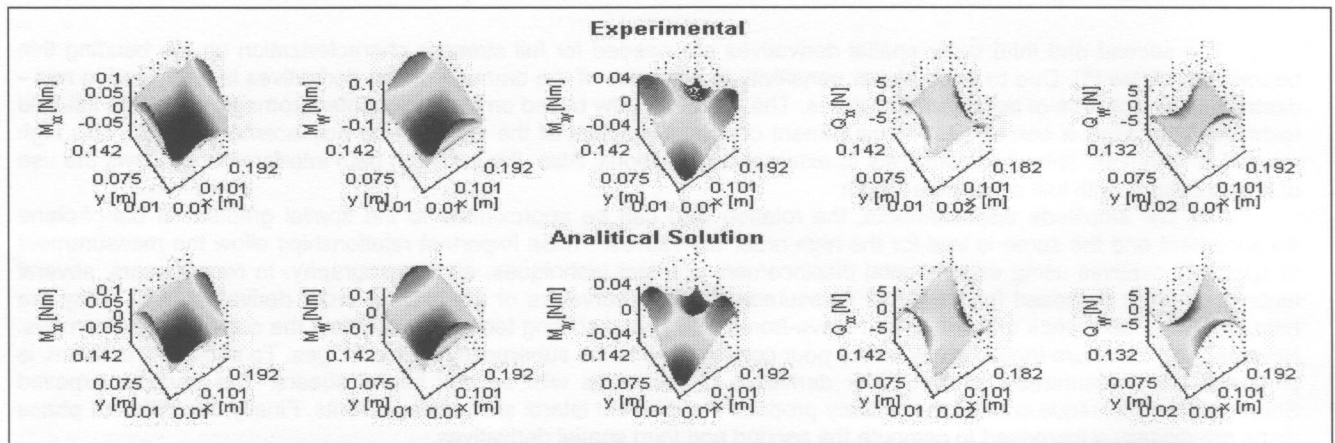


Fig. 2 – The plate's internal stresses for the experimental procedure and analytical solution.

4. CONCLUSIONS

Based on the superposition of phase maps representing the first order derivatives was possible to compute the second and third order displacement derivative, and consequently the plate's bending stresses. Despite of the plate boarder region, the results presented for experimental and analytical solution show a very good agreement. These stresses can be computed until the boarder. However, a superior number of interferograms are needed for the digital superposed procedure.

5. REFERENCES

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