SHAPE, DISPLACEMENT AND STRAIN MEASUREMENTS BY SAMPLING MOIRE METHOD

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Introduction

It is important to measure shape, displacement and strain of composite materials etc. to keep the safe of structures. Scanning moire method using a TV camera or digital camera is useful for the measurement. In this paper, a newly developed sampling moiré method analyzing phase of a moire fringe is introduced for the purpose [2-4]. The theory and some applications of the method to displacement measurement of a beam [4], and shape and strain measurement of a tire are shown.

Sampling Moiré Method

A grating pattern is recorded by a digital camera. The recorded image is analyzed by sampling moiré method. Figure 1 illustrates the appearance of a moiré fringe pattern by sampling moiré method. A grating pattern on an object (Fig.1 (b)) is recorded by a digital camera (Fig.1(a)). Though the digitized image (Fig. 1(c)) shows the grating, a moiré fringe pattern (Fig.1 (c)) appears by thinning-out the pixels. If every N-pixel (in this case, thinning-out index N = 4) from the first sampling point is picked up from Fig. 4(c), a moiré fringe pattern is obtained as shown in Fig. 4(d). If instead the second, third and fourth sampling points are selected, the images of moiré fringe patterns with π/2, π and 3π/2 phase-shift shown in Fig. 1(e), (f) and (g), respectively, are obtained. This process corresponds to the phase shifting of the fringe pattern. If all the sampled images that are thinned-out in Figs. 1(d)-(g) are interpolated using the neighboring data, the images become clearer and easy to observe as shown in Figs. 1(h)-(k) from Figs. 1(d)-(g), respectively. From these phase-shifted fringe patterns, the phases of the moiré fringes are analyzed.

The intensity of the n-th phase-shifted images $I_n(x, y)$ can be expressed as follows: (n=0, 1,….,.N-1)

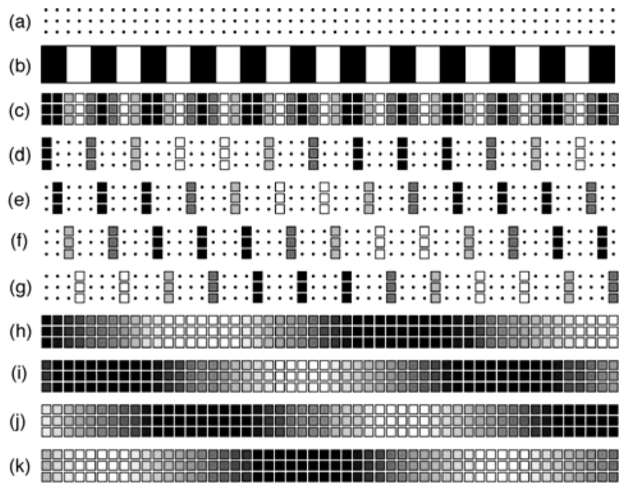


Fig. 1 Phase analysis by sampling moiré method: (a) Sampling points of camera; (b) Specimen grating; (c) Sampled image of Fig. (b); (d) Thinned-out image from Fig. (c) (N=4, α=0); (e) Thinned-out image from Fig. (c) (N =4, α=π/2); (f) Thinned-out image from Fig. (c) (N =4, α=π); (g) Thinned-out image from Fig. (c) (N =4, α=3π/2); (h) Interpolated image of Fig. (d); (i) Interpolated image of Fig. (e); (j) Interpolated image of Fig. (f); (k) Interpolated image of Fig. (g)

$$I_n(x,y) = I_a(x,y)\cos[\phi(x,y) + n\frac{2\pi}{N}] + I_b(x,y) \tag{1}$$

The phase change at a pixel point of the fringe pattern can be obtained from the frequency 1 of the discrete Fourier transform (DFT) of Eq. (1). As the results, the wrapped phase ϕ of the frequency 1 is expressed as follows.

$$\tan\phi(x,y) = -\frac{\sum_{n=0}^{N-1} I_n(x,y)\sin(n\frac{2\pi}{N})}{\sum_{n=0}^{N-1} I_n(x,y)\cos(n\frac{2\pi}{N})} \tag{2}$$

If the phase ϕ_m of the moiré fringe is analyzed when the phase ϕ_r of the reference grating i.e. sampling phase is given, the phase ϕ_s of the specimen grating is determined from Eq. (3).

$$\phi_s = \phi_r - \phi_m \quad (3)$$

From the phase ϕ_s of the specimen grating, shape, displacement and strain is accurately obtained according to the optical systems, respectively.

Deflection Measurement by Sampling Moiré Method

The sampling moiré method using phase shifting was applied to the deflection measurement of a beam under symmetric three-point bending [3].

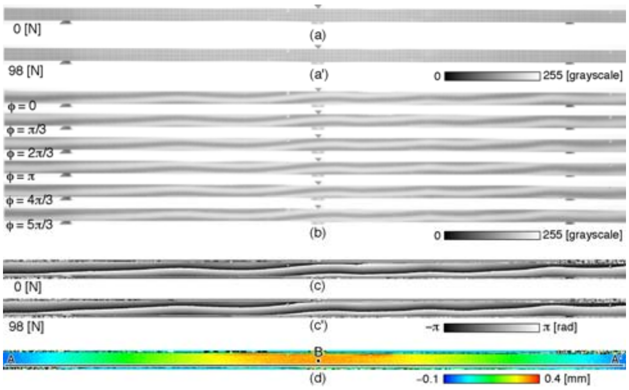


Fig. 2 Experimental results: images of the specimen before (a) and after (a') loading; (b) phase-shifted images obtained by sampling moiré method; wrapped phase distribution before (c) and after (c') loading at 98N; (d) deflection distribution

Shape and Strain Distribution Measurement of Rotating Tire

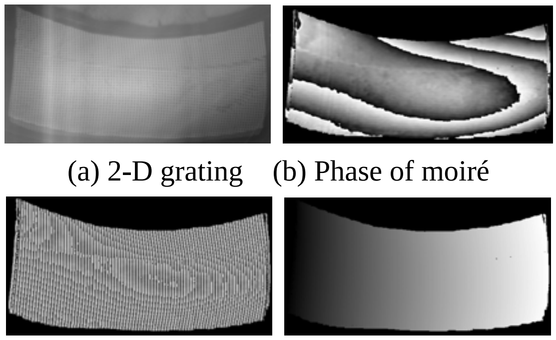
Tire is a kind of composite materials. The shapes were analyzed by Fourier transform grating method [5, 6]. In this paper, the shape and strain distributions of a tire rotating at 80km/h on a flat belt cornering machine were measured by sampling moire method.

The images of the grating were captured by two CCD cameras simultaneously with the trigger signal when the rotating object came at the same position.

Figure 3(a) shows the grating image recorded by the left camera, the phase distribution (Fig. 3(b)) of the moiré fringe pattern analyzed by sampling moiré method, the phase distribution (Fig. 3(c)) of the grating and the unwrapped phase distribution (Fig. 3(d)).

Figure 4 shows the measured shape and Fig. 5 shows the distributions for the x- and y-directional and shear strains, respectively.

Results and Discussion



(a) 2-D grating (b) Phase of moiré

(c) Phase of grating (d) Unwrapped phase

Fig. 3: Phase analysis (in x-direction)

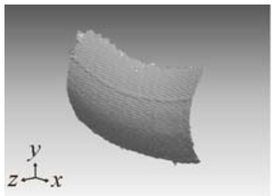
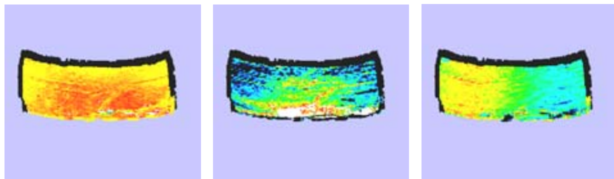


Fig. 4 Analyzed shape



(a) *x*-directional (b) *y*-directional (c) Shear

Fig.5 Analyzed strain distributions

Sampling moire method is useful to measure the shape, displacement and strain of a moving object.

References

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