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Phase analysis for out-of-plane displacement measurement using laser lines generated in camera with diffraction grating

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Abstract: In this study, a sampling moire method in which parallel laser lines were generated in a camera using a diffraction grating was proposed. A green laser of line projection function, a diffraction grating and an industrial camera were used as an experimental device. Object images with laser line projection before and after displacement were taken by the camera. Displacements that calculated by a sampling moire method and a method of averaging center-of-gravity were be compared. Results show that the proposed method is more precision than method of averaging center-of-gravity.

Keywords: Displacement measuring; Phase analysis; Diffraction grating; Sampling moire method; Light-section method; Laser line

Introduction

Displacement measurement of large infrastructure structures such as bridges has important implications for preventing accidents. Sampling moire method is a displacement measuring method that is suitable for displacement measuring of large infrastructure structures as it measured in a high speed and with high accuracy [1]. The principle of sampling moire method is phase analysis. In generally, a grid pattern was pasted on the measurement target or a grid pattern was projected on the measurement target. Images taken by the camera before and after the displacement were used to compute the phase difference.

In order to apply phase analysis to the light-section method, it is necessary to project multiple parallel slit lights, which is not an easy thing without using a complete optical system. For solving this problem, we proposed a method that can generated parallel laser lines in a camera. In this method, a single laser light is projected and a diffraction grating is placed in front of the imaging lens of the camera so that multiple parallel lines can be photographed. The principle of proposed method is the same with computer generated hologram method [2,3]. The measurement accuracy is compared with the displacement computed based on the center-of-gravity.

Experimental method

Figure 1 shows a schematic diagram of the measuring experiment. A metal flat plate is fixed as an object to be measured on a stage installed 5 m in front of the laser. The laser line is projected on it. A diffraction grating was place in front of the camera lens. The distance between the laser and the camera is 1 m. The laser used is a green one with a wavelength of 532 nm. The camera used was an industrial camera (Toshiba Teli, BU40M) with a pixel pitch of 6.9 μm. The focal length of the lens used is 12 mm, and the lattice constants of the diffraction grating is 0.254 mm. Before imaging, camera was focused manually. In the experiment, the object was moved closer to the laser manually by moving the stage and images were taken with the camera at each position. The phase of the captured image is calculated by the sampling moire method, and the displacement is calculated from the difference from the phase at the 0 mm position. In addition, the displacement is also calculated by using the amount of movement of the center of gravity with the same images.

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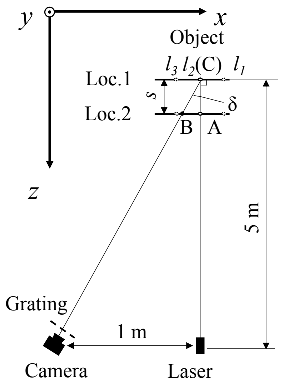
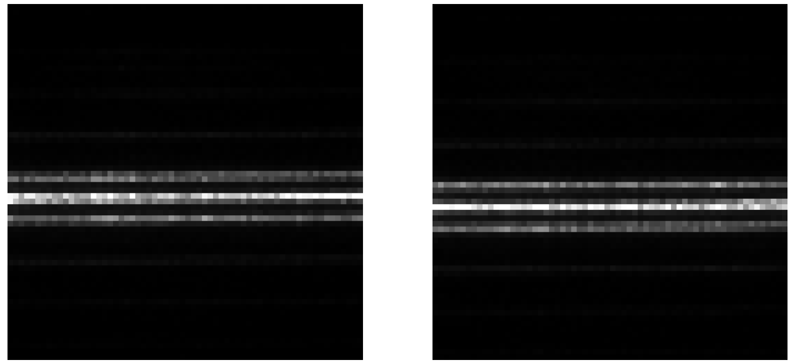


Fig. 1 Schematic illustration of measuring system



(a) Basic position (0 mm) (b) 25 mm away from basic position

Fig. 2 Multi-line images

Experimental results

Figure 2 shown the captured images at the 0 mm and 25.0 mm positions. It was shown that three bright laser lines are photographed in the image. Comparing position of laser lines in basic position and in the case of 25 mm away from basic position, it can be seen that laser lines are moving slightly downward. Using those images, displacements were computed out. The measured displacement by sampling moire method and method of amount of movement of the center-of-gravity were 21.7 mm and 19.1 mm respectively, when the reality displacement was 25.0 mm. It shown the sampling moire method is more precision than method of amount of movement of the center-of-gravity. Residual standard deviation of the fitting line that based on 5 points measured results were also computed out. Residual standard deviation of sampling moire method was 0.3 mm and that of based on movement of the center-of-gravity was 0.6 mm.

Conclusions

It was confirmed that multiple parallel laser lines can be generated in the camera by installing the diffraction grating in front of the camera. Phase analysis by the sampling moire method was used for the generated multiple laser line images, and the displacement was measured from them. As a result, it was possible to measure a value closer to the given movement amount than the method of obtaining the displacement from the movement amount of the center of gravity.

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