Automated Shadow Moiré Fringe Analysis Using Two Light Sources

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Introduction. Shadow moiré method is an effective optical technique for surface profile measurement of diffusely reflecting objects. For accurate measurement, phase-shifting technique is usually adopted to the shadow moiré measurement system. However, the specimen or system may be moved during the time of image capture, and not suitable for in-line measurement. In order to overcome this drawback and make an automated in-line measurement, a shadow moiré system consisted of two light source of different color, and a color CCD camera is proposed. The phase shift is introduced by using two light sources illuminate the grating from different position simultaneously. The two moiré fringe patterns captured by the color camera are processed by an automated fringe analysis scheme using spiral phase transform (SPT), optical flow and digital filtering techniques. The proposed automated fringe analysis scheme was applied to simulated surface profile and real specimen. The principles and test results are presented.

Principles. The schematic of experimental set-up for shadow moiré with two light sources is shown in Fig. 1. The intensity of moiré fringe pattern, I, can be described by

\[ I(x,y) = a(x,y) + b(x,y) \cos[\theta(x,y)] \]  

where \((x,y)\) is the position, \(a(x,y)\) is the background intensity, \(b(x,y)\) is the amplitude, and \(\theta(x,y)\) is the phase of moiré fringe. After removing the DC term, SPT operator can be applied to obtained cosine signals and their quadrature signals given as

\[ b(x,y) \sin[\theta(x,y)] = -i \exp(-i\beta) \text{SPT}\{\bar{I}(x,y)\} \]  

The parameter, \(\beta\), in Eq. 2 can be obtained by calculating the fringe orientation angle using optical flow approach. The wrapped phase can be determined from

\[ \theta(x,y) = \arctan\left\{ -i \exp(-i\beta) \text{SPT}\{\bar{I}(x,y)\} / \bar{I}(x,y) \right\} \]  

After unwrapping, the height of surface can be calculated.

Fig. 1 Schematic set-up for shadow moiré system with two light sources.

The flow chart of the fringe phase analysis is given in Fig. 2.

Test Results and Conclusion. Moiré fringe patterns of an inclined flat plate was simulated with light incident angles of 45° and 43.5°, respectively. Test results are shown in Fig. 3. An error of 1.5% is achieved with the maximum height of 1 mm. Figure 4 shows the result of a convex circular disk. Comparison to the result obtained by using four-step phase shifting method, a RMS error of 8 \(\mu\)m can be achieved between them for a height of 370 \(\mu\)m.

Fig. 2. The fringe phase analysis flow chart

Fig. 3 Moiré fringe patterns of an inclined flat plate was simulated with light incident angles of 45° and 43.5°.

Fig. 4 (a) convex plate specimen, (b) green fringe pattern, (c) red fringe pattern, and (d) wrapped phase.

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References.