Thickness and parallelism measurements using a quasi-common-path interferometer with a remote phase control module

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Introduction. With the ongoing development of automatic fabrication in industry, optical instruments for measuring the fabricated components become popular since they are with the abilities of full-field, non-contact, and high-precision inspection. Among which, the phase-shifting interferometers\(^{(1)}\), multi-wavelength interferometers\(^{(2)}\), and scanning white-light interferometers\(^{(3)}\) are particularly useful for thickness, flatness, and parallelism examinations. However, they are inapplicable to in-situ measurements since their double-path configuration makes them be highly sensitive to perturbations propagating from environment.

To surmount this drawback, we developed an innovative interferometer, which contains two important features: common-path apparatus and remote phase control module and two measurement modes: phase-shifting and phase-scanning, capable of in-situ measurements of thickness and parallelism of mechanical parts. The configuration, measurement theory, and experimental results of this interferometer are demonstrated in the following sections.

Configuration and theory. Figure 1 (a) presents a schematic diagram of the proposed interferometer. It is composed of a white light laser, phase control module (PCM), plastic fibre, and interferometric module (IM).

Fig. 1 (a) Schematic of the proposed interferometer; (b)magnification of the optical flat, sample, and gauge block.

The white light laser emits a low-coherent beam to the PCM. The PCM, which comprises a colour filter, two retro-reflectors (RR1 and RR2), a beam-splitter, and a compound stage (i.e. a stage assembled by mounting a nano-stage on the platform of a translation stage) on which RR1 is fixed, converts the incoming beam into two co-axial beams having a direction toward the entrance of the plastic fibre. The plastic fibre delivers the incoming beams for a distance to the IM. The IM includes a lens, a beam-splitter, an optical flat, a gauge block, the sample wrung on the gauge block, a z-stage on which the optical flat, sample, and gauge block are placed, and a CCD camera; wherein the lens expands and collimates the beams from the plastic fibre to illuminate the optical flat, sample, and gauge block simultaneously, and the optical flat, sample, and gauge block reflect the incoming beams to the CCD camera to generate an interference pattern having an intensity of

\[ I = I_0 \left[ 1 - \gamma \cos \frac{4\pi}{\lambda} \left( w_g - L \right) \right] = I_0 \left[ 1 - \gamma \cos \frac{4\pi}{\lambda} w \right]; \quad (1) \]

of which \(\lambda\) denotes the central wavelength of the source, \(\gamma\) is an envelope function, and \(w, L\) and \(w_g\) represent the gap between the sample (or gauge block) and optical flat, the amount by which the distance between RR and the beam-splitter exceeds that between RR and the beam-splitter, and contour height of the sample (or gauge block), respectively. Further demonstration about \(w, L\) and \(w_g\) is given by Fig. 1(b).

According to Eq. (1), the interferometer is capable of inspecting the sample using two measurement modes: phase-shifting and phase-scanning. The former is when the band-width of the source is narrow, and it examines the parallelism of the opposite surfaces of the sample using phase-shifting technique. The latter is when the band-width of the source is broad (i.e. the colour filter in Fig 1(a) is withdrawn), and it retrieves the thickness of the sample using phase-scanning technique (i.e. optical coherence tomography).

Note the interferometer is designed to install the PCM in an independent space isolating environmental perturbations and the IM in a workspace. The interferometer can therefore implement the measurements while the phase is remotely modulated using the PCM and the environmental perturbations around the IM are resisted due to the nature of common-path design of the IM.

Experiments and results. To implement the proposed interferometer, a setup composed of the interferometer and an image processing system was constructed and conducted to measure three gauge blocks. The measurement results are shown in Table 1, which validate the feasibility of the proposed interferometer.

References

(1) https://www.zygo.com/?met/interferometers/