In-situ measurement of curved surfaces on ultraprecision machine tools via chromatic confocal probes

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Ultra-precision machining is often used for fabricating optical components due to its extremely high processing accuracy. However, robust surface metrology and form error compensation is necessary because of errors caused during the machining process, the measurement process, and from the local environment. In the field of ultra-precision machining, on-machine measurement systems are getting attention because they can avoid errors caused by repositioning workpieces and also improve measuring efficiency. In this research, we used a chromatic confocal probe for on-machine measurement due to its high measurement accuracy and stability. However, the measurement of highly sloped surfaces is still a challenge because of the significant measurement errors occurring due to the angle of incidence between the probe and workpiece.

This study investigated the three-dimensional measurement accuracy of a chromatic confocal probe based on-machine measurement system. The chromatic confocal probe used in this research had a 4.5 mm working distance and a 300 µm measuring range. On-machine measurements were performed on multiple reference spheres with varying radii and probe angles to establish the effects that different measurement ranges and surface inclinations have on measurement results. In addition, errors due to the angle of incidence between the probe and workpiece were calculated via the analysis of measurement data from a reference sphere Measurements were taken at different probe incidence angles on a tilted flat once the center of the probe was aligned with the center of main spindle on the machine tool. By subtracting the computed angle of incidence error from multiple sets of measurement data, a dataset that more accurately reflects the true error in the surface was established, which can subsequently used for form error compensation on curved surfaces. Throughout the process, the s inusoidal measurement error observed on a tilted flat, caused by probe misalignment with respect to the center of the main spindle was removed.

By measuring a reference sphere, result indicate that measurement error increased as the angle between the probe and surface increased, and that the overall shape of measurement error rotated as the probe was rotated about its main axis. In addition, after error compensation, the range of measurement error was about 50 nm which is very close to the noise level of the probe. This research has shown an improvement in the measurement accuracy of chromatic confocal probe based on-machine measurement and will contribute to the improvement of precision and efficiency in ultra-precision machining.

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