In-line micro-scale form and surface texture measuring sensor based on focus-variation microscopy

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Abstract

In-line measuring sensors play an important role to increase the productivity of future manufacturing industries, by avoiding bottle-necks in inspection processes. A compact in-line and on-machine areal surface texture and form measurement instrument based on focus variation has been developed. Considering the feasibility of operating in real-time inside a production machine, the current prototype has been designed with the dimensions of 80 mm (diameter) × 200 mm (length) and the typical time for a single measurement is less than 20 s. The instrument design is presented. The in-line measurement performance of the instrument has been compared with measurement results acquired by a benchtop focus variation instrument in a controlled laboratory.

Design concept and requirements

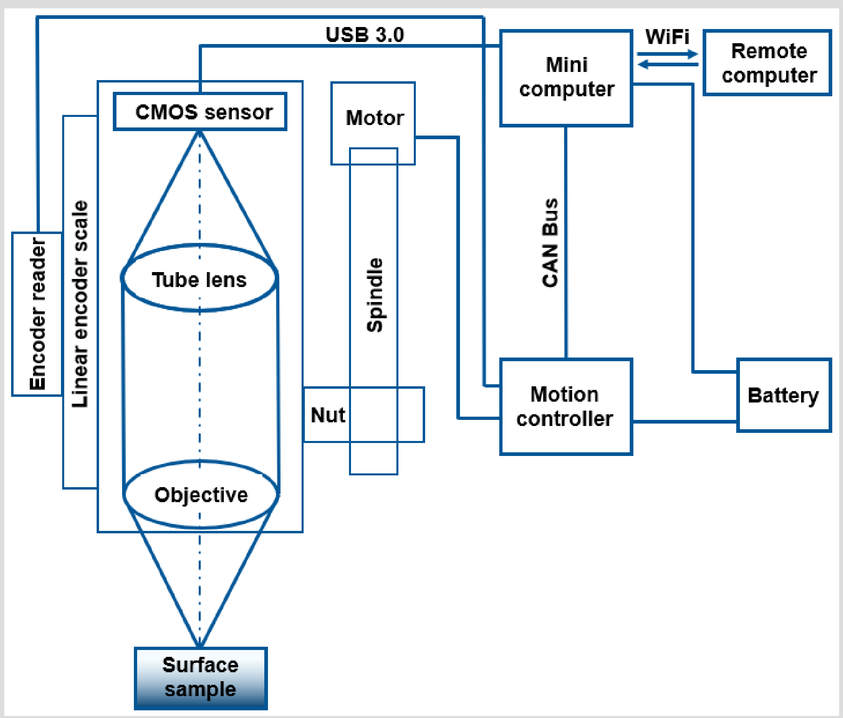

Fig 1. A conceptual diagram of the on-machine FV sensor.

Motion stage accuracy requirements:

- Absolute position accuracy: < 1 µm
- Resolution: < 25 nm
- Repeatability: < 250 nm
- Pitch: < 20 µrad
- Yaw: < 20 µrad
- Straightness: < 1 µm

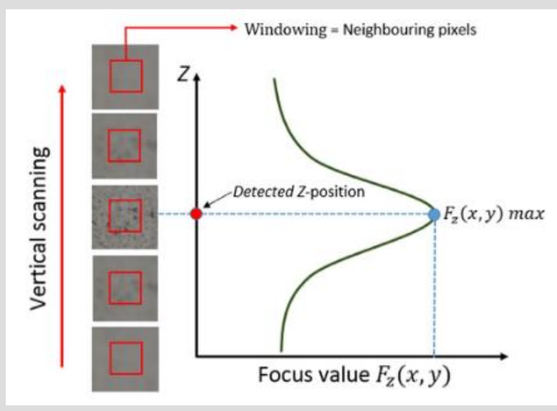

Fig 2. The principle of the FVM method.

Design of the sensor

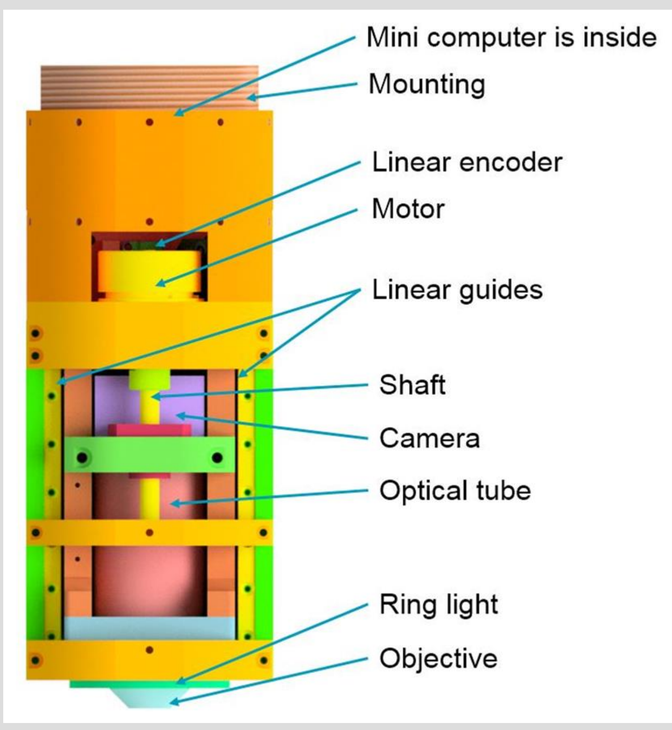

Fig 3. The prototype design.

The motion stage calibration

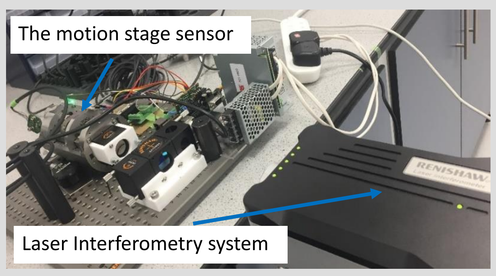

Fig 4. The experimental setup.

An interferometer (Renishaw XL-80) is used to measure linear, pitch and yaw errors for 20 mm travel. The overall measurement uncertainty arising from the repeatability of the measured errors of linear, pitch and yaw, and also from the atmospheric effects on the interferometric measurements was estimated < 100 nm (at a coverage factor k = 2).

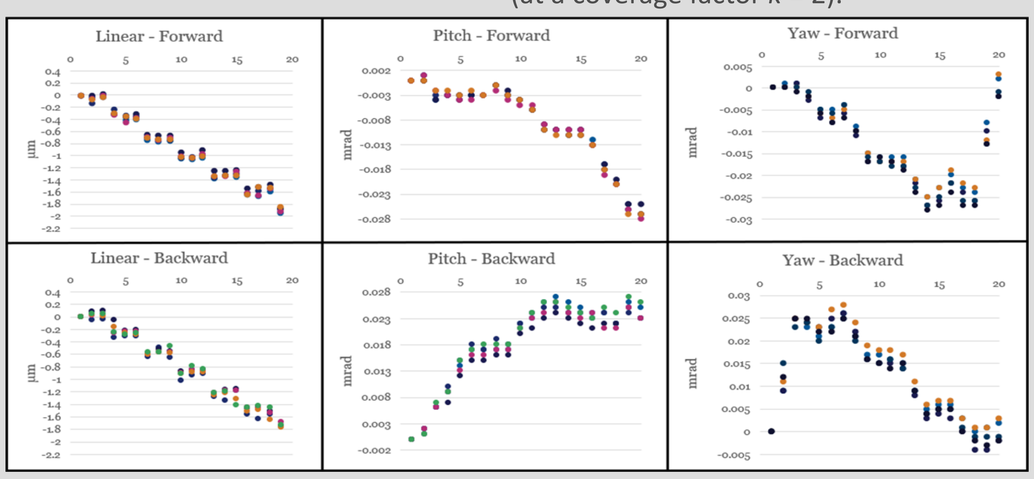

Table 1: Pitch, yaw and linear errors.

The in-line measurement

An optical system with uncorrected aberrations and distortions is installed within the sensor. The developed sensor has been integrated into a hybrid ultra-precision machine in the Centre for Precision Manufacturing at the University of Strathclyde (Glasgow) for evaluating the sensor performance. An array of channels has been manufactured by laser machining process and measured afterwards. In addition, a calibrated artefact with a step height of 1 mm was measured.

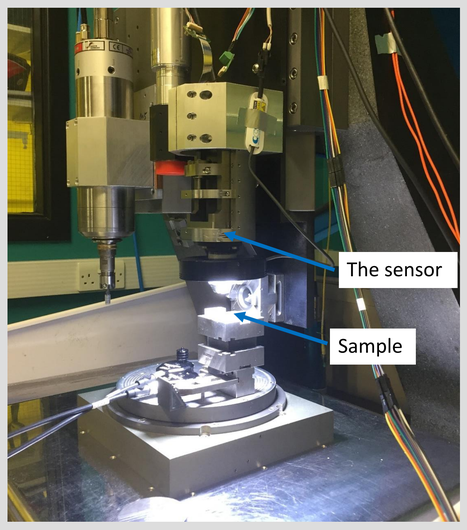

Fig 5. The in-line measurement experiment setup.

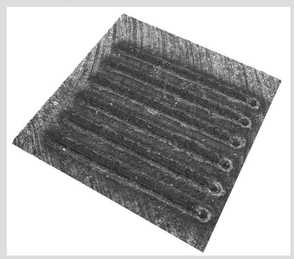

Fig 6. An array of channels measurement results.

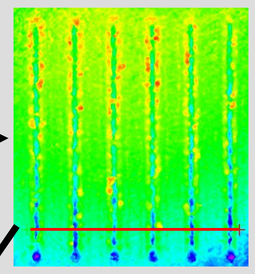

Fig 7. A cross section of channels.

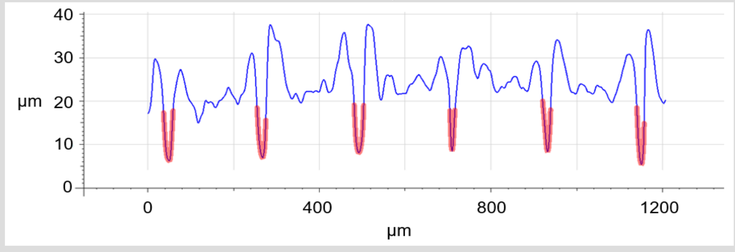

Fig 8. 2D cross section profile of channels.

Conclusion

- A focus variation based prototype sensor with dimension of 80 mm diameter for on-machine areal surface topography measurement is presented
- The motion stage has been calibrated with pitch and yaw errors are < 35 µrad and linear error is < 2.1 µm for 20 mm travel range
- The sensor has been integrated into a hybrid ultra-precision machine and In-line measurement has been performed for measuring a laser machined surface

References

[1] Darukumalli, S., Santoso, T., Syam, W.P., Helmli, F., Leach, R. (2019). On-machine optical surface topography measurement sensor based on focus variation. Proceedings of the 19th EUSPEN International Conference.

Acknowledgements

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