On-machine optical surface topography measurement sensor based on focus variation

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ABSTRACT

With the trend to increasingly implement quality assurance and thus measurement technology as an integral part of production, requirements on measurement systems have changed. Considering the feasibility of operating in real-time inside a production machine, a focus variation (FV) 3D sensor prototype has been designed with the dimensions of 80 mm (diameter) × 200 mm (length) and the typical time for single measurement is less than 20 s. The instrument design is presented. The performance of the on-machine sensor has been compared with measurement results acquired by a benchtop focus variation instrument. Additionally, the current prototype real-time wireless signal strength has been studied in a milling machine and the results are presented.

Current in-situ FV instruments

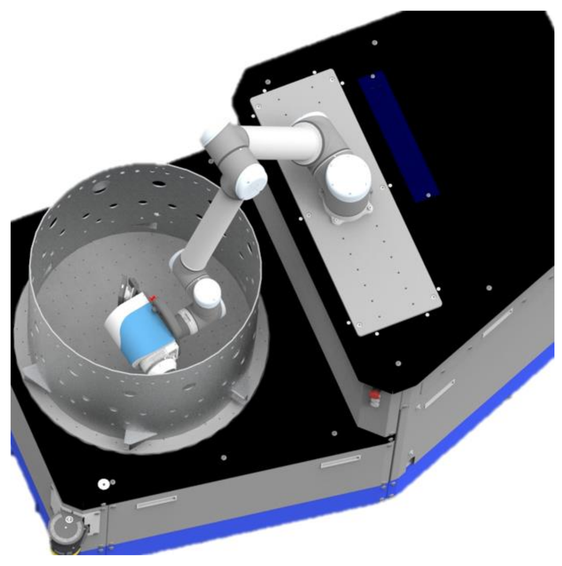
Alicona Cobot is an in-situ FV instrument which combines a collaborative 6 axis robot and a robust optical FV 3D sensor to deliver traceable and repeatable measurements in a production environment. Various options, depending on application can be implemented and some of the practical applications are presented below.

Disk Cobot
is designed to measure i.e. break edges and defects on turbine discs with mass up to 120 kg. Thus, manufacturers prevent sharp edges which can lead to safety failings.

Figure 1. Disk Cobot

Compact Cobot
is a universal solution applicable in all industries to measure micro structured surfaces, including with large components. Optionally, the Cobot can be located at a machine tool to automatically measure parts directly in the machine (no unclamping).

Figure 2. Compact Cobot



Turbine Cobot
is used to measure turbine cases. The Cobot enables the teaching of up to 500 measurement positions which are then automatically measured.

Figure 3. Turbine Cobot

Concept design of the next generation prototype

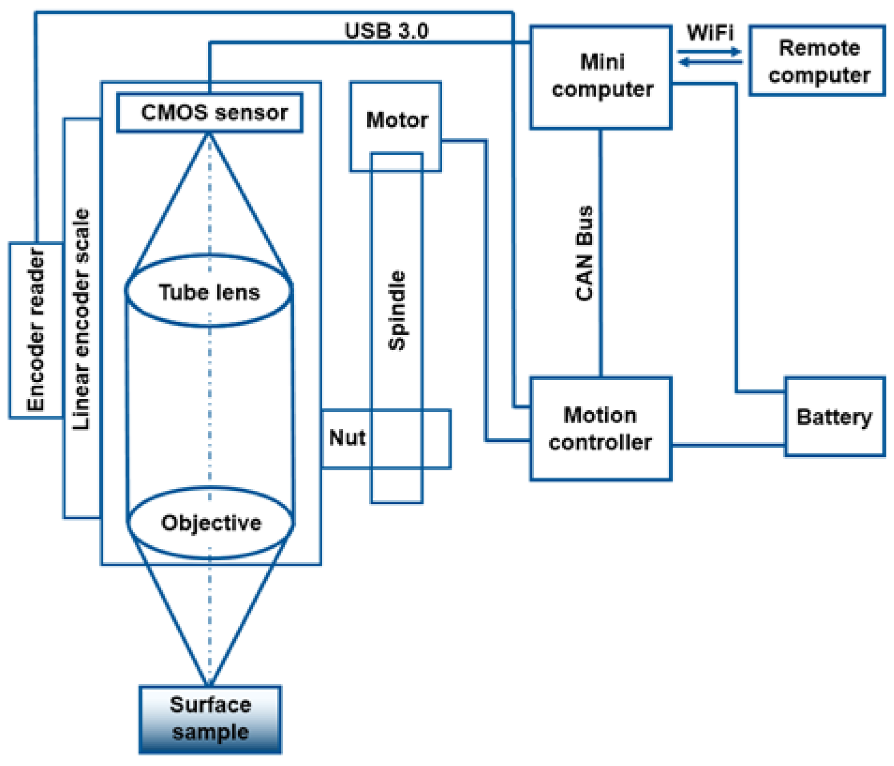


Figure 4. Concept diagram

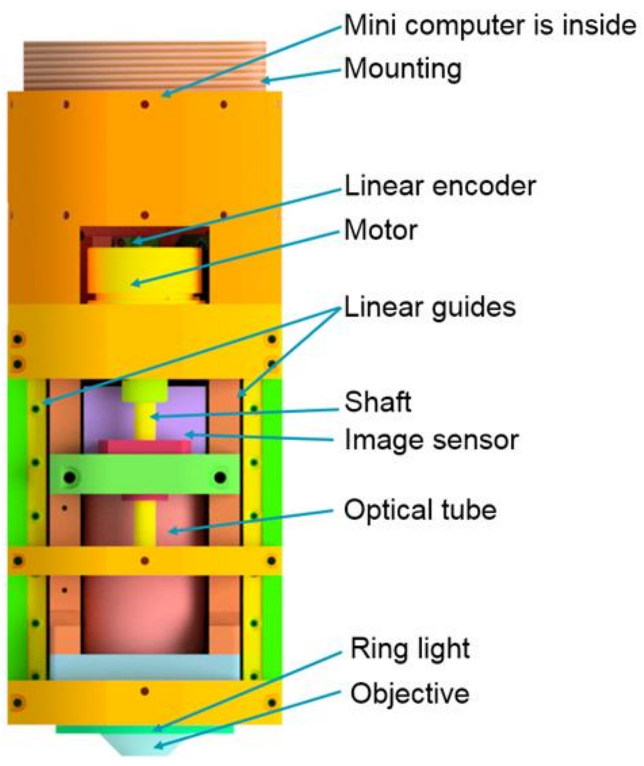


Figure 5. Prototype design

Test case: On-machine measurement

1. A milling machine is turned on and a milling process is in operation on a part.
2. The automatic tool changer of the machine will pick the sensor from its tool magazine.
3. The sensor is positioned on the part and measures the desired part's surface. This is done by using the milling machine software that can controls the tool changing process.
4. The captured areal surface measurement data is processed locally on minicomputer built in to the sensor.
5. The areal surface measurement results can be used for QC of the part, for optimizing the future milling processes and/ or for compensating the error of the milling on the current part.
6. Once the measurement is finished, the sensor is placed back into the tool magazine, where the battery will be recharged using a built-in wired/wireless charging outlet.

Key features

- On-machine Integration
- Small dimensions: 200 mm (length) × 80 mm (diameter)
- Industry 4.0 framework compatibility
- Quick surface measurement: each measurement take less than 20 s.
- Cost effective
- Versatility

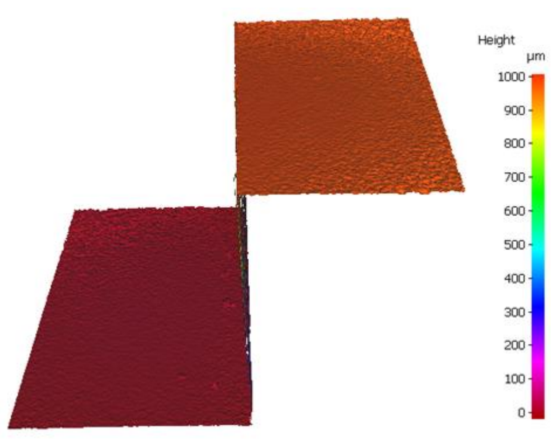


Figure 6. Step height measurement with the 10× objective and with 0.0001 mm vertical resolution.

Instrument	Step height/mm
Prototype	0.99997 ± 0.003
Benchtop	1.00012 ± 0.0005
Reference	0.9999 ± 0.0001

Table 1. Step height measurement results of the calibration artefact (Alicona IF-Calibration tool) with a step height of 1 mm (DKD calibration value is 0.9999 mm ± 0.0001mm at k = 2. The uncertainties in the above table were computed based on the linear encoder accuracy.

Instrument measurement noise method	Measurement difference /µm	Estimated repeatability /µm
Prototype	0.456	0.110
Benchtop	0.193	0.027

Table 2. Instrument measurement noise estimated using difference method (ISO 25178 – 700) and the proprietary estimation of the measurement repeatability value provided by the software.

Use case	Signal strength /dBm	Uploading speed /Mbps	Downloading speed /Mbps
Machine door open	-25	41.84	1.78
Machine door closed	-25	34.14	1.72
Machine in operation	-26	33.08	1.65

Table 3. WiFi throughput monitoring in a real time milling scenario

Conclusion and future work

Conclusion: Due to the lack of flatness deviation adjustment, optical adjustment for aberration and distortion, the instrument measurement noise is approximately three times higher than that of the benchtop FV instrument.
Future work: will be to correct for flatness deviation, optical aberrations and distortion, and a comprehensive test of the developed sensor and quantification of measurement uncertainty of the results.

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