INTRODUCTION
Today, more than ever, small, precise, mechanical parts such as automotive components containing flat, cylindrical or conical surfaces with form tolerances of less than 1 micrometer are being manufactured in high volumes. Frequently, the 3-D information on entire surfaces is needed to evaluate the correct function of these parts. Tactile systems are usually insufficient for these types of measurements due to the probing force or lengthy measurement times.

Figure 1 shows an example of a parallelism measurement on a pin with a 4mm diameter performed with a tactile and non contact optical stylus. The 0.5 gram tactile force caused a parallelism error of 0.8 µm.

FIGURE 1. This is a typical tactile parallelism measurement of a pin and the resulting measurement error due to the stylus force.

INTERFEROMETRICAL STYLUS SYSTEM
An interferometrical stylus system for form measuring machines which allows form and diameter measurements on precision mechanical parts with tolerances of less than 1µm has been developed, built, tested and already used under shop floor conditions.

The optical system is based on a novel concept of short coherence heterodyne interferometry working with two wavelengths [1]. It is divided into two subsystems: a modulation interferometer and a small, robust optical probe connected through a single monomode optical fiber [2].

The interferometer employs a broadband fiber-optic light source and works at an optical wavelength of 1.55µm and a synthetic wavelength of 36µm.

Under laboratory conditions we achieved distance equivalent noise level of 1σ < 1nm at a sampling frequency of 10kHz. Fig. 3 presents measurement of the distance equivalent noise of an interferometrical stylus and Fig. 4 shows compared distance measurements between an interferometrical stylus and a Polytec Vibrometer.

Currently, several custom, application specific, non-contact probes have been developed and built. Fig. 5 shows a fiber probe (microstylus) with a diameter of 35µm and optical probe with a diameter of 1.2mm and two optical outputs for cylinder and cone measurements.

FIGURE 5. Non-contact interferometrical probes. Tactile and interferometrical probe for the MFU110WP form measuring machine, Mahr Company and a fiber probe with a diameter of 35µm for the Altera Nano optical coordinate measuring machine, Mycrona Company.

Furthermore, custom software for post measurement processing and visualization of 3-D interferometrical data has been developed.

FIGURE 4. Compared distance difference measurement between an interferometrical stylus and a Polytec Vibrometer.

MEASURING MACHINES

For fast measurement of high volumes of precision parts, such as automotive parts close to the production line, we have integrated the interferometrical stylus system on to an unrivaled, high speed, rotational measuring machine.

FIGURE 6. Example of 3-D measurements on a very precise cylinder and cone.

The machine uses air bearings for the rotary table (C axis) and translation stage (Z axis). The maximum rotation speed for high precision measurements is 1000 RPM with a maximum error of both axis (roundness and straightness)
of less than 50nm. A typical measurement of a 20mm high cylinder including part fixturing, data acquisition of approximately 300,000 points and calculation of roundness, straightness, parallelism and diameter can be achieved in less than 2 minutes.

For universal applications we have used the form measuring machine type Mahr MFU100 and combined the interferometrical probe with a tactile probe [3].

Thus this measuring machine is used for both tactile and optical measurements during one measurement cycle. In order to examine the measuring capability of the system for tolerances smaller than 1µm we developed dedicated processing algorithms and performed a substantial amount of test measurements. A cylinder gage certified by the German National Metrology Institute (PTB) and production parts served as test objects for a %GRR and Cg capability study.

For form and diameter measurement of small, microscopic structures, such as holes with a diameter of 100µm, we have integrated the 35µm fiber probe on to a Mycrona ALTERA Nano optical coordinate measuring machine.

This machine was used to evaluate and create traceability of the patented micro-hole gage developed by the PTB. Results of this measurements are shown on Figs. 10 and 11.
CONCLUSION

An interferometrical stylus system for form measuring machines which allows form and diameter measurements on precision mechanical parts with tolerances of less than 1µm has been developed, built, tested and already used under shop floor conditions.

The optical system is based on a novel concept of short coherence heterodyne interferometry and achieved distance equivalent noise level of \(1\sigma < 1\text{nm}\) with a sampling frequency of 10kHz.

In order to examine the measuring capability of the system for tolerances smaller than 1µm we developed dedicated process algorithms and performed a substantial amount of test measurements.

The interferometrical stylus is already working in following machines:

- Mahr MFU100WP for universal measurements
- Bosch FMS 1000 for fast measurements near the production line
- Mycrona ALTERA Nano for measuring of small structures

Further a special software for post measurement visualization and processing of 3D interferometrical data has been developed.

REFERENCES

