attoSENSORICS
Ultra Precision Sensors

In situ Position Capturing in Coordinate Measurement Machines

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In situ position capturing in coordinate measurement machines

Live visualization of measurement data via the new measurement software WAVE

Introduction

Coordinate measurement machines (CMM) have highest requirements towards precision. CMM determine geometrical dimensions of simple and complex products and components. They are used for quality control, e.g. to identify the abrasive wear (tribological measurements) or to determine the manufacturing accuracy. CMM measure more than just distances, they are capable of capturing a broad range of geometries: angles, profile of a surface, parallelism, symmetries, tolerances, circularity, and much more. For those applications, CMM provide an accuracy in a sub-micrometer range. To enable this level of accuracy, CMM need even more accurate sensors to be calibrated. Furthermore, the position of the touch probe needs to be recorded on a more precise level than sub-micrometers. The currently most used solution for position acquisition of the CMM axes are glass-scales. However, they only measure the displacement of the column the touch probe is connected to relative to the bridge of the gantry. Since glass-scales do not measure the displacements of the touch probe itself, they cannot detect the actual overshoots and motion of the touch probe. Because of the contactless measurement technology, attocube's IDS (Industrial Displacement Sensor) is capable of focusing on the touch probe directly and capturing the motions at the point of interest. The new measurement software WAVE will display and save the measurement data and it includes a function for zooming into past data for analyzing overshoots and error motions.

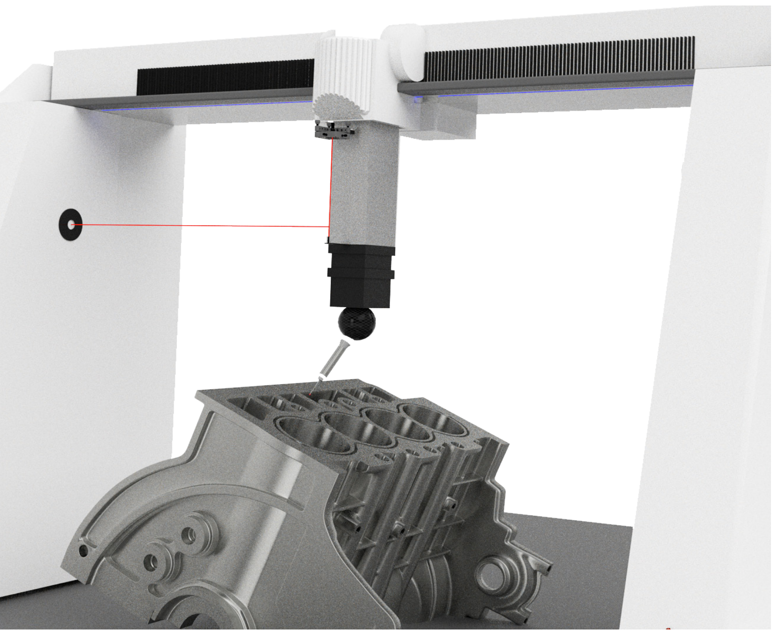

Figure 1: *Methods for position detection in CMM*

State of the art: linear encoders for position detection

Conventional CMM include several linear encoders (glass-scales) for detecting the position of the touch probe. E.g. to detect the horizontal position of the touch probe, the connected column includes the scanning unit that scans the glass scale included in the connected bridge (see figure 1 and 2). However, it is not the exact position of the touch probe, because there is a distance between the scales and the touch probe itself. Especially while moving the touch probe, the position detected by the linear encoder differs from the actual position of the touch probe. Motions like overshoots or vibrations in the nanometer range cannot be identified nor quantified by linear encoders.

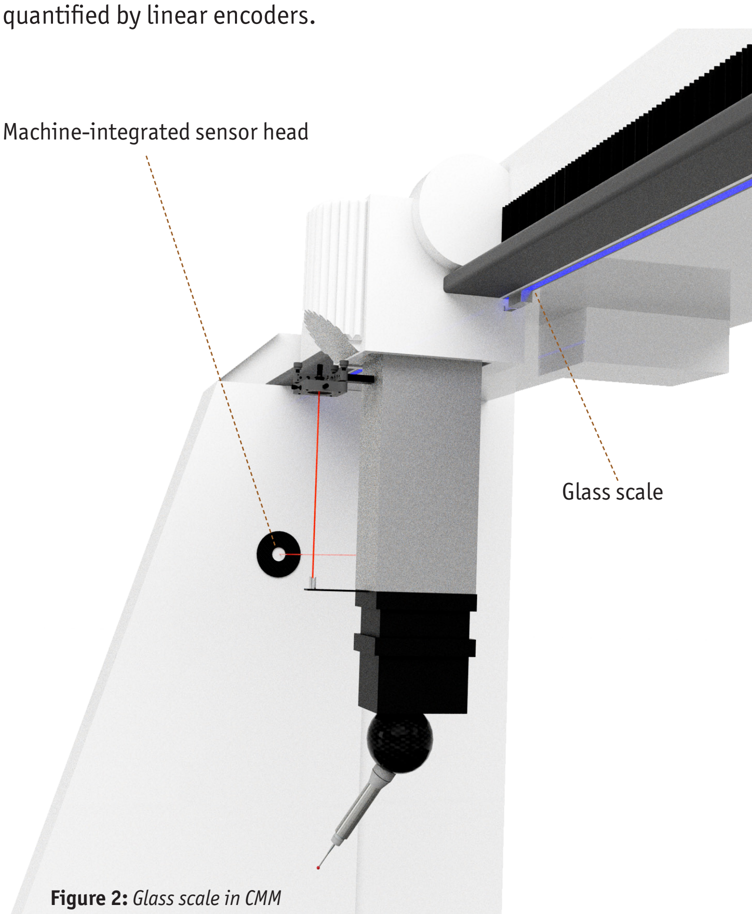

Figure 2: *Glass scale in CMM*

An *in situ* measurement focusing directly on the touch probe would provide more accurate information about the position of the touch probe and about the motions and vibrations of the CMM.

Improved position detection with laser interferometers

The IDS3010 is capable of detecting the touch probe's position directly and not by capturing the column's position. This facilitates the identification of overshoots and vibrations that cannot detected by linear encoders. The compact design of the IDS3010 and of the sensor heads enable an easy machine-integration even for space-limited applications. Furthermore, the IDS3010 can capture motions in a distance of up to 5 meters – even with a nanometer accuracy.

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Setup Description

To show the benefits of the IDS3010 in measuring short and long displacements, we have created a CMM-demonstrator to show the position detection in a CMM performed by an IDS3010. The measurement setup is shown in figure 3. A touch probe is mounted on a linear guide moving the probe on one axis, while the linear guide is integrated into a bridge.

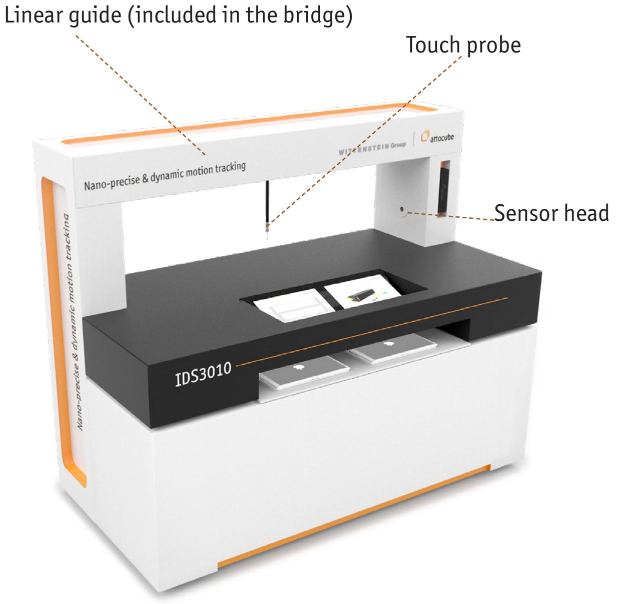


Figure 3: *Demonstrator for Coordinate Measurement Machines*

The sensor head and the IDS3010 are mounted in the columns of the bridge and the laser beam is reflected by a small retroreflector with a diameter of 3 mm. The sensor head used in this measurement setup is a M12/C7.6 (M12-thread and collimating optics with a beam diameter of 7.6 mm) that is used for long range applications.

The touch probe was moved over a long distance of more than 0.8 m and over a short distance in 10 µm steps. Since the IDS3010 is focusing on the lower part of the touch probe it is capable of detecting even short vibrations arising from the motion in combination with the stiffness of the touch probe.

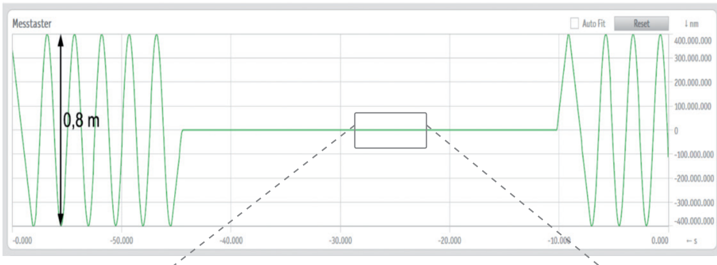
New Measurement Software WAVE

The IDS3010 was connected to a laptop via Ethernet interface and the data were processed by the attocube's measurement software WAVE. The streaming function enables users to zoom into past data for live-analyses of the captured motions. Furthermore, a live Fast-Fourier-Transformation (FFT) facilitates vibration analysis based on the data transmission of up to 1 MHz in picometer resolution.

Measurement Results

Figure 4a shows a screenshot of the measurement software WAVE including the displacement captured over a whole demonstration cycle by the IDS3010: in the first 15 seconds and the last 10 seconds, the touch probe moves in oscillations with 0.8 m distance.

Figure 4a: *Displacement graph in WAVE*



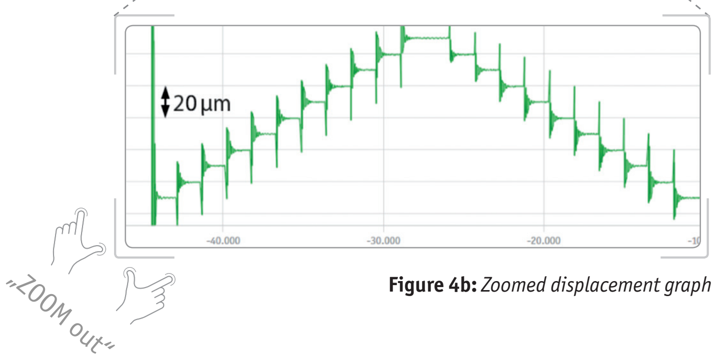


Figure 4b: *Zoomed displacement graph*

In between those long distance oscillations, the touch probe seems to stop instead of doing 10 µm steps. This is caused by the scale of the figure 4a that is adapted to long distance motions. To investigate those 10µm, we use the zoom function of WAVE. It is possible to zoom the time and/or the displacement. In this case, we use the displacement-zoom resulting into an increase of the scale of the y-axis to a few micrometers. By this zooming, the micrometer-steps become visible (see figure 4b).

Each 10 µm step took around 2 seconds. While the displacements between the steps are 10 µm, the graph does not show perfect steps: after stopping the touch probe, it shows overshoots in the micrometer range occurring from imperfections of the linear motor and from the stiffness of the touch probe. Furthermore, a dying-out oscillation can be seen at the beginning of each step which means that the touch probe finally stops after 0.4 seconds. The small noise at the end of every step results from vibrations that were brought into the system by the environment. This noise demonstrates that the touch probe is not nanometer stabile under ambient conditions and without vibration compensation.

Summary: detecting small and large distances

The measurements show that the IDS3010 is capable of capturing motions over a long distance and overshoots with an amplitude in the nanometer range. The overshoots identified by the IDS3010 would not be measured by a comparable linear encoder because linear encoders are capable of detecting the positions at the bridge – but they do not provide in-situ measurements on the touch probe. By measuring small and long distances with an accuracy in the nanometer range, the IDS3010 suits the requirements of position detection in CMM. There are applications in CMM that need more information than linear encoders provide, e.g. pitch and yaw measurement or vibration analysis. Because of the compact design and the high accuracy, the IDS3010 is a reasonable solution for those applications.

Outlook: three axes of CMM

To capture motions of more than just one-dimensional displacements, several IDS axes can be used. Figure 5 shows the exemplary structure of how to measure the displacements of all three CMM-axis with one IDS3010. Using accessories like mirrors and retroreflectors, more complex setups can be realized. Using more sensors facilitates to measure more motions than just the displacements, e.g. pitch and yaw measurements.

Besides the real-time position detection of the touch probe, the IDS3010 has more potential application fields in CMM:

- Calibration of coordinate measurement machines
- *In situ* position acquisition of the touch probe
- Vibration analysis of the touch probe and components of CMMs (e.g. identification of overshoots)

Reference

[1] IDS application: Calibration of machine tools and coordinate measuring machines: https://www.youtube.com/watch?v=8dfW5AVZ7dU

[2] Presentation IDS3010 in coordinate measurement machines: https://prezi.com/q13boaz1zrka/18-april-koordinatenmessmaschine-11-april/

[3] Tutorial measuremnt software WAVE: https://www.youtube.com/watch?v=k4ZtV0UHLxQ

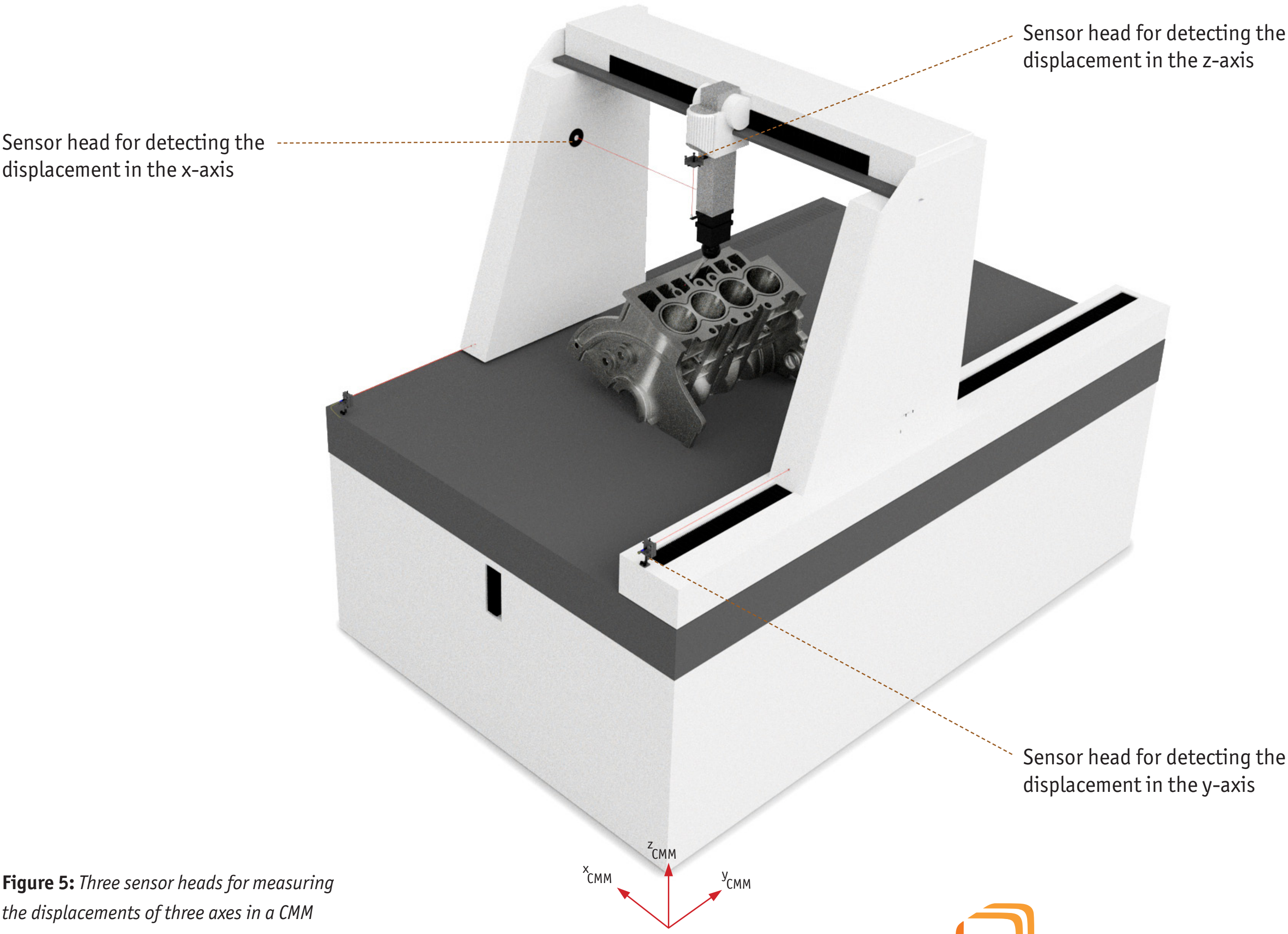


Figure 5: *Three sensor heads for measuring the displacements of three axes in a CMM*