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Position Capturing in Coordinate Measurement Machines

Real-Time Position Detection of the Touch Probe with attocube's IDS3010

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Introduction

Coordinate measurement machines (CMMs) have the highest requirements towards precision. CMMs determine geometrical dimensions of simple and complex products and components. They are used for quality control, e.g. to identify abrasive wear (tribological measurements) or to determine the manufacturing accuracy. CMMs measure more than just distances; they are capable of capturing a broad range of geometries, such as angles, profile of a surface, parallelism, symmetries, tolerances, or circularity. For those applications, CMMs provide an accuracy in the sub-micrometer range. To enable this level of accuracy, CMMs 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 associated measurement software WAVE will display and save the measurement data and includes a function for zooming into past data for analyzing overshoots and error motions.

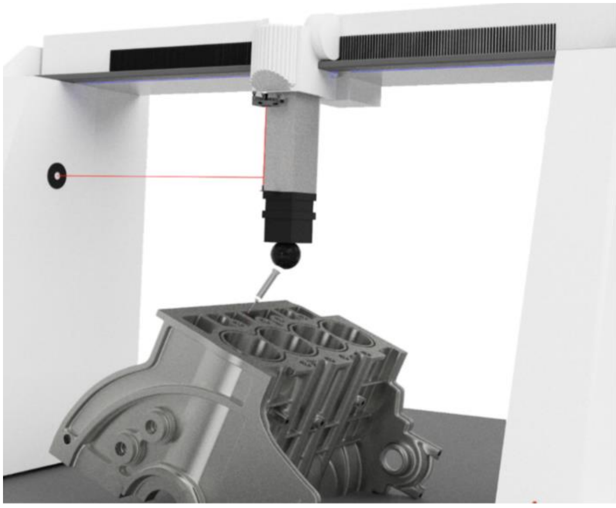

Figure 1: Position detection in CMMs.

Conventional CMMs include several linear encoders (glass scales) for detecting the position of the touch probe. To detect the horizontal position of the touch probe, the connected column includes a scanning unit that scans the glass scale included in the connected bridge (see Figure 1 and 2). However, this 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. An in situ measurement focusing directly on the touch probe can provide more accurate information about the position of the touch probe itself and about the motions and vibrations of the CMM.

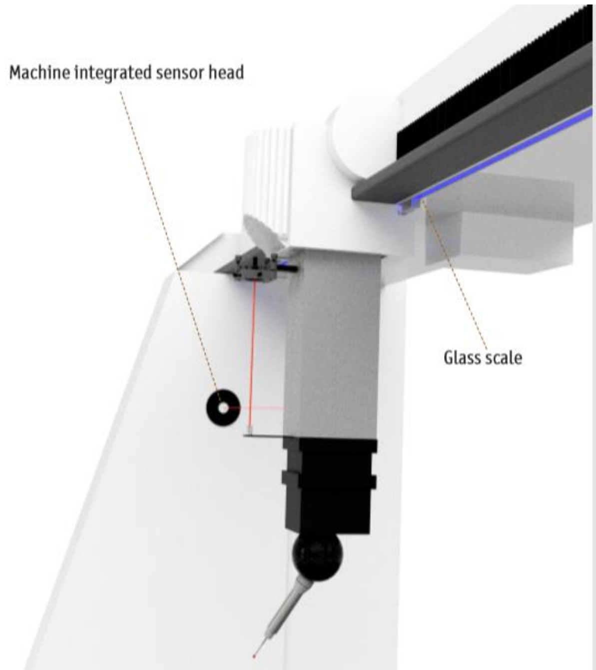

Figure 2: Glass scale in CMMs.

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 linear encoders cannot detect. The compact design of the IDS3010 and its sensor heads enable an easy machine integration even for space limited applications. Furthermore, the IDS3010 can capture motions at a distance of up to 5 meters with an accuracy in the nanometer range.

Setup

To show the benefits of the IDS3010 in measuring short and long displacements, we have created a CMM demonstrator to show the position detection performed by our interferometric system. 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.

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.

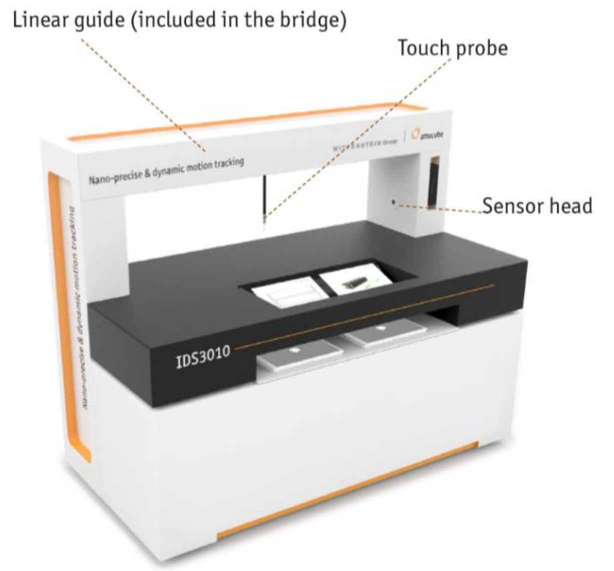

Figure 3: attocube's demonstrator for a CMM in combination with the IDS3010.

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

The IDS3010 was connected to a laptop via Ethernet interface and the data was processed by 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 the vibration analysis, based on a data transmission of up to 1 MHz with picometer resolution.

Measurement Results

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

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 Figure 4a, which is adapted to long distance motions. To investigate the micrometer-steps, we use the zoom

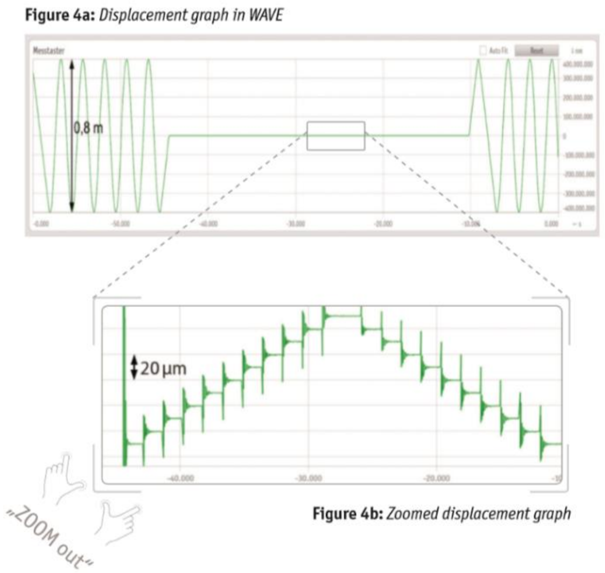

Figure 4: Displacement captured by the IDS3010 and visualized using attocube's WAVE software, including a zoomed-in part resolving the micrometer-steps.

function of WAVE. It is possible to enlarge the time and / or the displacement axis. In this case, we use the displacement-zoom to increase the resolution of the y-axis to a few micrometers. By doing so, 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 decaying 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 stems from environmental vibrations. This noise demonstrates that under ambient conditions and without vibration compensation, the touch probe is not stable at the nanometer scale.

Conclusion

The measurements show that the IDS3010 is capable of capturing motions over a long distance and including overshoots with an amplitude in the nanometer range. The overshoots identified by the IDS3010 cannot be measured by a comparable linear encoder, which does not provide in-situ measurements on the touch probe. By measuring small and long distances with an accuracy in the nanometer range, the IDS3010 perfectly suits the requirements of position detection in CMMs. There are applications in CMMs that need more information than linear encoders provide, e.g. pitch and yaw measurement or vibration analysis. Because of the compact

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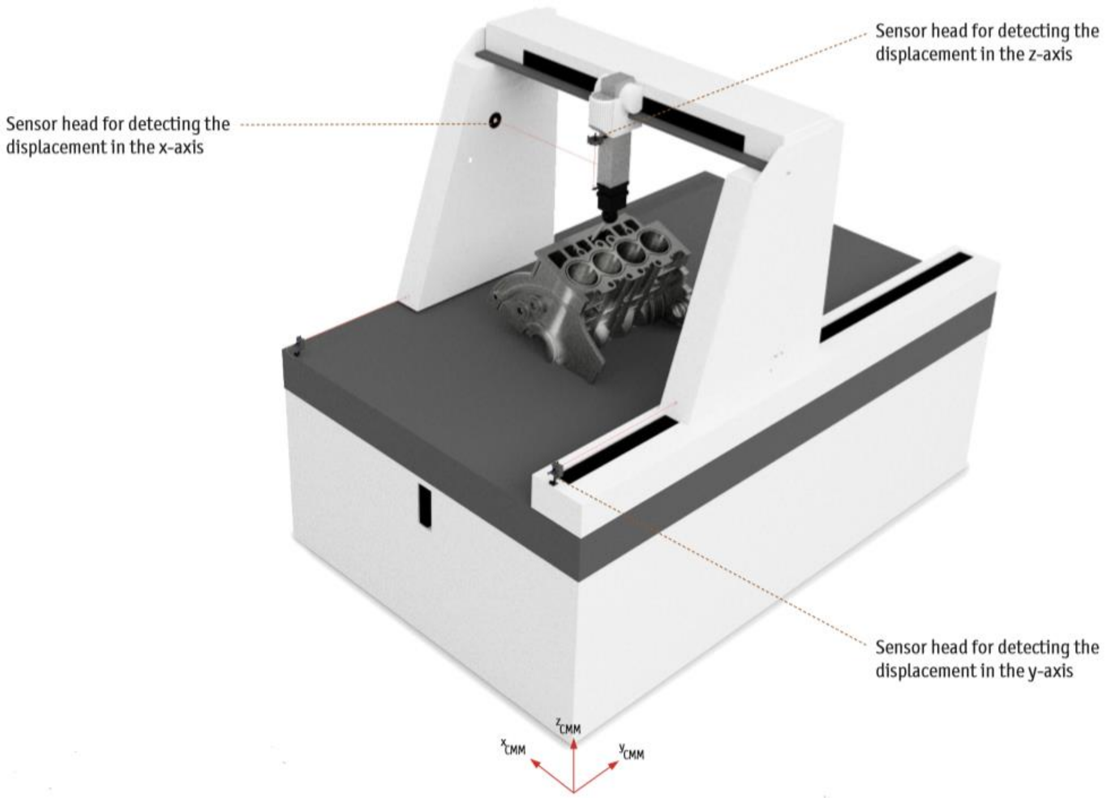

Figure 5: Potential setup for a simultaneous measurement of the displacement of all three CMM-axes with a single IDS3010.

design and the high accuracy, the IDS3010 is an ideal solution for those applications.

To capture motions of more than just one-dimensional displacements, several IDS axes can be combined. Figure 5 shows an exemplary structure of how to measure the displacements of all three CMM-axes with one IDS3010. Using accessories like mirrors and retroreflectors, even more complex setups can be realized.

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

- 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)