PICOSCALE Interferometer: Measurement of radial run-out and wobble

Abstract
The **PICO**SCALE *Interferometer* is a displacement sensor with picometer resolution. It may be applied in industrial applications to measure (and eventually correct) the radial run-out of a rotating workpiece or spindle.

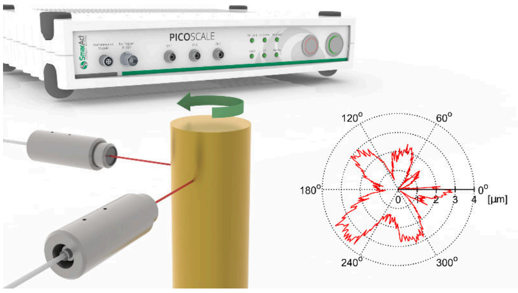

Figure 1. *Schematic view of the setup.* **PICO**SCALE *sensor heads are used to characterize the motion of a rotating target.*

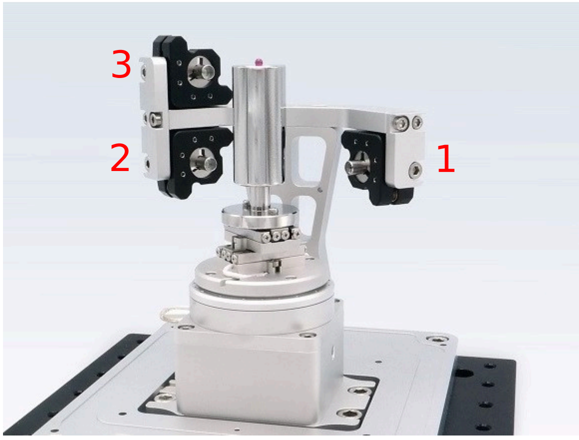

Figure 2. *Experimental setup. Three* **PICO**SCALE *sensor heads with line focused probe beam are targeting a polished cylinder, which is mounted on an xy- and a rotary stage. See text for details.*

1. INTRODUCTION

In high precision engineering the precise knowledge of the movement of a rotating target is of crucial interest. Radial run-out and wobble of a rotating spindle may have significant influence on the quality of a workpiece, and thus needs to be reduced. However, any correction requires an error signal, and thus the run-out and wobble need to be measured accurately. Subsequently, by applying adequate control loops or lookup-tables, the rotating target may be kept on the desired trajectory.

2. SETUP

The setup of this demonstrator is shown in Figure 2. A polished cylinder (stainless steel) was mounted on a SmarAct xy-stage as well as a rotary stage. The xy-stage can either be used to set a specific eccentricity to prove the capability of measuring large run-outs of up to 1 mm, or to correct for it. Two line focusing sensor heads (Order Code: PS-SH-L01) were assembled at a specific height with a 90° orientation to measure the eccentricity, and a third sensor head was mounted above the second one. The latter pair was used to infer the wobble of the cylinder. A **PICO**SCALE Controller with increased laser power was used for these experiments (Order Code: PS-CTRL-V1.4-HP), which is optimal for low-reflectivity or cylindrical targets.

3. MEASUREMENT PROCEDURE

The cylinder was rotated by small increments and at each angle the relative displacement of the target with respect to each sensor head was recorded. In Figure 3 the values for the x- and y-direction are shown. The 90° phase shifted signal is (in first order) interpreted as the eccentricity of the sample.
The wobble is calculated from the position data of sensor heads 2 and 3. Consequently, a numerical fit is applied to the data that incorporates the wobble of the pin. Thus the effect that each sensor head records the shape of an ellipse instead of a circle is taken into account. The residues from the pin are due to the non-perfect surface of the pin which is overlaid with bearing errors. Figure 4 shows these residues of sensor head 1, for all recorded angles between 0 and 360°. The residues are within $\pm 1.5\,\mu m$.
The line focusing heads allowed to track eccentric movements of up to 1 mm while being insensitive to wobble. Thus, the **PICO**SCALE can be used in high precision engineering or wherever radial run-out and wobble are crucial parameters.

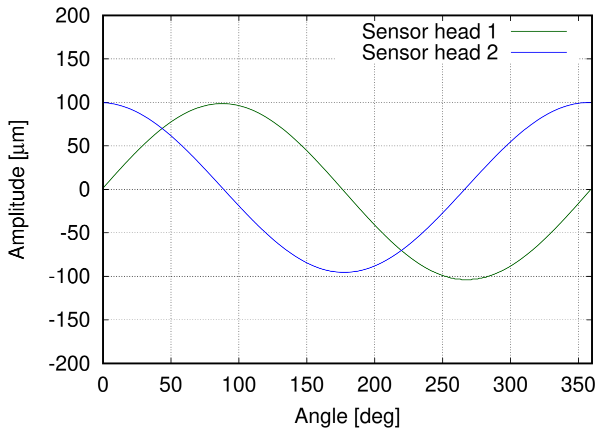

Figure 3. *Measurement of the eccentric movement. The x- and y-direction is shown, that are measured by sensor head 1 and 2, respectively.*

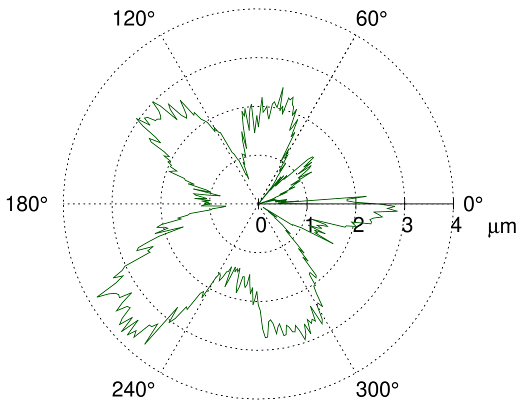

Figure 4. *Residues of the data measured by sensor head 1 after the calculated eccentric movement and wobble are subtracted.*

4. VARIOUS PIN DIAMETERS

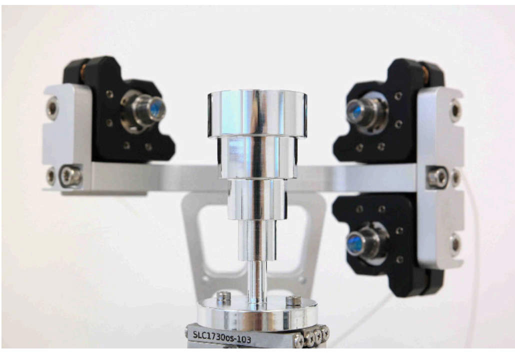

Figure 5. *Probe pin with different diameters ranging from 25 mm (top) down to 5 mm (bottom).*

The L01 sensor heads have been aligned to various diameters of a cylindrical surface, see Figure 5. The goal is to determine the maximum eccentric movement of the sensor head in dependence of the pin diameter. The results for the smallest pin diameter are shown in Figure 6. All measurements with larger diameters showed similar results, and maximum eccentricities of more than 0.7 mm were always possible. The surface quality of the pin was the limiting factor, which was polished aluminum.

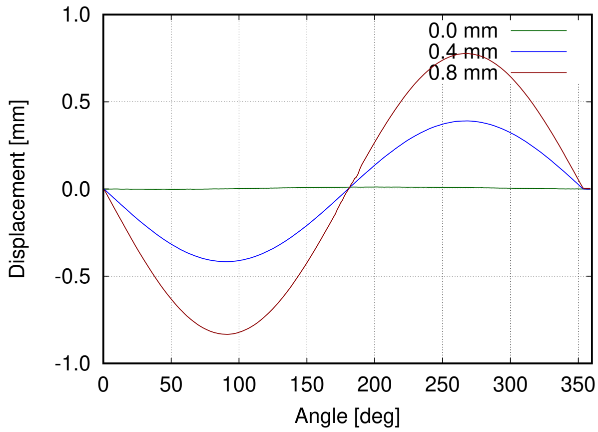

Figure 6. *Displacement measurements of a rotating pin with a diameter of 5 mm and some (artificially introduced) eccentricities. Eccentricities of 0.8 mm were tracked.*

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