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Long range wire based yaw and straightness measuring system for a 50 m bench

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Abstract

In dimensional metrology, 50 m benches are commonly employed for the calibration of measuring tapes and laser distance meters. The measuring carriage requires a precise guiding over multiples joint rail segments that form two 50 m long guiding rails. We present an economic solution for surveying the carriage's yaw and straightness over 50 m. By means of a thin polymer wire and two image sensors, the carriage behaviour is precisely characterized. The obtained results show a yaw accuracy better than 2 µrad over the whole measuring range and a good repeatability.

Keywords: Wire based straightness, yaw calibration, tape measuring bench, long range yaw measurement

1. Introduction

Long distance benches are often used for the calibration of tapes. To perform precise measurements, the alignment of the guiding rails for the measuring carriage needs to be known and regularly verified in order to estimate the magnitude of the Abbe error contribution to the measurement uncertainty. Angular interferometers are frequently used to characterise very precisely the yaw of carriages over quite long ranges. However, often they lack enough power to cover the full 50 m range and cannot be used to measure simultaneously straightness, angle and distance. Furthermore, laser straightness interferometers (Wollaston) and laser based straightness sensors can be used for the characterization of the guiding rails, however they are limited in distance to a few meters [1], [2] or suffer from noise at long distances. Instead of lasers, a taut wire can be used as straightness reference to align precisely structures over long distances [3], [4]. At METAS, we developed an economic straightness and yaw measurement system consisting of a wire taut over 50 m and two optical wire sensors fixed onto the moving carriage. Our system design allows the simultaneous measurement of yaw and straightness over the whole 50 m movement of the carriage.

2. Setup and working principle

The developed system as shown in figure 1, is composed of three main parts: a taut polymer wire and two optical sensors, placed on each side of the measuring carriage.

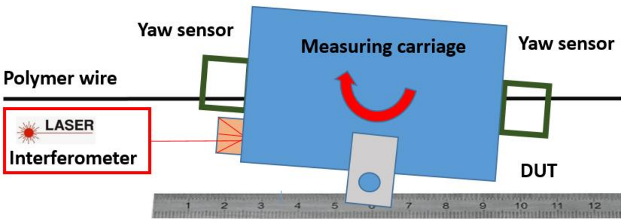

Figure 1. Schematic setup – top-down view

In a first step, the 8-braid PE fibre wire with a diameter of 0.16 mm (Balzer, Irone line 8) was taut over 50 m. The wire was fixed on a hock at one side of the bench and straightened over a pulley with a 2 kg weight at other end of the bench. The resulting wire sag is less than 5 mm over 50 m. For the horizontal position detection of the wire, we used a Basler monochrome image sensor daA1280-54um, which has a 1.2 M Pixels CMOS chip with 3.75 µm square pixels combined with a collimated illumination. The illumination is composed of a 5 mm round green led, where the lens was filed off, polished and fitted with a BK7 convex lens (LA1951-A, Thorlabs). Both optical sensors were then mounted on the front and the rear of the moving carriage and adjusted to the wire height and position. Indeed in order to capture a sharp and contrasted wire image over the whole measuring range, the wire has to be positioned as close as possible to the CMOS detector at the beginning and the end of the bench.

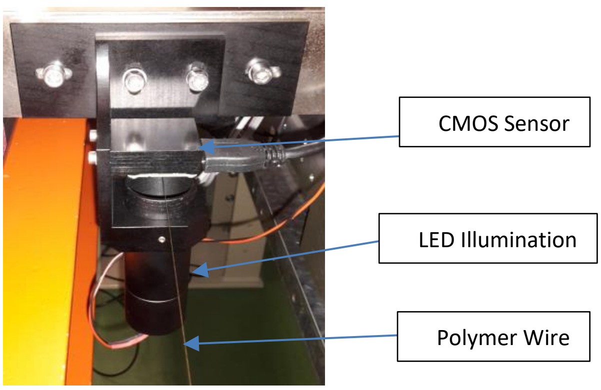

Figure 2. Yaw sensor with CCD and LED illumination

To determine yaw and straightness values at a specific carriage position, the lateral wire positions were extracted from the two image sensors by summing up all image lines into one profile and calculating the centre of gravity after background subtraction. For straightness, the mean wire position from both sensors was used. To obtain the yaw, the wire positions from the front and rear sensors were subtracted and divided by the distance separating both sensors. Before each series of measurements, the setup was set to zero at the beginning of the bench.

3. Results

In order to assess the performance of the developed system, the yaw of the carriage was measured simultaneously with an angle interferometer and with the yaw sensors, every 0.5 m along the 50 m bench. Figure 3 shows the difference between the values measured with the two systems. The yaw results obtained with the wire system are in good agreement with the values from the angle interferometer which was considered to be the reference. Over the entire length of the 50 m bench, a maximal difference of 3.5 µrad is observed.

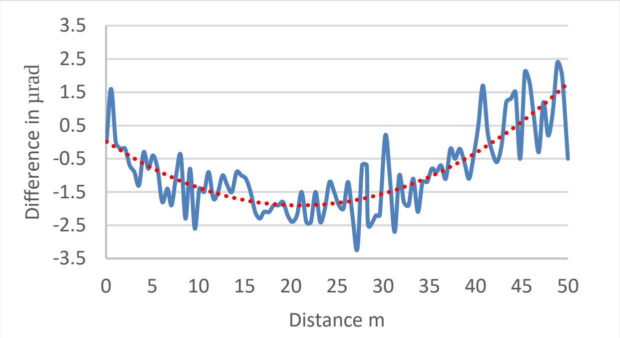

Figure 3. Difference of yaw measured with the wire method and the angle interferometer (without wire sag correction)

The location of the maximal difference between both methods is found around 25 m, where the distance between CMOS sensor and wire is maximal. In fact, the illumination collimation quality and the alignment of the illumination in vertical direction can lead to errors in the evaluation of the lateral wire position. Theses deviations can be minimized by adding a correction due to the gravitational wire sag. After including a corresponding correction, the obtained yaw accuracy is better than 2 µrad over the whole measuring range (figure 4). The increase of difference observed after 25 m is principally due to the noise of the angle interferometer. For a distances of 25 m, interferometer noise is about 1 µrad.

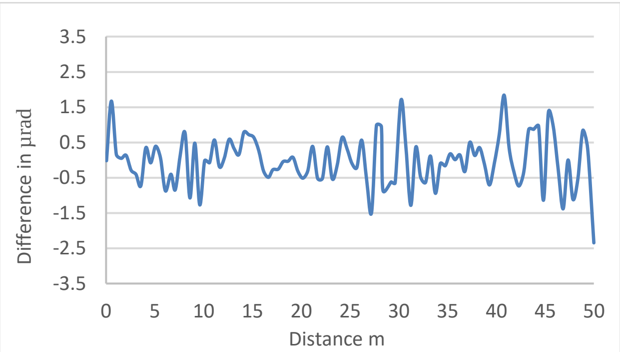

Figure 4. Difference of the yaw results measured with angle interferometer and the wire method after calibration (sag correction)

In a second step, the yaw and the straightness of the measuring carriage were measured simultaneously, while using the laser interferometer to position precisely the carriage every 0.5 m along the 50 m bench. The measurement results, shown in figure 5 and figure 6, agree well with pervious characterization results performed on the 50 m bench. The known ditch due to a straightness deviation of the guiding rails around 34 m and the associated yaw, are clearly identifiable. The carriage yaw up to 20 meters is within ±25 µrad, and over the whole range within ±80 µrad.

The stability and reproducibility of the wire method was also examined by doing consecutive measurements at 25 m and multiple measurements over the time along the bench. The observed yaw and straightness measurement stabilities and reproducibilities were better than 2 µrad and 20 µm respectively.

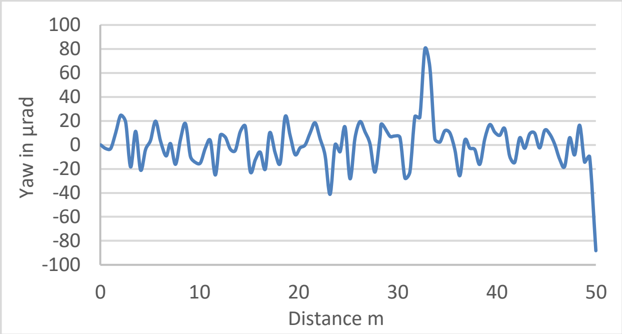

Figure 5. Carriage yaw measurement along the 50 m bench

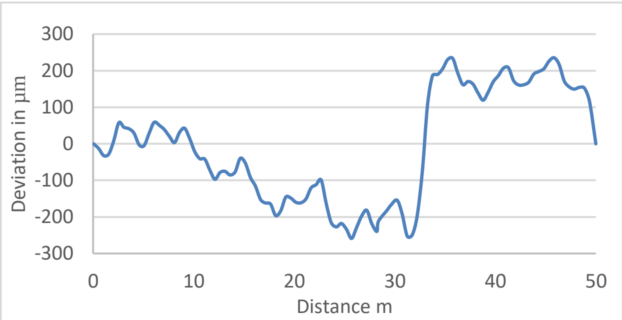

Figure 6. Carriage straightness measurement along the 50 m bench

4. Conclusion

The results show that the developed system allows a precise and accurate measurement of yaw and straightness over long distance. The performance of our wire setup allow us to track changes of the guiding rail over time and furthermore estimate and correct the Abbe error for each measuring point during the calibration process. Our solution is simple to install, is cost effective, has low power consumption and does not require an additional laser. By correcting the effect of the gravitational wire sag, the proposed wire method produces reliable values over a distance of 50 m. A new adjustment of the guiding rails is planned and due to the new measurement method easy to perform.

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