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LASER INTERFEROMETRIC MEASUREMENT OF MACHINE TOOLS

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Abstract: This paper deals with a positioning accuracy measurement on a machine tool to perform calibration. The principle of laser interferometric measurement is introduced, a Renishaw XL-80 laser interferometer is applied to perform measurements. The methodology of using the system is presented through a practical measurement. The deviations in certain positions are determined, thus the pitch error table of the machine tool can be refreshed. Thereafter a test running is performed in order to check the accuracy of the machining centre.

Keywords: *laser interferometer, backlash, positioning accuracy*

1. INTRODUCTION

Nowadays the production of dimensionally accurate workpieces is indispensable [1]. This aspect can be provided by the use of numerically controlled machine tools. These machines, e.g., milling station or turning machine can provide the production of high precision parts. However, after a certain period of operation, the machines need to be checked, calibrated. Since there are many parameters, which have an effect on the accuracy of a machine tool, e.g., heat, lubricants, vibrations etc., therefore planned maintenance is essential.

Lasers (Light amplification by stimulated emission of radiation) are widely used not only in laboratory purposes, but also for industrial measurements. There are several types of lasers, e.g., gas-, solid-state-, fiber-, and semiconductor lasers. Laser interferometers [2–4] are good tools to determine the positioning accuracy of a machine tool. These devices contain a high monochromatic and coherent laser beam source ensured by stimulated emission, a stabilizer/compensator, and a stationary-, moving mirror.

The main goal of the article is to present the methodology of measuring with a Renishaw XL-80 [5], laser interferometric system. The unit is capable to communicate with computers through an USB cable in order to establish the possibility of data acquisition. This laser interferometer is applicable in the field of machine tool calibration. A compensation unit called XC-80 is used, which consists of temperature, pressure, and humidity sensors. Aligning the measuring mirrors and the laser head unit requires a great deal of care. The measurement of positioning accuracy of a Mazak VTC-800 machining centre is essential, since the accuracy of recent parts produced on the machine tool was no longer adequate. The axis x to be measured has 3000 mm distance, during the measurement 40 mm position increments are applied.

The paper is organised as follows: Section 2 describes the structure and elements of the measurement. A practical measurement is discussed in Section 3. The positioning error of the Mazak machining centre is measured and analysed. Knowing the deviations, the correction of the error is performed with the pitch error compensation table of the machine. The concluding remarks are given in the last Section.

2. Methodology of measurements

Laser interferometric measurements usually contain a laser head unit, a stationary mirror, and a moving mirror as it is shown in *Figure 1*. The principle of laser interferometer measurements is based on the phenomenon of interference. The moving mirror must be placed on the object to be measured, and then the stationary mirror must be placed in a stable fixed place. Then, the laser beam emitted by the head unit is divided into two parts perpendicular to each other, but with equal intensity, thanks to the beam splitter. Then one laser beam will return to the head unit from the stationary mirror, while the other will return from the moving mirror. The amount of displacement is obtained from the interference of the laser beams arriving from two different paths.

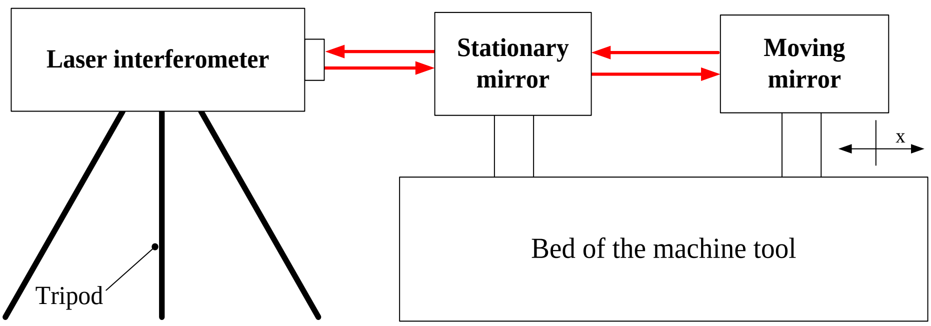

Figure 1. *Scheme of the measurement*

A Renishaw XL-80 laser interferometer (see *Figure 2*) is used to perform measurements, the specification of the unit can be seen in Table 1. A compensator unit is essential to get accurate measurement data, therefore it consists of intelligent sensors, which can measure the air temperature, the pressure, and the relative humidity [5]. It is a key factor to get precise displacement values in the course of measurement.

Table 1
Specification of the Renishaw XL-80

Name	**Value**
Linear resolution	~1 nm
Range	0–40 m (expandable to 80 m)
Heating up time	<6 minutes
Compensator unit	XC-80
Dynamic capture rate	50 kHz
Travel velocity	up to 4 m/s

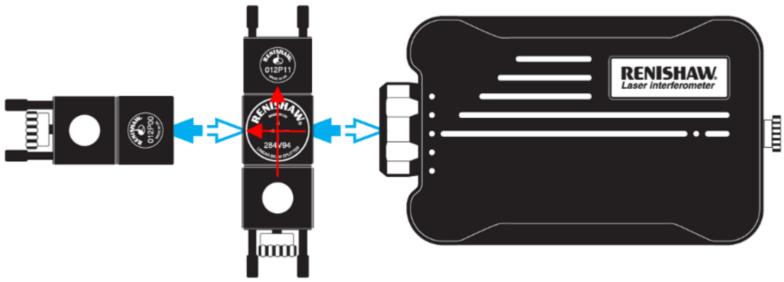

Figure 2. *Renishaw XL-80 interferometer and its mirrors with the directions of the laser beams*
(Source: XL laser system user guide, Renishaw plc)

2.1. Setup of the measurement

Before starting the measurement, the system must be set. Accurate adjustment (see Figure 3) of the measuring system often takes more time than the entire measurement. In order to be able to measure accurately, it is important that the path of the laser beam from the laser unit to the moving mirror and back to the laser head should be coaxial.

Therefore, it is necessary to pay attention to the placement of the units, which can be performed with the help of eye gauge, the XL-80 unit and the optics must be aligned.

After the appropriate placement, turn on the laser to make sure that the laser beam is exactly parallel to the movement to be measured. To check this, caps can be attached to the mirrors, which make the point visible, where the beam reaches the cap. Then, the following steps must be followed:

- targeting the point on the moving mirror with the laser at the far end of the measurement,
- moving the machine (and the moving mirror) to the nearest point of the measurement,
- if the laser beam has moved away from the target area, then readjustment is needed with the set of the appropriate knobs in the proper direction and magnitude,
- check again at the far point and – if necessary – correction.

Once this is done, the system is ready to perform machine calibration.

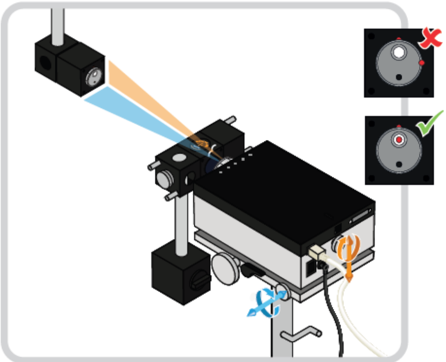

Figure 3. *Adjustment of the laser beam and the mirrors*
(Source: XL laser system user guide, Renishaw plc)

3. PERFORMING CALIBRATION ON A MACHINE TOOL

A Mazak VTC-800 machining centre is analysed. The set-up of the measuring system is shown in *Figure 4*. The positioning accuracy will be determined, and the backlash will be also checked.

The LaserXLTM/Linear Measurement software is used to capture the measurement data. Before measurement several tasks need to be performed. The first-, last targets must be defined, the interval size, measurement type are also important to give. When the measurement is performed in the position increments, the minimum period halt, stability of reading, tolerance window, and overrun step size must be also necessary, an example is shown in *Figure 5*. After setup, the measurement can be started.

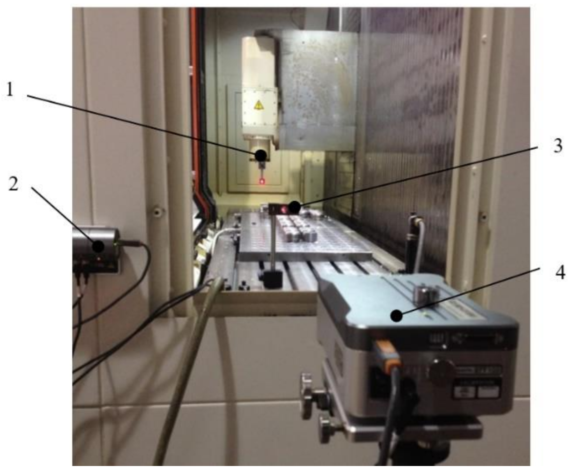

Figure 4. *The set-up of the measurement system: 1 – moving mirror placed on the spindle; 2 – XC-80 compensator; 3 – stationary mirror; 4 – laser interferometer head unit*

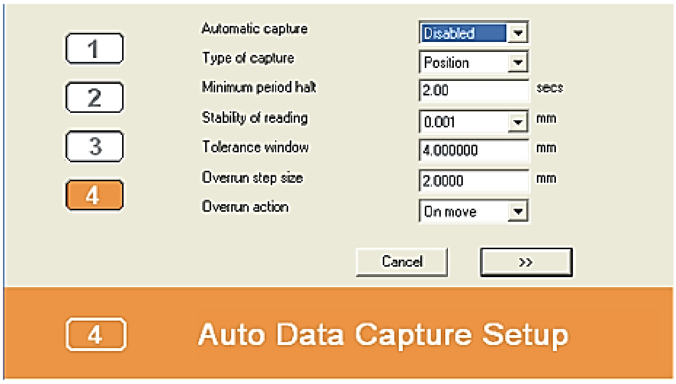

Figure 5. *Fourth step of measurement settings*

The measurement values are displayed and saved in an .rtl file format. Thereafter the Pitch-error table on the machine tool must be filled in with the correction values. A rounded value must be given in microns, e.g., 1 µm, and then the correction must be checked with another measurement. If the results are worse than they were either changing the sign will solve the problem since the type of transmitter can also determine the measurement or the data form must be changed (incremental, absolute forms).

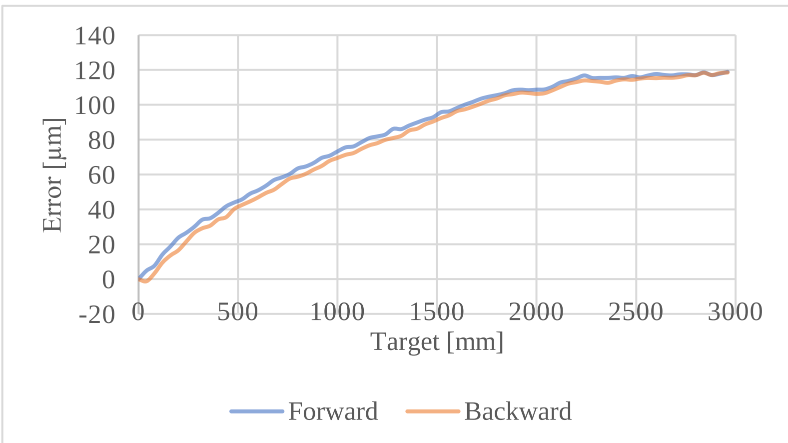

Figure 6. *Measurement result without calibration of the machine tool*

The results of a bidirectional measurement are shown in *Figure 6*, which is performed on a Mazak VTC-800 machining centre. The deviations of axis x of the machine are measured, 40 mm displacement increment is used. The length of the axis is 3000 mm, the total measurement points are 75.

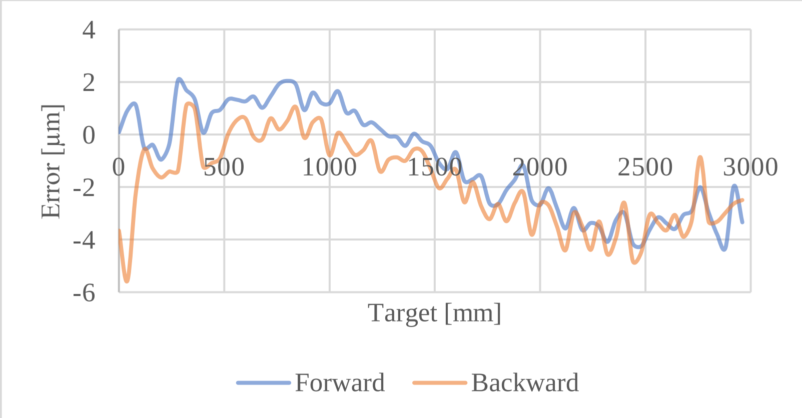

Figure 7. *After calibration*

It can be seen that the machining centre has relatively high deviations (>100 µm) from the desired positions at the travelling distance of axis x. Therefore, corrections are essential.

After refreshing the pitch error table, a test measurement is performed, which is shown in *Figure 7*. The bidirectional measurement shows that the deviations became smaller. Thereafter, trial production followed, which showed that the accuracy of the machine tool is satisfactory.

4. Summary

The article dealt with a laser interferometric measurement of a machining centre, which used a Renishaw laser interferometer. The principle of laser interferometry was briefly introduced. The methodology of the measurement was presented. The positioning accuracy of the Mazak VTC-800 machining centre was checked. The results, and quality of the produced workpieces showed that calibration is needed. The correction data was determined and typed to the pitch error table of the control unit. Thereafter test production was performed, which proved to be adequate.

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