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THE EXPLANATION OF THE PARAMETERS OF CNC MACHINES

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Abstract: Contribution deals with the calibration of the CNC machines, which are required to produce accurate and high-quality products. It is possible to produce accurate parts only if we have accurate machine. Parameters describing positioning of the CNC machines contain ISO 230-2. However their interpretations are not complying with the VIM terminology in metrology. For this reason we decided to explain right interpretations of the terms using in metrology and describe the mathematical model of measurements according ISO GUM.
Keywords: CNC machines, calibration, metrology, mathematical model

1. INTRODUCTION

CNC (**C**omputer **N**umerical **C**ontrol) machines can be defined as computer-controlled machines, which also meet the classification of the measurement system, because there are measuring systems in the axes of these machines [1]. These can be realized by two ways. By indirect measuring is monitored variable position of the servomotor monitored, which made movement. The position of an NC feed axis can be measured through the ball screw in combination with a rotary encoder. Changes in the driving mechanics due to wear or temperature cannot be compensated. Direct measuring systems are designed to immediately provide the information about the relative motion due to the machine frame. The target value is compared with the actual value as a result of feedback operation. The motion system of the CNC machine corrects the immediate value of the actuator of reading a linear encoder [2].

2. PARAMETERS OF THE CNC MACHINES

Parameters for determination of positioning of numerically controlled axes, including CNC machines contain ISO 230-2. Nine standard parameters are evaluated according to this standard. These can be divided between local parameters expressing the position and positioning and the global parameters, reflecting the positioning of the axis. Actually between the recommendations, of the ISO standard and metrology approach to evaluation can be found some irregularities.

Accuracy **A** according to ISO 230-2 is expressed like range derived from the combination of the systematic deviations and the estimator of the standard uncertainty of positioning using a coverage factor of 2 [3]. Accuracy of measurement according to VIM 3 is defined like closeness of agreement between a measured quantity value and a true quantity value of a measurand [4]. Repeatability **R** according to ISO 230-2 is expressed like maximum value of the repeatability of positioning at any position along or around the axis [3]. Measurement repeatability by VIM 3 is defined like measurement precision under a set of repeatability conditions of measurement [4].

We pointed only some of the differences, which are also grafically shown in Figure1 and Figure2. For this reason we decided to offer even other possibility of expressing the results that characterize positioning of CNC. It is the expression of the average positional deviation in the axis and its uncertainty. This parameter is expressed in direct and reverse direction with the uncertainty of the measurement result, which includes the contribution of the uncertainty of determining the positional deviation of repeatability and other contributions, which appears systematically.

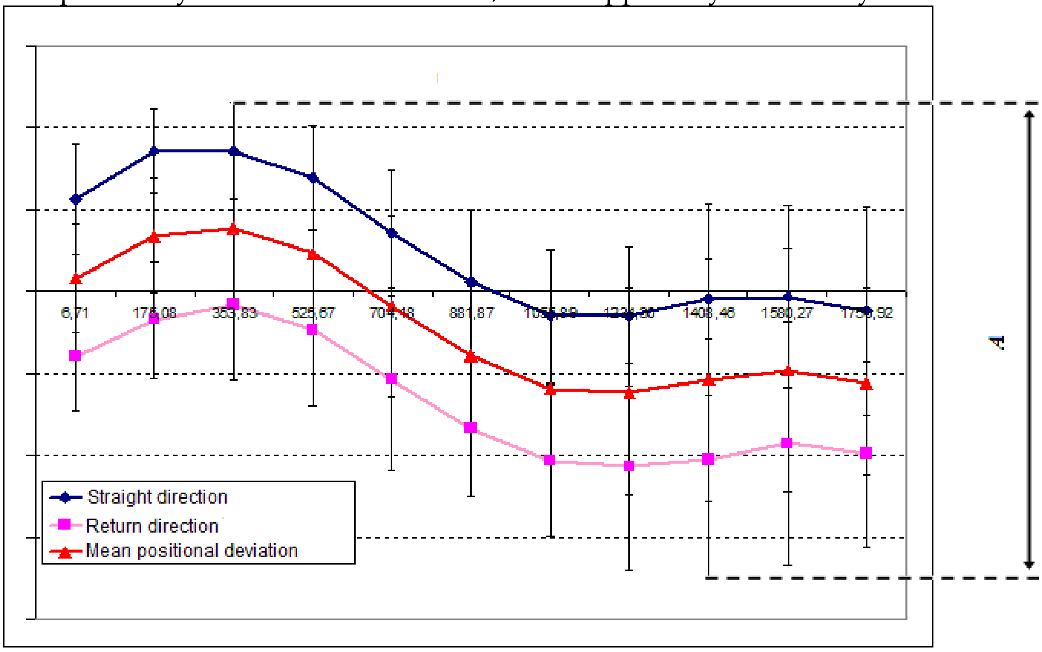

Figure 1: Graphical representation of selected parameters according to ISO 230-2

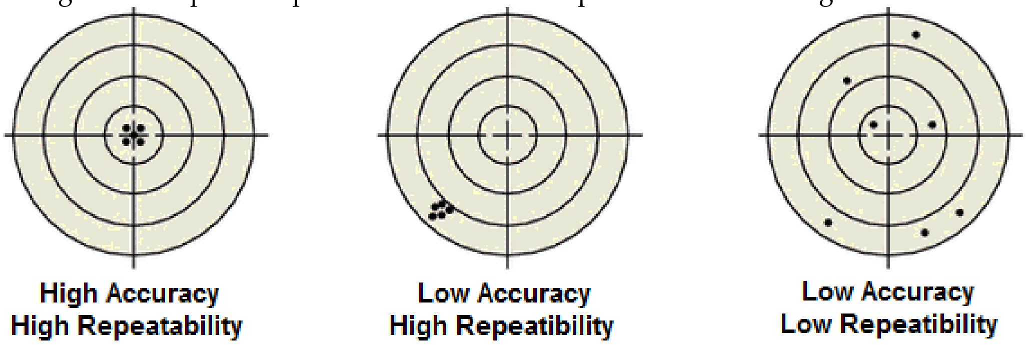

Figure 2: Graphical representation of selected parameters according to VIM 3

3. MATHEMATICAL MODEL OF MEASUREMENT

Below is expressed mathematical model of measurement of the CNC machine by using of laser interferometer. The proposed model is describing mean bi-directional positional deviation of an axis as follows:

$$\overline{x} = \overline{P} - P_{nv} + (P_{nv}\alpha\Delta t) + \delta_{cos} + \delta_{abbe} + \delta_{cc} + \delta_{res} \quad (1)$$

where: x mean positional deviation in position, $\overline{P}$ is position determined from the series of measurements (n = 5), P_{nv} is nominal value of length – position set by control unit of CNC machine, α is coefficient of the thermal expansion, δ_{cos} is correction of the cosine error, δ_{abbe} is correction of the Abbe error, δ_{cc} is correction of the indication of the standard from the certificate of calibration, δ_{res} is correction of the resolution of standard, $\Delta t = (t_{CNC} - t_{20})$ is difference between temperature of machine and reference temperature.

3.1. Sources of errors and uncertainties in measurement of the CNC machines

In the following we analyzed some sources of errors and uncertainties in measurement, which are considered in the mathematical model of measurement (1).

- **Estimation of measured position (conventionally true value)**

Estimation of measured position determined by a series of 5 measurements (recommendations of ISO 230-2) is given by:

$$\overline{P}_n = \frac{\sum_{i=1}^{n} P_i}{n} \quad (2)$$

- **Sources caused by the environment (Edlén equation)**

Expression of Edlén equation shows how the refractive index varies with environmental changes in temperature t, realitive humidity RH and air pressure P. These changes affect the wavelength of the source HeNe laser interferometer, and therefore can not be ignored. The refractive index of the environment n_{tprh} is described as follows:

$$n_{tprh} = n_0[1 + K_T(t - 20) + K_p(p - 101.325) + K_{rh}(rh - 50)] \quad (3)$$

where K_t, K_p, K_{rh} are coefficients of equation for reference conditions of environment.

- **Cosine error**

If the laser beam is not parallel to measured axis of a CNC machine, than occurs a difference between the real distance and the measured distance. This error of unadjustment is known as a cosine error, because its magnitude depends on the angle between the laser beam and the axis of the machine (Figure 3). If, as a reflector a flat mirror is used, than the beam must be perpendicular to it. If the machine changes its position form point A to point B, than the beam stays perpendicular to the mirror, but moves on its surface. The distance measured by the laser interferometer L_{LMS}, will be smaller, than the real distance L_M, according to, according to:

$$L_{LMS} = L_M.\cos\varphi \quad (4)$$

where L_{LMS} is length measured by the laser interferometer and L_M is real length of the measured object.

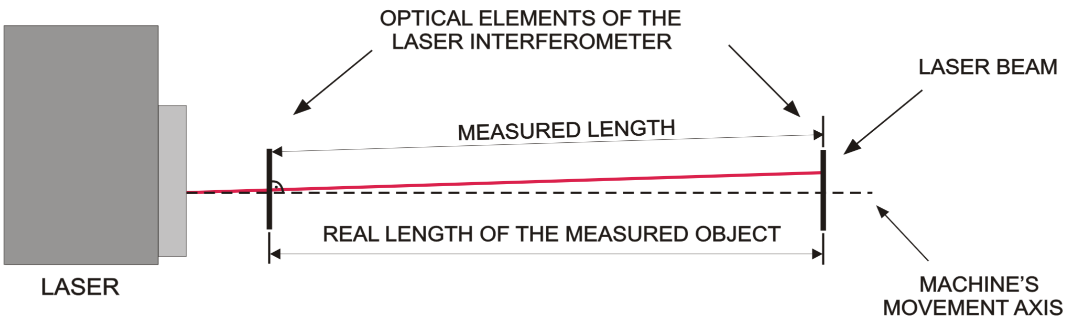

Figure 3: Sample of cosine error

- **Abbe error**

An Abbe error occurs when, during measurements, the measured part does not move perfectly straight and there appear angular movements, which cause sloping of the retroreflector. The sloping of the reflector is the greater the longer is the distance between the axis of the measurement and the axis of movement. This distance is called Abbe offset. Abbe error is expressed as follows:

$$\varepsilon = L.\tan\alpha \quad (5)$$

where L is a distance between the axis and the measurement axis of the movement of optical components, α is the yaw angle of retroreflector.

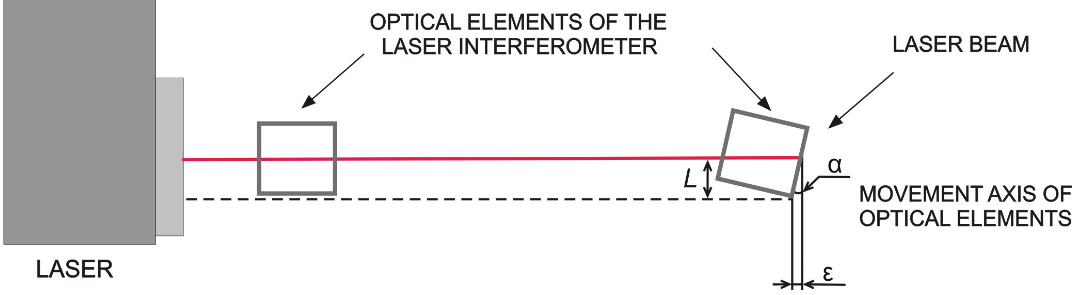

Figure 4: Sample of Abbe error

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4. CONCLUSIONS

In contribution are explained parameters describing positioning of the CNC machines. Actually there are some some differences between the recommendations of the ISO 230-2 and metrological approach to the evaluation of measurement of CNC machines. Designed procedure described in this contribution represents the intersection between these approaches and offers other possibility of evaluation of positioning CNC machines.

Acknowledgements

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