AUTOMATIZED SYSTEM OF MEASURING AND REGULATION IN TURNING OPERATIONS

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A novel approach to the simulation of the dimensional wear of cutting tools with a subsequent element of correction in limit boundaries of parametrically determined optimal shifts is presented and discussed. Described in details is, however, only one aspect belonging to the polynomial transform of experimentally found discrete values of the cutting point positions to a continuous functional form, compatible with used SW. Special attention is paid to the proposal of the simulation scheme working with the mathematical model in the simulation environment with particular values of the given simulation parameters.

Keywords
Cutting, sensor, workpiece, component, optical, scanning, measurement

1. Introduction

Optoelectronic sensors and inductive and capacity sensors are used in the contactless detection of objects in automation technology. Diminishing returns and soaring power requirements are two of the reasons. They are used mostly where a bigger range is needed. The distance between a sensor and a readable object in the big inductive and capacity sensors can be 100 mm. By means of optoelectronic sensors objects can be detected that are a few meters away and the dimensions of optoelectronic sensors are much smaller than the dimensions of inductive and capacity sensors [Chrzanowski 2004].

However, nowadays optoelectronics have a wider application elsewhere in manufacturing technologies. The principle of the optical sensor is described in this article. Logically, raising the quality of the technical components in the control systems increases the demands on the measurement of process properties. Actual measuring machines must be able to workpiece with sufficient metrological and operative properties that are achieved by using a microcomputer. Optical sensors, working by a one way barrier, are used in the process of measuring the wear dimension of a machine tool [Chrzanowski 2002].

Primary units and receptors are lined up with each other in the optical axis at one way light barriers. When a beam of light between the primary unit and the receptor is cut by an object the electrical properties are changed at the receptor transistor (or receptor diode). This change is evaluated by the electronics as a recognized object and it signals the change of aspect of the exit. The primary unit together with the receptor make their own sending and receiving cone and its width depends on the angle of the open optic and it is usually in the range +/– 1.3° to +/– 10°. The primary unit and the receptor must be assembled in such a way that the receptor is situated on the axis of the sending cone. In this way the greatest efficiency is obtained (the emission of the light of the primary unit is the largest). During the primary unit and receptor setting movement it is important that their mechanical axis is in line with their optical axis (as a consequence of assembly and manufacturing tolerances).

2. Description of the measuring equipment

A measurement of the wear of the equipment was made by means of an optical scanner. It follows that optical scanners working with a change of the incident light have a characteristic linear dependency between the incident light F and the electric recoil on a suitable extent [Vedral 1999].

Two methods are used to measure the position of the primary unit and the receptor of the light beam during the measurement of the wear of a machine tool by an optical scanner. The way of measuring the wear of machine tools requires the change of workpiece dimension causing a change of incident light on the receiving part of the scanner. The scanner is composed of an infrared light emitter and a receptor that is made of a photosensitive material. A light beam is sent to the light receptor and at a certain position in its path the beam is obstructed by the working area of the workpiece. The proportion of the light beam that arrives at the receptor depends on the calibre of the workpiece. By the wear of the implement the calibre enlarges. The construction arrangement of the individual units of the sensor is shown in figure 1.

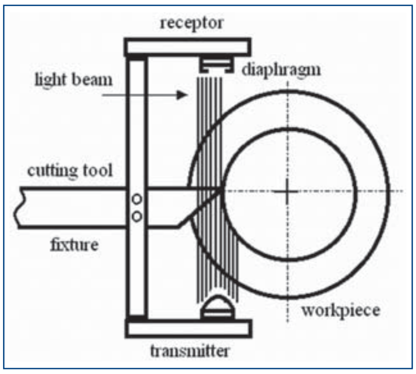

Figure 1. *An optical scanner situated on the tool holder*

A useful attribute of optical sensors is the possibility of the mechanical setting of its sensitivity by changing the light dimension. I chose a sensitivity setting on the side of the receptor by changing the width of the entrance part of the gap using an iris. The iris is composed of an iron deck situated at the entrance to the receptor. In the deck there is a hole with dimensions much bigger than is needed to scan because the hole is covered with an iris with a regulable area according to a need. The dimensions of the iris x, y (figure 2) may be changed to get a suitable sensitivity.

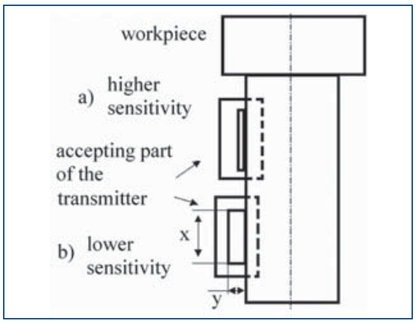

Figure 2. *The change of the primary unit sensitivity by changing the dimensions of irises x, y*

The greater the dimension x of the iris is and the smaller the dimension y is, then the larger is the sensitivity of the primary unit. It follows that the smallest dimension y of the iris is then the greatest is the sensitivity of the primary unit. If the dimension x was its least then the sensitivity would be its lowest. There would be a difficulty in setting a beam to a workpiece. The coefficient of sensitivity $K_{\check{s}}$ we can define as proportion

$$K_{\check{s}} = \frac{x}{y} \tag{1}$$

We can use two types of one way barrier as a solution to the problem. The second scanner solution could be based on the reflection of the light beam, a short reflex optical scanner. This method would be preferable but the measurement of the reflected light would depend on the abrasiveness of the surface of the workpiece and there could arise errors in measurement.

The Method and conditions of measurement

One of the parameters that characterises the blunting of a tool is its wear. The allowed wear is from 0,06 to 0,15 mm. This amount is important and it is used during the testing of the scanner function. As a model assigment a special micrometrical screw was used with which we could make an adjustment of a sharp point of 1 mm. A scanner was put on the table. As a workpiece alternative with a changing calibre we used a micrometer screw situated vertically in the beam of the sensor. By using an adjustment screw we move the point which substitutes for the workpiece into the beam so that it is partly stopped down. This position is set as the start point and it is derived from the amount of the micrometer screw adjustment and also from the microammeter reading. A moving covering point is moved a first measured amount away and it will be out of the amount of micrometer screw of a microammeter. A moving covering point will be moved away and in the second measurement will be moved to the same location as in the previous measurement. The same thing is done 10 times at the same location of the moving covering point.

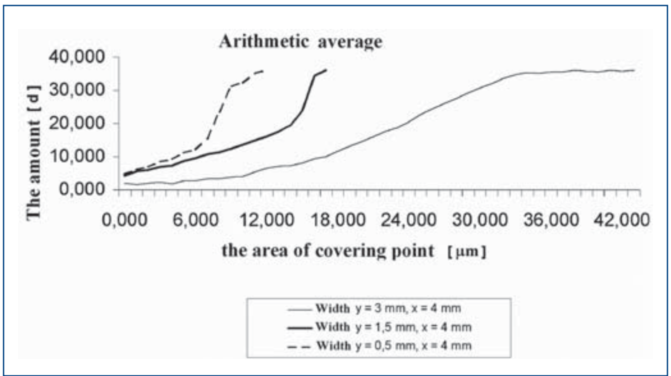

Figure 3. *The graphical dependence of the arithmetical average of the microammeter on the area of the covering point at the width of the covering iris at 0.5 mm, 1.5 mm and 3 mm*

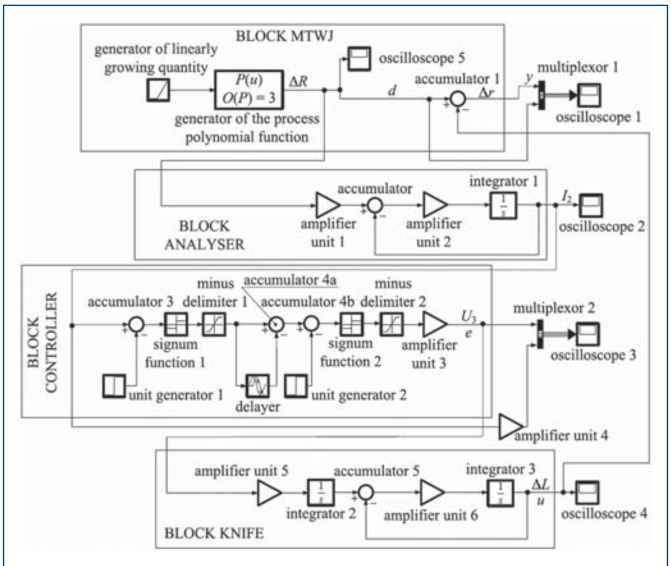

Figure 4. *The simulation model of the correction for wear of the machine tool at a single point*

In summary, The current was measured by microammeter at different amounts of the position of the covering point. The graphical dependence of characteristic amounts is in figure 3. We can see that the dependence of measured current on the area of a covering point at a certain distance is linear. The graphical dependence (figure 3) of the arithmetic mean of the microammeter on the area of the covering point at the widths of the covering iris 0.5 mm, 1.5 mm and 3 mm showed a linearity for a certain area of measurement that can be useful for measuring.

3. The solution of correction for the wear of the machine tool

The model necessary for simulation (see Fig. 4) was formed in the environment of Matlab Simulink. It consists of the following blocks:

- block of the system MTWJ (machine, tool, workpiece, jig), in which the cutting tool wear is realised;
- block of the scanner with an amplifier and low-pass RC filter (removal of short-term disturbing effects);
- block of the generator consisting of a comparative unit (with adjustable threshold level) and a pulse generator (with adjustable length of the pulse duration);
- block of the shifting mechanism of the knife (for realisation of the correction of the cutting tool wear by shifting the knife by the value of the wear).

The complete simulation model (see Fig. 4) is given by connection of its individual parts discussed above. The parameters of these parts

measured	$t_1 \neq 0$			$t_1 = 0$
time [min]	1.50×10^2	2.33×10^2	3.00×10^2	0
ΔR [μm]	2.10×10^{-5}	5.60×10^{-5}	1.12×10^{-4}	0
WS [m]	1.50×10^{-4}	4.00×10^{-4}	8.00×10^{-4}	0
power of variable	X^3	X^2	X	1
coefficient	5.33×10^{-12}	-8.44×10^{-10}	1.47×10^{-7}	0

Table 1. *Values of coefficients of the polynomial function for the given values of WS*

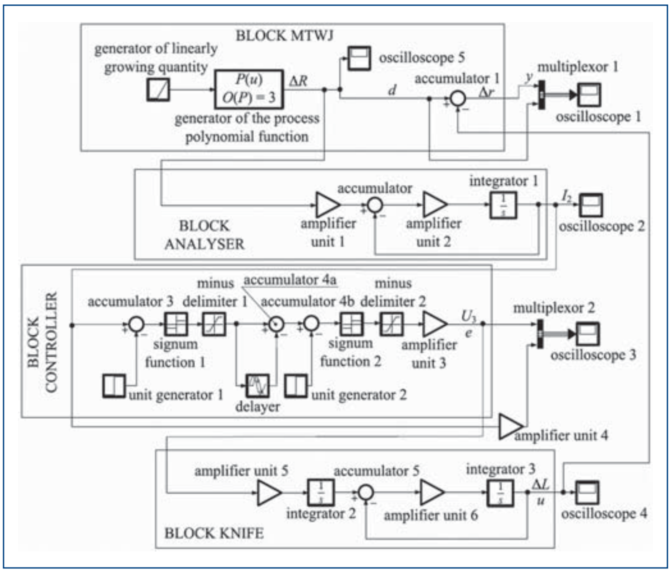

Figure 5. *A continuation of the rising curve from oscilloscope 1*

must be set on prescribed values. Program Microsoft Excel contains a procedure for automatic computation of coefficients necessary for the generator of the polynomial function, but on the basis of own values, so that the output coefficients do not correspond to the given table. That is why I wrote a procedure for calculation of these coefficients for third-degree polynomials that is based on the Lagrange interpolation method. The error due to substitution of the real function by this polynomial is negligible. The program generates the table of measured values of the cutting tool wear (coefficients WS).

Microsoft Excel automatically recalculates these values on the values of changes of the workpiece dimensions that serve for the generation of the polynomial function. The higher degree of the polynomial in the simulation process in Matlab, the more accurate is the analysis. Particularly, for tool P20 with durability 300 min. and workpiece 140109.3 we obtained values ΔR (wear of the dimensions) listed in Table 1.

The values of ΔR are calculated from formula

$$\Delta R = WS.tg8^o \quad (2)$$

After substituting values ΔR into the table the program calculates the coefficients for the polynomial function of the third order. A general form of such a function is

$$y = k_3x^3 + k_2x^2 + k_1x + k_0 \quad (3)$$

Coefficient k_0 is necessarily equal to zero, as for time $t = 0$ the tool wear is also equal to zero and the change of dimensions of the workpiece is also equal to zero.

Figure 5 contains the resultant shape of regulation with correctly set length of duration of the controlling pulse 2.52 s. Here $\Delta r = \Delta R - \Delta L$ where Δr denotes the change of the workpiece radius, ΔR is the change of position of the tool point and ΔL the shift of tool point in the process of correction.

4. Conclusions

Finding the most suitable solution to the problem of measuring of machine wear was needed. Some of the best solutions were a capacity scanner, a tenzometrical scanner, an inductive scanner, a vibrating scanner and an optical scanner. I tested the functioning of all types of scanners (from the suggestion of connecting, choosing the type and parameters of the screws, choosing the circuit and stability parameters, the practical construction of the area connection and the setting of the screws, designing and building the circuit, and testing the functioning of the circuit in action), that was about 80 % of all my time expended on the solution of the problem. The best was found to be an optical scanner because of its high sensitivity and resistance to environmental changes.

The inferiority of the other types of scanners was for a variety of reasons. The capacity scanner was too disturbed by changes in the environment. The inductive scanner had insufficient sensitivity and was disturbed by electromagnetical fields. The tenzometrical scanner inclined to an overloading of deformation powers and the piezoelectrical scanner needed a sensitive high-frequency booster with a zonal forward filter, whose parameters are easily affected. Scanning of machine attrition by vibration frequency is inexact because the effect depends on the tool setting of the system.

The examinations of the measurement of the wear of a machine tool and measurement of the abrasiveness of a cutting area made in test conditions were very useful and they promise an economical proposition. The advantage of a scanner is its simplicity of construction, resistance to a disturbance, simple maintenance and low unit costs. One alternative to using a scanner is to use it to control the dimension of a screw. This would have an advantage because it is a contactless way of measuring. It could also be used in the automatic control process as an active unit to keep the exactness of the dimension of the screw.

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