LAYER OF THE TOOL TESTING DURING CUTTING MATERIAL X120MN12

KRATOCHVÍL Jiří[1], SADÍLEK Marek[2], PAGÁČ Marek[3]

VSB - Technical University of Ostrava, Czech Republic, EU
jiri.kratochvil@vsb.cz, marek.sadilek@vsb.cz, marek.pagac@vsb.cz

Abstract

This article extends the series of articles focusing on introduction and testing the behaviour of impedance layer applied on cutting edge of the tool. This coating functions as a regular cutting tool coating, but also it creates an electric circuit. According to presumption of the Theory of Cutting this layer should wear out during the cutting, it means to cut down its intersection. Decreasing the intersection of the layer leads to change of impedance until the cut-off of electric conductor. The electric circuit will be disrupted. In this sense it is possible to evaluate achievement of wear out criteria of the cutting tool edge. The tools, which are able to report its wearing this way are called „intelligent tools“. This article will be analysed and evaluated behaviour of such impedance layer on exchangeable cutting edge made of cutting ceramics during cutting of X120Mn12 material.

Keywords: Cutting tools, tool wear, coating

1. INTRODUCTION

One of the current priorities is the reduction of production costs in development trend in machining. One of the many solutions to this problem is to use 100 % of the cutting tool, that is, its entire tool life, while respecting the requirements for surface quality.

Several methods have been proposed to monitor tool wear. There are two main categories: direct methods and indirect methods.

Direct methods, such as machine vision systems, use a charged-couple-device (CCD) camera or optical microscope [1]. Direct methods have the advantage of capturing actual geometric changes arising from the wear of the tool. However, direct measurements are very difficult to obtain due to the continuous contact between the tool and the workpiece, and are made almost impossible by the presence of coolant fluids [2]. These difficulties severely limit the application of a direct approach [3].

Indirect methods correlate or match appropriate sensor signals to tool wear states. The advantages are a less complicated setup and greater suitability to practical application. In indirect methods, tool condition is not captured directly, but estimated from the measurable signal feature [2].

Online monitoring of the cutting process and determining the exact time when it is necessary to replace the cutting edge during the cut (because of termination of durability or other failure of cutting edge - i.e., tool breakage) increase productivity and reduces costs [1], [4], [12].

There are many ways to diagnose the cutting edge and monitor tool wear during cutting, but none of these diagnostic methods are as yet widespread - mainly because of the difficulty of monitoring and evaluation, special requirements for use, requirements for instrumentation and high value of requirements and tools.

The vast amount of literature in this field suggests that a variety of process parameters in the metal cutting environment can be tapped and used to predict the cutting tool-state. There are some typical applications scenarios along with their correlation to tool wear under experimental conditions. It is provided to cover [5]:

- acoustic emission,
- tool temperature,
- cutting forces (static and dynamic),

- vibration signature (acceleration signals),
- miscellaneous methods such as ultrasonic, pneumatic and optical measurements, workpiece surface finish quality, workpiece dimensions, stress/strain analysis and spindle motor current.

Uehara developed an insert coated with an electric resistance film perpendicular to the side cutting edge on the flank face [6]. In other literature can be found an insert with electric resistance film, which is parallel to the cutting edge on the end and side flank faces [7].

2. EXPERIMENTAL CONDITIONS

The experiment was conducted in the laboratories of Department for Machining, Assembly and Metrology on VSB - Technical University of Ostrava at the following conditions.

2.1. Machine - MORI SEIKY NLX 2500/700

This machine is a turning - milling center with CNC control enabling automatic run according to the generated CNC program.

2.2. Tool

The whole experiment was carried out using Exchangeable Sensor-Integrated Inserts from the Kyocera Company. These inserts are made of nitridic cutting ceramics KS6000, which is coated with an electric resistance film from Nitride Titanium (TiN) [2], [14]. Thanks to the special impedance layer coating it´s possible to use all eight edges. The impedance layer TiN on particular edges creates an electric circuit with contact surface at the bottom of the insert. All the edges on insert were numbered for better guidance.

Gripping of the insert was done with the holder XCSRNR2525M-1204SEN (**Figure 2**). The holder has set of contacts prolonging the electric circuit from the insert further through the holder body onto the jack. The jack was connected to data logger ALMEMO 2590-4S.

Figure 1 Kyocera Insert KS6000

Figure 2 Holder XCSRNR2525M-1204SEN

2.3. Material for Experiment - X120Mn12

Manganese Steel X120Mn12 is resistant to wear-out, hence its weldability and machinability is difficult. It´s suitable for components exposed to a huge abrasion at simultaneous pressure and push: cutters, pins, cases, strings, stone, coal and coke mills cylinders, cement mills. Chemical compositions you can see in **Table 1** and mechanical features of material in **Table 2**.

Table 1 Chemical composition

C (%)	Mn (%)	Si (%)	P (%)	S (%)	Cr (%)
1.1 - 1.3	12 - 13	0.3 - 0.5	max. 0.1	max. 0.04	max. 1.5

Table 2 Mechanical Features of Material

Rm (MPa)	Re (MPa)
1130	390

2.4. Measuring tools

Data logger ALMEMO 2590-4S was used for monitoring and recording of electric resistance. This data logger was able to measure the electric resistance in range 0 - 500 (Ω) and record with program ALMEMO AMR Control 5.13 into a data file on a computer.

Measuring of wear was executed with microscope INTRACO Micro. This microscope takes a picture of the measured component and after calibration through optical scale it is able to measure the marked dimensions, see **Figure 3**.

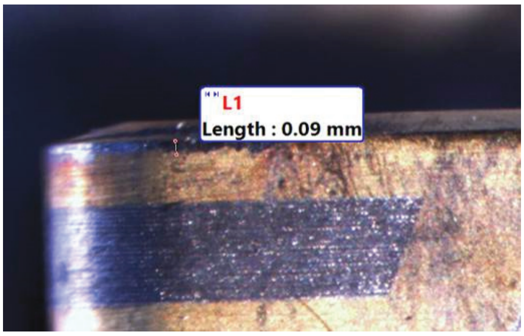

Figure 3 Illustration of measuring with digital microscope

2.5. Processing liquid Blasocut 2000 CF

Blasocut 2000 CF is a water miscible cooling and lubricating substance without chloride content on basis of mineral oils. It´s suitable for regular cutting in concentration 5-8 % [11, 12].

3. EXPERIMENTAL PART

Experimental work was carried out in longitudinal turning. The test ran at constant cutting depth a_p = 1.6 mm at constant feed f = 0.1 mm and with change of cutting speeds v_c = 250, 300 and 500 m·min^{-1}. At two of the cutting speeds v_c = (250 and 300) m·min^{-1} the test was repeated with usage of processing liquid during the cutting.

3.1. Testing without use of processing liquid during cutting

- *Test 1 Cutting conditions v_c = 250 m·min^{-1} f = 0.2 mm a_p = 1.6 mm*

During the test there were 5 tool paths in total. The tool paths covered 0.23 m during 1.14 min. in cutting. In the last tool path the electric resistance started to increase until the disruption of impedance layer and break of the cutting edge. In **Figure 4** we can see the dependency of electrical resistance and tool wear in time. The colours in the **Figure 4** illustrate measuring of electric resistance in particular tool paths. After each tool path the tool wear was measured and the progress was marked with black colour.

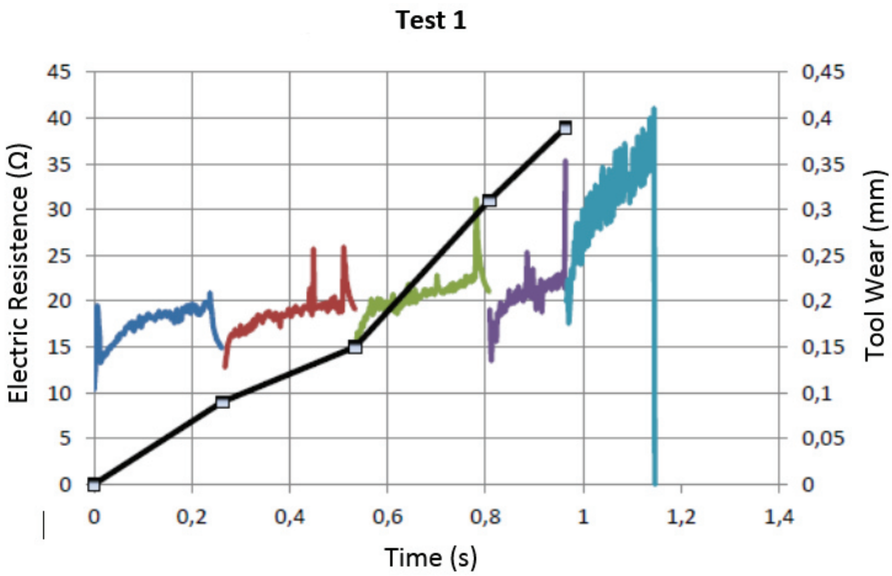

Figure 4 The dependence of electrical resistance and tool wear on the machining time (v_c = 250 m·min^{-1} f = 0.2 mm, a_p = 1.6 mm)

- *Test 2 Cutting conditions $v_c = 300$ m·min^{-1}, $f = 0.2$ mm, $a_p = 1.6$ mm*

During the test (see **Figure 5**) the tool was only approx. 42 s in cut and tool paths covered 0.13 mm, after that it reached the criterion of tool life. The criterion of tool life is defined by width of the impedance layer on the back. During this test was reached the interesting progress of electric resistance values. By the end of measuring the outputs reached slightly negative values with crossover to positive values. The return of positive values could be caused by sticking of the residual material (built up edge) to the cutting tool edge, similar as at the cutting of cast-iron (see Article [14]). Negative values of electrical resistance haven´t been registered yet at any material.

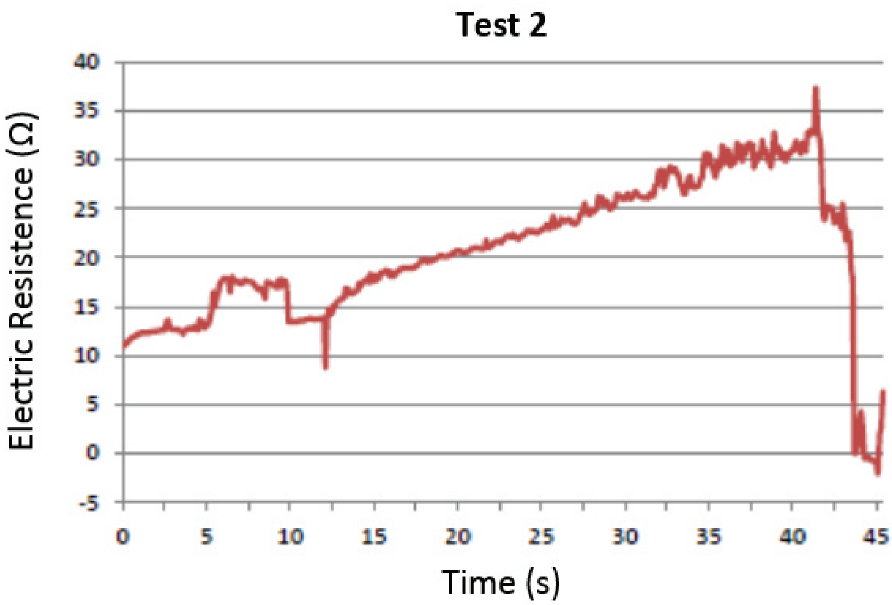

Figure 5 The dependence of electrical resistance on the machining time (v_c = 300 m·min^{-1}, f = 0.2 mm, a_p = 1.6 mm)

3.2. Testing with the use of processing liquid Blasocut 2000 CF during cutting

- *Test 3 Cutting conditions v_c = 250 m·min^{-1}, f = 0.2 mm, a_p = 1.6 mm*

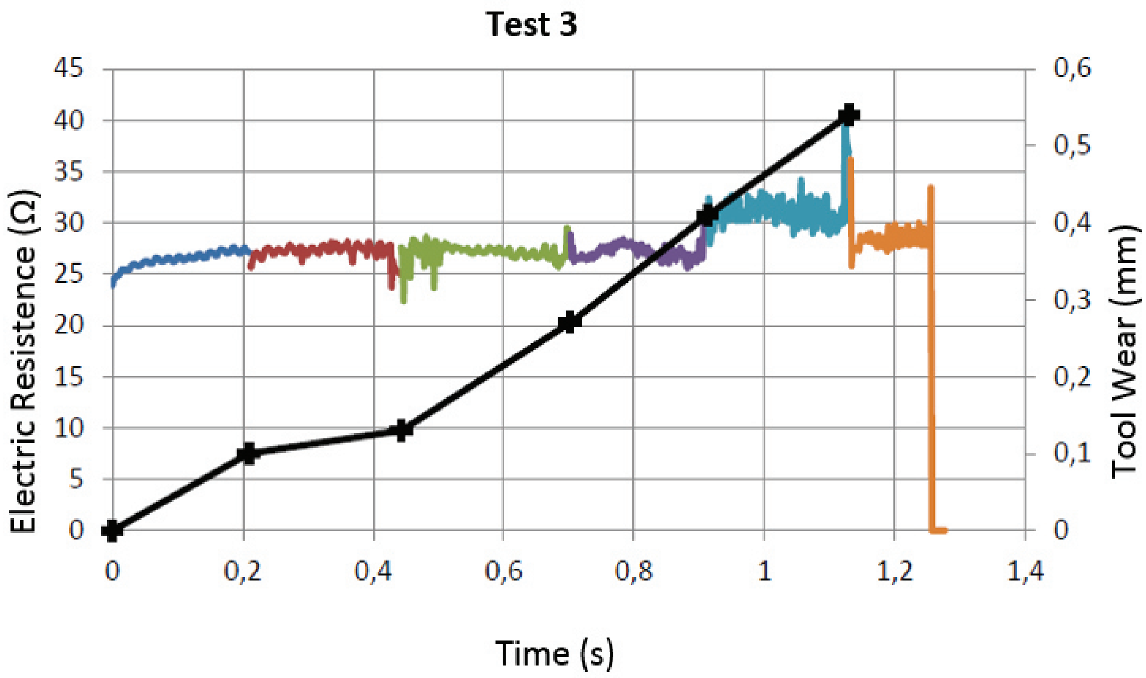

Figure 6 The dependence of electrical resistance and tool wear on the machining time (v_c = 250 m·min^{-1}, f = 0.2 mm, a_p = 1.6 mm)

The durability of the tool was 6 cuts, after that however it came to a brake as well. The total cutting time of the tool (tool live) was 1.28 min. and the machined surface measured 0.31 m. The dependence of electrical resistance and tool wear on the machining the time is visible in **Figure 6**. Damage of the tool is again indicated by zero value of electrical resistance in the measured electric circuit.

- *Test 4 Cutting conditions v_c = 300 m·min^{-1}, f = 0.2 mm, a_p = 1.6 mm*

The tool machined the length 0.2 m while cutting 0.66 min. In penultimate tool path there is visible the sharp increase of electric resistance when moving out from the cut. Such states occur in lesser rate at each move out of the tool from cut. In case that they are stronger, they can indicate the approaching impedance layer breakdown. Their incidence is caused by rapid change of temperature at the cutting edge. Electric resistance then reacts in the circuit according to formula (1) [14]. Brake of the tool appeared at the sixth tool path again, which was signalized by the disruption of impedance layer on the tool.

$$R = R_0 \cdot (1 + \alpha \cdot \Delta\theta) \qquad (1)$$

Where:

R electrical resistance (Ω),

α temperature coefficient of electrical resistance (K^{-1}),

Δθ temperature difference,

R_0 initial resistance (Ω).

In **Figures 6** and **7** there is visible the flatter progress of electric resistance dependency. This phenomenon is caused by usage of processing liquid, which affects the tool with smaller thermal stress.

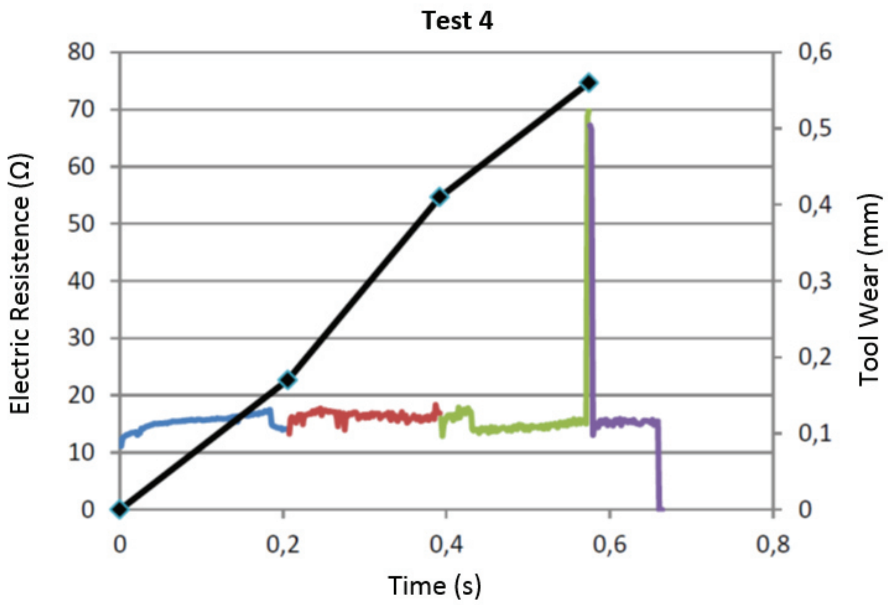

Figure 7 The dependence of electrical resistance and tool wear on the machining time (v_c = 300 m·min^{-1}, f = 0.2 mm, a_p = 1.6 mm)

4. CONCLUSION

Combination of machined material X120Mn12 and tool material nitridic ceramics Ks6000 was not well fitting. Due to combination of these materials the tool reached the permitted tool wear fast ($VB_{b\ max}$ = 0.55 mm). By the use of processing liquid the machining lifetime was prolonged, which corresponds to the theoretic premises of machining and also to the declaration of the processing liquid producer.

By means of processing liquid has no influence on reaching the zero value of electrical resistance on the monitored circuit, which represents disruption of the impedance layer and thus achievement of tool life criterion or destruction of the cutting edge.

With usage of processing liquid there are lower values of electrical resistance at move out of the tool from the cut.

Tools with applied impedance layer can be used to identify the state of tool at cutting.

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