Dependence of the Resistance of the Integrated Layers on the Wear of Ceramic Cutting Tool

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The article focuses on the issue of the applied integrated resistance layers. Conductive layers are applied on the non-conductive material of cutting insert made from nitride ceramics. The layer is applied so that the cutting edge and adjacent surface create closed conductive circuit for each cutting edge separately. Throughout turning process come about wear of cutting edge and therefore wear of resistance layer. It results in decreasing of cross – section of resistance layer and increasing values of resistance. The records are carry out after individual cuts. The aim is to find the dependence between the course of wear and the course of electrical resistance during machining ductile iron EN-GJS-700-3.

Keywords: Integrated resistance layer, Turning, Wear, Ceramic, Machining.

1 Introduction

The durability of cutting tools is very often monitored factor during machining as their durability is very essential for both producers of cutting tools and the customer. During the machining process, a large amount of heat is accumulated in the area of the cutting tool part, which causes considerable stress of the cutting edge. Together with the forming chip and the pressure, which is produced on the surface, the tool material tends to mechanical and chemical processes. By combining these phenomena there is an irregular loading of the cutting edge and this is reflected in its wear. [1] The literatures [2, 3, 4] describe the basic wear mechanisms (abrasion, adhesion, diffusion, oxidation, plastic deformation and brittle fracture). The wear is very often becomes evident on flank as abrasion and oxidation and on face rake as abrasion, adhesion, diffusion and oxidation. The big influence on the wear of cutting tool and its process has cutting tool geometry, machining process and cutting conditions. The wear of cutting tool is determined experimentally based on direct and indirect methods. These methods are both time-consuming and financially demanding and their choice is not always sufficient. The method for determination of wear on the basis of apply resistance layers is not widely explored and it exists in Japan sources.

2 Diagnostics of wear of the cutting tool using resistance layers

Experimental determination of the wear can be measured with the use available methods that are divided into direct and indirect methods. Direct methods contain the method of apply resistance layers. The exchangeable cutting insert is coated very thin resistance layer, which becomes thinner during machining. These layers are based on coatings reaching the tenth of micrometre thickness. When the layer is completely worn, the electrical circuit breaks. Its width on both flank and rake face of insert corresponds to the size of the wear criterion. [5] (see in Fig. 1)

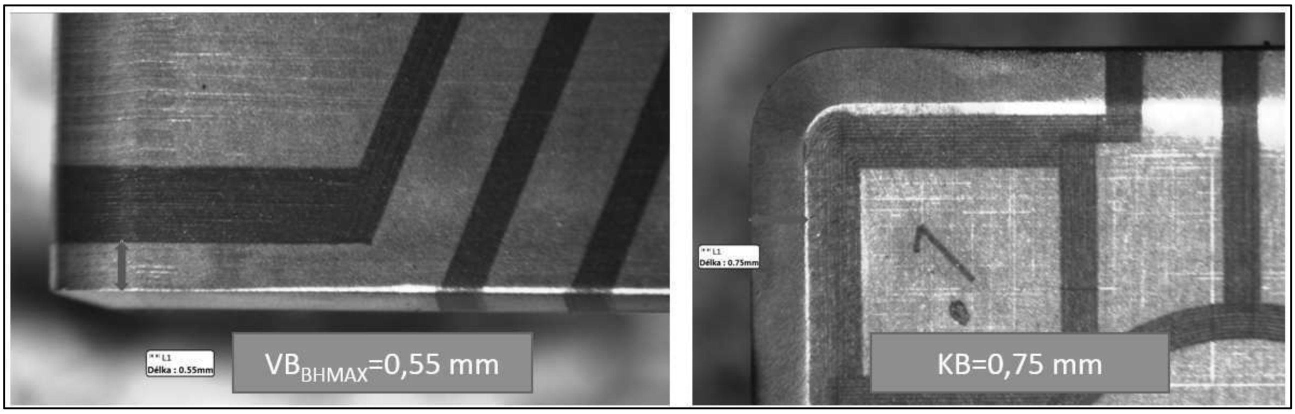

Fig. 1 *Size of the resistance layer on flank and face rake of the insert*

The influence on the adhesion and integrity of the resistance layer can have especially the leaving chip, the change of temperature in cut point or the action of the process liquid. The electrical resistance, which is recorded all the time of machining, is output of loop. The loop is made up special tool holder with contact and connected data-logger (Fig. 2). As the wear of resistance layer increases, its surface decreases and electrical resistance increases – reduction of cross-section conductor. When the resistance film is completely removed, resistance value should be show infinity and becomes unmeasurable. The final wear is evaluated on basis of direct microscopic method with the use workshop microscope.

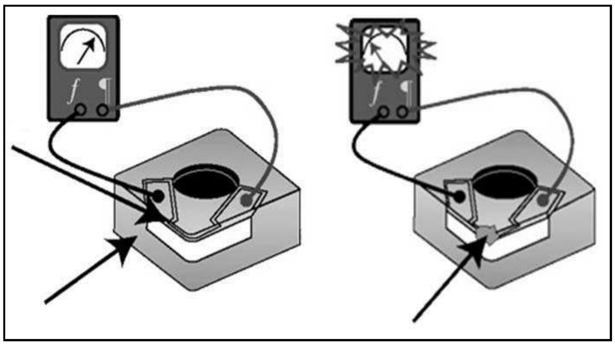

***Fig. 2** VBD circuit diagram*

3 The evaluation of dependence of the wear and the electrical resistance

Experimental activity deals with the determination possible dependence between the wear of cutting tool on the electrical resistance during machining process. The resistance layers' titanium nitride (TiN) of thickness 0,3 μm were applied on the insert made from cutting ceramics, marked KS 6000 (see in Fig. 3), which is made on Si_3Ni_4 silicon nitride. The insert has very good resistance against mechanical wear of cutting edge and it is suitable used for machining grey cast iron and it is applicable in interrupted cutting process. The resistance layer was removed in certain places by laser technology to avoid creating a separate electrical circuit. The width of individual belt on flank and face of insert defines the amount of wear. On the flank surface is value 0.55 mm and on rake face surface there is value 0.75 mm. The ceramics cutting tools based on silicon nitride are mainly specified for machining of cast iron. When the steel is machined, the affinity can occur and thus destruction of the measurement and the loss of value of the results. This is reason why the machined material was selected ductile iron EN GJS 700. It is material designed for mechanically stressed machine parts dynamically and abrasionally. Its machinability is difficult, and abrasion is high. [6] This material has higher mechanical properties which is desirable for short-term tests of cuttability of exchangeable cutting inserts. It causes faster entrance of the wear of cutting tools. [7, 8]

***Fig. 3** Ceramics inserts with applied resistance layer*

From the publications dealing with the issue, it is confirmed that electrical circuit will be cut off when cutting tool is completely cut off. The circuit closes when the tool is cut again. The circuit is again measurable. The tests were realized in condition of the continuous cut. Table 1 describes diagram of testing, the semi-finished product was machined in three cutting speeds, in constant feed rate and cut depth.

***Tab. 1** Design of experiment*

Experiment		
Cut	A – full material, continuous cut	
Dimension of semi-finished product	Ø 270 mm, L = 295 mm	
Cutting conditions	v_c [m · min^{-1}]	325, 515, 645
	f [mm]	0.1 mm
	a_p [mm]	2 mm

Wear inspection on the cutting tool was realized with the use workshop microscope Intracomicro with digital camera with adequate magnification. The all experiment A1 – A3 didn't achieve critical wear on flank surface or rake face surface, the electrical circuit didn't interrupt. The tests were prematurely terminated because of the inserts breakage and thus damage to the resistance layer. The tested inserts showed especially wear on the flank surfaces as well as on face rake surfaces (see in Fig. 4).

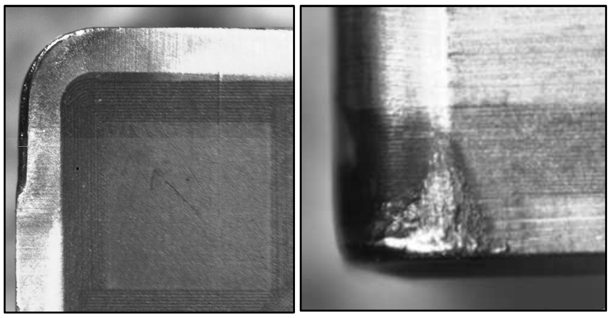

***Fig. 4** The wear on rake face and flank of cutting tool*

The electrical resistance values could be influenced by the resulting layer on the flank surface of cutting tool. There is no loss of cutting material. It could be adhering of material to the surface of insert, known as build up edge (see in Fig. 5). The negative effect of this form of wear distorts the behaviour of resistance layer. From theory of physics is known, that with increasing cross-section of conductor the resistance decreases. In the case, the resistance decreases due to the influence the increasing volume of the resistance layer. These phenomena caused local extremes in charts and one-time jumps.

Machining of ductile iron in condition of interrupted cut had typical process of wear, which confirms theory of machining. In short time interval was achieved sharp increase of the wear, then its linear increase. The machining for the lowest cutting speed caused, that the values of the electrical resistance were between 10 to 16 Ω. Regular protrusions are caused by exit from the cut and subsequent start of the next machining. In time 201 s there was significant outflow of electrical resistance, and then the resistance stabilized. This deviation is caused by breaking of adhering layer on the flank of cutting tool. Removing of build-up edge caused reduction of cross-section of resistance layer and increasing of values of electrical resistance (see in Tab. 2). Test was finished due to insert destruction.

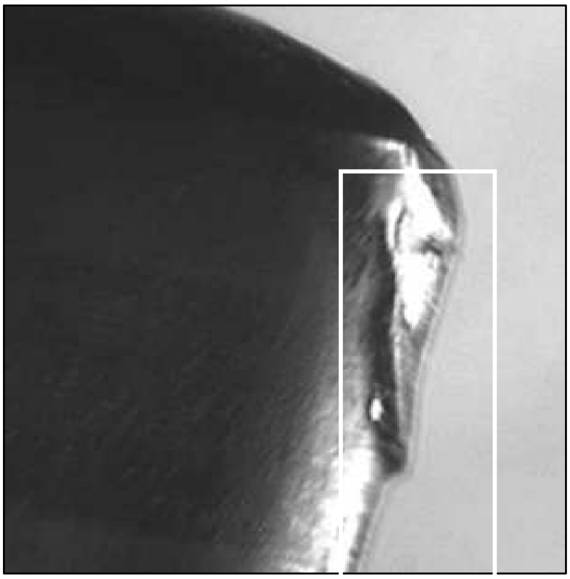

Fig. 5 *Applied material layer*

Tab. 2 *The results of experiment A1*

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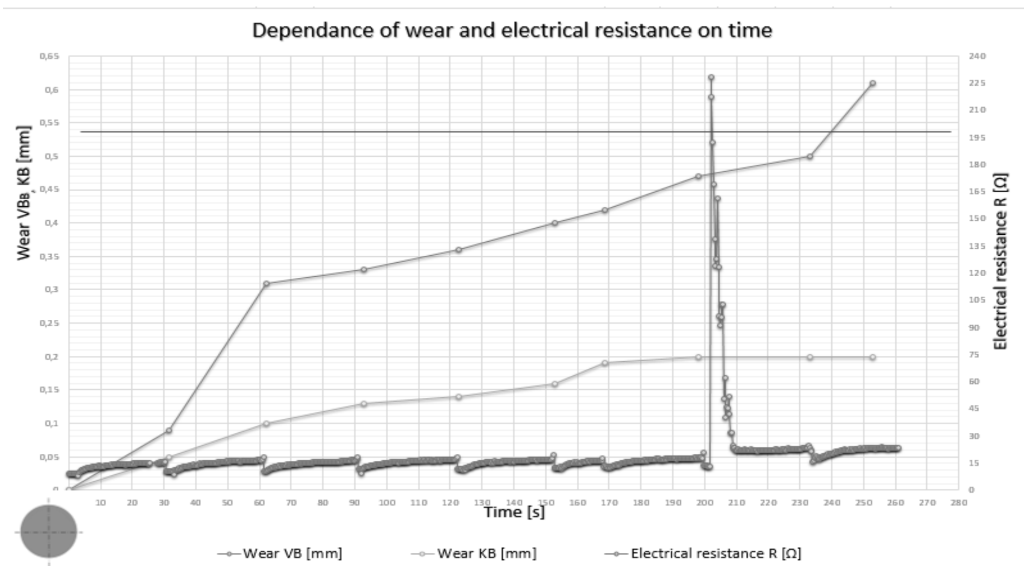
<tr><th colspan="2">Experiment A1 – v_c = 325 m · min^{-1}</th></tr>
<tr><td colspan="2">
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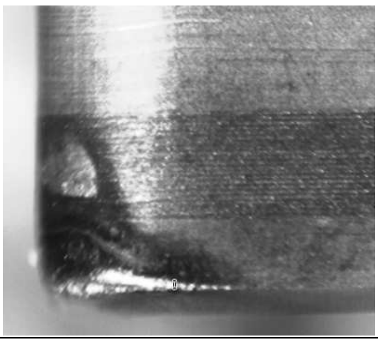
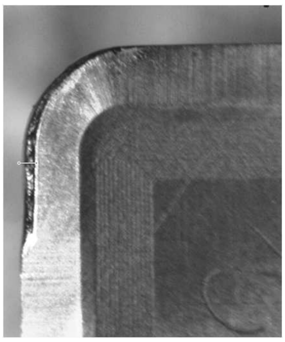
<tr><td></td><td></td></tr>
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Flank wear of cutting tool for higher cutting speed (v_c = 515 m · min^{-1}) has steep increase, especially at the beginning of turninn. Compared with previous case, there has also been a signifacant increase in electrical resistence. Again, we may see drops caused by ending and beginning of the new cut (see in Tab. 3). At the end of machining there are minor increase of electrical resistance along with the increase of temperature in cutting point. Longer machining time brought damage of cutting edge and test was stopped.

***Tab. 3** Results of Experiment A2*

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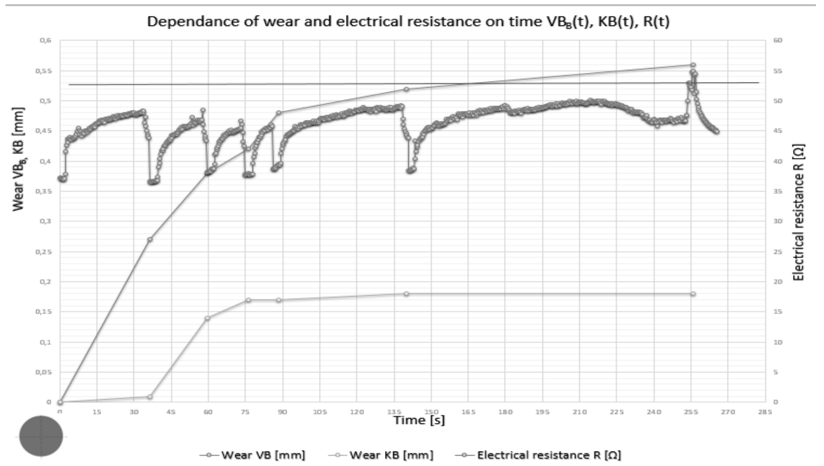
<tr><td colspan="2">
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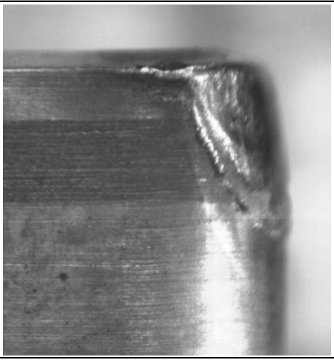
<tr><td></td><td></td></tr>
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Test which was realized at the highest cutting speed showed a typical progress of the flank wear with linear increase of values. Continuous wear was measured on the rake face of cutting tool. The resistance layer was covered with build-up edge (see in Tab. 4). The end of machining was detected sharp deviation of electrical resistance, which was caused by breaking of adhering layer from flank rake. The following process was not stable, because came about gradual destruction of the insert.

***Tab. 4** Results of Experiment A3*

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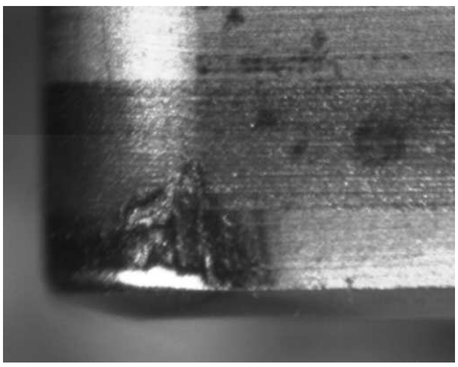
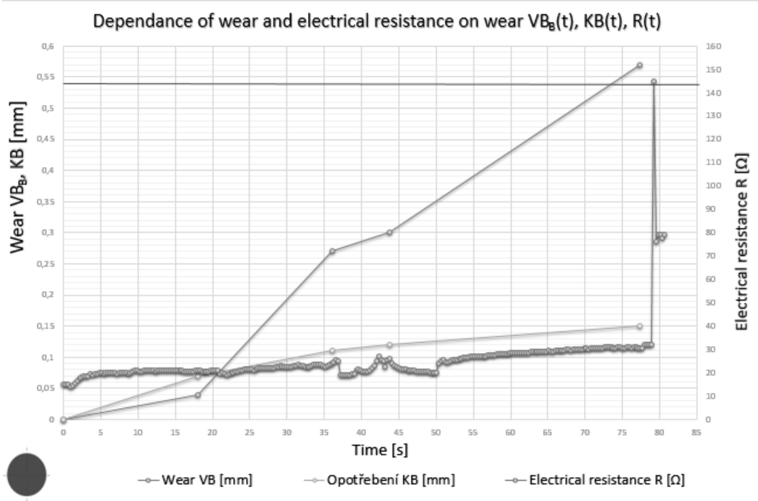
<tr><td></td><td>
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4 Conclusion

The wear of cutting tool is inseparable embodied in machining process. The aim was to verify cutting tools with coating resistance layer and to try to find out the dependence between wear process of cutting tool and the electrical resistance. The basis of experiment was the testing of ceramic insert with nitride resistance layer KS 6000 during longitudinal machining of ductile iron. This material has bad machinability and therefore, it was a prerequisite for faster insert wear and a shorter machining time. The main followed factors were flank wear, size of electrical resistance and rake face wear of cutting tool.

Wear criterion was defined by width of resistance layer. Wear process at all three cutting speed had a standard progress with a gradual increase of values. In the progress, layer of machined material stuck to surface of cutting tool and it influenced size of electrical resistance. When layer (build-up edge) was separated from insert, the device detected deviations during machining. This effect caused narrower cross section of conductor and higher values of electrical resistance. Continuous progress of electrical resistance was measured for cutting speed 515 $m \cdot min^{-1}$, where build up edge hadn't influence on its decrease just as other cases.

Dependence between electrical resistance and wear progress didn't show. The values of electrical resistance were significantly influenced by build-up edge on the resistance layer, which can be observed at the graphical illustration of the individual experiments. Machining of ductile iron is very complicated, it can be observed from the results and early ending of tests due to of destruction cutting edge. For comparison, the next aim will be to test the selected inserts in conditions of interrupted cut for which the inserts has a more suitable use. During the experiment, the attention was paid especially for wear and electrical dependence.

The influence of machining on the machined surface was not separately tracked. The surface roughness was in common extent during machining by ceramics cutting tools. Let's assume that the residual stress which are brought into surface won't be deviating from normal value. From practice experiences of previously tests were residual stress measured by X-Ray method. The values achieved hundreds megapascals and was tensile stress (+). This stress aren't desirable because they decrease the resistance against fatigue and increase friction and cracks propagation. For next testing of ductile iron will take roughness of machined surface into consideration.

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