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

Šárka Malotová1, Robert Čep1, Jiří Kratochvíl1, Michal Šajgalík2, Andrej Czán2

1Faculty of Mechanical Engineering, VŠB-TU Ostrava, 17. listopadu 2172/15, Ostrava – Poruba, Czech Republic. E-mail: sarka.malotova@vsb.cz, robert.cep@vsb.cz, jiri.kratochvil@vsb.cz.
2Faculty of Mechanical Engineering, University of Žilina, Žilina, Univerzitná 1/8215, 010 26, Slovakia. E-mail: michal.sajgalik@fstroj.uniza.sk, andrej.czan@fstroj.uniza.sk.

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](image-url)

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
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.

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                  |
| Dimension of semi-finished product | Ø 270 mm, L = 295 mm |
| Cutting conditions | [m · min⁻¹] | [mm] | [mm] |
| | 325, 515, 645 | 0.1 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).

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.

Flank wear of cutting tool for higher cutting speed \( v_c = 515 \text{ m} \cdot \text{min}^{-1} \) has steep increase, especially at the beginning of turninn. Compared with previous case, there has also been a significant increase in electrical resistance. 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.
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.

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. Wear process at all three cutting speed had a standard progress with a gradual increase of values. 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 · 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.

Acknowledgement

Article has been done in connection with projects Education system for personal resource of development and research in field of modern trend of surface engineering - surface integrity, reg. no. CZ.1.07/2.3.00/20.0037 financed by Structural Founds of Europe Union and from the means of state budget of the Czech Republic and by project Students Grant Competition SP2018/150 and SP2018/136 financed by the Ministry of Education, Youth and Sports and Faculty of Mechanical Engineering VŠB-TUO.

References

[1] PETRŮ, J., PETŘKOVSKÁ, L., ZLÁMAL, T., MRKVICA, I. (2014). Resistance of sintered carbide materials against heat shocks induced by cutting process. In: METAL 2014: 23rd International Conference on Metallurgy and Materials, Conference Proceedings. Brno: Tanger, 2014, p. 973-978. ISBN 978-808729454-3.

[2] BRYCHTA, J., ČEP, R., NOVÁKOVÁ, J., PETŘKOVSKÁ, J. (2008). Technologie II. 2. díl. Ostrava: VŠB - Technická univerzita Ostrava, 2008. ISBN 978-80-248-1822-1.

[3] DAVIM, J. Paulo. (2008). Machining: fundamentals and recent advances. London: Springer, c2008. ISBN 978-1-84800-213-5.

[4] MONKOVÁ, K. et al. (2017). Surface machining after deposition of wear resistant hard coats by high velocity oxygen fuel technology. Manufacturing Technology. Univerzita J. E. Purkyne, 2017, vol. 17, no. 6, 919-925. ISSN 12132489.

[5] PETRŮ, J., ZLÁMAL, T., ČEP, R., SADÍLEK, M, STANČEKOVÁ, D. (2017). The effect of feed rate on durability and wear of exchangeable cutting inserts during cutting Ni-625. In: Technicki vjesnik - Technical Gazette. 2017, vol. 24, no.1, p. 1-6. DOI: 10.17559/TV-20131221170237. ISSN 1330-3651.

[6] Continuously cast casting profile: ductile iron EN-GJS-700. In: UCB Technometal, s.r.o., 2012. Available from: https://www.unitedcastbar.cz/storage/get/105-en-gjs-700-2.pdf.

[7] ČEP, R., KYNCL, L., MALOTOVÁ, Š., PETRŮ, J., ZLÁMAL, T., CZÁN, A. (2017). Testing Ceramics Inserts at Irregular Interrupted Cut on Material 14MoV6. In: Engineering Review, University of Rijeka, 2017, p. 67-73, ISSN 1330-9587.

[8] ČEP, R., MALOTOVÁ, Š., ZLÁMAL, T., VRBA, V., BORZÁN, M. (2017). Tracking of the development wear of cutting tools with different geometry during parting-off. MTem - AMaTUC 2017: 13th International Conference on Modern Technologies in Manufacturing, Romania, 2017, Vol. 137, 22, p. 8. ISBN: 978-275989027-9.DOI: 10.1051/matecconf/201713703003.

10.21062/ujep/119.2018/a/1213-2489/MT/18/3/444
Copyright © 2018. Published by Manufacturing Technology. All rights reserved.