ISSN 1213–2489
e-ISSN 2787–9402

DOI: 10.21062/mft.2023.094 http://www.journalmt.com

Wear Analysis of Indexable Inserts after Machining of Austenitic Steel 1.4404

Karel Sramhauser (0000-0002-7225-8313)[1], Natasa Naprstkova (0000-0003-4433-0581)[2], Iryna Hren (0000-0003-3942-2481)[2], Frantisek Spalek (0000-0002-0953-9104)[1], Tomas Vlach (0000-0003-2326-4183)[2], Radim Kunes (0000-0002-7907-2511)[1], Ondrej Tupy (0000-0003-0448-5570)[1]

[1]Faculty of Agriculture and Technology, University of South Bohemia in České Budějovice. Studentska 1668, 370 05 Ceske Budejovice. Czech Republic. E-mail: sramhauser@fzt.jcu.cz, fspalek@fzt.jcu.cz, kunesr@fzt.jcu.cz, tupyon@fzt.jcu.cz

[2]Faculty of Mechanical Engineering, J. E. Purkyne University in Usti nad Labem. Pasteurova 3334/7, 400 01 Usti nad Labem. Czech Republic. E-mail: natasa.naprstkova@ujep.cz, iryna.hren@ujep.cz, tomas.vlach@ujep.cz

This article is about comparison of the wear of indexable CNMG carbide inserts from two different manufacturers when turning austenitic stainless steel 1.4404, which is not intended as the primary material to be machined from the point of view of the tested inserts. The main goal was to detect the different course of wear after testing inserts of the same type according to ISO 6987 showing the connection between the design and processing of the inserts in connection with the selected cutting parameters. The type of wear that was observed was the main flank wear VB_{max}, depending on the length of the machining time. Optical and electron microscopes were used to analyze the flank wear. According to the assumption, it was found that the layout of the cutting edge geometry and coating layers has a noticeable effect on the degree of wear of the evaluated cutting inserts. At the same time, it was found that the tested indexable inserts achieved very good service life values despite the fact that the tested material does not belong to the primary use group. Evaluation of cutting tool wear has a major economic potential for manufacturing companies attempting to minimize costs by trying to use as many universal cutting tools as possible or looking for opportunities to expand the applications of already used cutting tools.

Keywords: Tool Wear, Turning, Cemented Carbide, Austenitic Steel, Indexable Cutting Insert

1 Introduction

Coated indexable inserts made of cemented carbides belong to the already commonly known type of cutting tools that have their place in the portfolio of manufacturing companies. A fundamental aspect affecting the process of machining is the appropriate selection of the cutting tool based on its parameters and properties. This is mainly about the geometry of the cutting edge and its subsequent change during machining, which is related to the quality of processing and the design of functional surfaces such as, for example, the chip shaper [1]. At the same time, it is necessary to take into account the appropriate selection of the tool from the point of view of use on a specific type of machined material. The increasing cost of tools, despite the growth in costs of energy, material and employee wages, cannot be taken lightly [2]. However, from the point of view of financial and time (or personnel) capacities, a manufacturing company rarely decides to invest in research, or at least to carry out a test series of the wear of cutting tools for a specific production process [3, 5]. This would involve identifying and purchasing suitable test material or using in-house material (thus reducing self-inventory) while simultaneously researching the cutting tool market, purchasing several sets from multiple manufacturers, and conducting a series of trials to select a cutting tool from the data obtained with the best ratio of its purchase price and lifetime [4].

In the long therm, the cost of selecting a suitable cutting tool appears to be quite marginal compared to the costs associated with inappropriate selection of a particular cutting tool [6]. Manufacturing companies are increasingly aware of this fact. Despite its limits in terms of the possibilities of using special measuring devices, in which manufacturing companies are reluctant to invest due to their limited usability for other activities [7, 8], laboratory research of phenomena occurring during the machining process has a very significant potential for commercial use in practice [9, 10]. The way to reduce the complexity of laboratory research is to focus on testing such cutting tools that can withstand the highest possible number of applications within the company (and ideally are already in real use). Such a cutting tool can be tested in terms of its limits, either for primary or alternative use cases, which the company could use in terms of production. From the point of view of tool life, we can hypothetically orient ourselves according to the manufacturer's recommendations for the given type of machined material. However, these recommendations are based on testing on standard materials under specific cutting conditions that may not match the specific needs of the manufacturing company. Based on this, it can be assumed that under specific conditions, cutting tools can achieve a worse, equal or even better service life during the machining of materials in terms of primary and alternative use recommended by the tool manufacturer [11, 12].

A number of scientific studies deal with the optimization of the cutting process by adjusting individual cutting parameters. Due to the enormous amount of data that needs to be monitored and recorded during the machining process, several methodologies are used, e.g. Taguchi method or means of analysis of variance (ANOVA). Apart from the economic aspect, these procedures currently also have the motivation to take into account the importance of the ecological aspect of waste management [13, 14, 15]. The possibilities of recycling used or no longer usable cemented carbide cutting tools are constantly evolving and there is a general effort to make the recycling process as efficient as possible. However, despite modern recycling procedures, the use of dangerous chemicals is still required, due to the different composition of tools, worn tools need to be thoroughly sorted, and last but not least, even the packaging of cutting tools cannot be unified in terms of material due to the specific requirements of cutting tools [16]. For these reasons, the maximum use of existing cutting tools (except for special applications) is an opportunity to reduce material and personnel costs.

2 Experiment

Obtained data presented in this article are part of a long-term research study of cemented carbide cutting tools wear carried out at the Faculty of Mechanical Engineering of the Jan Evangelista Purkyně University in Ústí nad Labem in cooperation with the Faculty of Agriculture and Technology of the University of South Bohemia in České Budějovice. Part of the research is also cooperation with the manufacturing companies. The experimental material, the equipment used and the evaluated indexable cutting inserts with selected cutting conditions are described in the following text. Process of machining was performed on a Doosan Lynx 220LM CNC lathe (Seoul, Korea) with installed a Fanuc i-series control system. The tested cylindrical samples with initial diameter of 50 mm and a length of 330 mm were machined to final diameter of 23 mm due to ensure the stability of the system. The standard clamping of the test workpieces was in a CNC lathe chuck with a tailstock at the opposite side. The cutting parameters were unified to ensure the stability of the machine-tool-workpiece system during cutting process. Values of cutting speed v_c for the experiment was chosen to be 80, 100 and 120 $m \cdot s^{-1}$, the depth of cut ap was set to 1.5 mm, and the feed rate f was set to 0.3 $mm \cdot rev^{-1}$ so that the experiment could be closer to the cutting conditions used in conventional real-world machining. The stability of the cutting process was ensured by a series of preliminary tests to determine the appropriate parameters of depth of cut ap and feed rate f used in this research. As a criterion for the cessation of the machining phase, the durability of the cutting edge for a given indexable cutting insert or the achievement of wear of the main flank VB_{max} at the level of 0.3 mm was determined. This value was chosen based on the recommendations used in industrial practice for a ridge wear limit of 0.3 to 0.5 mm for coated carbides [17]. Tool wear progression as a function of tool engagement time was observed using an Olympus SZX10 stereomicroscope (Olympus Corporation, Tokyo, Japan) equipped with a Bresser MicroCam-II digital camera (Rhede, Germany) equipped with measurement software. The measurement of VB_{max} was realized after each removal of the machined material, i.e. when the process was stopped, the VBD was removed from the tool holder and measured by the micrometric method. The disadvantage of this method is that it is laborious and time-consuming. However, this is a reliable method of measuring cutting tool wear, which is why the procedure was chosen. Subsequently, the size and extent of wear of the indexable insert was evaluated using a Tescan Vega 3 scanning electron microscope (Tescan Orsay Holding as, Brno, Czech Republic) supplemented with a Bruker X-Flash analyzer (Billerica, MA, USA), which was used to map the elements of the worn cutting tool [18, 19]. The use of a scanning electron microscope (SEM), which uses primary and secondary electrons created by interaction with the atoms of the sample surface to form an image, makes it possible, compared to standard microscopy, to take the resulting photo at high magnification with a high depth of field preserved. Using the detector, the reflected electrons are processed into the resulting sharp image of the observed surface [20, 21]. For the purpose of identifying different types of wear and their localization, electron microscopy represents one of the possibilities to analyze with great accuracy the changes that have taken place on the cutting tool and to relatively effectively determine the individual parts of the tool-workpiece system (e.g. in the case of using the aforementioned mapping of elements) [22, 23].

2.1 Experimental material

Testing was carried out on material 1.4404 according to ČSN EN 10027-2. This stainless steel used in industrial environments is particularly resistant to pitting in the presence of chlorides. It resists sulfuric acid and phosphoric acid very well. Steel 1.4404 has very good weldability without the risk of intergranular corrosion occurring in the thermally affected area. In need to achieve mirror surface, is i difficult to achieve it by polishing. It is appropriate use this material for cold forming applications and it has good workability. Steel 1.4404 is used for welded constructions in aggressive industrial environments, for the manufacture of pressure vessels and components in the pharmaceutical, chemical and textile industries. In need of purity of the product, is it possible to use 1.4404 material for contact with food and dishes. [24]. According to the chemical characteristics, steel 1.4404 should be austenitic or austenitic-ferritic. This was confirmed after making a metallographic cut, which was subsequently etched and examined on an Olympus LEXT OLS 3100 laser confocal microscope. The expected austenitic structure of the delivered steel 1.4404 according to ČSN EN 10027-2 was proven. The image of the etched structure also shows local grain twinning, which probably arose due to the chemical composition of the tested steel, see Fig. 1 [25].

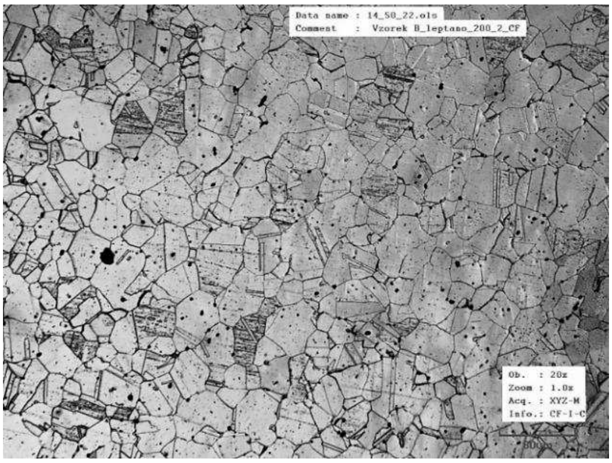

Fig. 1 *Etched strucutre of 1.4404 according to ČSN EN 10027-2, magnified 200×*

The chemical composition of experimental material after electrospark analysis carried out on a Bruker Q4 TASMAN is shown in Tab. 1. Chemical analysis of the tested material confirmed compliance of chemical constitution according to the standard, see Tab. 2 [24].

Tab. 1 *Chemical composition of the experimental steel 1.4404 according to measurements Q4 TASMAN [wt. %]*

C	Mn	Si	Cr	Ni	Mo	P	S
0.022	1.407	0.578	17.24	10.6	2.007	0.041	0.007

Tab. 2 *Chemical composition of the experimental 1.4404 according to ČSN EN 10027-2 [wt. %]*

C	Mn	Si	Cr	Ni	Mo	P	S
≤ 0.03	≤ 2	≤ 1	16.5 - 18.5	11 - 14	2 – 2.5	≤ 0.045	≤ 0.03

A sample was taken from the tested blank for hardness analysis. Vickers and Rockwell hardness measurements were performed by applying ten indentations of the indenter evenly distributed across the cross-section of the sample taken. Based on the obtained values of hardness according to Vickers $HV_{0.5} = 219 \pm 10.6$ and hardness according to Rockwell $HRC = 18 \pm 0.9$, the expected hardness of the supplied material was confirmed as 1.4404.

2.2 Tested indexable cutting inserts

CNMG 120408 type indexable inserts were chosen for the purpose of the experiment. This type was chosen based on the high frequency of use by manufacturing companies in practice. The reason is the wide range of uses of VBD type CNMG in terms of technology (turning, milling, drilling, reaming), when due to its design, this type of insert allows the use of higher f (up to 0.5 mm/rev) and can withstand higher cutting forces and higher cutting temperatures during machining superalloys, for example (up to 1300°C). A disadvantage may be a higher tendency to generate vibrations. The design of the VBD is specified by the ČSN ISO 6987 standard. The aim of the experiment was to evaluate the course of wear of CNMG 120408 type inserts during machining of material that is not intended for the primary machining group. For that reason, inserts with primary application area P (carbon steels, ferritic stainless steels and alloy steels) were selected, while testing was carried out on material corresponding to application area M (cast steels, austenitic stainless steels and ductile irons). The first representative is the CNMG 120408E-FM GRADE T9325 insert, see Fig. 2, whose main support material is classified as a functional gradient substrate of the HC type, composed of tungsten carbide WC with a cobalt binder [25]. Using EDX analysis, a TiCN coating with a thickness of 7.2 ± 0.5 μm and an Al_2O_3 coating with a thickness of 5.1 ± 0.2 μm were identified.

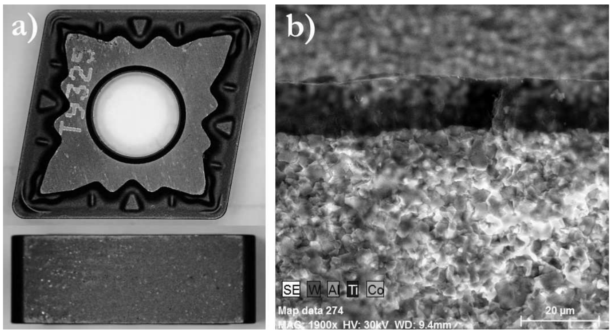

Fig. 2 *Photo of CNMG 120408E-FM T9325 (a), EDX analysis of CNMG 120408E-FM T9325 coating layers (b)*

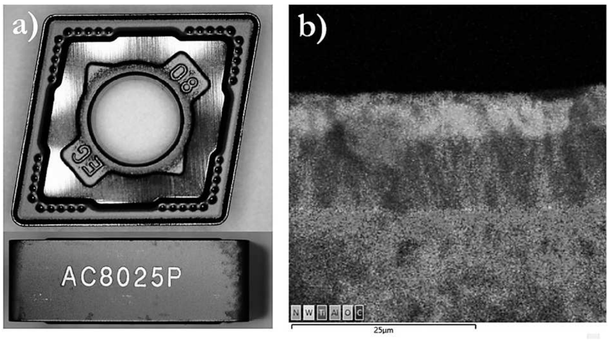

Fig. 3 *Photo of CNMG 120408-EG AC8025P (a), EDX analysis of CNMG 120408-EG AC8025P coating layers (b)*

The chip breaker with the manufacturer's designation FM is designed with positive geometry and is intended for finishing to semi-roughing machining of steels and cast irons, or superalloys. CNMG 120408E-FM GRADE T9325 is primarily designated for machining of group P materials. Alternative use is recommended by the manufacturer for machining groups M and K [26]. The second insert tested is the CNMG 120408-EG AC8025P. It is a plate with a HC-type substrate coated with layers of TiCN, Al_2O_3 and TiN [26]. EDX analysis proved the presence of a TiCN coating layer with a thickness of 9.9 ± 0.1 μm, an Al_2O_3 layer with a thickness of 4.3 ± 0.3 μm and a TiN layer with a thickness of 1.5 ± 0.1 μm, see Fig. 3.

According to the manufacturer, the EG type chip breaker together with the deposited coating layers should have an effect on reducing the tendency to crack on the blade, and at the same time, this type of edge construction should resist pitting wear well (thanks to the spherical shape on the VBD face) and should retain its strength even after increase in wear [27].

3 Results

After reaching the limit value of wear VB_{max} = 300 μm, the obtained data were analyzed and based on them a tool life graph was compiled for individual inserts showing the development of the measured maximum wear of the main spine of the insert VB_{max} depending on the length of time T [min], after which the edge was in engagement, for each specified cutting speed until the time limit value is reached. It is a complex graph comparing the smoothness or continuity of the courses with each other between the individual determined cutting speeds v_c. In Fig. 4. a graph of CNMG 120408E-FM T9325 wear is shown depending on the time of the tool in engagement and the specific cutting speed. Each cutting speed has its own specific mark, and from the highlighted value of the VB_{max} main flank wear limit at the level of 300 μm, there are vertical lines that show on the timeline the moment when the wear limit is reached at each cutting speed. During the machining of material 1.4404, at v_c = 80 m·min^{-1} the service life T = 36.53 min was reached, at v_c = 100 m·min^{-1} the service life T = 27.27 min was reached and at v_c = 120 m·min^{-1} the service life was reached T = 24.1 min.

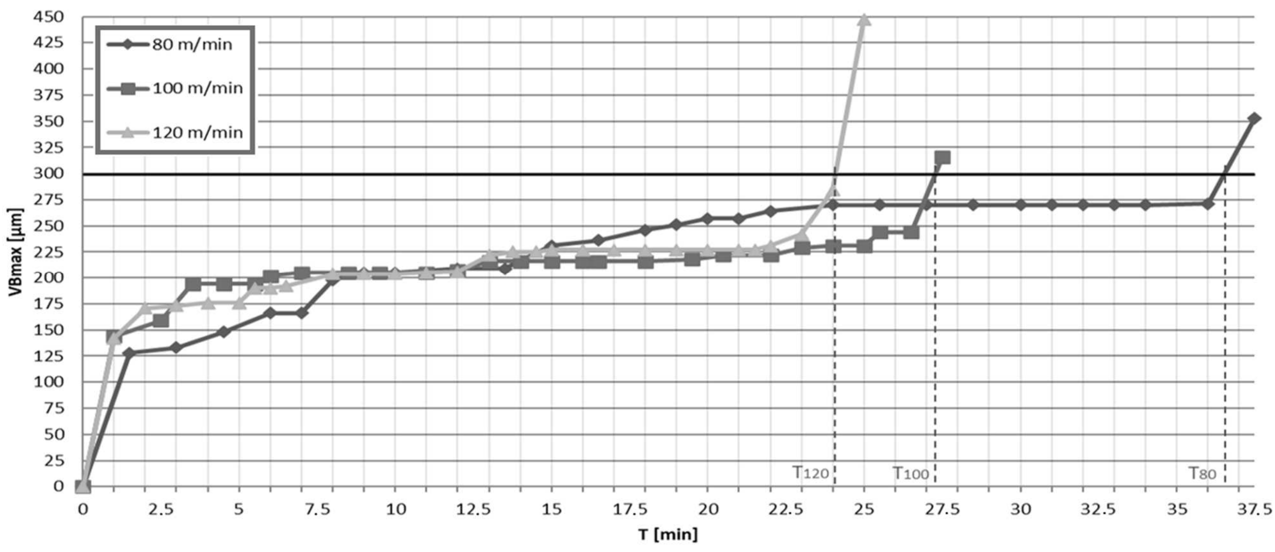

Fig. 4 *VB_{max} wear progressions of CNMG 120408-FM GRADE T9325 after turning 1.4404 austenitic steel*

In Fig. 5. a graph of CNMG 120408N-EG AC8025P wear progression is shown depending on the time of the tool in engagement and the specific cutting speed. During VBD testing on material 1.4404, at v_c = 80 m·min^{-1}, machining was interrupted after T = 60 min due to the saving of test material for other sub-parts of the experiment – thus the limit wear rate of the main spine VB_{max} was not reached at all. This value was included in the tool life evaluation as part of the experiment, even though the VBD could continue to be machined in terms of lifetime. At v_c = 100 m·min^{-1} the service life T = 44.24 min was reached and at v_c = 120 m·min^{-1} the service life T = 22.89 min was reached.

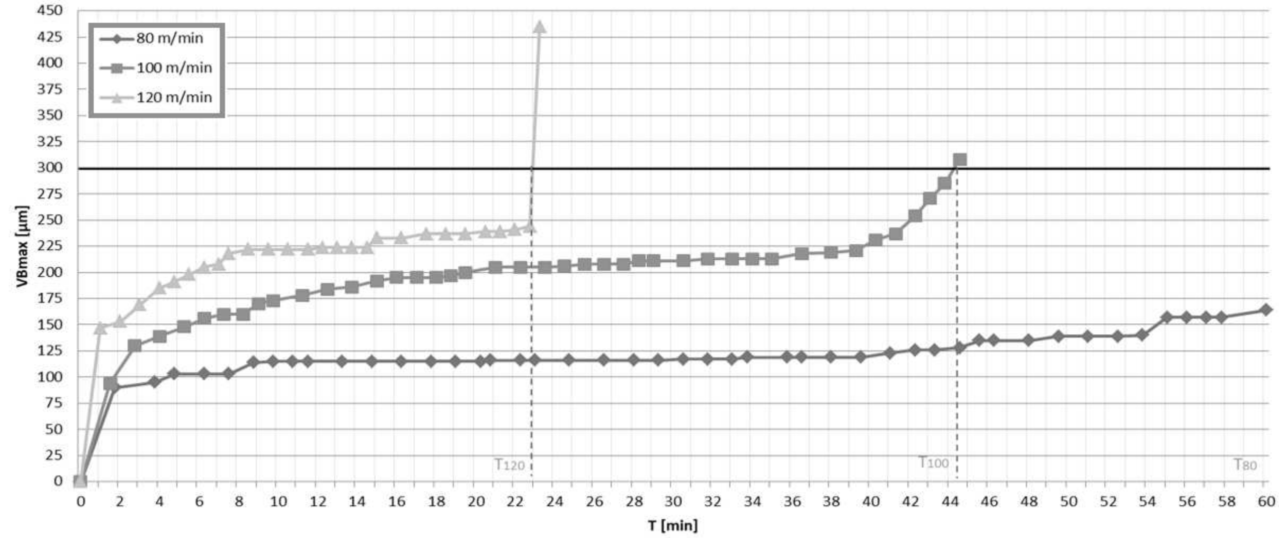

Fig. 5 *VB_{max} wear progressions of CNMG 120408N-EG AC8025P after turning 1.4404 austenitic steel*

In addition to the analysis of wear processes, after reaching the main flank wear limit, individual inserts were examined using SEM in order to identify the degree of wear and individual types of wear. The images are sorted according to the cutting speed, and the solid line indicates the types of wear, possibly adhered workpiece material in the form of a build-up edge (BUE), and the type of exposed coating layer/substrate is indicated by a dashed line.

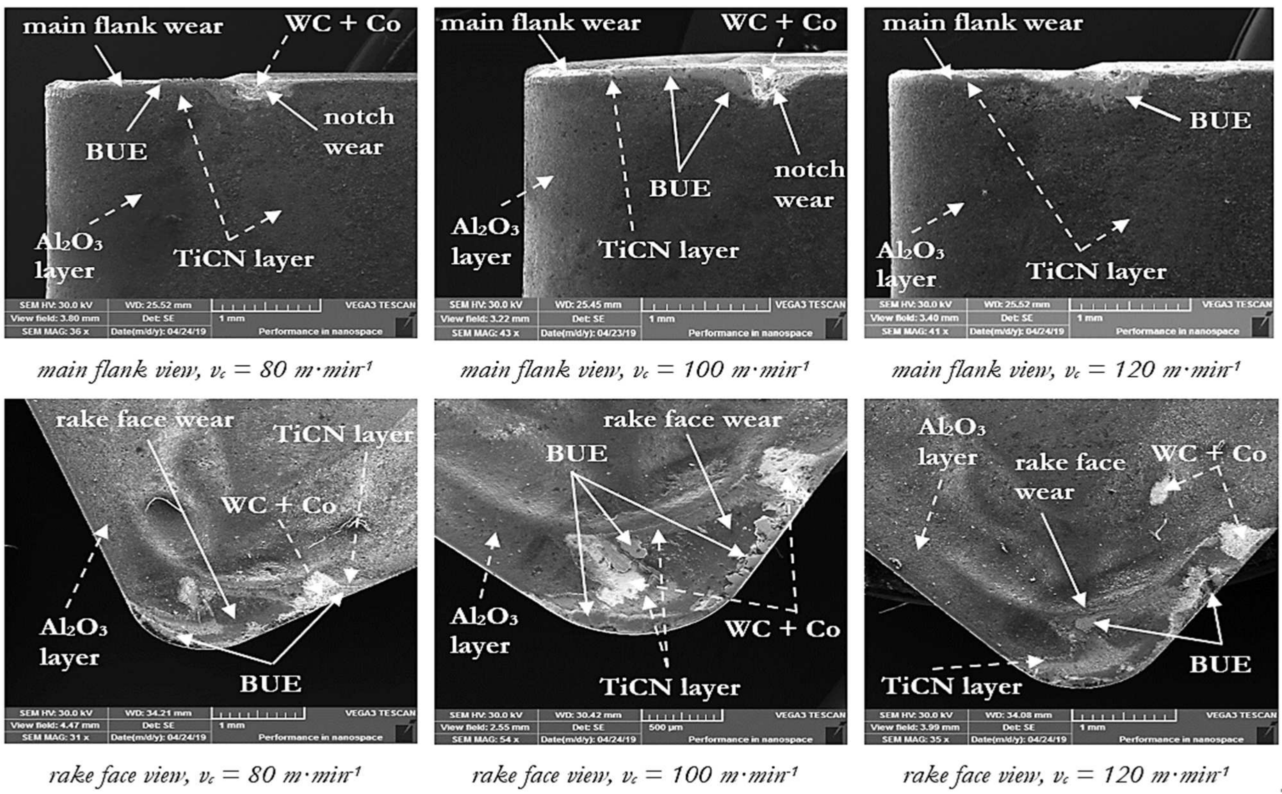

Fig. 6 *SEM analysis of worn CNMG 120408-FM GRADE T9325 after cutting 1.4404 austenitic steel*

In Fig. 6, the worn surfaces of the main flank and face of the CNMG 120408-FM GRADE T9325 insert are photographed using SEM. SEM analysis confirmed the commonly occurring wear types characteristic of cemented carbide cutting tools. These are the presence of a flank wear, a crater wear on tool face, notch wear on the main flank and on the face of the tool [28]. The degree of wear was dependent on the location of the functional area of the cutting tool and the applied cutting speed. At the cutting speed v_c = 80 m·min^{-1}, wear of the outer layer of the Al_2O_3 coating to the level of the TiCN coating was identified in the area of the wear surface of the main flank. BUE was also identified in this area. In the area where the chip leaves the edge surface, wear in the form of notch wear was identified up to the level of the substrate WC + Co. A layer of TiCN was also exposed below this area, probably by abrasion of the outgoing chips. The TiCN layer and the substrate were also exposed on the face of the tool in the area related to the departure of the chip from the cutting edge surface. A similar wear distribution was also achieved at a cutting speed of v_c = 100 m·min^{-1} with the difference of a larger BUE of the workpiece material at the chip exit point on the main flank and along the edge line on the tool face. After reaching the wear limit at a cutting speed of v_c = 120 m·min^{-1}, wear in the form of notch wear was practically not visible, while a larger amount of adhered material of the workpiece in the form of BUE was identified precisely in the area of cutting contact between the cutting edge and the workpiece.

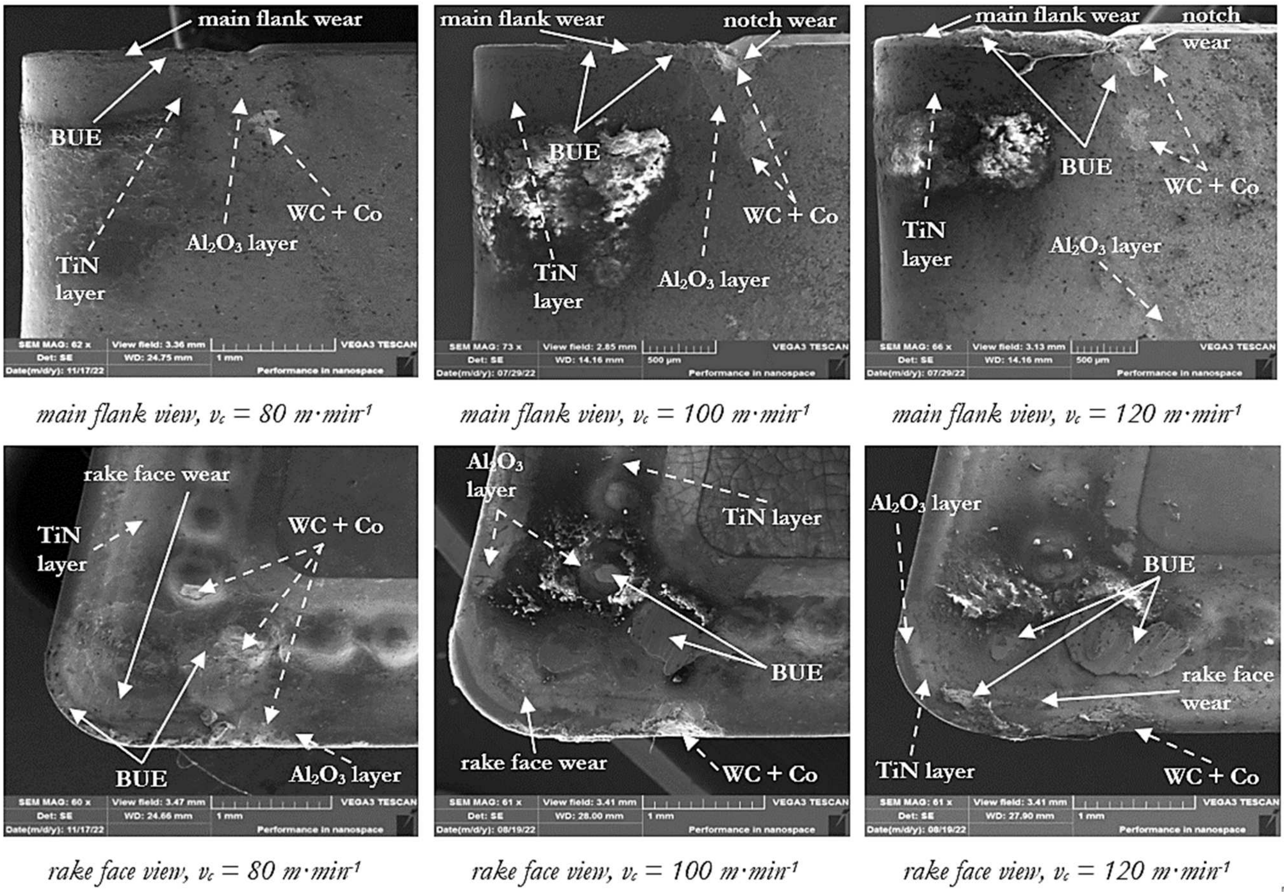

Fig. 7 *SEM analysis of worn CNMG 120408N-EG AC8025P after cutting 1.4404 austenitic steel*

The same analysis of the worn CNMG 120408N-EG AC8025P insert was performed using SEM, see Fig. 7. SEM analysis confirmed commonly occurring wear types characteristic of cemented carbide cutting tools. These are the presence presence of a flank wear, a crater wear on tool face, notch wear on the main flank and on the face of the tool. The degree of wear was expected to depend on the location of the functional area of the cutting tool and the applied cutting speed. At a cutting speed of v_c = 80 m·min^{-1}, wear of the outer layer of the TiN coating to the level of the Al_2O_3 coating was identified in the area of the wear surface of the main flank. BUE was identified in the edge line and on the tool face. In the area where the chip leaves the cutting edge, wear was identified up to the level of the WC + Co substrate, however this wear did not reach the set critical level as mentioned above. A layer of Al_2O_3 coating was also exposed under this area, probably by abrasion of the outgoing chips. The Al_2O_3 coating layer and the substrate were also exposed on the tool face in the area related to the formation and departure of the chip from the cutting edge surface. More intense wear was also achieved at a cutting speed of v_c = 100 m·min^{-1} with a smaller proportion of BUE of the workpiece material at the chip exit point on the main flank and along the edge line on the tool face compared to a cutting speed of v_c = 80 m·min^{-1}. The exposure of the Al_2O_3 layer was particularly pronounced on the face of the tool, and the wear on the main flank of the tool caused by chip wear reached up to the level of the WC + Co substrate. After reaching the wear limit at a cutting speed of v_c = 120 m·min^{-1}, there was significant wear in the form of notch wear compared to lower cutting speeds, while a significant amount of adhered workpiece material in the form of BUE was identified, especially on the tool face. Significant notch wear corresponds to a sudden increase in wear, or by reaching the critical wear value VB_{max} above the level of 300 μm.

4 Discussion of experimental results

The aim of the experiment was to map the course of wear of selected inserts when applied to a type of material that does not fall into the primary use group. For this, CNMG 120408 type inserts from various manufacturers were selected when they were examined. Despite the fact that the ČSN ISO 6987 standard specifies the basic proportions of used inserts, each manufacturer adjusts its product according to the possibilities of its development and technology. Even during the macro analysis of the unworn inserts, there was an obvious difference in the design of the cutting edge and the chip breaker. The manufacturers of both examined inserts describe the used chip breakers as suitable for machining steels, cast steels, or superalloys. These aspects are obviously due to the primary use – i.e. for semi-roughing to finishing operations in application group P. The material in application group M – austenitic stainless steel 1.4404 – was used in the experiment. This article does not describe produced chips, however, wear caused by their rubbing against the tool body was observed in both examined inserts and was similar in extent for both representatives, where wear occurred up to the level of the carrier material. However, at no stage of the experiment did there occur any complications associated with the formation of chips - i.e. the breaking of the cutting edge during the backward movement of the chip between the workpiece and the tool or the winding of the chips on the lathe chuck. Also due to the properties of austenitic steel, from the point of view of chip formation, selected inserts can be considered suitable for machining corrosion-resistant austenitic steel.

SEM/EDX analysis of the deposited layers revealed a different composition of the coatings in the investigated inserts. The difference was both in the types of coatings used and in their resulting total thickness, where the coating of the CNMG 120408N-EG AC8025P insert with the application of three coating layers with a total thickness of 15.2 ± 0.5 μm works better compared to CNMG 120408-FM GRADE T9325, where two were applied layers with a total thickness of 12.3 ± 0.7 μm. This fact probably had the greatest influence on the resulting course of wear, or the service life achieved as a result of the used cutting speed. According to the analyzed wear courses during the cutting speed, v_c = 120 m·min^{-1}, almost identical results were achieved, when the wear of the main flank suddenly increased during the crossing of the set critical wear limit, see Fig. 4, 5. For both inserts, at the highest tested cutting speed, the greatest adhesion of the workpiece material in the form of BUE occurred on the tool edge, at the point of separation of the tool and the workpiece, and on the tool face. A diametrical difference in wear patterns was observed at lower applied cutting speeds. While at the cutting speed, v_c = 100 m·min^{-1} the resulting difference in the service life achieved was approximately double, at the cutting speed, v_c = 80 m·min^{-1} the wear courses were even more different, if we consider that after 60 minutes CNMG 120408N-EG AC8025P in the frame, the experiment was discontinued. The CNMG 120408-FM GRADE T9325 insert during the cutting speed, v_c = 80 m·min^{-1} reached the critical wear limit after 36.53 min in engagement, which is a satisfactory result considering the application on the alternative use group. In contrast, CNMG 120408N-EG AC8025P achieved a main flank wear value of 164 μm after 60 minutes in engagement at the same cutting speed.

Machining of austenitic corrosion-resistant materials is usually associated with difficult distribution of the heat generated during the separation of the workpiece material. Unlike other materials, a smaller part of the heat escapes through the mass of the chip, and as a result, the generated heat is distributed to a greater extent in the body of the workpiece and the cutting tool, which results in a greater tendency to dimensional changes, the formation of internal stress and less resistance to plastic deformation. The difference in wear patterns at the lower tested cutting speeds was therefore probably caused by the applied coating layers, when, due to their composition and thickness, these layers at lower speeds had a major influence on the distribution of the generated heat and maintaining the strength of the edge during machining of the material properties of austenitic stainless steel. When the cutting speed was increased, the function of the coatings was reduced to such an extent that, despite their differences, a similar course of wear was achieved when the cutting speed was applied, v_c = 120 m·min^{-1}.

In terms of observed types of wear, characteristic wear was observed for cemented carbide cutting tools.

To a greater or lesser extent, the formation of BUE has been observed. The types of wear, their distribution and size differed slightly with respect to the applied cutting speed, however, these mentioned phenomena were not fundamentally different between the tested inserts when compared by SEM.

5 Conclusions

The aim of the experiment was to analyze the course of wear of indexable inserts of type CNMG 120408 from two different manufacturers on a type of material that does not fall into the primary application area, but is nevertheless accepted by the manufacturer as an alternative application area. Austenitic stainless steel 1.4404 was used as the test material. Testing took place under identical cutting conditions in series at cutting speeds v_c = 80, 100 and 120 m·min^{-1} with regard to the stability of the machine-tool-workpiece system. Unworn inserts were subjected to EDX analysis of the coating layers using SEM. After reaching the set limit value of main flank wear VB_{max} = 300 µm, the obtained data were analyzed and plotted in graphs mapping wear trends depending on the tested insert and cutting conditions, respectively cutting speeds. At the same time, after reaching the specified limit value of wear, the inserts were subjected to analysis using SEM in terms of the rate of wear and identification of the type of wear, including its location. The results of the experiment can be summarized in the following points:

- The investigated CNMG 120408 inserts achieved good results in terms of cutting edge life, given that it was a machining process of austenitic stainless steel, which is associated with the problem of poor heat dissipation from the cutting site. Different insert lifetimes were observed due to specific cutting conditions, while the main factor determining the change during wear was an increase in the cutting speed v_c.
- The individual forms of wear corresponded to forms occurring during machining with cemented carbide cutting tools. As the cutting speed increases, a greater tendency to form BUE at the cutting edge and face of the tool was observed. At the same time, more intense wear was observed in the place where the cutting edge of the tool and the workpiece surface are separated in the form of notch wear. Wear of the coating layers was observed in areas of flank wear and wear on the face of the tool near the cutting edge as well as further away in places where the chip left the cut and rubbed against the body of the tool.
- The composition of the coating layers and their overall thickness had the main influence on the service life of the tool edge and the course of wear. Depending on the decreasing cutting speed v_c, a difference was observed in the course of wear between the tested inserts, where CNMG 120408-FM GRADE T9325 had up to two times shorter time to reach the specified wear limit during the reduction of the cutting speed compared to CNMG 120408N-EG AC8025P with an overall greater coating thickness layers and a larger number of individual applied coatings. During the testing of CNMG 120408N-EG AC8025P at v_c = 80 m·min^{-1}, the specified value of tool wear in the form of main flank wear was not even reached even after 60 minutes of the tool in engagement.

Despite the identical marking of the examined inserts according to the ČSN ISO 6987 standard, the properties of the inserts are in fact greatly influenced by the properties that the manufacturers of cutting tools have included in their know-how. However, these differences have a very fundamental effect on practical use, namely on the service life during the machining process. This fact can and should be considered especially when a manufacturing company would like to use a cutting tool under non-standard conditions, such as different cutting conditions or use on a different machined material than the one it is primarily designed for, in order to save costs for choosing a suitable tool determined by the cutting tool manufacturers.

Acknowledgement

The article was supported by the OP VVV Project Development of new nano and micro coatings on the surface of selected metallic materials - NANOTECH ITI II., Reg. No CZ.02.1.01/0.0/0.0/18_069/0010045

References

[1] DE VOS, P. (2014). *Realities of Today's Manufacturing Production Economics.* Secotools.com. Available online: https://www.secotools.com/article/122479?language=en

[2] DENKENA, B., MICHAELIS, A., HERRMANN, M., POTSCHKE, J., KRODEL, A., VORNBERGER, A., PICKER,

T. (2020). *Influence of tool material properties on the wear behavior of cemented carbide tools with rounded cutting edges*. Wear, 456–457, 203395. Available online: https://linkinghub.elsevier.com/retrieve/pii/S0043164820302386, ISSN 00431648

[3] SURESH, R., BASAVARAJAPPA, S., GAITONDE, V., SAMUEL, G. (2012). Machinability investigations on hardened AISI 4340 steel using coated carbide insert. In: *International Journal of Refractory Metals and Hard Materials,* Vol. 33, pp. 75–86. ISSN 02634368

[4] GRYC, J. (2009). Nové obráběcí nástroje. In: *M.M Průmyslové Spectrum*. Vol. 12. Available online: http://www.mmspektrum.com/clanek/nove-obrabeci-nastroje

[5] ASTAKHOV, V.P. (2004) The assessment of cutting tool wear. In: *International Journal of Machine Tools and Manufacture*, Vol. 44, pp. 637–647. Available online: https: //linkinghub.elsevier.com/retrieve/pii/S0890695503003122. ISSN 08906955

[6] SIDDHPURA, A., PAUROBALLY, R. (2013). A review of flank wear prediction methods for tool condition monitoring in a turning process. In: *International Journal of Advanced Manufacturing Technology*, Vol. 65, pp. 371–393. ISSN 0268-3768

[7] PETRU, J., SCHIFFNER, J., ZLAMAL, T., SADILEK, M., STANCEKOVA, D. (2015). Investigations of Cutting Tool Wear While Machining Inconel 718. In: *Manufacturing Technology*, Vol. 15, No. 3, pp. 396-403. CZ, ISSN 1213–2489

[8] JANASEK, A., CEP, R., CEPOVA, L., KRATOCHVIL, J., VRBA, V., PETRKOVSKA, L. (2012). Tool Life Reliability of Indexable Cutting Inserts. In: *Technological engineering,* Vol. 9, pp. 30–34. SK, ISSN 1336-5967

[9] ZHU, D., ZHANG, X., DING, H. (2013). Tool wear characteristics in machining of nickel-based superalloys. *In: International Journal of Machine Tools and Manufacture*, Vol. 64, pp. 60–77. ISSN 08906955

[10] BI, Z.M., WANG, L. (2013). Optimization of machining processes from the perspective of energy consumption: A case study.In: *Journal of Manufacturing Systems*, Vol. 31, pp. 420–428. ISSN 02786125

[11] KUNTOGLU, M., SAGLAM, H., (2019). Investigation of progressive tool wear for determining of optimized machining parameters in turning. In: *Measurement*, Vol. 140, pp. 427-436. ISSN 0263-2241

[12] USCA, U. A., UZUN, M., SAP, S., KUNTOGLU, M., GIASIN, K., PIMENOV, D. Y., WOJCIECHOWSKI, S. (2022). Tool wear, surface roughness, cutting temperature and chips morphology evaluation of Al/TiN coated carbide cutting tools in milling of Cu–B–CrC based ceramic matrix composites. In: *Journal of Materials Research and Technology*, Vol. 16, pp. 1243-1259. ISSN 22387854

[13] SERIN, G., SENER, B., OZBAYOGLU, A., UNVER, H.O. (2020). Review of tool condition monitoring in machining and opportunities for deep learning. In: *International Journal of Advanced Manufacturing Technology*, Vol. 109, pp. 953-974. ISSN 0268-3768

[14] WANG, J., WANG, P., GAO, R. X. (2015). Enhanced particle filter for tool wear prediction. In: *Journal of Manufacturing Systems*, Vol. 36, pp. 35-45. ISSN 02786125

[15] KARA, F. (2017). Taguchi optimization of surface roughness and flank wear during the turning of DIN 1.2344 tool steel. In: *Materials Testing*, Vol. 59, pp. 903-908. ISSN 2195-8572

[16] FREEMANTLE, C.S., SACKS. N. (2015). Recycling of cemented tungsten carbide mining tool scrap. In: *Journal of the Southern African Institute of Mining and Metallurgy*, Vol. 115, No. 12, pp. 1207-1213. ISSN 24119717

[17] SHEIKH-AHMAD, J., DAVIM., J. P. (2012). Tool wear in machining processes for composites. In: *Machining Technology for Composite Materials* [online]. Elsevier, pp. 116-153. ISBN 9780857090300

[18] KUSMIERCZAK, S., SLAVIK, M. (2018). Analysis of Al-Si layer on steel sheet during thermo mechanical processing using microscopic methods. In: *Manufacturing Technology*, Vol. 18, No. 5, pp. 769-774. CZ, ISSN 1213–2489

[19] SRAMHAUSER, K., NAPRSTKOVA, N., SVIANTEK, J., STANCEKOVA, D., VAN TUONG, N., NOVOTNY, J. (2022) *Analyses of Tool Wear and Chip Type for Different Coated Carbide Inserts in Turning Hardened 1.6582 Steel.* Coatings [online]. 12(7), ISSN 2079-6412

[20] NAPRSTKOVA, N., SRAMHAUSER, K., CAIS, J., STANCEKOVA, D. (2018). Using of the Electron Microscope to Evaluate the Tool Wear for a Selected Cutting Insert. In:

Manufacturing Technology, Vol. 18, No. 4, pp. 635-640. CZ, ISSN 12132489

[21] NAPRSTKOVA, N., CAIS, J., KRAUS, P., VAN, N. T. (2016). *Tool Wear Evaluation of Selected Inserts after Turning by Electron Microscopy*. Manufacturing Technology [online]., 16(5), 1068-1073 ISSN 12132489

[22] MÜLLER, M. (2016). Evaluation of single-lap adhesive bond quality by means of electron microscopy methods. In: *Manufacturing Technology,* Vol. 16, No. 5, pp. 1056-1062. CZ, ISSN 1213–2489

[23] SVOBODOVA, J. (2014). SEM and EDS Analysis Used in Evaluation of Chemical Pre-treatment Based on Nanotechnology. In: *Manufacturing Technology*, Vol. 14, No. 3, pp. 461-467. CZ, ISSN 1213–2489

[24] ČSN EN 10088-3. Korozivzdorné oceli – Část 3: Technické dodací podmínky pro polotovary, tyče, válcované dráty, profily a lesklé výrobky z ocelí odolných korozi pro obecné použití. Praha: Úřad pro technickou normalizaci, metrologii a státní zkušebnictví, 2015, Třídící znak 420927.

[25] VARIN, R.A., KRUSZYNSKA, J. (1987). Control of annealing twins in type 316 austenitic stainless steel. In: *Acta Metallurgica.* Vol. 35, No. 7, pp. 1767-1774. ISSN 00016160

[26] DORMER PRAMET. Katalog (2019). [Online]. Available from WWW: https://www.dormerpramet.com/cs-cz/downloads/literature

[27] SUMITOMO. Turning Tools 2018 – 2019. 2018. [Online]. Available from WWW: https://www.sumitomotool.com/fileadmin/user_upload/Blaetterkataloge/index.php?catalog=Sumitomo_Catalogue_2018-2019_C-F

[28] SANDVIK COROMANT. *Příručka obrábění: kniha pro praktiky*. Překlad Miroslav Kudela. 1. české vyd. Praha: Scientia, ©1997. 1 sv. (různé stránkování). ISBN 91-972299-4-6