CBN TOOLS WEAR DEVELOPMENT DURING HIGH SPEED MACHINING OF S600 BOHLER STEEL AND ITS INFLUENCE ON MACHINED SURFACE

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Keywords: high speed machining**,** hard machining, tool wear, surface roughness.

Production technologies have experienced great progress in recent years. On leading positions is especially high speed machining (HSC) which draw attention of many production companies and researchers. Many investigations had been done in cutting tools and machines, but these are still questions about tool wear and it influence on machined surface when HSC is applied. This paper is aimed to document and describe the process of wear on cutting edge of a tool made from cubic boron nitride (CBN) during finish turning operation of hardened steel S600 Bohler. To document and measure the size of wear was used portable digital microscope with measurement option. The experiment also investigated the influence of tool wear on surface quality..

Introduction. High speed machining is a combination of increasing the cutting speed and dry or hard machining. It follows the reduction of cutting and friction force and total cutting resistance. The sectional size of chips is smaller and speed of chip flow is higher. The temperature of the chip increases, but thanks to higher speed it can´t transfer the heat into the tool and workpiece. The temperature load on machine is also lower. It also improves the quality of the machined surface and reduces tool wear. In general, cutting speed during HSC rises up to 10 times higher than during standard machining, but it depends on exact machining operation and machining conditions.

HSC as a method of machining can be divided by the use of coolant (or lubricant) into these groups:

- minimum quantity of lubricant machining (MQL)
- machining with high volume of coolant (Flood cooling)
- dry machining

MQL is a method that uses minimum volume of lubricant. It is a waste-free and ecological method. As a lubricant is used oil aerosol transported on cutting edge by compressed air (flow speed is 5-30 $ml.h^{-1}$). Oil mist prevents thermal shocks, which can appear when liquid cooling is applied.

Flood cooling is a method that uses large volumes of coolant. It has a beneficial effect on the heat transfer from the area of the cut and the friction conditions at chip removal. Disadvantages are thermal shocks of tool, which affect its life and higher production costs due to prize for coolant and ecological disposal [12].

Dry machining is machining without use of any coolant or lubricant. By this method of machining is possible to significantly reduce the production costs, and what is more, it is very environmentally friendly [11]. If is dry machining with high cutting speeds applied on hard or hardened materials, it´s called hard machining. Hard machining and especially hard turning of steel workpieces harder than 50 HRC with cubic boron nitride (CBN) can be essentially performed as rough, precision and high precision operation when the *Rz* parameter is less than 1 μm [2]. In particular, precision finishing of hardened steel components using tools made from cubic boron nitride in proper application offers manufacturers an attractive alternative to traditional grinding. And, what is more, it can often cut manufacturing costs, decrease production time, improve overall product quality and eliminate environmentally dangerous coolants.

Tools made from cubic boron nitride used for turning are made in geometry with negative rake angle and cutting edge reinforced by a chamfer. There are no special geometries for chip control; the development of tools is focused into improving surface finish of machined parts by special finishing geometries. By using these geometries there is option that feed is doubled or tripled compared to the standard geometry. This can provide faster cycle times or better surface roughness when using standard feeds. But with these special finishing geometries comes up problems with surface integrity, cutting forces and prediction of tool wear. Standard types of tool wear are shown in Fig. 1.

The aim of the experiment in this paper was to document and describe the process of wear on cutting edge and its influence on surface roughness during finishing operation of hard turning. Secondary objective of the experiment was demonstrating the use of digital microscope in engineering production.

Materials and methods. For the experiment was used discarded tool for cold rolling made from steel 1.3343, named as S600 BOHLER. Workpiece was thermally treated – hardened on hardness 63 HRC in whole diameter and tempered to eliminate residual austenite. The workpiece was divided to the sections with length of 50 mm, separated by groves.

As tools were chosen CBN inserts from Sandvik Coromant. For standard geometry there were inserts CNGA 120408- S01018A, grade of CBN 7025 a CNGA 120408-T01020 grade of CBN 7050. For EXCEL geometry there was CNGX 1204L025-18AXA, grade of CBN 7025. They were mounted in tool holder PCLNR 2020K 12, also from Sandvik Coromant. Experiment was performed on mechanical lathe SUI-40 I.

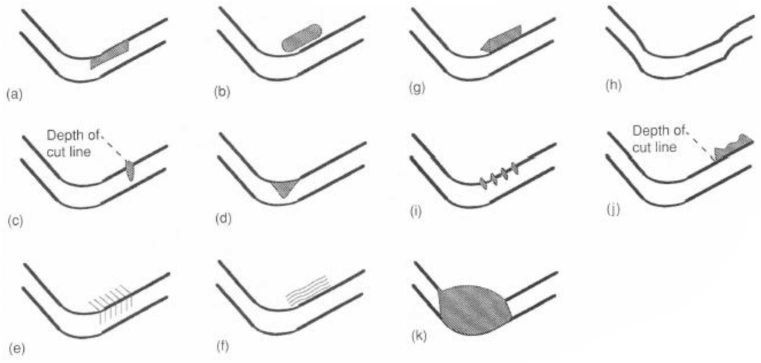

Fig. 1. Types of wear on cutting edges:
(a) flank wear, (b) crater wear, (c) notch wear, (d) nose radius wear. (e) thermal cracks, (f) parallel (mechanical) cracks, (g) built up edge, (h) gross plastic deformation, (i) edge chipping or frittering, (j) chip hammering, (k) huge fracture [3].

For observation and measuring of wear on cutting edge of the insert was used digital microscope VEHO Discovery VMS-001 with magnification range 20-200x. Digital microscope was connected to the computer and operated by software MicroCapture veho_vms004 [4]. Before the experiment the measurement function of software was calibrated for selected magnification.

To measure the surface roughness was used Mitutoyo Surftest 301. This device allows measuring all kinds of roughness characteristics, but for the experiment we had chosen parameter *Ra* – mean arithmetic deviation of profile.

For the comparability of results, we selected following constant cutting parameters:

- depth of cut, a_p = 0.15 mm,
- cutting speed, v_c = 108 m.min^{-1}

The only variable cutting parameter was feed per revolution, because we used recommended parameters for each tool:

- CNGA 120408 grade 7050, f_n = 0.1 mm
- CNGA 120408 grade 7025, f_n = 0.1 mm
- CNGX 1204L025 grade 7025, f_n = 0.21 mm

Results and discussion. The experiments were performed as dry hard machining, and started by testing of insert CNGA 120408-T01020, grade 7050. In

Fig. 2 we can see that there is extreme damage of cutting edge after machining first section of workpiece. This happened because of high content of abrasive particles in the workpiece. So we suggest that CBN grade 7050 is tougher and would perform better in interrupted cuts and hard materials but without abrasive particles. From this experiment due to damage of the cutting edge aren´t any measurements of surface roughness or flank wear.

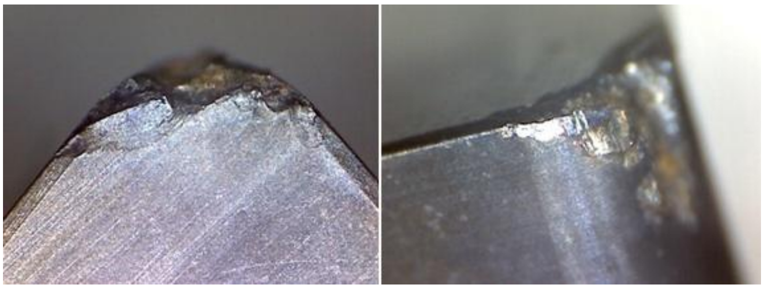

Fig. 2. Wear of insert CNGA 120408-T01020 grade 7050.

The second used insert was CNGA 120408-S01018A grade 7025. In this case the insert was able to machine the workpiece without being destroyed rapidly. The size of flank wear and surface roughness were measured right after machining of one section. After machining seventh section (cutting time 7.78 min) the flank wear reached the value of 0.24 mm, and crater wear on cutting edge started to be excessive so the experiment was stopped (Fig. 3). Table 1 shows the size of wear and surface roughness for each machined section. Progress of surface roughness of machined workpiece is represented by graph in Fig. 7. Progress of flank wear is shown by graph in Fig. 6.

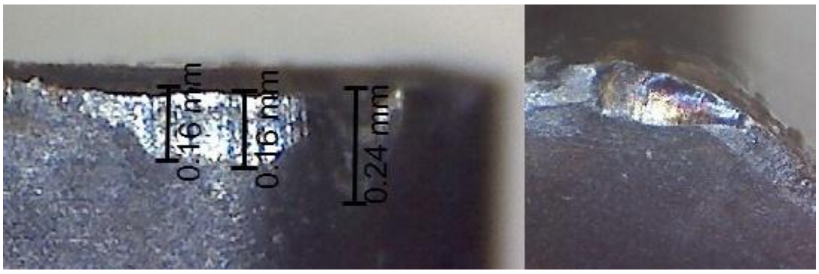

Fig. 3. Flank wear (left) and crater wear (right) after machining seventh section (CNGA 120408- S01018A grade 7025).

Last type of the insert was CNGX 1204L025-18AXA, grade 7025 (Excel geometry).The tool was able to machine six sections of workpiece (cutting time 3.17 min). Table 1 shows size of wear and surface roughness for each machined section. In Fig. 4 and 5 is shown the wear on flank and face of the insert. Notice the dark zone (mark A) in Fig. 5, this is the spot where the cutting edge from cubic boron nitride is soldered to the carrying insert. This dark zone means that the temperature in cut exceeded acceptable limits and solder started to melt. This is the reason why we stopped the process at this point, even when size of flank wear wasn´t very high (VB_{max} = 0.12 mm). Progress of surface roughness of machined workpiece is represented by graph in Fig. 7. Progress of flank wear is shown by graph in Fig. 6.

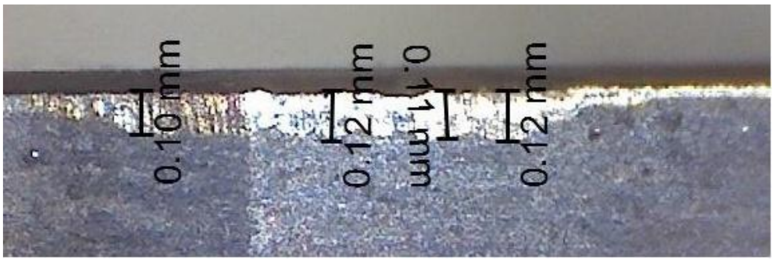

Fig. 4. Flank wear after machining, tool CNGX 1204L025-18AXA grade 7025.

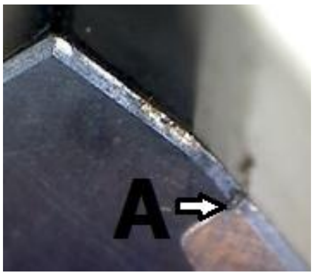

Fig. 5. Crater wear and thermal influence on solder after sixth machined section (CNGX 1204L025-18AXA grade 7025).

Table 1.

Values of measured flank wear and surface roughness

Machined section	**Flank wear VBmax, mm**		**Surface roughness Ra, µm**	
	CNGX 7025	**CNGA 7025**	**CNGX 7025**	**CNGA 7025**
1	0.06	0.07	0.6	0.59
2	0.07	0.08	0.42	0.74
3	0.07	0.09	0.67	0.84
4	0.1	0.09	0.74	0.91
5	0.12	0.21	0.44	0.93
6	0.13	0.23	0.54	0.99
7	-	0.24	-	0.99

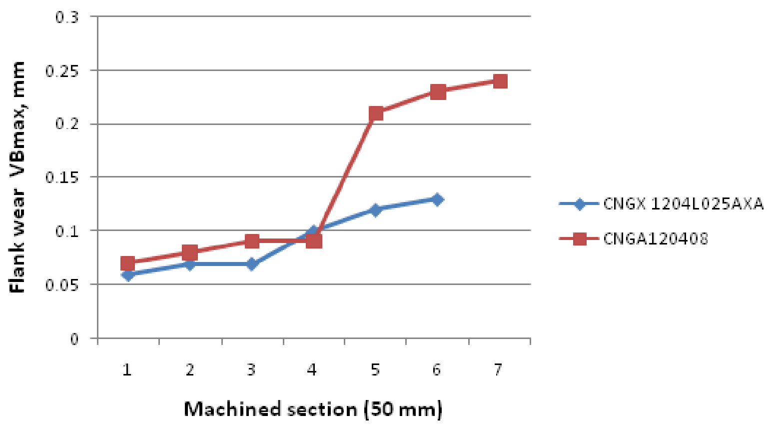

Fig. 6. Values of flank wear for tools CNGA 120408 grade 7025 and CNGX 1204L025 grade 7025.

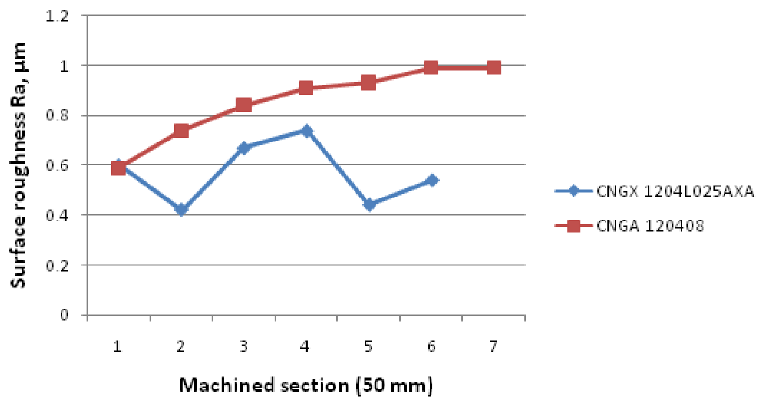

Fig. 7. Values of surface roughness of workpiece generated by tools CNGA 120408 grade 7025 and CNGX 1204L025 grade 7025.

Discussion. The insert CNGA 120408-T01020 grade 7050 is a tough type of cubic boron nitride and is mainly used in operations with interrupted cuts. However, we used it on the manufacturer's recommendations and the experiment showed it wasn´t right decision. The tool suffered from excessive wear nearly at the end of machining the first section. This means that CNGA 120408-T01020 grade 7050 isn´t right choice to machining S600 Bohler steel with hardness 63 HRC.

Different outcome is from machining with CBN grade 7025. This grade is harder than 7050, what means that is more wear resistant. Thanks to that insert CNGA 120408- S01018A grade 7025 was able to machine the S600 Bohler steel.

The process of wear on cutting edge of this tool was predictable, without extreme deviations. As is seen from the graph in Fig. 6, during machining section 5 the value of maximum flank wear raised more significantly. Experiment was stopped after machining seventh section (cutting time 7.78 min) the flank wear reached the value of 0.24 mm, and crater wear on cutting edge started to be excessive. Maximum surface roughness reached the point 0.99 µm.

Another tool made from CBN grade 7025 was CNGX 1204L025-18AXA. This type of insert has special finishing geometry with wiper surfaces. But instead of standard wiper insert, this one doesn´t have radius on the edge. Cutting edge is straight and thanks to that the chip thickness is constant, what provides better distortion of forces and heat on it. But on the other hand, because of wiper surfaces on the end of cutting edge the generated cutting force is higher compared to the standard geometry of inserts. This causes higher vibrations due to the insufficient rigidity of the machine and requested quality of the surface don´t have to be achieved. This was proved by the experiment. As is seen in Fig. 10, the size of wear graduated almost constantly, but line of graph in Fig shows that surface roughness was unpredictable and very various. Its values didn´t graduate smoothly but literally were "jumping" from one value to another. Minimal value of surface roughness was 0.42 µm when flank wear had maximum value 0.07 mm, and maximal value of surface roughness was 0.74 µm, when flank wear had maximum value 0.12 mm. Overall, the quality of surface was unpredictable, because the machine wasn´t able to handle bigger cutting forces generated during machining this type of material with this tool. The process was stopped after that we discovered thermal influence of tool – the solder in joint of CBN edge and carrying insert started to melt.

Conclusion. During the machining all tools suffered from excessive wear because of chemical composition of workpiece. Its hardness was reached by thermal treatment – hardening and carbide particles, which had extreme abrasive effect on cutting edge. Used were two different grades of CBN, 7025 and 7050. Selection of tool CNGA 120408 grade 7050 proved to be unsuitable for this type of workpiece material. Tool suffered from excessive wear right after start of machining.

Different situation occurred when tool CNGA 120408 grade 7025 was in cut. This standard geometry was able to machine the workpiece with continuous and stable growth of flank wear size and value of surface roughness, but special finishing geometry had unstable results. The values of surface roughness for tool CNGX 1204L025-18AXA were unpredictable because of higher cutting forces generated during machining and the machine wasn´t able to handle them. So this means that when we are deciding if to use wiper geometries in order to improve surface roughness or shorter machining times, it is necessary to calculate with rigidity and performance of the machine.

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