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# THE EFFECT OF TOOL WEAR ON CHIP FORMATION IN HARD TURNING

*Д. ЗАБО, Я. КУНДРАК*
*ВПЛИВ ЕФЕКТУ ЗНОШУВАННЯ РІЗАЛЬНОГО ІНСТРУМЕНТУ НА СТРУЖКОУТВОРЕННЯ ПРИ ТОЧІННІ ЗАГАРТОВАНИХ СТАЛЕЙ*

*У статті представлене порівняння особливостей процесу різання залежно від ступеня зношування інструмента по задній поверхні. Дослідження було виконано з використанням методу кінцевих елементів. Досліджувався процес токарської обробки деталей високої твердості, коли використалася зміцнена сталь 16MnCr5, 62±2 HRC із включеннями кубічного нітриду бора (CBN). Досліджувалися головна сила різання, температура різання й морфологія стружкоутворення.*
*Ключові слова: точіння загартованих деталей, зношування інструмента, стружкоутворення*

*В статье представлено сравнение особенностей процесса резания в зависимости от степени износа инструмента по задней поверхности. Исследование было выполнено с использованием метода конечных элементов. Исследовался процесс токарной обработки деталей высокой твердости, когда использовалась упрочненная сталь 16MnCr5, 62±2 HRC с включениями кубического нитрида бора (CBN). Исследовались главная сила резания, температура резания и морфология стружкообразования.*
*Ключевые слова: точение закаленных деталей, износ инструмента, стружкообразование*

*This paper compares the cutting process characteristics depending on the extent of the tool flank wear. The research was executed with Finite Element Method analysis. The researched cutting process was hard turning, when case hardened steel 16MnCr5, 62±2 HRC was cut by a cubic boron nitride tool insert (CBN). The examined data were the main cutting force, the passive force, the cutting temperature and the chip segmentation morphology.*
*Keywords: hard turning, tool wear, chip formation*

## *1. INTRODUCTION*

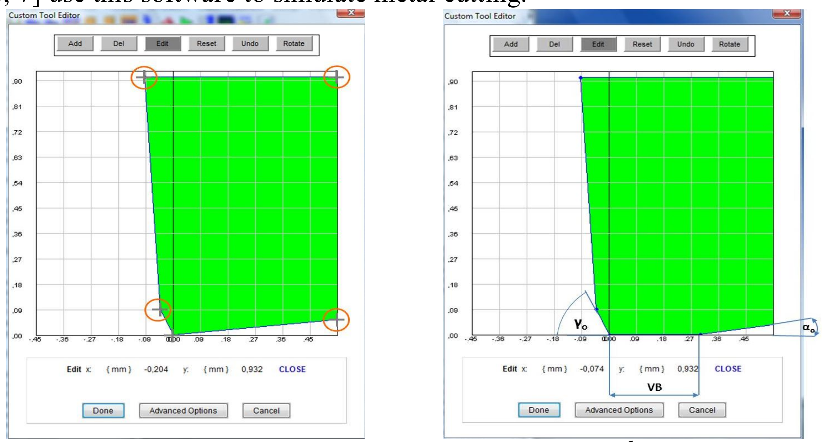
When creating machines and equipment, one of, if not the most important aspect is that they should operate the longest possible time according to the expected requirements.

Therefore the accuracy and the life of the parts from which these pieces of equipment are assembled are extremely important. An essential condition for providing a long lifetime of the machine parts is their high wear resistance. One fulfilment method of this requirement is to increase the number of hardened surfaces (>45 HRC) and to machine them with high surface quality and accuracy. Among the finish metal cutting processes which have high productivity and provide the required geometrical accuracy is hard turning. In case of cutting hardened steels with geometrically defined cutting edges is superhard or superhard coated tool inserts (ceramics, PCBN) are applied with special tool geometry. In chip removal with geometrically defined cutting tool in case of hardened materials, the removed chip has a special morphology. The mechanism of the chip removal mechanism develops under the influence of the following conditions: the mechanical. thermal, thermomechanical properties of the material; the cutting conditions; the divergence of shearing in the primary zone; the tribological relationship between the tool face and the rear of the chip; the possible interactions between primary and secondary zones; the dynamic response of the machine-tool structure and its interaction with the cutting process [1].

From our investigations the effect of the tool flank wear changes is presented in this paper. The fact that the tool flank wear directly or indirectly may affect the change of the cutting process characteristics as well as the accuracy of the machined parts underlines the importance of its research [1, 2].

*2. EXPERIMENTAL WORK*

The experiment was executed with the application of Finite Element Method (FEM). For investigation of effect of the tool flank wear on the cutting force, the passive force and the cutting temperature was carried out by means of the 2D version of Third Wave Advant EdgeTM 5.5 program package the modelling of optimised for cutting processes, therefore several researchers [4, 5, 6, 7] use this software to simulate metal cutting.




*a* *b*

Figure 1 – The cutting tool applied by us in the Custom Tool model editor, in case VB=0mm and b) in case VB=0.3mm

In this program a special material flow stress model used to describe the workpiece material quality used by us (16MnCr5), on the basis of the special literature [3, 5, 6, 7, 8, 9, 10,11, 12]. The process parameters of the experiment are listed in Table 1.

In the FEM simulation 6 different values of flank wear (VB) were examined. The modelling of the orthogonal cutting tool in the Third Wave Advant EdgeTM 5.5 system is created with the Custom Tool Editor [12]. An instance of tool configuration in displayed in Figure 2. The cursor appears as a ”+” on the editor surfaces.



Table 1 – Software input parameters

| ***Workpiece*** | | ***Process*** | |
|---|---|---|---|
| Workpiece length | 5 mm | Depth of cut | 0.2 mm |
| Workpiece height | 3 mm | Length of cut | 3 mm |
| Workpiece material | 16MnCr5 | Feed | 0.15 mm/rev |
| ***Tool*** | | Cutting speed | 180 m/min |
| Rake angle | -26° | Friction coefficient | 0.35 |
| Rake face length | 1.2 mm | Coolant | Not used |
| Relief angle | 6° | ***Simulation*** | |
| Relief face length | 2 mm | Max. nodes | 24000 |
| Cut. edge radius | 0,01 mm | Max. element size | 0.1 mm |
| Material | CBN | Min. element size | 0.01 mm |
| Flank wear | 0-0.5mm | Mode | Standard |

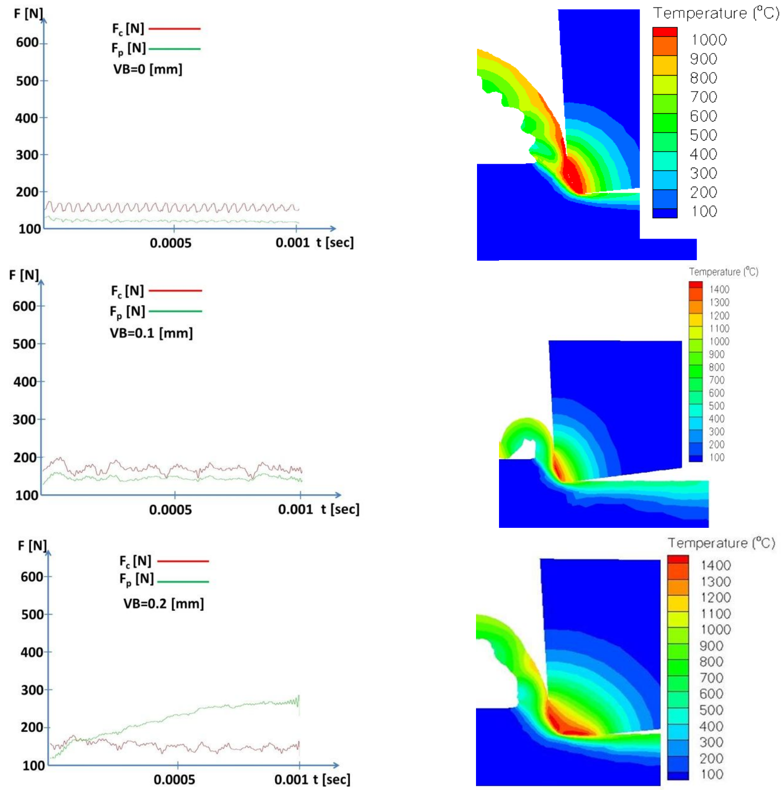



Figure 2 – Connection between the cutting temperatures and cutting force components depending on the tool wear extent in the case of vc=180 m/min, ap=0.2 mm, f=0.15 mm/rev, VB=0-0.2 mm

*3. EXPERIMENTAL RESULTS*

The results of the experiments are listed in Figure 3 and Figure 4. The showed data are the results of the main cutting force, the passive force, the segmentation and the cutting temperature of the removed chip.

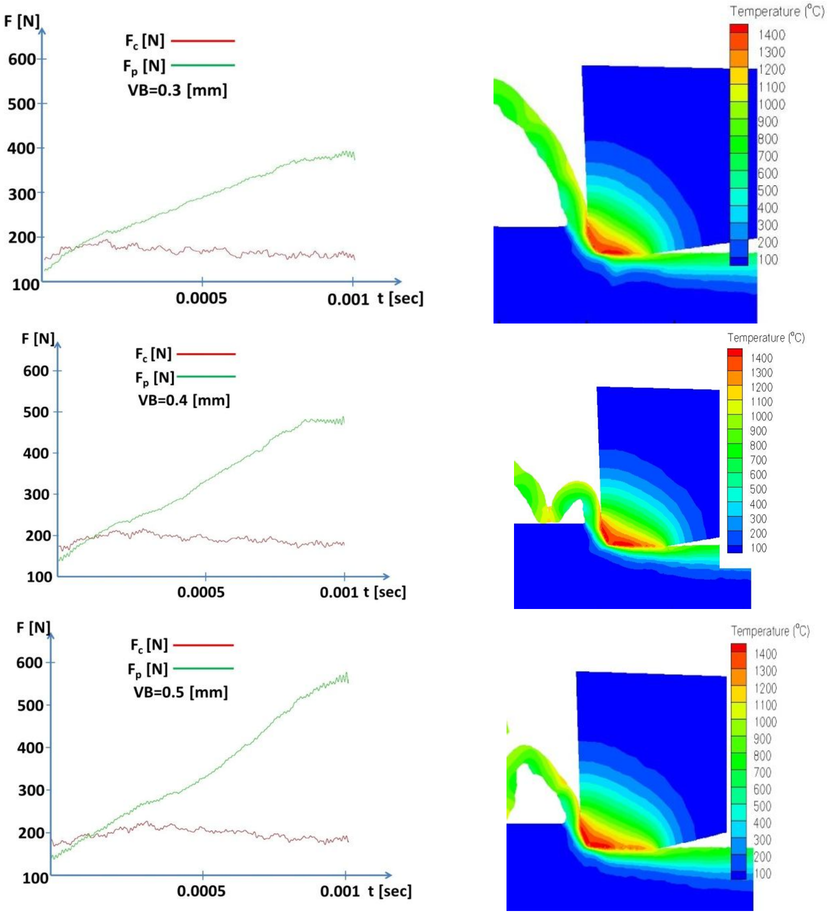



Figure 3 – Connection between the cutting temperatures and cutting force components depending on the tool wear extent in the case of vc=180 m/min, ap=0.2 mm, f=0.15 mm/rev, VB=0.3-0.5 mm

If the extent of flank wear increases, the passive force and the cutting temperature will be higher and higher too. The highest cutting temperature VB=0.5 mm (≈1400 °C) approaches the melting point of the workpiece material, and the passive force approaches 600 N. This is approximately a five time increase of the value of VB=0. This increase can be extremely harmful to the geometrical accuracy of the manufactured parts, because the in radial flexible splay out will be too high.

The formation of the main cutting force and passive force depending on flank wear is presented in Figure 5. The maximal values of plastic strain and cutting temperature are shown in Figure 6.

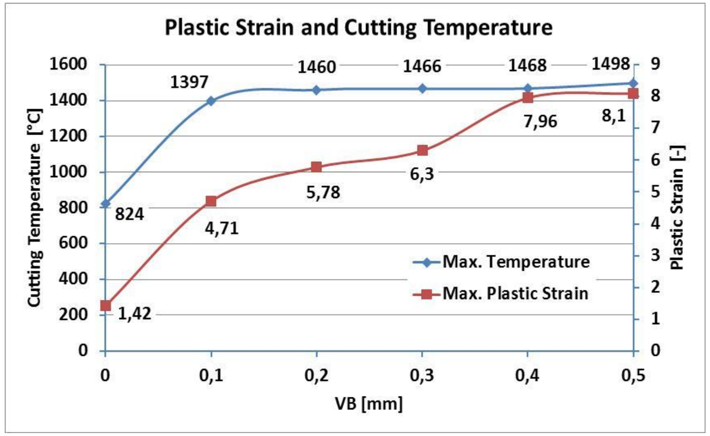



Figure 4 – The cutting temperature and plastic strain depending on flank wear

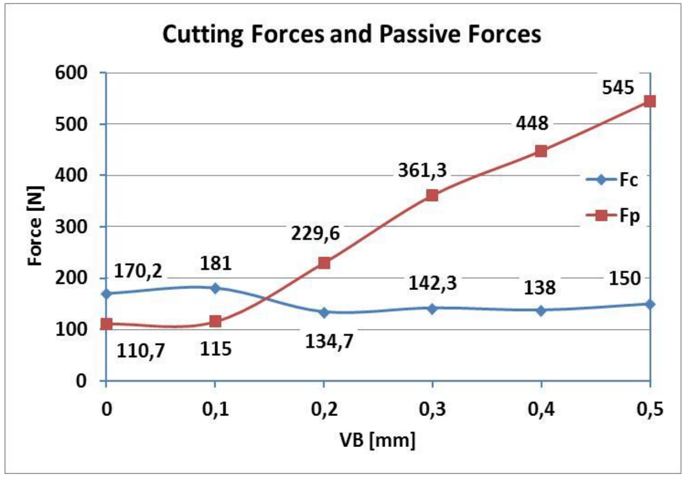



Figure 5 – The values of the main cutting force and passive force depending on flank wear

*CONCLUSION*

In this paper the main cutting force, the passive force, the plastic strain, the cutting temperature and the chip segmentation were researched depending on the tool flank wear. The experimental results showed that, when the flank wear of cutting tool is on the increase, the values of the passive force and the cutting temperature are significantly higher. The main cutting force did not change significantly. The chip segmentation disappeared from flank wear VB=0.2 mm. The highest difference of values measured between VB=0 and VB=0.5 mm values of flank wear is 181.8 % in the case of cutting temperature, 492.3 % in the case of passive force is, 135.5 % in the case of the main cutting force, 570.4 % in plastic strain. It was found that, if the flank wear is higher than VB= 0.3 mm, it is express by harmful to the geometrical accuracy and the surface quality of the machined parts.

*ACKNOWLEDGEMENT*

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## SURFACE INTEGRITY OF HONING

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*ШОРСТКІСТЬ ПОВЕРХНІ ПРИ ХОНІНГУВАННІ*
*Складові поверхневої якості значно впливають на експлуатаційні властивості. Тип механічної обробки, використовуваних інструментів і технологічні особливості впливають на шорсткість і мікротопографію поверхні після механічної обробки й на її трибологічні властивості. У статті запропоновані важливі трибологічні й поверхневі характеристики точності оброблених поверхонь при хонінгуванні, а також методи для їхнього визначення.*

*Составляющие поверхностного качества значительно влияют на эксплуатационные свойства. Тип механической обработки, используемых инструментов и технологические особенности оказывают влияние шероховатость и микротопографию поверхности после механической обработки и на ее трибологические свойства. В статье предложены важные трибологические и поверхностные характеристики точности обработанных поверхностей при хонинговании, а также методы для их определения.*

*Component surface quality greatly influences the working properties. Type of machining, the applied tools and technological characteristics have an effect on the roughness and microtopography of the machined surface and on their tribological properties. The article introduces important tribological and surface roughness characteristics of honed or microfinished surfaces and suggests methods for their determination respectively.*

### *1. SURFACE QUALITY OR INTEGRITY*

Deterioration of machine elements in most cases is the consequence of various abrasion, fatigue and corrosion stresses, which have a very close relationship with the surface quality of the components.

Surface quality of the components is determined by surface microgeometry (2D and 3D) and properties of the layers close to the surface (texture, remaining stress and microhardness) [1, 4]. Surface quality improvement microfinishing procedures (grinding, honing, superfinishing, lapping, microfinishing) are mainly designed and applied for cylindrical, and polygon, plane surfaces [2].

Surface quality improvement and decreasing the roughness of the surface generally have a positive influence on the tribological characteristics of the components. Attention will be paid to the relationship between surface microtopography and tribology.

### *2. TRAJECTORIES AND SURFACE MICROTOPOGRAPHY*

Arithmetical mean deviation $R_a$ from the mean line of the profile or maximum height of irregularities $R_{max}$ or height of irregularities $R_z$ given on the drawings of the components give insufficient requirements for the microgeometrical picture of the component.

The values $R_a$, $R_{max}$, $R_z$ and similar surface roughness index-numbers characterize the surface microgeometry of the component in one direction - in the direc-