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Influence of Nano–Wear of Tool on the Magnitude of Cutting Forces

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The paper presents results of research by means of Scanning Probe Microscopy (SPM), the rake face wear of inserts covered with titanium nitride. The influence of nano–wear on the magnitude of cutting force has been described.

Keywords: SPM microscopy, nano–wear, coatings topography, cutting forces

1. Introduction

Every day new materials are being formed, weighting less and at the same time having higher strength parameters, however at the same time being more difficult in machining. Due to increasing machining requirements new tool materials are being created. Tool contour and angles change, excessive wear of a cutting tool is not allowed. The parameters of machining increase as well as tool life. The paper presents the nano–wear of cutting inserts. The nano–wear has the influence on the cutting forces during turning and therefore effect on the machined surface i.e. for the surface shape and roughness. Using scanning probe microscopy (AFM and STM) we are able to investigate the wear of inserts covered with TiN, TiC [4] or other compounds as well as ceramic inserts. Knowing the real time of the wear of applied layers upon examination we conducted the investigation on the influence of nano–wear on the magnitude of cutting forces. In the next stage of research we will check the influence of nano–wear on the machined surface quality.

2. Conditions of conducting research and samples

Commercially available six blade cutting insert, marked as WNMG 060404–WF has been used in the research.

The sample: titanium nitride layer on a substrate of sintered carbide,

Cutting tests have been carried out with the following parameters of machining:

- cutting speed: $v_c = 300$ m/min
- feed rate: $f = 0{,}05$ mm/rev, $f = 0{,}1$ mm/rev, $f = 2$ mm/rev, $f = 3$ mm/rev
- depth of cut: $a = 1$ mm
- machined material: C45 steel, 30 HRC ± 2

Conditions of conducting the research:

- STM (scanning tunneling microscope), constant current mode, current of 0,80 nA, the needle with a diameter of 0.25 mm, wire prepared of Ir-Pt (iridium 10%, platinum 90%) by cutting with a wire cutter,
- scanning direction: along the x–axis and y–axis
- scanning was performed at atmospheric pressure and room temperature.

The wear of the rake face of the surface layer of the sample was the subject of investigation. Measurements were made on the surface layer of samples, before machining and after periods of turning lasting respectively: 36 s, 1 min 12 s, 2 min 24 s, 4 min 48 s. Selected results have been included in the paper.

3. The research stand

Research was carried out on the stand presented in Fig.1.

Machine cutting tests have been conducted on the numerically controlled lathe SL10 made by HAAS. Measurement signals from Kistler's force gauge type 9121, Kistler's amplifier type 5070 A and A/C converter card type 2855A4 were transferred and recorded on a PC hard drive using Kistler's DynoWare program. Fig. 2 presents the distribution of forces during machine cutting, explains denotations used in experimental courses of machine cutting forces. The following denotations were adopted: $F_z = F_c$ – cutting force in z direction, $F_t = F_y$ – feed force, $F_p = F_x$ – thrust force.

The exemplary courses of cutting forces components obtained from the research presents Fig. 3.

Figure 1 The research stand for measurements and registration of 3 components of cutting forces in turning, 1 – NC lathe, 2 – force gauge, 3 – amplifier, 4 – data recorder - PC computer

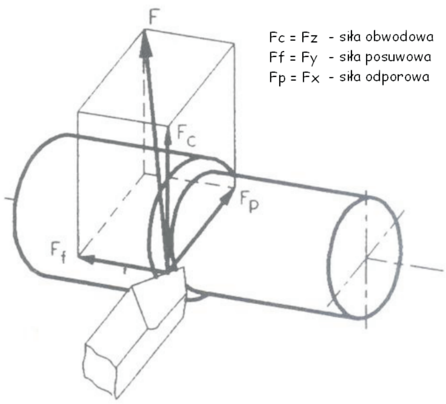

Figure 2 The distribution of forces in cylindrical turning [6]

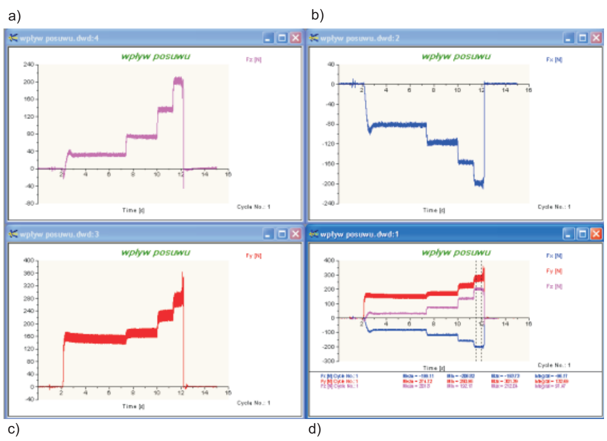

Figure 3 a), b), c) Exemplary courses of cutting force components in turning. F_x – thrust force, F_y– feed force, F_z – cutting force in z direction, d) Cumulative chart of components of cutting forces

4. Results of the research

Fig. 4 presents three dimensional topography of the surface of the new insert covered with a layer of titanium nitride (TiN). Grains of a varying size in the range from 700 to 1000 nm with oval rounded edges form the top layer [1].

The study was conducted using a number of scan areas, each surface scanned along the x–axis and the y–axis. Figs 4, 7–11 shows the results of measuring the surface layer of examined inserts. Figures marked with a letter b) show the two–dimensional surface with a marked measuring x and y axes. Figures marked with the letter c) respectively show the micro–geometry of the surface measured along the x and y axis. Figs marked with a letter c) present the three–dimensional surface of the examined samples. The measured values are given in nanometers.

4.1. *The wear of insert covered with TiN layer*

Fig. 5 presents the wear traces of the sample after 1 minute 12 seconds of operation. Still can be observed hilly structure. The height of grains with traces of wear varies in the range of 700–780 nm.

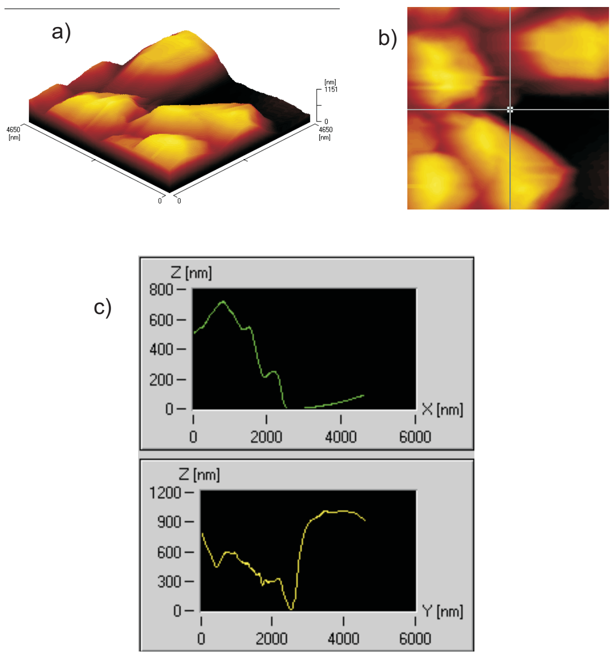

Figure 4 a), b) Image of TiN layer. The new insert, c) Surface geometry along x, y axis

Table 1 Mean values of components of the cutting force after 1 min 12 sec turning

Feed	Constant parameters			Cutting forces[N] – mean value		
	α_v	$\boldsymbol{V}_c$	material	$\mathbf{F}_x$	$\mathbf{F}_y$	$\mathbf{F}_z$
$\boldsymbol{V}_{f1}$= 0,05 mm/rev	1mm	300 m/min	C45	82	100	48
$\boldsymbol{V}_{f2}$= 0,1 mm/rev				110	152	69
$\boldsymbol{V}_{f3}$= 0,2 mm/rev				115	198	128
$\boldsymbol{V}_{f4}$= 0,3 mm/rev				210	205	167

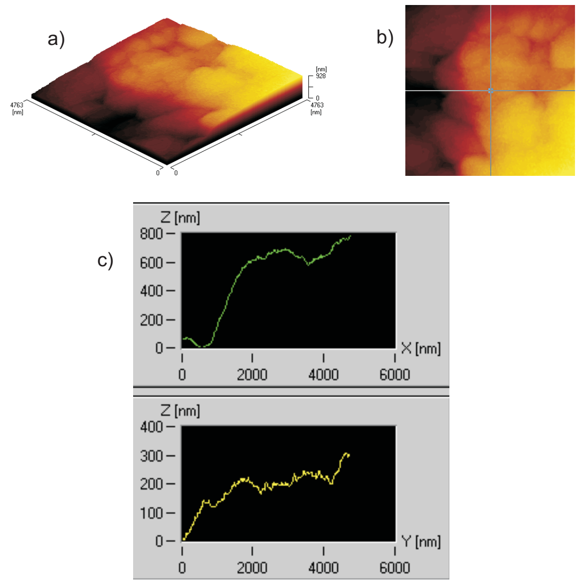

Figure 5 a), b) Abrasive wear of the tool (TiN) after 1 minute 12 sec. of cutting,c) Geometry of surface along x, y axis

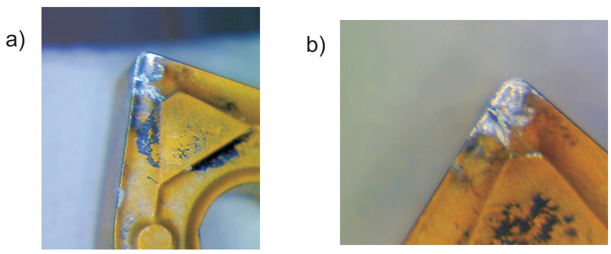

Figure 6 a) Traces of cutting tool wear after 1 min. 12 sec. of work, b) after 2 min. 24 sec. of turning

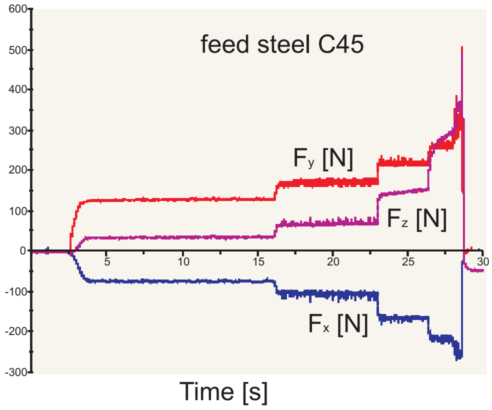

Figure 7 The cumulative chart of components of cutting forces - the first test of turning

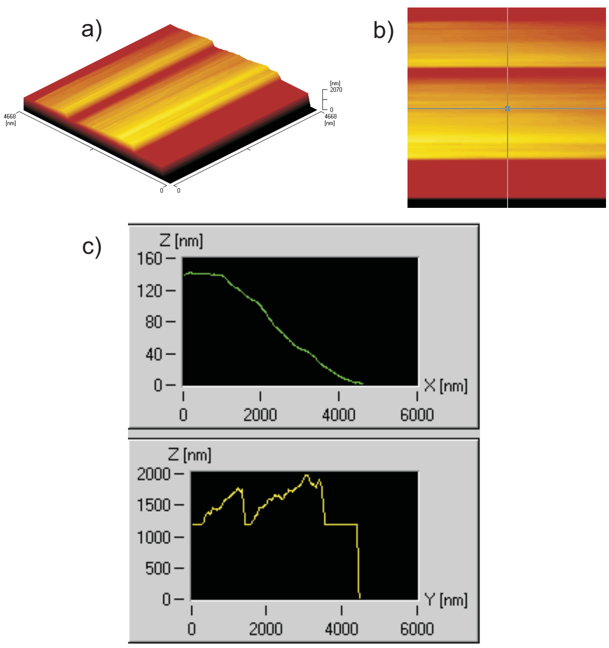

Figure 8 a), b) Abrasive wear of the tool (TiN) after 2 min 24 sec of work, c) Geometry of surface along x, y axis

Table 2 Mean values of components of the cutting force after 4 min 48 of turning

Feed rate	Constant parameters			Cutting force [N] – mean value		
	α_v	$\boldsymbol{V}_c$	material	$\mathbf{F}_x$	$\mathbf{F}_y$	$\mathbf{F}_z$
$\boldsymbol{V}_{f1}$= 0,05 mm/rev	1mm	300 m/min	C45	82	138	42
$\boldsymbol{V}_{f2}$= 0,1 mm/rev				93	182	70
$\boldsymbol{V}_{f3}$= 0,2 mm/rev				132	238	132
$\boldsymbol{V}_{f4}$= 0,3 mm/rev				205	269	221

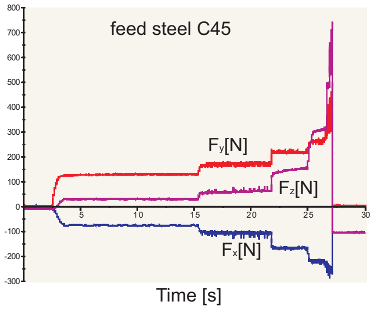

Figure 9 The cumulative chart of components of cutting forces – the second test of turning

Photographs of wear traces of inserts after the time of turning equal to 1 minute 12 seconds and 2 minutes 24 seconds are presented on the Fig. 6.

After 2 minutes, 24 seconds of operation the granular structure disappeared from topography and a terraced structure formed (Fig. 8). Tabs 1, 2, 3, present the values of components of the cutting forces generated by the turning of C45 steel. Turning conditions: constant cutting speed of 300 m / min and a constant depth of cut equal to 1 mm for different feed values. Mean values of the cutting force components were read from the graph (Figs 7, 9, 11).

Table 3

Feed rate	Constant parameters			Cutting force [N] – mean value		
	α_v	$\boldsymbol{V}_c$	material	$\mathbf{F}_x$	$\mathbf{F}_y$	$\mathbf{F}_z$
$\boldsymbol{V}_{f1}$= 0,05 mm/rev	1 mm	300 m/min	C45	98	143	120
$\boldsymbol{V}_{f2}$= 0,1 mm/rev				102	170	148
$\boldsymbol{V}_{f3}$= 0,2 mm/rev				160	260	210
$\boldsymbol{V}_{f4}$= 0,3 mm/rev				260	280	362

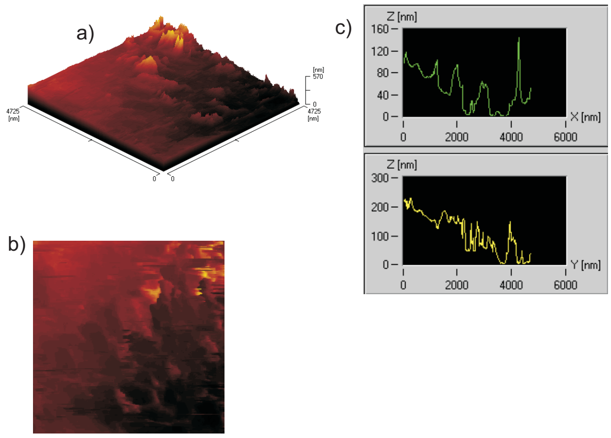

Figure 10 a), b) Abrasive wear of the tool (TiN) after 4 min 48 sec of work, c) Geometry of surface along x, y axis

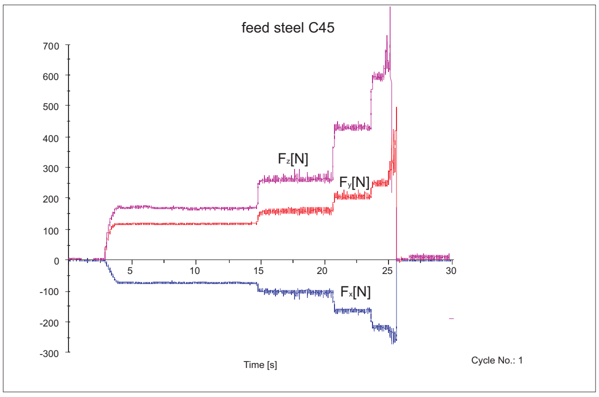

Figure 11 The cumulative chart of components of cutting forces - the fourth test of turning

After 4 minutes, 48 seconds of operation TiN coating has been worn off (Fig. 10). Remained visible structure of sintered carbide of a height varying in the range of 150–220 nm [5].

5. Conclusions

1. The process of the abrasive wear of the cutting insert covered with TiN layer runs in an analogical manner during turning on conventional machines [3,4].

2. After 4 minutes 48 seconds of cutting it can be seen the lack of TiN layer on the measured surface.

3. By comparing the force charts (Fig. 7. Tab. 1., Fig. 9., Tab. 2, Fig. 11, Tab. 3.) it can be stated that during the cutting process occurs the abrasion of TiN layer what generates the increase of values of all components of the cutting force.

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00–00–59/08 : "Adaptation of the educational infrastructure of the Faculty of Mechanical Engineering of Technical University of Lodz to predict needs and expectations of the labour market of the region of Lodz through the purchase of the equipment predicted for the modern teaching methods".

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