STUDYING OF THE CAPABILITY OF THE CERMET TOOLS DURING TURNING OF STEELS

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ABSTRACT

This research is an attempt to present experimentally the capability of the hot pressed ceramic tools for turning different types of steel. The experimental study was achieved for semifinishing, finishing and fine turning. In this case, the tool wear, life, cutting force developed during machining, process quality and productivity were taken into consideration. The executed study shows that, the metal composite ceramic tools may be successfully used for steel turning and may replace in several cases the cemented carbide and white ceramic tools to ensure higher process quality and productivity.

KEYWORDS

Machining, turning, alumina base ceramics, cermet, and process quality.

1 INTRODUCTION

Present-day production practices make severe demands on machine tools. The great increase of the machining quality and productivity may be obtained by using tools that offer high cutting properties. The diamond, polycrystalline cubic boron nitride (CBN) and ceramic recently manufactured cutting tools meet the needed requirements.

Because of its low bending strength, brittleness and steel solubility at relatively low temperature (750˚C), the diamond tools applied basically for machining nonferrous metals and alloys and nonmetallic materials.

The CBN has approximately the same hardness similar to the diamond and far exceeds it in red hardness, moreover this material more inert to ferrous metals. Therefore, the CBN cutting tools find a wide application for steel and cast iron machining. Furthermore, they may be used for machining light nonferrous alloys and some difficult-to cut materials.

Ceramic is a highly efficient tool material that deprived of rare earth elements such as tungsten and cobalt, which offer the basic components of cemented carbide and high-speed steels. The ceramic tools find an application in semi-finish and finish turning of high strength and quenched cast iron, hardened steels and non-metallic materials.

Ceramic tools successfully replace the cemented carbide in several cases, when the latter failed due to its rapid wear. If the cemented carbide tools failed because of chipping of the cutting edge, then the application of ceramic tools should not be allowed.

Recently, the manufactured ceramics may be subdivided into three basic groups that vary in chemical composition, method of production and application. These groups are as following: alumina base ceramics (nonmetallic, white or cold pressed), cermets (black, hot pressed ceramics (carboxides), or metal ceramic composites), and silicone-nitride base ceramics.

Silicone-nitride tools are used for cast iron machining applications. The disadvantages of the white ceramic inserts are the lower mechanical strength, brittleness, and the capability of chipping the cutting edges during cutting. As a result, the cermets were created for perfecting of ceramics. The carboxides consist of up to 60% aluminum oxide with various metallic carbides (tungsten, titanium, molybdenum and complex carbides of these metals). Cermets were attained the most distribution. This type beside the white ceramics has the higher thermal conductivity, heat resistance and impact strength.

2 EXPERIMENTAL STUDY

The current investigation studies the capability of the cermets beside different tool materials during semifinishing, finishing and fine turning of steel. Some mechanical, physical properties and chemical compositions of the employed tool materials are illustrated in table 1.

During the laboratory study, the experiments were achieved for machining preliminary turned and heat-treated steel samples of different types. The characteristics of the studied samples are presented in table 2.

As a result of strength test (according to value of destroying feed, and at repeated loading during turning of 25 mm length sections of the 100 mm diameter samples), the square form of cutting cermet inserts was selected for optimum finish turning. The inserts clamped mechanically on tool shank and have the following geometry: γ (rake angle)=-5˚, α (clearance angle)=5˚, λ (cutting edge inclination angle)=4˚, β (wedge angle)=90˚, and φ (entering angle)=φ_1(end cutting edge angle)=45˚.

Table 1. Chemical composition and some mechanical and physical characteristics of the employed cutting tool materials.

Tool material	Chemical composition (%)	Some physical and mechanical characteristics		
		Density (g/cm^3)	Hardness	Transverse rupture strength (MPa)
High speed steel	C=0.75, Si=0.3, Cr=4.13, V=1, W=18.25, Mo=0.7, Co=5	8.75	63-65 HRC	2600-3000
Cemented tungsten-carbide	WC=92, Co=8	14.4-14.8	≥ 87.5 HRA	≥ 1570
Cemented titanium-tungsten carbide	Type 1: WC=79, TiC=15, Co=6. Type 2: WC=66, TiC=20, Co=4	11.1-11.6 9.5-9.8	≥ 90 HRA ≥92 HRA	≥ 1129 ≥935
White ceramic	$Al_2O_3 \geq 99$, $MgO \leq 1$	3.85-3.9	90.5 HRA	300-350
Cermet	Al_2O_3 = 75, and 25 – cemented titanium-molybdenum tungsten carbide consist of (TiC=53, WC=6, and Mo_2C=41)	4.46	91.8 HRA	370-440

Table 2: Characteristics of the steel samples to be machined.

Steel type	Chemical composition (%)					Ultimate tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	Reduction of area (%)	Hardness (HB)
	C	Si	Mn	Cr	W, V, Ni, Ti					
Medium carbon	0.42 to 0.5	0.17 to 0.37	0.5 to 0.8	Up to 0.25	-	≥ 568	≥ 535	≥ 19	≥ 40	≤ 229
Nickel-chromium	0.41 to 0.49	0.17 to 0.37	0. 5 to 0.8	0.45 to 0.75	Ni 1-1.4	≥ 1030	≥ 835	≥ 10	≥ 45	≤ 207
Chromium - manganese	0.24 to 0.32	0.17 to 0.37	0.8 to 1.1	1.0 to 1.3	Ti 0.03 - 0.09	≥ 1470	≥ 1280	≥ 9	≥ 40	≤ 229
Wear resistant austenitic	1.0 to 1.5	-	11.0 to 15.0	-	-	780-880	300-340	≥ 15	20-30	≤ 200
Heat resistant	0.35 to 0.45	0.8 to 1.2	0.15 to 0.6	4.5 to 5.5	W 1.6–2.2 V 0.6-0.9	1150	-	10-13	≥ 45	≤ 345
Alloy tool	0.9 to 1.05	0.15 to 0.35	0.8 to 1.1	0.20 to 0.90	W 1.2–1.6	-	-	-	-	≤ 225

For evaluation the cermet tool ability, the following parameters was measured: the cutting force, the tool life, and the roughness of the machined surfaces.

Therefore, the formula for computation the tangential component of cutting force was revealed during finish turning of different steels (heat resistant, wear resistant austenitic, and chromium manganese steel) with the help of cermet tool, which have the following shape:

$$Fz = \frac{C \times t^x \times f^y}{v^n} \tag{1}$$

Where:

Fz – tangential component of cutting force (N);

C – constant depending upon the material to be machined, tool geometry, cutting fluid and other machining conditions;

x, y and n – exponents depending on cutting conditions;

t – depth of cut (mm);

f – feed rate (mm/rev);

ν – cutting speed (m/min).

The values of the coefficient C and the exponents for different materials were determined experimentally and presented in table 3.

It was established that the cutting force variation has the same character during turning with the help of white ceramics and cermet tools under the cutting speed of 100 to 300 m/min, the feed (*f*) of 0.13 mm/rev, and the depth of cut equaled 1 mm. Moreover, it was observed that the cutting force developed during cutting using of metal ceramic composites was more than that of the white ceramics.

Table 3: The values of the coefficient C and the exponents for different machined materials

Work machined material	Tool material: Alumina base ceramic				Tool material: cermet			
	C	x	y	n	C	x	y	n
Heat resistant steel	232	0.99	0.74	0.14	299	0.87	0.87	0.08
Chromium manganese steel	234	0.86	0.57	0.1	310	0.91	0.64	0.13
Austenitic steel	461	0.95	0.84	0.14	265	0.89	0.71	0.06

The relationship (tool life (T)-speed) obtained during finish turning by using cermet tool with cutting speed ranging from 50 to 400 m/min have the following forms:

For wear resistant austenitic steel

$$v = \frac{2465}{T^{0.74} \times f^{0.39} \times t^{0.03}} \tag{2}$$

For heat resistant steel

$$v = \frac{2602}{T^{0.89} \times f^{0.6} \times t^{0.3}} \tag{3}$$

For chromium-manganese steel

$$v = \frac{9058}{T^{1.07} \times f^{0.09} \times t^{0.2}} \tag{4}$$

The mechanisms of the cermet insert wear rendered distinctive. The insert turned dull basically by its flank surfaces and in lesser degree by its face. The depths of the wear crater are 5 times less than that by using cemented carbide tools.

The obtained surface roughness of the machined samples measured after finish turning by cermet tools with speed ranged from 100 to 300 m/min (t=1-2 mm, *f*=0.13-0.2 mm/rev) corresponded to 7th and 8th class of surface finish (Ra ranged from 1.25 to 0.63 μm). As a wear criterion, the amount of the land wear such as 0.3-0.4 mm was taken. Under this value high accuracy and surface finish of the machined samples were attained. By the comparison studies, it was established that the obtained roughness during cutting of short surfaces with cermet tools was close to that obtained by nonmetallic ceramic tools, and somewhat better than that obtained by using cemented carbides, and considerably better than that derived during cutting with the aim of high speed steel tools.

Also, a study to establish the suitability of the cermet tools for steel fine turning was achieved. In this case the cutting speed ranged from 120 to 420 m/min. As this takes place, the basic requirements for tool materials stemming from the specific features of the fine turning process were taken into consideration. These requirements are the production of sufficiently sharp and smooth cutting edges after sharpening, and the tool wear resistance should be sufficient to ensure the dimensional and the high quality of the machined surface.

The cermet inserts were grounded with diamond wheel at speed of 29m/sec ensuring the roughness of the working tool surfaces up to 9th-10th class of surface finish (Ra ranged from 0.32 to 0.16 µm). A numerous measurements were achieved by means of light section method, and as a result, it was established that the cutting insert nose radius was 10 to 15 µm. The relationship between the nose radius and tool wedge angle is shown in figure 1 and was determined in the following form:

$$r = 0.244\beta - 6.45 \qquad (5)$$

Where r – the tool nose radius or corner radius in microns,

β – tool wedge angle in degrees.

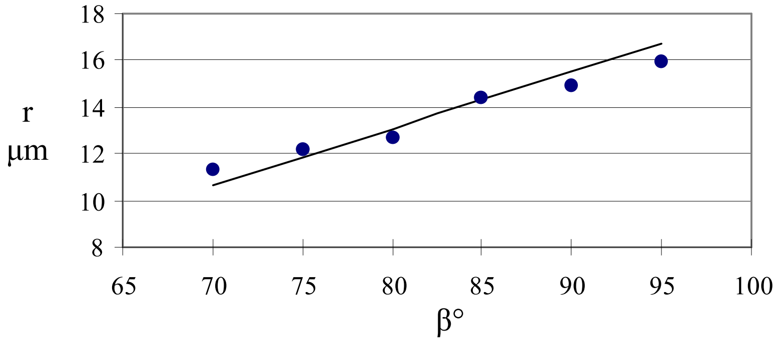
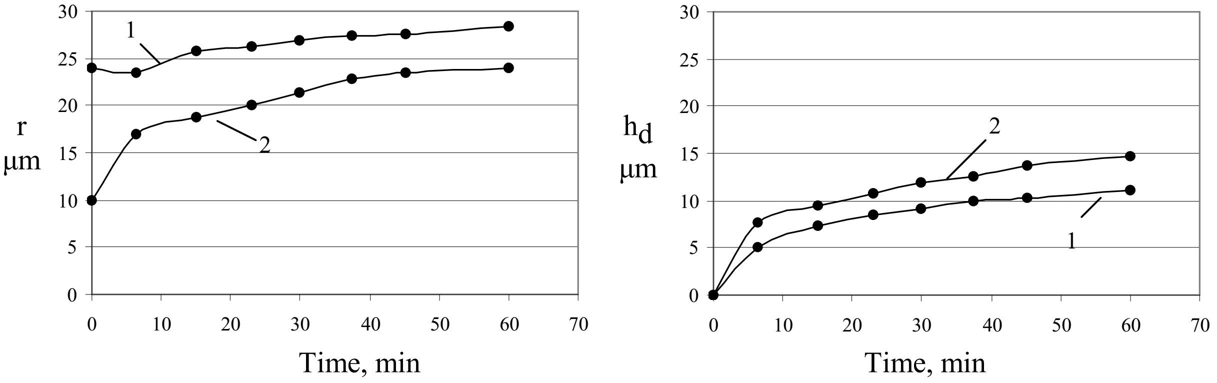


Figure 1: The relationship between the cermet tool nose radius (r) and its wedge angle (β)

The derived wedge of the cutting edge is good prerequisite to successful working of cermet tools. In conditions of fine turning, through commensurability the value (r) and thickness of cut or chip layer (a), the tool wedge plays a significant role in machined surface formation.



a) b)

Figure 2: The nose radius (a) and tool wear (b) variation at the time under fine turning of nickel-chromium steel by cermet tool with the following cutting conditions (f=0.037 mm/rev; t=0.1 mm; α=6°; γ=-10°, r=0.5 mm), where 1- r_{in}= 10-12 µm, and 2- r_{in}= 22-25 µm

The experimental data presented in figure 2 shows that the increase of the initial value of the cutting edge radius (r_{in}) leads to intensive drop in tool dimensional wear h_d growing. Along with this, it was established that with a rise of (r_{in}), the machined surface roughness rises (Rz rises to 20-25%). The obtained experimental results about the relationships between the relative dimensional wear and cutting speed for cemented carbide and cermet tools have clearly pronounced extreme character.

As shown in figure 3, the minimum relative cermet tool wear as less as 4-5 times than for cemented carbide tools, and it accomplished under more higher cutting speed.

The obtained surface roughness of the fine turned samples with the aim of cermet tools corresponded to 8th – 9th class of surface finish (Ra ranged from 0.63 to 0.32 µm).

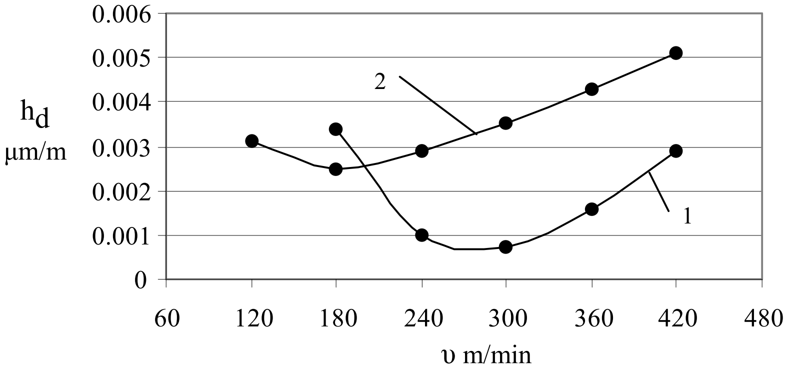


Figure 3: Effect of cutting speed on relative dimensional tool wear under fine turning of nickel-chromium steel with the following variables (*f*=0.037 mm/rev; t=0.1 mm; α=6°; γ=-10°, r=0.5 mm), Where 1- with the aim of cermet tool, and 2- by using cemented titanium-tungsten carbide tool type 2

Additionally, a study under of laboratory conditions to establish the suitability of the cermet tools for steel semifinish turning was achieved. At this stage, the machined surface samples corresponded to 5th – 7th class of surface finish (Ra ranged from 5 to 1.25 µm). Along with this, samples of medium carbon and alloy tool steels were machined. During machining the tool feed ranged from 0.1 to 0.5 mm/rev and depth of cut of 2-5 mm. The cutting speed was increased 2-2.5 times (ν ranged from 120 to 300 m/min) beside that, which taken during cutting with the cemented titanium-tungsten carbide tool type 1 (table 1). Therefore, in addition to improvement the machined surface quality, the productivity of the manufacturing operation also improved at least twofolds.

CONCLUSIONS

The result of the experimental study and testing of the turning tool provided with carboxide inserts ensure the possibility of its successful use for semifinishing, finishing and fine turning of different types of steel. The machined surface roughness improved at least for one class of surface finish and the process productivity increased 2-2.5 in several cases beside that achieved using cemented carbide and white ceramic tools.

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