MACHINING THE ZIRCONIUM-DIOXIDE ENGINEERING CERAMICS

Gellért Fledrich
Institute for Mechanical Engineering Technology,
Faculty of Mechanical Engineering, Szent István University, Gödöllő, Hungary
www.geti.gek.szie.hu

Abstract In place of brittle ceramics used so far have appeared up-to-date so called tough ceramic materials resisting better against mechanical effects [2]. Such material is the zirconium-dioxide, too. The important advantage of hard-turning is the applicability of universal tool. Various outlines can be formed by a tool given. Machining ceramics in case of using traditional machining (turning, milling, drilling) requires special technological conditions (tools, machine-tools, technological parameters, etc.) which are developing presently. We would like extending our research work in this course, too.

Keywords polycrystal diamond, cubic boron nitride, two-way force measuring, thermocamera, heat ring, surface roughness

1. INTRODUCTION

By industry development the demand is increasing for such materials to be applied at higher temperature beside at heavy physical and chemical load. The structural ceramics can have an important role exactly in this segment. The zirconium –dioxide is also such material [4]. At long-term it is predicted establishing the possibility of computer directed material structure starting from atomic level and of product manufacturing. However until the manufacturing technologies do not reach this level the role of ceramics hard-machining is increasing [5]. The zirconium-dioxide deriving from its lower hardness and from other characteristics is suitable to machine by tool having regular edge can become a potential material at piece or small- and medium series production. To ensure this it has to be known its cutting characteristics [6].

My research work focusing a part of this in keeping with the recommendation of the company producing and developing zirconium-dioxide semi-finished products.

2. MATERIALS TESTED AND THEIR FORMS.

The common properties of engineering ceramics are that they have outstanding physical and chemical characteristics in very high temperature range [3]. The ceramics tested by us have got high hardness (1250-1800 HV), because of this it can be cut by polycrystal diamond and cubic boron nitride tools. The material tested is zirconium-dioxide ceramics. The specimens used at turning tests were cylindrical, their diameters were 16 and 20 mm (Figure 1.)

Figure 1. The zirconium-dioxide (Zn40)ceramics used at tests.

The ceramic properties tested [7].

	Dimension	
Material		ZN 40
Main component		ZrO_2-MgO
Density	g/cm^3	5,74
Bending strength	MPa	500
Compression strength	MPa	1600
Young modulus	GPa	210
Poisson - ratio		0,3
Vickers hardness HV0,5		1240
Thermal convectivity	W/mK	3
Linear coefficient of thermal expansion	$10^{-6}K^{-1}$	10,2

Cutting tests

During turning the work-piece rotating movement is the main movement, the auxiliary movements are the turning tool movement in feeding and depth of cut directions [1] (Figure 2.). I have set the cutting speed by the work-piece revolution number.

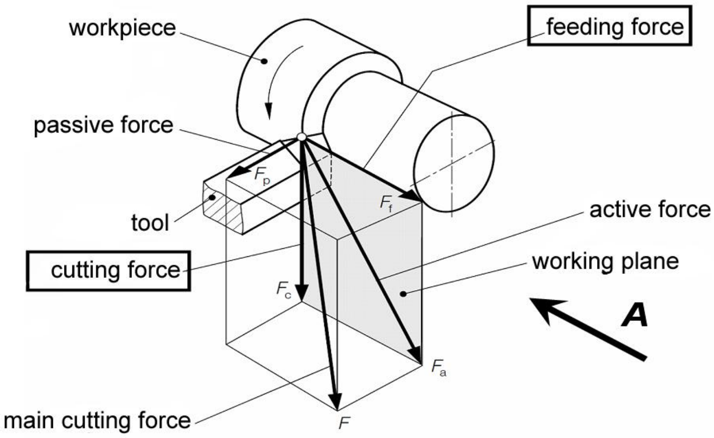

Figure 2. Cutting force components (ISO 3002/4, DIN 6584).

To measure the axial and tangential components of the cutting force I have used a measuring tool-head with strain gange developed and manufactured by me. The 3D –model of the measuring tool-head can be seen in Figure 3-4.

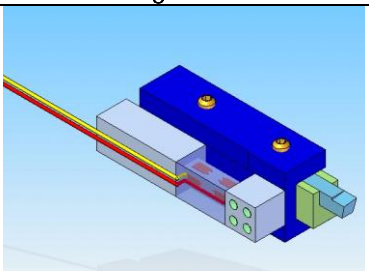	
Figure 3. The model of the measure tool-head	Figure 4. The photograph of the measuring tool-head finished with the holder clamped.

I have used the Spider 8 measuring amplifier for the tests. I have connected four channels. I have coupled to the O-channel the revolution marker, I have measured the tangential and feeding-directional forces on the 1 and 2 channels. The 3. channel served to measure the tool displacement, here I have connected an inductive displacement tele-transmitter restored by spring.

Heat affected zone tests.

The heat arising during cutting influences considerably the removal of stock process as well as influences very much the tool durability. I have also made shots with thermo-camera during cutting to study the heat affected zone formed. Figure 5. shows the thermo-camera.

Figure 5. Thermocamera used for tests.

3. DISCUSSION

During cutting I have measured the main and feeding- directional forces affecting the tool. As a result of this I illustrate a diagram on Figure 6.

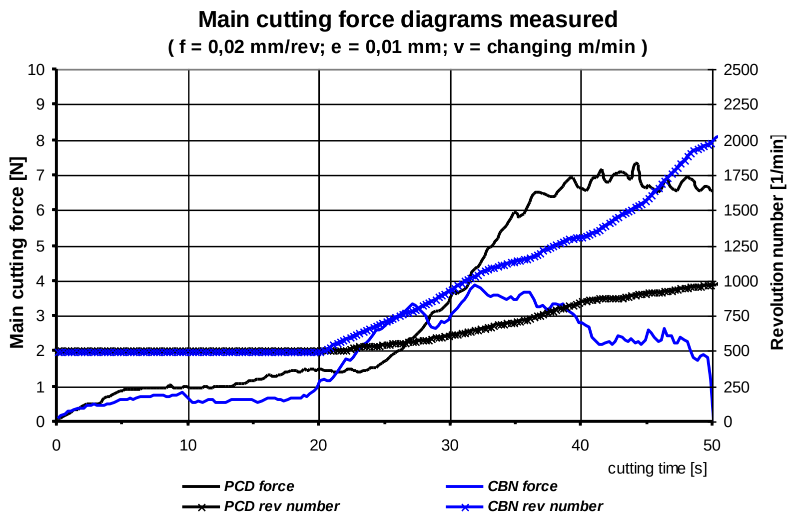

Figure 6. Main cutting force diagram.

I illustrate the main cutting force change with straight lines on the diagram in the function of alteration of cutting time and revolution number. The other thicker line shows the value of revolution number and it can be read from the right axis. It can be seen that the small forces at the beginning of cutting, they increase suddenly after some time in both cases of cutting tools. However the value of main cutting force has increased only for some time by increasing the revolution number at cubic boron nitride (CBN) tool. Approximately over 1000 r.p.m the force shows again decreasing tendency. In case of polycrystal diamond tool the force increase neither increased further. It is likely that it can be explain with chip removal as well as with the tool and ceramic heat conduction characteristics. Further evaluations are needed. The Figure 7. is similar to the previous Figure, however here I have presented the forces in feeding direction. The amount of arising forces approximately is half of the amount of main cutting forces in both cases of tool materials. It is interesting that the two forces show similar characteristics in tendency. However it can be likely that because of the wear of tool edge the two forces will show different change from one another.

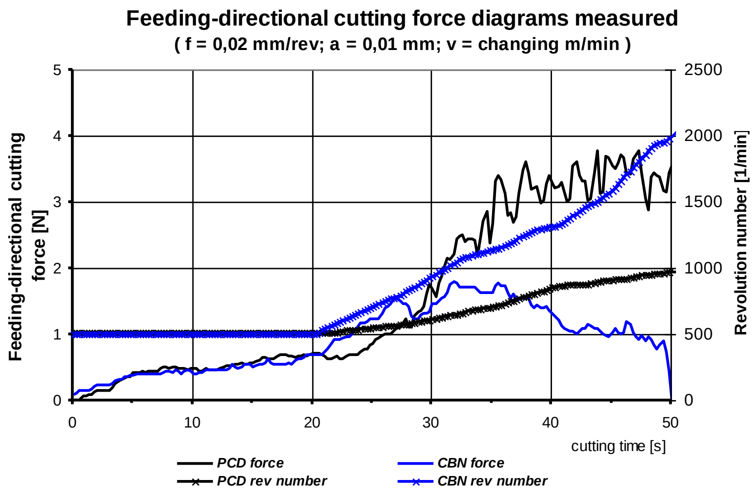

Figure 7. Diagram of cutting force in feeding direction.

I show again the change of main cutting force in the next diagram. However I have set the cutting speed to 50m/min. The feeding value was 0,02 mm/rev. The depth of cut values were: 0,02-0,03-0,04 mm.

By increasing the depth of cut the main cutting force also increases. Near straight proportion is between the two values.

However in case of 0,04 mm depth of cut the great degree of force fluctuation allows conclude to the damage of main cutting edge. This could be seen in microscopic pictures later. The force increase is significant in the beginning period. In the first spot of contact both the ceramic and the tool are at ambient temperature. During cutting substantial heat develops and the warming up starts. However this warming up increases the force value for some time then it sets in near constant value as in the diagram can be seen. (Figure 8.)

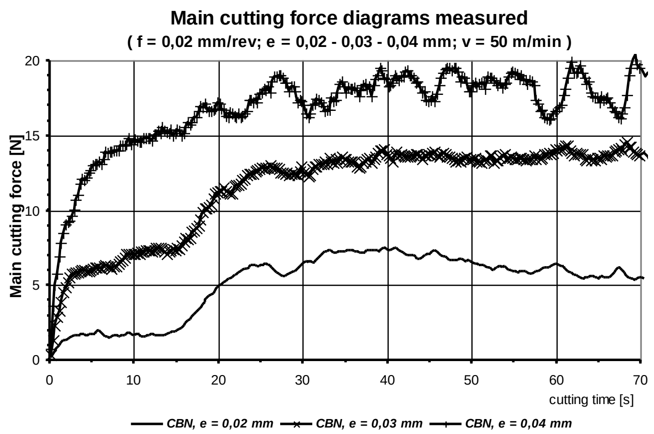

Figure 8. Main cutting force diagrams.

In the Figure 9. the change of force in feeding direction can be seen connected with the previous diagram. At 0,04 mm depth of cut it shows great fluctuation. This force change is less optimal at such parameters set.

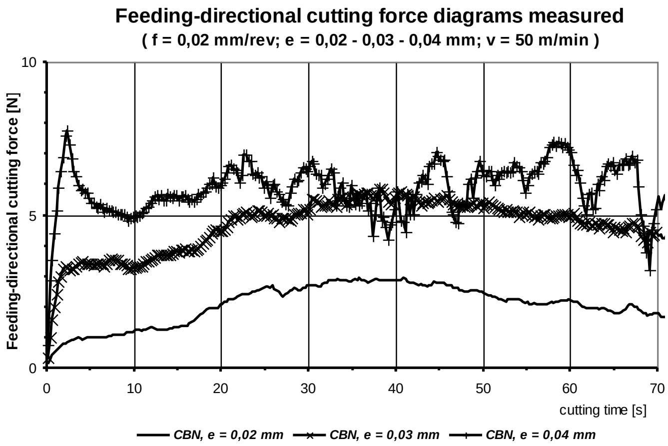

Figure 9. Diagrams of force in feeding direction.

Thermo-camera pictures from the heat affected zone formed during cutting can be seen in Figure 10. It can be unambiguously seen in the picture that because of the ceramic good heat insulation a heat ring formed on the work-piece at the tool edge which has increased significantly the tool edge thermal load. The first picture was made at the beginning of cutting here rather the tool point warmed up. By increasing the cutting length the tool and ceramic temperatures also increased significantly. The second picture shows this. The red colour shows the heat ring formed and the tool point namely the hottest points.

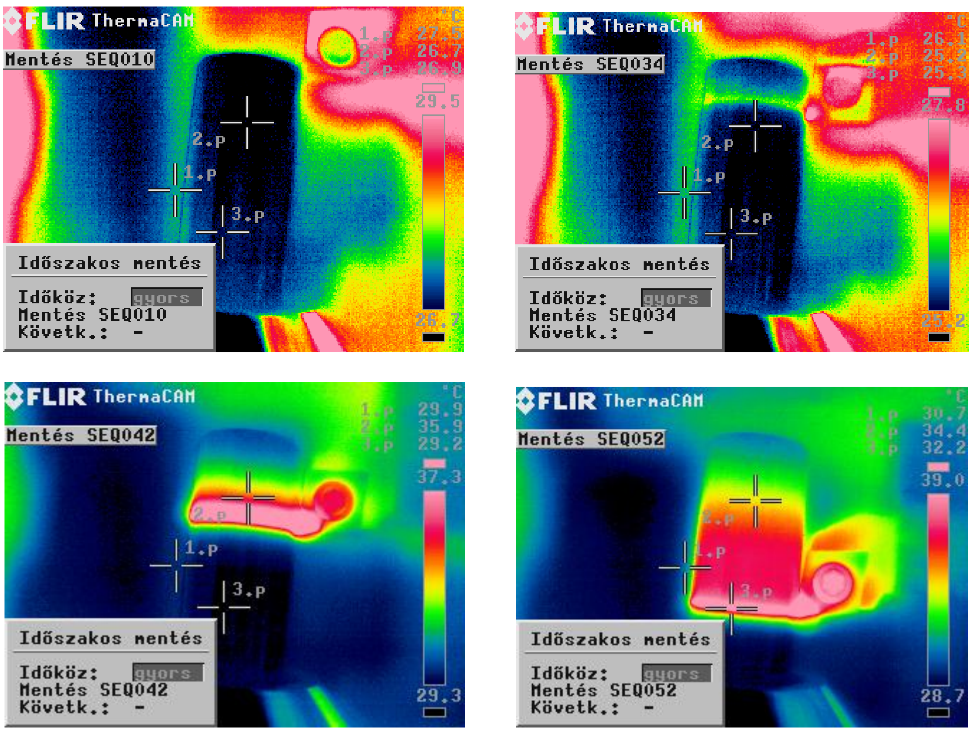

Figure 10. Thermo-camera picture, from the beginning to the end of cutting.

4. SUMMARY

Trend characterizing steel turning appears at using CBN turning tool, local cutting force maximum can be identified.
Comparing the two cutting tools it can be stated that increasing the cutting speed the diamond turning tool has resulted significant cutting force increase, which has caused significant cutting heat evolution.
Surface roughness at identical cutting parameters:

- CBN: 2,8-3,2 R_a
- PCD: 2,9-3,2 R_a
- Original surface grinded: 05, R_a.

It is possible turning zirconium-dioxide semi-finished product. The condition of the starting surface has got definite importance how is possible to turning the surface point of view. The raw-product surface grinded has damaged the PCD-tools in case of all cutting parameters tested.
The hardness recommendation accepted for tools in technical literature (3-4 times higher hardness difference in favour for the tool) can not be used at raw-products grinded in case of zirconium-dioxide ceramics, Softer, 2 times higher hardness can be used.
Testing the cutting speed and cutting force connection-zirconium-dioxide turning with CBN-tool-similar trend can be established as steels turning with carbide. A local maximum value can be measured which origin can be traced back to surface-tribological processes and to sudden change of thermal equilibrium. The phenomenon validity can be extended from the steel/carbide connection to the zirconium-dioxide/CBN friction, chip removal connection, too. The CBN and PCD-tools have resulted significantly different cutting forces. It can be stated that the cutting speed increase has resulted well measured increase in cutting force in case of diamond turning tool which has called forth significant heat evolution.
This is significantly unfavourable tribological connection.
The standard PCD and CBN –tools used did not result different surfaces regarding the surface roughness.
Based on measuring it can be stated that at surfacing the removing material as dust can be easily recompressed – verified by microscopic pictures – which results significant modification of power effects.

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