STUDY OF THE SURFACE ROUGHNESS OF CARBIDE BLANKS PROCESSED BY GRINDING

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Abstract: *This paper presents a study of surface roughness carbide blanks DK460UF (91%WC and 9% Co). The samples tungsten carbides were machined with diamond grinding wheels with different grain size, with different cutting regimes, using cutting medium. The aspect of machined surfaces were examined by scanning electron microscope (SEM). The results of experimental studies have shown that machined surfaces of tungsten carbide by grinding have small roughness if it uses grinding wheel with little grit.*
Key words: *tungsten carbide, grinding, roughness, cutting regime.*

1. INTRODUCTION

Grinding process of the metal carbides is far from being considered a known problem, it requires a constant deepening and intensification of research efforts in the field of cutting. Carbides used for tool manufacturing consist of tungsten carbide, titanium and tantalum, with a binder, cobalt. Due of their general characteristics, regarding their 80 HRC hardness, high strength to wear and, specially, high thermal stability up to 900° C, tungsten carbide is used in cutting machine most of metallic materials with great cutting speeds compared to the tools made of other materials (100-300 m/min). Carbide's hardness increases with a higher tungsten carbide content and decreases with the cobalt percentage increase. Carbides wear resistance is higher than that of speed steels and increases with hardness increase. Carbides are widely used in producing cutting tools necessary for processing high hardness materials in order to obtain a high quality surface finish, increase productivity and reduce processing time. Tungsten carbides have excellent mechanical properties, like, strength, hardness, tensile strength resistance and abrasion resistance. Processing tungsten carbides requires knowledge about the influence of physical, chemical and mechanical machining processes, which is why it is very important to select the appropriate processing parameters to achieve the desired technological effects, mainly the machined surface quality. It is important to know the machinability of these materials, assessing this characteristic is based on criteria such as grinding wheel wear, cutting forces, machined surface quality, etc. The grinding wheel, the machine tools and the cutting medium are the factors that determine the performance of the grinding process.

2. LITERATURE REVIEW

The carbide micro-structure has a great influence in residual stresses which occurs after machining and can lead to fracture in exploitation (Ling Yin et al., 2004).

Grinding is a complex process influenced by many factors.

A summary of these factors is presented in Fig. 1.

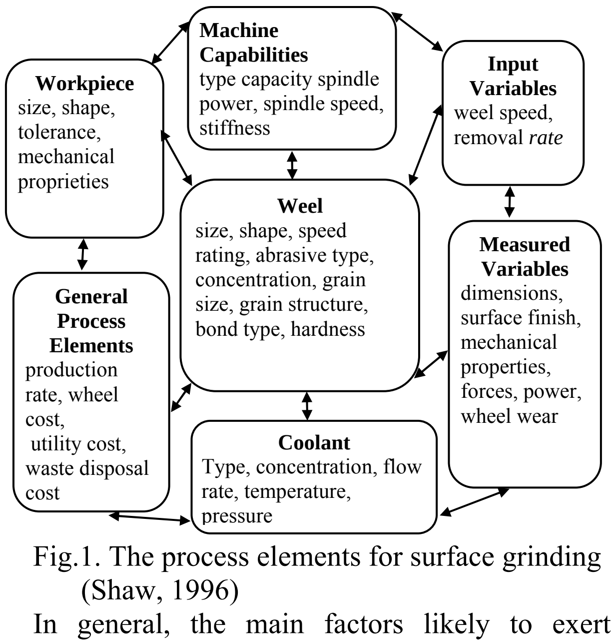


Fig.1. The process elements for surface grinding (Shaw, 1996)

In general, the main factors likely to exert influence on the roughness are (Vulc et al., 2013)

1) Grinding wheel parameters (the nature of the abrasive grain, wear state, etc.)

2) Cutting regime parameters (the feed and the cutting speed have a greater importance)

3) Orientation of the chips on the machined surface (this factor depends on the geometry of the active part of the tool or the existence of additional structural elements for crushing or proper conduct of chips),
4) Technological system components rigidity and cutting tool's rigidity, primarily,
5) The presence and nature of coolant - lubrication,
6) Properties of processed material, adding, to the commonly known properties, the degree of elastic recovery after the tool crosses.

Carbides that have high hardness require high cutting forces, in comparison with other materials, that is causing accelerated wear of the grinding wheel. The aim of the Zelwer and Malkin research (Zelwer & Malkin, 1974) was to decrease the rate of grinding wheel wear. The volume of material removed, depth of cut and cutting speed are important factors in influencing the abrasive wear rate. Increasing the volume of material and the cutting depth leads to an increased wear. To obtain a low rate of abrasive wear it can use larger diameter wheels, in the absence of other alternatives, but having the disadvantage of a high cost. Te wear is lower due to higher number of active grains on the disk circumference.

From research it was found that the grinding wheels for machining carbides can use, in optimal conditions, diamond grinding wheels or abrasive discs with cubic boron nitride grains. Binder hardness, the forces connecting the diamond abrasive grains and the binder materials and porosity are relevant in determining the grinding capacity of the wheel. Porous grinding wheels demonstrated a greater capacity than conventional wheels and they are easy to balance and recondition.

The hardness of the binder is essential to avoid plastic deformation of the grinding wheels and increase the grinding wheel capacity when dealing with fine grains (Zhong & Venkatesh, 2009).

Grinding process was studied and designed in terms of conditions imposed by the material, cutting data, cutting forces. Research was conducted on correlating the factors influencing process with time and costs related to it. Optimization was on minimizing costs. The studies were based on a set of constraints regarding the accuracy of processing, the surface roughness, the depth of cut, the technical characteristics of the cutting tool correlated to the cutting system (Krar & Ratterman, 1990).

For processing tungsten carbide are used resin-bonded diamond wheels. Irregularity of the diamond layer prevents thermal degradation of the binder, which provides better retention of abrasive grains and thus a higher life for the grinding wheel (Luo et al., 1997). The resistance and the thermal conductivity of the binder are low. For improving these characteristics, it contains small quantities of SiC, Al_2O_3, Ag, Cu, Fe, graphite, MoS_2. (Tsuwa, 1964).

Some research has shown that coarse grit grinding wheels have more cutting edges than the fine grain, which increases the specific energy and the amount of material removed. In contrast, the processed surface quality is inadequate, observing ditches where the carbide grains were situated in the valley and on their peaks there were cobalt particles. Grinding wheel wear takes different forms, such as, abrasive grain wear, tear, their deployment. Breaking occurs at a large scale and the acting grains are worn (McSpadden & Hughesb).

Numerous researches have been made in order to determine the influence of the process components. These elements include requirements or process characteristics, the requirements of surface processing, and the variable and constant parameters. Generally, there are known the surface processing requirements, such as size, shape, roughness, precision components and elements related to the surface functionality. These constraints are related to cost and productivity elements that fix the other parameters. Cutting forces that accompany the grinding process of carbides depend on a number of factors, cutting speed, depth of cut, grinding wheel (Marinescu et al., 2004).

The heat generated during the grinding process of carbide influences both the quality of the obtained surface and grinding wheel wear. It is determined by the characteristics of the cutting regime and of the carbide, the nature of the grains and of the cutting medium, which has an important role in reducing it (Liu et al., 2003).

Considering the conditions of grinding process, known by the previous research, this paper aims to measure the surface roughness of the tungsten carbide used for building the cutting tools which machine the holes, processed with different grinding wheels, under different cutting regimes.

3. EXPERIMENT DESIGN

Given the aspects showed in connection with the grinding process of carbides, an experimental study was performed in order to determine an optimal cutting regime in terms of obtaining a good roughness of the carbide cutting tools.

3.1. Preparing the experiment

Material used: tungsten carbide - 91% WC and 9% Co - DK460UF. Dimensional characteristics of the samples are: diameter $-5\cdot10^{-3}$ m, length - $50\cdot10^{-3}$ m.

Grinding wheels: The previous research has the results that grinding carbide can do using diamond grinding wheels. It were chosen two grinding wheels, D46VB4P/A, with the average grain size $46\cdot10^{-6}$ m and D54P150/A-C100, with the average grain size $54\cdot10^{-6}$ m.The diameter of the wheels is $125\cdot10^{-3}$ m, and maximum cutting speed of 60 m/s.

Machine: Processing was done on CNC machine tool *HAWEMAT*3000, with high stiffness.

Fig.2. CNC machine tool *HAWEMAT 3000*

Cutting environment: Emulsion 3%, pressure of 10^6 N/m^2.

Cutting regime: The domain of variation of parameters is a result of previous research, cutting speed 40 m/s, 55 m/s, depth of cut $0.01\cdot10^{-3}$ m, $0.03\cdot10^{-3}$ m and feed 0.005 mm/rev, 0.008 mm/ rev.

Surface roughness is measured with a roughness Meter, *MITUTOYO* with the following features:

- Measuring Length: $4.8\cdot10^{-3}$ m
- Measuring range: $600\cdot10^{-6}$ m
- Measurement Speed: 0.5 mm/s
- number of the measuring points: 6000
- Reference Length: $0.8\cdot10^{-3}$ m

Fig.3. Roughness Meter *MITUTOYO*

The comparative study of the machined surface was made with the electronic microscope.

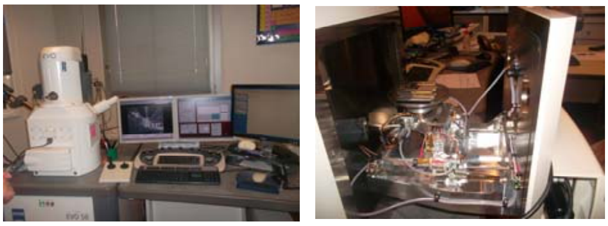


Fig.4. Scanning Electron Microscope

3.2. Experiment design

For designing experiment it was used the Design Expert program. The matrix of the experiment was made by the program, in which it was introduced the input factors, and for each factor was chosen two values, which define the level of input variation. (Table 1).

Table 1. The process parameters and their level of variation

Level	Speed v [m/s]	Feed f [mm/rot]	Depth of cut a_p [mm]
-1(min)	40	0.005	0.1
+1(max)	55	0.008	0.3

The experiment was conducted in two phases:

1. At this stage, the samples of tungsten carbide were machined with D46VB4P/A grinding wheel, with varying cutting regime parameters. The 2^3 factorial experiment include three factors: speed, feed and depth of the cut at two variation levels, roughness measured in each case, the data are presented in Table 2.

Table 2. Cutting conditions and the roughness obtained by grinding with D46VB4P/A wheel

Std	Speed v [m/s]	Feed f [mm/rev]	Depth of cut a_p [mm]	Roughness R_z [μm]
4	55.00	0.008	0.010	0.322
1	40.00	0.005	0.010	0.281
6	55.00	0.005	0.030	0.388
2	55.00	0.005	0.010	0.228
7	40.00	0.008	0.030	0.511
3	40.00	0.008	0.010	0.306
5	40.00	0.005	0.030	0.407
8	55.00	0.008	0.030	0.450

The results showed in the table 2 allowed to represent the roughness variation relative la cutting parameters, using D46VB4P/A, with Design Expert.

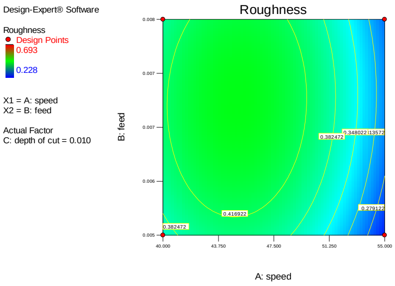


Fig.5. The variation of roughness relative to v, f a_p =0.01mm

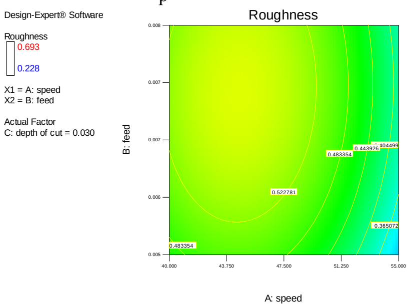


Fig.6. The variation of roughness relative to v, f a_p =0.03mm

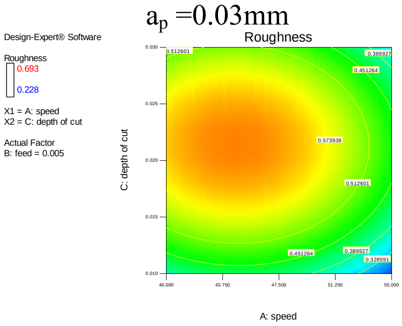


Fig.7. The variation of roughness relative to v, a_p, f = 0.005 mm/rev

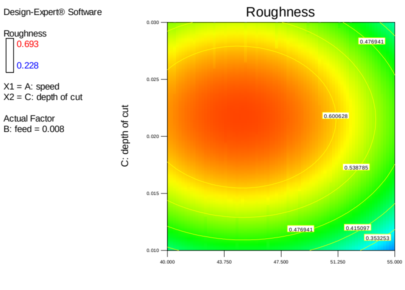


Fig.8.The variation of roughness relative to v, a_p, f = 0.008 mm/rev

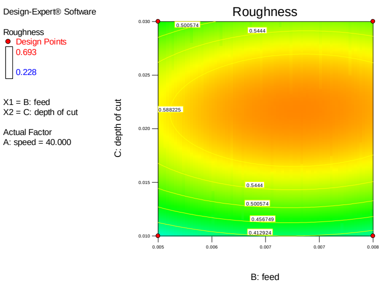


Fig.9. The variation of roughness relative to f, a_p v = 40 m/s

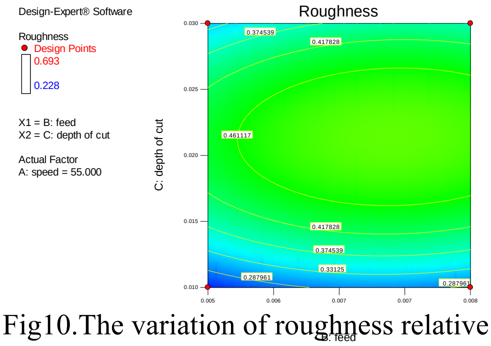


Fig10.The variation of roughness relative to f, a_p v = 55 m/s

2. In the second stage, the samples of tungsten carbide were machined with D54P150/A-C100 grinding wheel, with the same cutting regime parameters. The roughness was measured in each case, the data are presented in Table 3.

Table 3. Cutting conditions and the roughness obtained by grinding with D54P150/A-C100 wheel

Std	Speed v [m/s]	Feed f [mm/rev]	Depth of cut a_p [mm]	Roughness R_z [μm]
8	55.00	0.008	0.030	0.768
6	55.00	0.005	0.030	0.644
4	55.00	0.008	0.010	0.470
1	40.00	0.005	0.010	0.687
7	40.00	0.008	0.030	0.537
5	40.00	0.005	0.030	0.530
2	55.00	0.005	0.010	0.423
3	40.00	0.008	0.010	0.529

From the results summarized in table 3 it was represented the variation of roughness parameters in relation to the cutting regime, using D54P150/A-C100 wheel. The graphical representation was performed using Design Expert program.

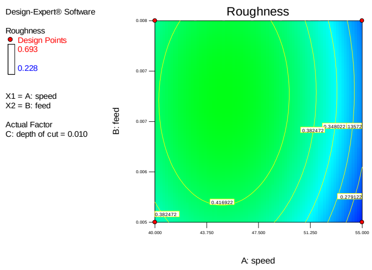


Fig.11. The variation of roughness relative to v, f a_p =0.01mm

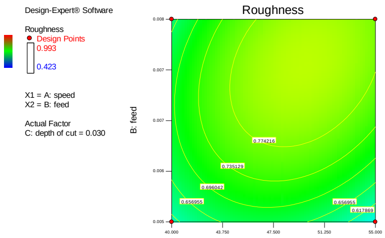


Fig.12. The variation of roughness relative to cu v, f, a_p =0.03mm

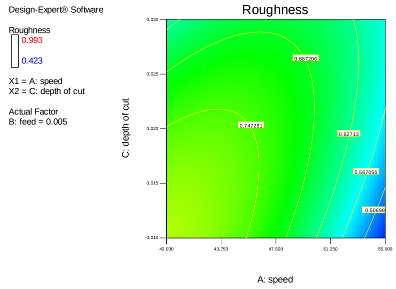


Fig.13. The variation of roughness relative to v, a_p, f = 0.005 mm/rev

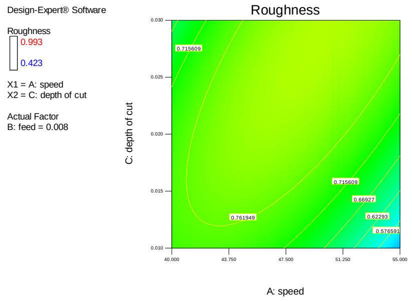


Fig.14. The variation of roughness relative to v, a_p, f = 0.008 mm/rev

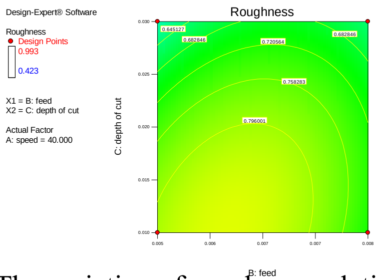


Fig.15. The variation of roughness relative to f, a_p

v = 40 m/s

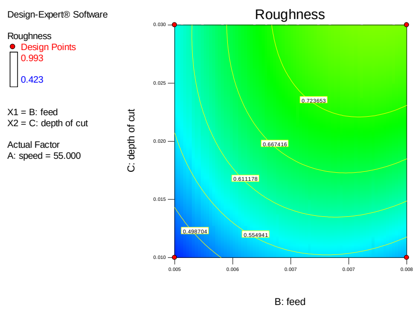


Fig.16. The variation of roughness relative to f, $a_{p,}$ v = 55 m/s

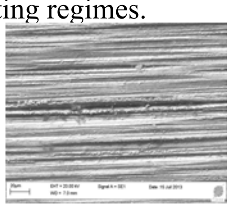
In the first step, for the first group of experiments, the smallest value for roughness is $0.228 \cdot 10^{-6}$m, which was obtained in the cutting regime: v=55 m/s, f=0.005 mm/rev, $a_p = 0.01 \cdot 10^{-3}$ m. The roughness increases relative to increasing of depth of cut or relative to increasing of feed.

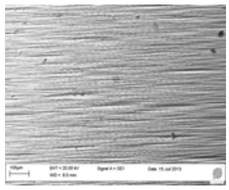
In the second step, for the second group of experiments, in the same cutting regime, the smallest value for roughness is $0.423 \cdot 10^{-6}$ m.

In conclusion, the grit of the grinding wheel influences the surface roughness. The small values of roughness were obtained using grinding wheels with small grit.

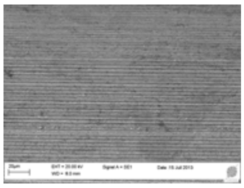
The machined surfaces were observed with the SEM.

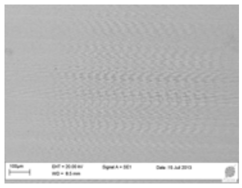
In fig. 17 are surfaces processed with grinding wheel D46VB4P/A, with different cutting regimes.





a)Surface before processing b)machined surface v = 40m/s, f = 0.008 mm/rev, a_p = 0.03mm



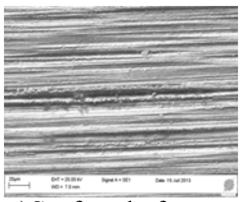


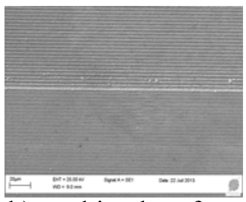
c) machined surface v=40m/s, f=0.008 mm/rev a_p =0.01mm

d) machined surface v=55m/s, f=0.005 mm/rev a_p =0.01mm

Fig.17. SEM photographs of the machined surfaces (grinding wheel D46VB4P/A, different cutting parameters)

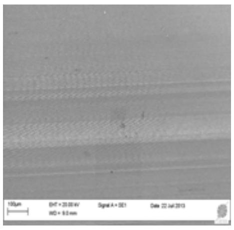
In figure 18 are surfaces processed with grinding wheel D54P150/A-C100, with different cutting regimes.

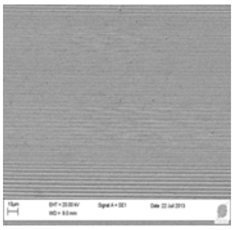




a)Surface before processing

b)machined surface v = 40m/s, f = 0.008 mm/rev, a_p = 0.03mm





c) machined surface d)machined surface
v=40m/s v=55m/s
f=0.008mm/rev, f=0.005mm/rev
a_p =0.01mm a_p =0.01mm

Fig.18. SEM photographs of the machined surfaces (grinding wheel D54P150/A-C100, different cutting parameters)

The images that are obtained with the SEM complete the results obtained by measuring.

4. CONCLUSIONS

The research demonstrated that the roughness of the tungsten carbide depends on the grit of the grinding wheel and on the cutting regime parameters. The results of the experiments are the determining of optimal parameters of grinding process in machining the carbide for building a cutting tool.

- For processing the tungsten carbide DK460UF it was used the diamond grinding wheels D46VB4P/A and D54P150/A-C100 which are characterized by the diameter of $125\cdot10^{-3}$m, grit $46\cdot10^{-6}$ m and respectively $54\cdot10^{-6}$m, the maximum speed 60 m/s.
- The optimal parameters of grinding process are: cutting speed v=55 m/s, feed=0.005 mm/rev, depth of cut a_p=0.01 mm, the grit of grinding wheel is $46\cdot10^{-6}$m. For this conditions, the value of the surface roughness is $0.228\cdot10^{-6}$m. This value is necessary for surfaces of carbide cutting tools using for processing holes.

These results are very important in designing the technology of machining the carbide tools.

5. ACKNOWLEDGEMENTS

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