STUDY OF THE INFLUENCE OF CUTTING REGIME PARAMETERS ON GRINDING FORCES IN PROCESSING TUNGSTEN CARBIDE DK460UF

SILVIA VULC

*Ph.D. student, Faculty of Engineering, "Lucian Blaga" University, Sibiu, Romania
vulcsilvia@yahoo.com*

Abstract: *This paper presents a study on grinding tungsten carbide DK460UF, through experimental investigation using diamond grinding wheel with 54 μm grain size. Different sets of experiments were performed to study the effects of the independent grinding parameters such as grinding wheel speed, feed and depth of cut on cutting forces. Test results showed that the feed and depth of cut influence significantly the cutting forces. The research was lead to optimize the process parameters for reducing cutting forces. In this way, for different parameters of cutting regime, it were measured the values of the components of the grinding force, tangential component, F_t and normal component F_n . The results of the experiment showed that it is better to use great speeds and small feed rate and depth of cut in grinding tungsten carbides, such as DK460UF.*

Key words: cutting forces, cutting regime, tungsten carbide

Introduction

Tungsten carbide has excellent physic-chemical properties such as, superior strength, high hardness, high fracture toughness, and high abrasion wear-resistance. These properties impinge wide application of tungsten carbide in industry for cutting tools. On the other hand, these unique properties can cause substantial difficulties during machining process, which can result in low machinability. Therefore, machining of tungsten carbide requires the knowledge about the physical effects of the process, as well as appropriate selection of machining method and cutting conditions, enabling desired technological effects. The mainly objective of machining of tungsten carbide is to achieve satisfactory geometric and physical properties of its surface texture. The most popular finishing method of tungsten carbides applied in the tooling industry is grinding with the diamond wheels. The tungsten carbide DK460UF consists of 91% WC and 9% Co. It is used in manufacturing cutting tools. The tools that process in special conditions, related to chip evacuation, cooling active part, reduction efforts, as the drill, having a high cutting length, has a relatively small stiffness. These extreme conditions encountered in processing require stringent specifications in terms of cutting tools, machine tool and related equipment used. Many of the disadvantages mentioned may be removed by manufacturing the tools from this tungsten carbide DK460UF, providing them with high resistance to wear, and thermal and mechanical resistance, the surface roughness has an important role in this way. The tungsten carbide DK460UF has special properties, such as its hardness, high strength to wear and, specially, high thermal stability. This tungsten carbide 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. The tool's surface quality requires a low surface roughness, a stringent form accuracy, as well as a low amount of surface damage.

Grinding tungsten carbides is a very complex process, involving many factors, namely, grinding wheel, machine tool, the cutting medium, surface characteristics, cutting regime parameters. The grinding process is accompanied by phenomenon such as grinding wear, chip formation mechanism, grinding forces, power consumption and vibrations.

Previous research determined the conditions for processing tungsten carbides and these conditions were concentrated in the following schema (fig.1).

Figure 1: Synthesis of process parameters in grinding tungsten carbides and the performance criteria

Source: (IMT Conference, 2013)

Cutting forces

The grinding force comes from the elastic deformation, the plastic deformation and the grinding swarf from the contact surface of the wheel and the work-piece. Meanwhile, the friction among the grinding grits, bond and work-piece can also contribute to the grinding force (Patnaik, 2010). In the recent years a number of researchers throughout the world have developed some grinding force for different kinds of work-pieces. Some researchers analyzed grinding force by using the stress concentration theory and the mathematical statistics theory (Zhang, 2007). The accuracy of the empirical equations is also verified by experimental measurements. Wearing of abrasives and its detachment from grinding wheel is a factor which affects the grinding process. The researches on machine tools, cutting tools and work-piece materials necessitated knowledge of cutting forces developed during machining. Therefore, accurate measurement and analyses of the cutting forces are important. Although much work has done for grinding in this area, the problems have not been solved completely (Demir, 2003). There are many considerations in the determination of the effect of grinding process parameters on grinding force of many materials.

It is well known that grinding force is one of the most important parameters in evaluating the whole process of grinding. The grinding force (fig.4) is resolved into three component forces, namely, normal grinding force F_n , tangential grinding force F_t and a component force acting along the direction of longitudinal feed which is usually neglected because of its irrelevance. The normal grinding force F_n has an influence upon the surface deformation and roughness of the work-piece, while the tangential

grinding force F_t mainly affects the power consumption and service life of the grinding wheel (Anak, 2008).

The aim of this investigation was to examine the influences of grinding parameters on grinding forces when grinding tungsten carbide DK460UF work-pieces. The diamond grinding wheels used had 54 μm grain sizes.

Grinding forces not only affect chip formation mechanics, grain wear and temperature distribution but also efficiency of the grinding operation. Grinding forces are the most important factors affecting grinding quality.

3. Design Experiment

3.1. Preparing experiment

Material used: tungsten carbide DK460UF - 91 % WC and 9% Co, in rectangular blocks of 20x50x100 mm.

Abrasives: previous research showed that the processing of these carbides can be achieved with diamond abrasive wheels. We selected two diamond grinding wheels, with a grit of 54 μm and different diameters, 250 mm, respectively 180 mm, width 10 mm. The wheels were run at a constant revolution of 3900 rev/min.

Cutting regime: The range of cutting regime parameters resulted from previous research. In this case, the grinding wheels speed was calculated:

$$v_1 = \pi \cdot D \cdot n / 1000 = 3.14 \cdot 250 \cdot 3900 / 1000 = 50 \text{ m/s} \quad (1)$$

$$v_2 = \pi \cdot D \cdot n / 1000 = 3.14 \cdot 180 \cdot 3900 / 1000 = 36 \text{ m/s} \quad (2)$$

Feed: $f_1 = 0,15 \text{ mm/stroke}$, $f_2 = 0,25 \text{ mm/stroke}$

Depth of cut: $a_{p1} = 0,01 \text{ mm}$, $a_{p2} = 0,03 \text{ mm}$

The measurement of the grinding forces was done with the KISTLER dynamometer, type 9257B (fig.2).

Figure 2: KISTLER Dynamometer type 9257B

Kistler dynamometer is based on a piezoelectric system for measuring forces. Forces acting on a quartz crystal are converted into an electrical charge proportional. Measuring range is very wide. These dynamometers are rigid systems allow accurate measurement of forces in dynamic regime. For data acquisition, use DynoWare software that enables the state the most important parameters to be amplified for data acquisition. These data can be plotted and thus can be considered cutting forces. Also, this software allows exporting data to Microsoft Excel, where you can process the data.

Piezoelectric force sensors do not require zero adjustment for this purpose – they are ready to operate at the push of a button.

Figure 3. Block diagram of a measuring chain

Figure 4. Cutting force during face grinding

U_o = Output voltage, A = Gain,

C_t = Sensor capacitance, C_c = Cable capacitance,

C_r = Range or negative feedback capacitor,

R_t = Time constant resistance (or insulation resistance of range capacitor),

R_i = Input insulation resistance, (cable and sensor),

Q = electric charge yielded by the piezoelectric element

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).

It was used a 2^3 full factorial experiment.

Table 1. The process parameters and their level of variation

The parameter	Values	
	Levels	
	- 1	+ 1
speed, v [m/s]	36	50
feed, f [mm/stroke]	0,15	0,25
depth of cut, a_p [mm]	0,01	0,03

Measurements were performed according to the experimental plan and obtained values were shown in Table 2.

Table 2. The grinding force values measured

No.	Speed v [m/s]	Feed f [mm/stroke]	Depth of cut a_p [mm]	F_t [N]	F_n [N]
1	50.00	0.25	0.01	45.860	98.480
2	36.00	0.15	0.01	29.260	76.860
3	36.00	0.25	0.03	50.530	107.410
4	36.00	0.15	0.03	48.070	95.230
5	50.00	0.15	0.01	19.210	65.050
6	50.00	0.25	0.03	37.670	77.540
7	36.00	0.25	0.01	41.420	91.480
8	50.00	0.15	0.03	27.350	79.670

The results showed in the table 2 allowed to represent the force components variation relative to cutting parameters, using diamond grinding wheel, with $54 \mu\text{m}$.

Figure 5. The variation of grinding force relative to cutting regime parameters, for tangential component F_t and normal component F_n

Depending on its value, cutting speed influences the cutting force components, but the size of the influence depends on the values of the other parameters of the cutting process.

For low speeds is a decrease of cutting forces, a phenomenon that leads to material particles to adhere to the surface of the grinding wheel.

It can be seen that the forces increase with increasing feed and depth of cut.

Grinding forces have a great influence in the process quality. An important effect of the forces value is the machined surface quality and the grinding wheel wear.

4. Conclusions

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.

Tungsten carbide DK460UF, with high content of WC, is used for manufacturing cutting tools. This material, also, is used for manufacturing drills for deep holes and small diameters. Because this tools work in specially conditions, it is very important to study the factors that have significantly influence in grinding process performance.

The surface quality is a characteristic that depends on many process conditions. The cutting forces influence the physical-chemical state of surface and under-surface level and the surface roughness. Knowing the parameters which influence the forces, this process element can be controlled during the grinding.

Regarding to the cutting regime parameters, the experiments showed that the low grinding forces are determined by small depth of cut and feed. The optimal values for these parameters were:

$$f = 0.15 \text{ mm/stroke}, a_p = 0.01 \text{ mm and } s = 50 \text{ m/s.}$$

In previous research, for the same parameters of the cutting regime, was determined the surface roughness: $0.428 \mu\text{m}$, a value which is imposed for surfaces of drills for deep holes.

Grinding forces affect grinding wheel wear, temperature distribution, efficiency of the grinding operation. Grinding forces are the most important factors affecting grinding quality.

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