Experimental study of surface roughness on a processed detail of tungsten carbide by using a grinding device on a diamond turning machine

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Abstract- Experimental studies of the roughness parameter for the processing of tungsten carbide by grinding of a diamond turning machine are presented. A grinding tool is used with a tool made of diamond powder and resin. The device is part of the equipment of the Moore Nanotech 350FG machine. After the initial measurements are made, two contactless measurements are made as well, via an integrated measuring system to the processing machine and via a three-dimensional optical profilemeter - Zygo NewView 3D Optical Surface Profiler and Laser Interferometer – ZygoVerifire respectively. According to the defined cutting modes, roughness parameters of the workpiece have been achieved with values for Ra of 3 to 9nm.

Keywords – experimental, study, diamond turning, grinding, tungsten carbide, roughness

I. INTRODUCTION

Diamond turning with diamond monocrystalline tool is one of the most important and successful technologies in precision machining of details over the last few decades. This is because SPDT technology integrates a large number of cutting-edge precision engineering methods, including the use of precision high speed machining tools and a precision air spindle, high strength and precision hydrostatic sliders. SPDT is already being used in a wide range of areas such as defense, energy, consumer products, and more. Diamond turning is a technology that uses monocrystalline diamond tools to produce components with surface accuracy and shape deviations below one micrometer, and surface roughness of less than ten nanometers by Ra [1]. In the 1980s, diamond turning became commercially available, contributing to the use of more sophisticated technologies to improve the process. SPDT is increasingly used for industrial and commercial purposes. The new technologies used include hydrostatic slides and a second rotary axis [2, 3]. In addition, a special device, later called a fast servo tool (FTS), which is capable of synchronized low- and high-frequency movement with the main spindle, has been developed with a further need for processing optical components such as toric lenses. Although the construction of this device first appeared in 1976, [4] the earliest evidence of its realization was in 1983 by Douglass [5], and later the device was made by Patterson [6]. In this period, well-known products manufactured through SPDT include a computer disk (hard disk) drive, scanner parts in photocopiers, and many other sophisticated components. In the past 20 years, SPDT technology evolved rapidly. It was accepted both in the industry and in academia. SPDT is an expensive process at the outset and is suitable for producing single pieces or small series. To expand the capabilities of SPDT, many different technologies have been added to the diamond turning machine such as ultrasonic vibrating [7], micromachining, raster cutting and grinding. At present, the complex multi-axis control system provides SPDT with the ability to handle complex shapes, not just spherical and aspherical surfaces, both axially symmetrical. The SPDT process involves several related processes as well as more conventional diamond turning. Other related processes are raster cutting, fast servo tool, slow servo tool (STS) / slow sliding servo feed and drilling.

With the increase in accuracy requirements of the machined parts, new tasks are placed before the diamond turning. Grinding device has been added to the diamond turning machines. They are a high-speed spindle with up to 60000 rev / min and a sanding tool made of fine diamond powder and resin (Fig.4). This device helps to process parts by grinding on a diamond turning machine, also allows handling complex geometric shapes.

The characteristics of tungsten carbide such as hardness and abrasion make it extremely difficult to process through the classic diamond turning methods. The high hardness of the material contributes to the rapid wear of the monocrystalline diamond tool due to the very high cutting temperature and the inability to cool down the cutting tool. The treatment of tungsten carbide by monocrystalline diamond melts the cutting tool. For this reason, it is necessary to use the grinding method of a diamond turning machine that includes a grinding tool and a special composite tool. Due to the composition of the composite tool, better cooling is provided and the cutting temperature in the working area is lower than in the conventional diamond turning process. This contributes to better results and less wear on the cutting tool. This report presents experimental processing of a tungsten carbide detail by grinding on a diamond turning machine.

II. MACHINE, DEVICE, TOOL AND DETAIL

The experiments were carried out in a real production environment. The machine used in the experiment is Moore Nanotech 350 FG, equipped with a grinding tool. The sanding tool is made up of diamond powder and resin. The workpiece has an aspherical profile, the material used is tungsten carbide.

Diamond turning machine –

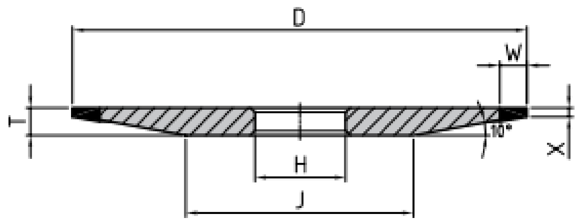
Figure 1 shows the machine on which the experiments were performed. Moore Nanotech 350 FG is a precision three, four or 5-axis digital programmable machine for processing aspherical, toroidal surfaces. The deviation from the geometric shape of the workpiece is less than 0.15μm and the deviation in terms of roughness parameters is less than 3nm.

Diamond turning machine Moore Nanotech 350 FG

B. Tool –

A special grinding tool for a diamond turning machine made of diamond powder and resin was used to conduct the experiment. The grain size used in the composite tools is FEPA46 for coarse processing and FEPA11 for finishing. Fig. 2 shows a grinding tool diagram. The tool used has a diameter of 20mm. On the scheme:

D - Diameter of the tool
T - Tool thickness
H - Connection hole
J - Diameter before slanting the tool
W - Width of the composite layer
X - Thickness of the composite layer



Scheme of a grinding tool

C. Detail –

Fig. 3 shows the processed detail. The machined part is aspherical, calculated by the formula [8]: the surface calculating equation is:

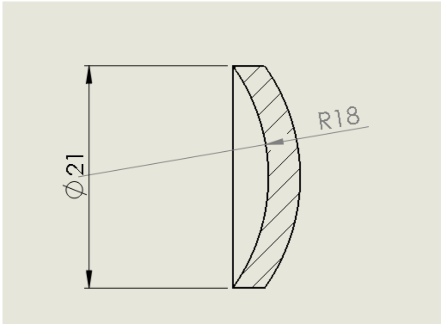
$$z(r) = \frac{r^2}{R\left(1 + \sqrt{1 - (1-k)\frac{r^2}{R^2}}\right)} + \alpha_4 r^4 + \alpha_6 r^6 + \ldots, \quad (1)$$

Where,

z is a component of the displacement of the surface from the top;

r is the distance from the axle;

(z) r are sages;
αi - coefficient describing the deviation of the axially symmetric quadrature fabric poisoned by R and k;
R - the radius of the sphere;
k - conic constant;



Scheme of the processed detail

III. EXPERIMENT AND RESULTS

The studies were conducted in a real production environment. The workpiece is made of tungsten carbide, the material data is given in Table 1. Three machining operations are made: rough, semi-finished and fine, with rough and semi-finished work using a FEPA46 diamond-sized tool; finishing - FEPA11, the grinding device is shown in Fig. 4. The data for the cutting modes for the respective treatments are given in Table 2. After each treatment, measurements of the profile of the aspher were performed; the studies were performed with the Moore Nanotech 350 FG integrated measurement system shown in Fig. 5. All machining was performed at 2500 spindle revolutions per minute and grinding at 40000 rev / min for all transitions. The selected cutting modes are consistent with the recommended cutting modes provided by the machine manufacturer and the workpiece and tool parameters.

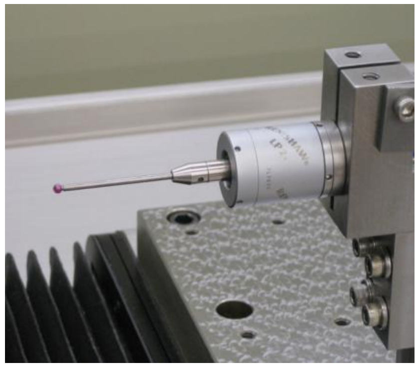
Table -1 Tungsten carbide data

Tungsten carbide J05(Fujiiloy)	
Parameter	Value
Density	14.65
Hardness	93,5MPA
TRS	1320MPa
Tensile strength	740MPa
Strength of pressure	3830MPa

Table -2 Data of mechanical machining

Processing type	Feed rate	Cutting depth
Rough	3mm/min	20 µm
Semi - finished	1mm/min	5µm
Fine	0.3mm/min	500nm

Grinding device on a diamond turning machine



Integrated measurement system

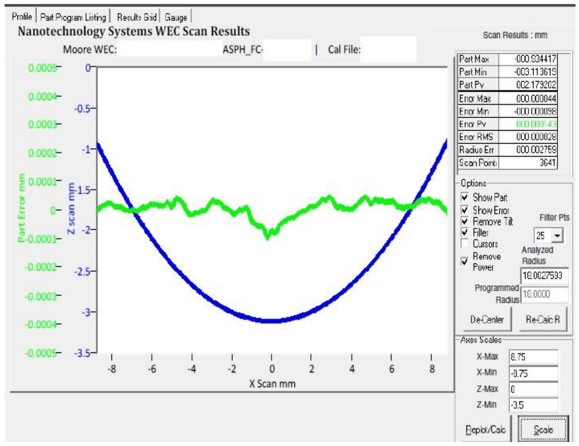
Until the desired profile of the workpiece is achieved, the measurements are carried out in the working environment of the machine through the integrated measuring system shown in Fig. 5. After each transition, measurements are taken to track deviations from the specified profile. After completion of the workpiece processing, two types of contactless measurements are made in order to finally determine the values of the roughness and profile obtained. Non-contact measurement methods are applied to determine more accurately the deviation from the nominal profile and to determine the roughness of the workpiece. Measurements of roughness parameters were performed with a 3D optical profile marker - Zygo NewView 3D Optical Surface Profiler shown in Fig. 6. Profile deviations were measured with the Zygo Verifire laser interferometer shown in Fig. 7. The results obtained in the form of profiling are shown in Fig. 8 and Fig. 9.

Zygo NewView 3D Optical Surface Profiler

Zygo NewView 3D Optical Surface Profiler is a three dimensional optical profilemeter designed for fast contactless measurements. It can measure many types of surfaces: smooth, coarse, flat, sloping and stepped surfaces. It has a high-resolution camera, high-quality three-dimensional surface visualization, and more. The error of the device is on the order of 0.01nm.

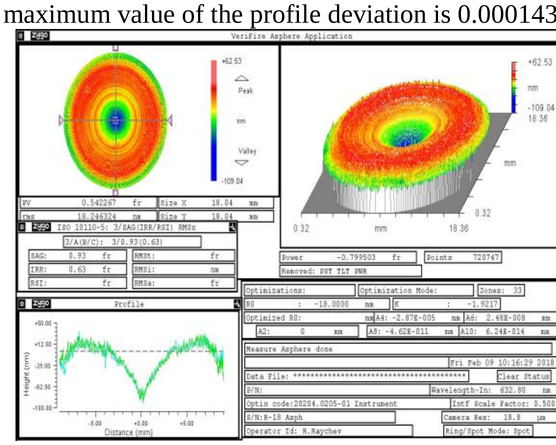
Laser interferometer Zygo Verifire

The Zygo Verifire laser interferometer is designed for fast and accurate measurements of flat and spherical (aspherical) surfaces. Used to measure optical elements such as prisms and lenses made of glass, plastic and various types of optical crystals. The device also offers three-dimensional visualization of the results. The deviation from the roughness parameters is in the order of 0.06nm.



Measured profile of the detail

In Fig. 8 is a graph showing the measurement of the section profile measured in the working area of the machine. With blue, the nominal profile of the asp is shown, and the deviations from the nominal equation of the asparagus are shown in green. The green graph is highly scaled in order to trace into which part of the profile of the asphere the deviations are greatest. The maximum value of the profile deviation is 0.000143mm.



Results of interferometer measurements showing profile deviations.

Fig. 9 shows the results of profile measurements using a laser interferometer. They confirm data from the integrated measuring system of the processing machine. Measurements for roughness parameters were performed with the three-dimensional optical profilemeter shown in Fig. 6. According to the defined cutting modes, the roughness at the center of the aspherical surface reached surface roughness of Ra = 3nm and Ra = 9nm at the periphery of the asphere.

It can be suggested that the roughness differences are due to the cutting speed, the section profile (asphere) and the measurement method. As the aspherical parts are processed, the revolutions are constant, but the cutting speed is different, it is higher at the periphery than the center. This explains the differences in the roughness of the workpiece. Due to the aspherical shape of the surface being treated, it is difficult to place the peripheral surface so as to be at an angle of 90 ° during the non-contact measurements, this fact explains part of the differences in roughness of the workpiece.

The results obtained fully justify the expectations. The resulting roughness parameters and shape deflections from the nominal profile prove the abilities of the grinding device on a diamond turning machine. The development of the diamond turning process and its accessories will helps to significantly improve the quality of the treated surfaces.

IV. CONCLUSION

The experiments performed show that by grinding with a composite tool on a diamond turning machine high quality surfaces can be achieved in terms of roughness and deviation from a given profile of the surface.

The grinding process is more suitable for the processing of solid materials, such as tungsten carbide, relative to the diamond turning process. The grinding tool structure provides better cooling compared to the monocrystalline diamond tool and thus reduces wear on the cutting tool.

The obtained parameters for roughness Ra 3nm to 9nm and deviation from the nominal profile of the surface with a maximum value of 0.000143mm prove the precision of the grinding process with a composite tool on a diamond turning machine.

V. AKNOWLEDGEMENTS

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