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THE INFLUENCE OF TECHNOLOGICAL PARAMETERS ON SURFACE TEXTURE OF DLD CEMENTED TUNGSTEN CARBIDE AFTER GRINDING

This paper presents the analysis of surface texture after grinding of claddings of tungsten carbide (WC). The workpiece material was cemented tungsten carbide produced by DLD (direct laser deposition) technology. The 3D surface topography was analyzed and the measurement results were obtained using Hommewerke T8000 surface profiler. The grinding process included two phases, i.e. stock removal and spark out. During the stock removal part axial depth of grinding a_p was selected as 5÷20 μm. Subsequently, a sample was sparked out. The number of spark out passes was equalled to 20. The variable parameters were feed v_f and depth of cut a_p. The main factor affecting machined surface roughness is the occurrence of micro grooves and protuberances on the machined surface, as well as other phenomena connected, inter alia, with the mechanism for material removal. This work can be also the starting point to the further research, related to the grinding performance analysis of tungsten carbide during the cutting with the tools with undefined geometry.

Key words: DLD cemented tungsten carbide, grinding, surface texture, machinability

1. INTRODUCTION

Tungsten carbide has excellent physical and 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, molds and dies. They also find the application as regenerative materials which are used to repair worn machine parts [6]. The unique properties of tungsten carbide can cause substantial difficulties during grinding process, which can result in low grinding performance.

It is clear, that the mechanical properties of the WC-Co composite strictly depend on the volume fraction and the morphology of two phases [1,2,5].

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In addition, it was concluded after the hardness tests, that the hardness of cemented tungsten carbides increases with the decrease of grain size [2]. Furthermore, it was found, that the microstructure of the carbides does not affect the dimensionally-shaped accuracy, as well as the surface roughness parameters values.

Powder metallurgy technology is the most common method for producing parts of cemented carbides. However, in case of individual or prototype production, this method is too expensive and time consuming [7]. Powder metallurgy technology can be replaced by laser technology [4], in particular by DLD technology (Direct Laser Deposition Technology). DLD is the evolution of the coating process using a laser beam, enabling building three-dimensional prototypes with high density by applying successive layers of material [3]. This process is used in the production of functional prototypes and regenerative parts with very high hardness, strength and wear resistance.

2. EXPERIMENTAL WORKS

The main objective of this work is the analysis of surface texture after grinding of cemented tungsten carbide obtained by DLD technology.

The study aimed to determine the machinability of DLD cemented tungsten carbide, based on the machined surface roughness measurement in terms of variable feed v_f and depth of cut a_p values (when grinding). The material was cemented tungsten carbide (88% of WC, 12% of Co, grain size-1.5 µm, thickness of the cladding-3 mm, based material-structural steel) which was obtained by direct laser deposition technology (P=3000 W, λ=900÷1030 nm) (Fig.1 and 2).

The FUM SPC 20B grinding machine was applied. DLD cemented tungsten carbide samples were grounded during plane grinding process (machining without coolant).

A metal – bond diamond plain grinding wheel (grit size D151=125÷150 µm, diamond concentration- 75 %), with a diameter of D=200 mm (S1010D-200x10x4x76) was used in grinding.

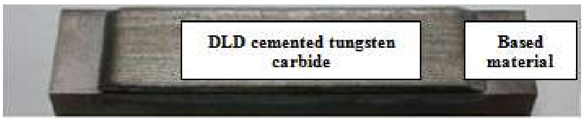


Fig.1.The view of the machined sample

Fig.2.Microstructure of WC-Co

The selected grinding process included two phases, i.e. stock removal and spark out (Fig.3). The number of passes during the material removal process was equaled to 20. The studies were conducted under variable depth of cut a_p and under variable feed v_f values. The grinding parameters are presented in Table 1.

Table 1

Cutting conditions applied in grinding

<table>
<tr><th colspan="20">Feed v_f [m/min]</th></tr>
<tr><td colspan="4">7.5</td><td colspan="4">10.5</td><td colspan="4">13.5</td><td colspan="4">16.5</td><td colspan="4">19.5</td></tr>
<tr><th colspan="20">Depth of cut a_p [µm]</th></tr>
<tr><td colspan="5">5</td><td colspan="5">10</td><td colspan="5">15</td><td colspan="5">20</td></tr>
<tr><th colspan="20">Cutting speed v_c [m/s]</th></tr>
<tr><td colspan="20">25</td></tr>
</table>

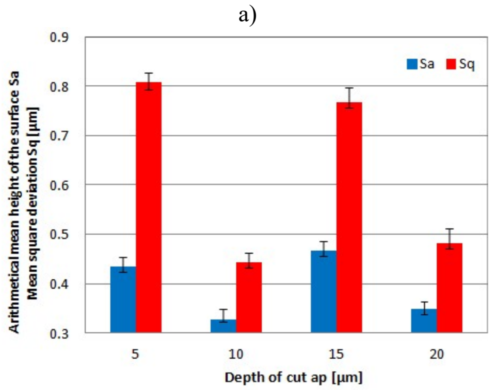
Fig.3. The image of the workspace

The 3D surface topography was analyzed and the measurement results were obtained using Hommewerke T8000 surface profiler and Turbo DataWin software. The measurement area was 1.47x1.5 mm. The following parameters were obtained: *St* – total height of the surface, *Sq* – mean square deviation, *Sa* – arithmetical mean height of the surface, *Sz* – maximum height of the surface including 10 points.

3. RESULTS

Figures 4 and 5 show graphs of basic surface texture 3D parameters in a function of depth of cut a_p, obtained after grinding process for v_f=7.5 m/min (Fig.4) and for v_f =19.5 m/min (Fig.5). Figures show, that values of the amplitude surface texture parameters decrease with the increase of feed values v_f.

a)



b)

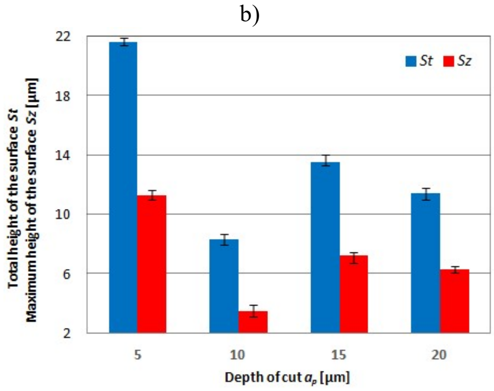
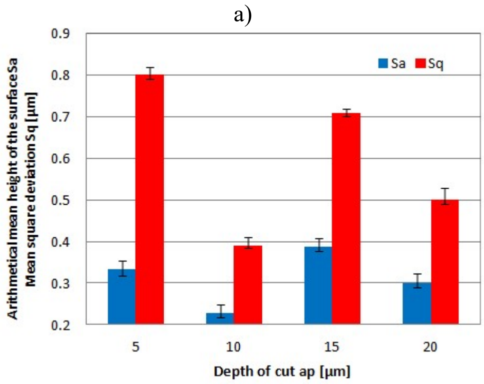


Fig.4. Surface roughness parameters values in a function of depth of cut obtained for v_f=7.5 m/min: a) *Sa* and *Sq*, b) *St* and *Sz*

It can be seen, that surface roughness increases initially and then decreases with an increase in depth of cut. The initial increase was caused due to the increase in depth of cut, which resulted in an increase in surface roughness. The decrease in surface roughness to certain value of depth of cut could be related with the lower requirement of specific energy at high depth of cut (material removal due to brittle fracture), causing reduction in friction between the wheel and the workpiece. It results in the improvement in the surface finish. This phenomenon allows to determine the most optional range of cutting parameters values, in which there is no deterioration of the surface.

a)



b)

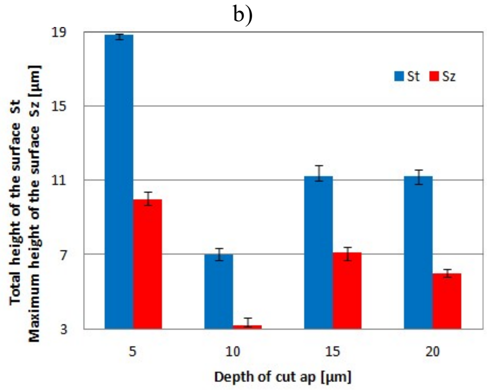


Fig.5. Surface roughness parameters values in a function of depth of cut obtained for v_f=19.5 m/min: a) *Sa* and *Sq*, b) *St* and *Sz*

Analyzed surface is random with a minor contribution of noticeable periodic waves generated stochastically. Autocorrelation function is rapidly disappearing which is characteristic of the random anisotropic surfaces (Fig.6). However, the basic direction of the traces left by active dominant grain grinding wheel profile is retained. Power spectral density distribution is stochastically dominated by components of relatively small wavelengths.

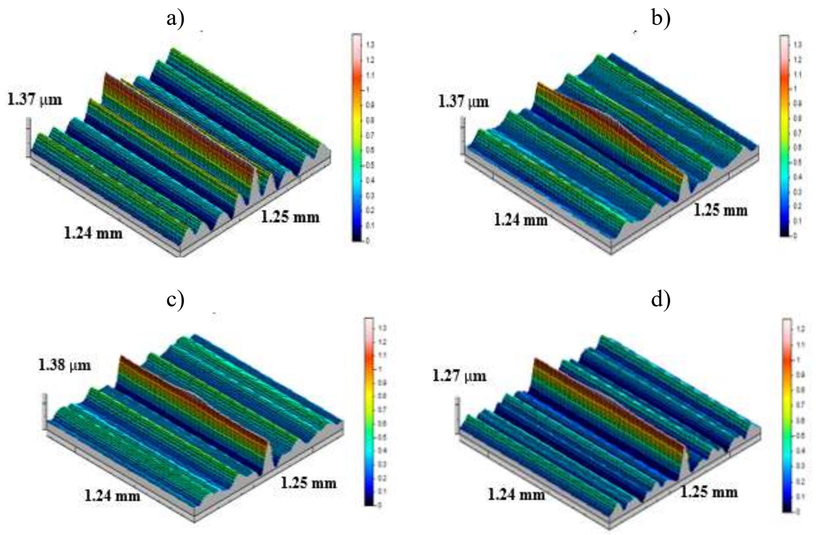


Fig.6. Autocorelation functions obtained after machining with: a) a_p=5 µm, v_f=7.5 m/min, b) a_p=20 µm, v_f=7.5 m/min, c) a_p=5 µm, v_f=19.5 m/min, d) a_p=20 µm, v_f=19.5 m/min

Surface topography after grinding reveals the occurrence of irregularities orientation perpendicular to the feed motion vector v_f (Fig.6). These irregularities are probably associated with discontinuities in the molded material during the DLD process (Fig.7).

Ordinate distribution of grinded surface of DLD cemented tungsten carbide has a very high *St*/*Sq* ratio. This could be a consequence of the porous nature of cemented tungsten carbide obtained by direct laser deposition technology. During the grinding process, pores open and form randomly distributed, deep, single cavities with a relatively small cross-sectional area on the machined surface. The use of different power values during laser process causes changes in the microstructure of the resulting claddings and thus changes in the porosity of the material. However, these changes occur during laser cladding process. The mechanism of changes in the porosity after direct laser deposition process has not been examined and specified yet.

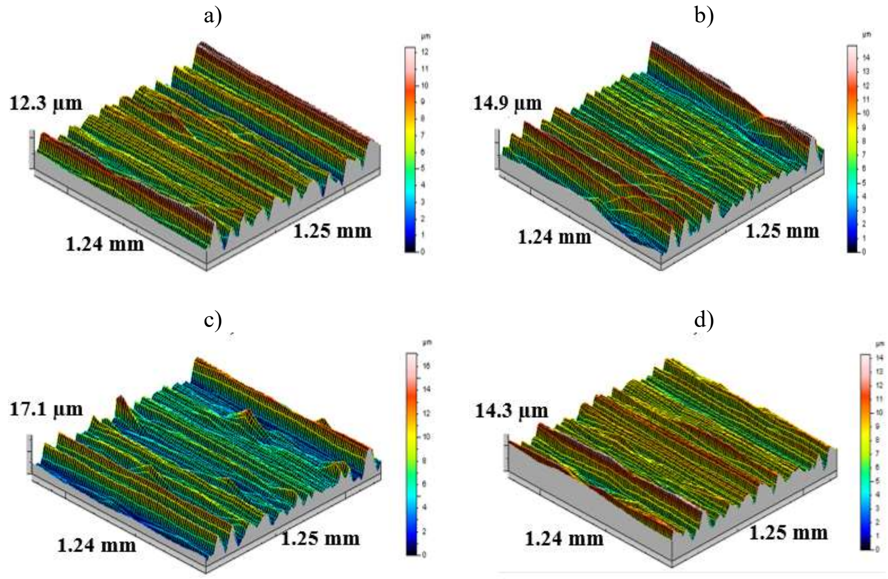


Fig.7. 3D images of machined surface obtained after grinding with different feed and depth of cut values: a) a_p=5 µm, v_f=7.5 m/min, b) a_p=20 µm, v_f=7.5 m/min, c) a_p=5 µm, v_f=19.5 m/min, d) a_p=20 µm, v_f=19.5 m/min

4. CONCLUSIONS

In the range of investigated factors during grinding it was found, that feed has a significant influence on surface roughness parameters values. *St* and *Sz* parameters showed the most significant changes in their values, while *Sa* and *Sq* parameters values remained at the similar level. Surface topography after grinding revealed the occurrence of irregularities orientation perpendicular to the feed motion vector v_f. These irregularities are probably associated with discontinuities in the molded material during the DLD process.

The main factor affecting machined surface roughness after grinding is the occurrence of micro grooves and protuberances on the machined surface, as well as other phenomena connected, inter alia, with the mechanism for material removal. This work can be also the starting point to the further research, related to the grinding performance analysis of cemented tungsten carbide during the cutting with the tools undefined geometry.

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WPŁYW PARAMETRÓW TECHNOLOGICZNYCH NA STRUKTURĘ GEOMETRYCZNĄ POWIERZCHNI WĘGLIKA WOLFRAMU PO SZLIFOWANIU

S t r e s z c z e n i e

Artykuł przedstawia analizę struktury geometrycznej powierzchni po szlifowaniu powłok z węglika wolframu. Materiałem obrabianym był węglik wolframu wytworzony technologią DLD (direct laser deposition). Obrazy 3D topografii powierzchni oraz wyniki zostały uzyskane za pomocą profilografometru Hommelwerke T8000. Proces szlifowania obejmował dwa etapy: usuwanie materiału oraz wyiskrzanie. Głębokość skrawania podczas pierwszego etapu mieściła się w zakresie 5÷20 µm. Następnie, próbki poddane zostały wyiskrzaniu. Liczba przejść narzędzia podczas wyiskrzania wynosiła 20. Zmiennymi parametrami podczas obróbki były posuw v_f oraz głębokość skrawania a_p. Głównym czynnikiem mającym wpływ na chropowatość powierzchni obrobionej jest występowanie rowków i wypukłości na obrabianej powierzchni, jak również inne zjawiska związane, między innymi, z mechanizmem usuwania materiału. Niniejsza praca stanowić może punkt wyjścia do dalszych badań, dotyczących skrawalności spiekanych węglików spiekanych podczas obróbki narzędziami o niezdefiniowanej geometrii.

Słowa kluczowe: węglik wolframu, szlifowanie, struktura geometryczna powierzchni, skrawalność