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FINISH GRINDING OF CERAMICS MATERIALS BY ULTRASOUND

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¶ **Abstract:** *Paper deals with power ultrasound influence in finish grinding hole process in materials of technical ceramics. Ceramics materials are characterized by hard hardness and by brittleness and whereas for using no – conventional or the abrasive methods for machining.*
To improve machining of ceramic materials using ultrasonic power ultrasonic technology applications that affect the grinding process. Whereby there are achieved with slight variations in shape, reduce the size of partial cutting forces in the grinding process, reducing the wear of cutting blade and so on.
Key words: ultrasound, abrasive, grinding, ceramics

1. INTRODUCTION

Industrial development is also done well by increasing industrial production provided a lower rate of growth in production consumption. This development trend is also implemented by rationalizing production technology components of hardmachining materials. One way to intensify the technological process is the use of power ultrasound in the finishing machining methods. Grinding process takes place in intensive plastic deformation of cutting layers, of high strength friction and the emergence of a large amount of heat. The temperature at the cutting increases the wear of abrasive grains.
Uneven deformation and uneven heating creates voltage fields that affect the greater depths of cultivated surface components.

2. GRINDING OF TECHNICAL CERAMICS

The grinding of ceramics shape and organize the production of dimensionally accurate products corresponding to removal of material. Factors that enable the machining of ceramics production chip deformation require use of fine grain diamond wheels, precision and accuracy of the settings blade, a small displacement and other optimal conditions. Wear on the wheel is accelerated when a large depth of cut, or when direct contact between the binder and workpiece material. Requirement of binder material is to maintain sharpness and preservation of grains / natural wear / and good resistance to abrasion and heat in direct contact and friction with the workpiece material.
Binder material should have both good adhesion and binding of particles - hardness of the blade, but also good deformation cutting forces in the operation. Cutting force in grinding is the sum of cutting forces exerted on the grains roll. [[11]], [[12]] Classic method of grinding ceramic materials, plastic deformation preceded violation in those cases where the poor cutting thickness of the layer should be minimized. The law of the minimum thickness for cutting ceramic layer does not apply because the plastic and elastic deformation in the zone before the abrasive grain is practically zero. The high hardness of ceramic materials, accompanied by characteristic brittleness, low plastic properties, including low capacity for earth has resulted in a different chip removal mechanism in grinding. Therefore there is

no deformation in the development of chips than steel plastic materials, but the secession of material, while the cultivated area of grain traces is sharper. [4]

Fig. 1 Workpieces of technical ceramics SiSiC [5]

To the machined surface in the construction of chip deformation in gentle machining than leaving no cracks, the thickness of cutting layer must be small. It is good sanding with a small shift. Cutting force in grinding is the sum of cutting forces exerted on the grinding wheel grains. In contrast to ceramics, metals, radial force is much larger than the tangential. The force required for the gradual deformation of the material has plastically deformed is very small. / grinding small feeding/.

Cutting force in grinding with a small shift is three times greater when co-grinding as in contrarotating. Grains of grinding wheel whilst quickly reach maximum thickness working in the field are formed cracks. [1]In this case, the material adjacent to the cutting edge is taken quarry mechanism, which cracks remain in the material collected. Danger crack is smaller in contrarotating grinding, cutting begins where the emergence of plastically deformed particles. Contrarotating grinding is advantageous to obtain high dimensional accuracy and the lower stiffness of machine headstock.

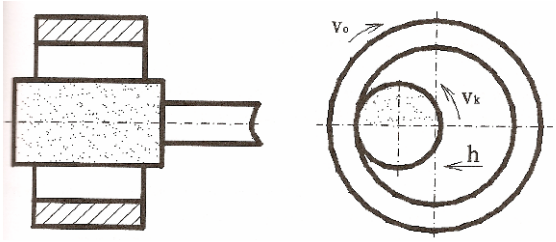

Fig. 2 Grinding of inside rotary surfaces by necking contrarotary way with radially in- feed [9]

On the Fig. 2 is grinding of inside rotary surfaces by necking contrarotary way with radially in- feed.

Condition of the chip deformation in grinding of ceramics is the use of fine-grained diamond grinding wheels with grain and the choice of optimum process conditions. [10] Diamond blades with fine grains are advantageous because they can cut the material without small pieces removing because surface grinding grain in the contact zone is small. In grinding with fine-grain rolls, the number of grains that have a fixed link is small, so that the workpiece material is in contact with the adhesive. Binder material from the tail rotor, making the blade wears well. Function bond grinding wheel is to maintain cutting property of grains and good abrasion resistance and thermal stability in direct contact with the workpiece..

3. TECHNOLOGY OF ULTRASOUND GRINDING

This method of machining use a variant of the longitudinal ultrasonic vibrations as an additional rotational movement in the cutting process by the grinding tool. The combination of ultrasonic oscillating sinusoidal movements with conventional grinding tool grinding kinematics of elongated holes leads to a modified grinding movement of each cutting tool grinding wedges. Cutting wedges are positioned in the resonant ultrasound systems plates of longitudinal standing

waves. In view of the ultrasonic vibration tool reduces the likelihood of significant characteristic of the grinding heat thus reducing the possibility that the emergence of micro cracks in machining.
Ultrasonic acoustic energy brought to the place of grinding process itself primarily affects the kinematics and dynamic effects of vibration movement of abrasive grinding grain. These effects are reflected in a periodic change of direction and immediate change in the value of cutting speed and cutting force. In Fig. 3 is shown the kinematics model of the ultrasonic grinding process.

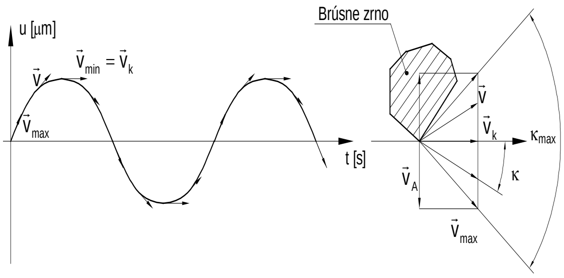

Fig. 3 Kinematics model of ultrasound grinding process [3]

Fundamental differences between the classical method the ultrasonic machining and machining technology with the support of ultrasound include the following:
• working with the support of ultrasound used the diamond tools in the form of standard grinding tools,
• the removal of material used abrasive particles (abrasive grains of diamond tools)
• movement tool in rotary ultrasonic grinding is a high-frequency axial (pulsating vibration) and axial rotation at the same time (as in the standard grinding),
• the classical ultrasonic grinding tool is acting pulsating vibration moving,
• the classical ultrasonic machining using the tool to transfer thrust-oscillation and the flow of the suspension, while not is in direct contact with the workpiece during operation,
• Support ultrasound tool is in direct contact with the workpiece..

In the course of ultrasonic grinding is continuously changing cutting speed and cutting force. These values harmony pulsates with period T and a frequency of 20 kHz [2].
The principle of ultrasonic machining - especially with the support of ultrasonic grinding significantly positive effect on the machining process:
• the constant oscillating motion at the cutting tool (several thousand times per second occur depending on the "lifting" frequency of the tool from the workpiece,
- facilitates chip evacuation,
- reduce the frictional forces,
- not blunt the tool - works under self - sharpening,
- reduces the size of the components of cutting forces (radial and tangential),
- significantly reduces the heat - thus decreasing the possibility of micro cracks,
- better reach surfaces (surface roughness).

4. MATERIAL OF TECHNICAL CERAMICS (SISIC – SILICON KARBIDE INFILTRATED BY SILICON)

SiSiC - Silicon infiltrated silicon carbide is a versatile material with excellent properties, particularly a wide temperature range. Good properties are obtained by special process during which infiltrate by molten silicon liquid [1]. Carbon originally contained in the components, the silicon reacts with the massive release of energy for silicon carbide. In this way, strengthen the already existing grains of silicon carbide on a three-dimensional matrix. This structure lends to the material its special properties and resistance to corrosion and oxidation. This is occurs completely tight material, which usages are generally limited to properties of silicon. A special feature is the infiltration firing of its very low shrinkage, which is almost zero. It is possible to produce large and complex shaped parts in tight tolerances. Silicon carbide is used for sliding sealing up of two sealing rings [7], [8].

Mechanical properties, including abrasion resistance are almost unbeatable when used to cause abrasion and abrasive media. Extremely high hardness, abrasion resistance, as well as good thermal conductivity of the predetermine the silicon carbide to protect against abrasion. It may work in addition to acidic fluorine acid no effects of corrosion on the material quality and finishing. The alkaline with pH upper than 10 is a material attack.

5. EXPERIMENTS OF ULTRASOUND CERAMICS GRINDING

To obtain objective results of the impact of power ultrasound in the process of grinding holes were carried out experiments under the same conditions of conventional grinding technology with the support of power ultrasound.

The process of grinding holes by contrarotating grinding with parameters:
-rotational speeds of workpiece
120 – 180 min^{-1}
-rotational speeds of tool
16 000 – 20 000 min^{-1}
-longitudinal shift
0.2 – 1.5 $m.min^{-1}$
-depth of cut
0.02 – 0.04 mm
-power of ultrasound generator
1 kW
-amplitude of ultrasound vibration
6 – 12 μm
-resonance frequencyof ultrasound system
22.8 kHz
-workpiece SiSiC
Ø 55 x 40 x 8 mm
-tool - diamond grains
Ø 39 x 15 mm


Fig. 4 Diamond tools [6]

Before starting the experiments, the tool was trued up, all ceramic samples centered on the shroud and control equipment. Measured values are listed in Table 1 in the standard grinding with the longitudinal shift f = 0.3 $m.min^{-1}$ SiSiC.

No.	Depth of cut [mm]	Workpiece speeds [min^{-1}]	Tool speeds [min^{-1}]	Ra [μm]	Rz [μm]
1	0.02	120	16 000	0.45	3.2
2	0.02	120	20 000	0.35	3.0
3	0.02	180	16 000	0.5	3.0
4	0.02	180	20 000	0.35	3.8

Table 1 Experiment results of standard grinding with the longitudinal shift f = 0.3 $m.min^{-1}$ SiSiC

Measured values are shown in Table 2 for ultrasonic grinding with the longitudinal shift f = 0.3 $m.min^{-1}$ of SiSiC.

No.	Cut depth [mm]	Workpiece speeds [min^{-1}]	Tool speeds [min^{-1}]	Ra [μm]	Rz [μm]
5	0.02	120	16 000	0.18	2.0
6	0.02	120	20 000	0.06	0.7
7	0.02	180	16 000	0.2	2.1
8	0.02	180	20 000	0.08	1.7

Table 2 Experiment results of ultrasonic grinding with the longitudinal shift f = 0.3 $m.min^{-1}$ of SiSiC.

The following chart compares the individual achievements of roughness Ra and Rz obtained in conventional grinding and grinding, with the support of ultrasound technology under the same conditions.

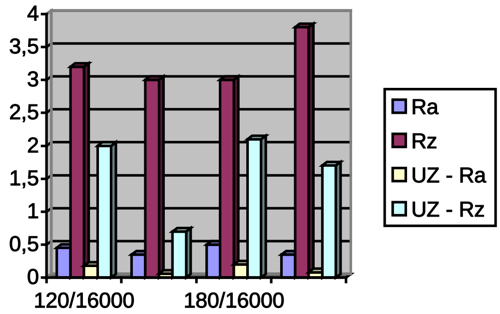

Fig. 5 Comparing of Ra and Rz in standard grinding and in grinding by ultrasound

6. CONCLUSION

The positive influence of power ultrasound on the process of grinding of hard brittle materials like ceramics, using appropriate types of tools and the right choice of process conditions is reflected in significantly higher productivity and intensification of the process of grinding. That argument can be justified by the results achieved to show statistical texture parameters' estimation using the arithmetic mean Ra profile variations considered, as well as the full depth of roughness profile Rz. The introduction of power ultrasound in grinding holes in the ceramic material SiSiC ensures significant improvement in quality, which is statistically significant in assessing the parameters of the surface structure of aid to Central arithmetic profile deviation Ra considered, and the largest amount of roughness profile Rz:

– major improvement parameters Ra, Rz was achieved on the workpiece of material SiSiC with the following technological parameters: longitudinal displacement - 0.3 m.min^{-1}, depth of cut - 0.02 mm, the frequency of rotation of the workpiece – 120 min-1, the frequency of rotation of the tool - 20 000min^{-1} and the parameters Ra about 82.86% and Rz about 76.6%,
– major improvement of the parameter Ra of the sample was obtained in SiSiC conditions: longitudinal displacement - 0.3 m.min^{-1}, cutting thickness - 0.02 mm, the frequency of rotation of the workpiece – 120 min^{-1}, the frequency of rotation of the tool - 20000 min^{-1} Ra was the improvement of 82.86%,
– at least a significant improvement of the parameter Ra of the sample was obtained in SiSiC conditions: longitudinal displacement - 0.6 m.min^{-1}, cutting thickness - 0.04 mm, rotation frequency of the workpiece - 120min^{-1}, frequency of rotation of the tool - 16 000min^{-1} and improvement of Ra was 58.34%,
– major improvement parameter Rz of the sample SiSiC was achieved in technological conditions: longitudinal displacement - 0.3 m.min^{-1}, thickness - 0.02 mm, the frequency of rotation of workpiece - 120min^{-1}, the frequency of rotation of the tool - 20 000min^{-1} and the improvement was 76.7% for Rz,
– least significant improvement in the Rz parameter for a sample of SiSiC been achieved in terms of: longitudinal displacement - 0.6 m.min^{-1}, cutting thickness - 0.02 mm, the frequency of rotation of the workpiece - 120min^{-1}, the frequency of rotation of the tool - 16 000min^{-1} and Rz improvement was 60%.

Here has been indicated above stated that machining with the support of technical ceramics power ultrasound significantly intensifies the processes of grinding and is possible to describe this kind of machining as perspective method of machining of hardmachining materials.

8. ACKNOWLEDGEMNET

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8. REFERENCES

1. Vasilko, K. et al., New materials and technologies and their machining, Alfa Bratislava, 1990, pg. 368, ISBN 80 – 05 – 00661 – 1
2. Berce, P., Ciutrila, G., Velíšek, K., & Pecháček, F., The precise inner grinding assisted by ultrasounds apply on the ceramic rings from bearings. In: Annals of MTeM for 2003 and Proceedings of the 6th International Conference Modern Technologies in Manufacturing, The 6th International MTeM Conference. Cluj-Napoca, Romania, 2.- 4.10.2003., Cluj-Napoca : Technical University of Cluj-Napoca, 2003. - ISBN 973-656-490-8, pg. 43-48
3. Velíšek, K., Pecháček, F. & Mihalčák, P., Application of power ultrasound by grinding. In: Computer integrated manufacturing: Proceedings of the International Conference CIM 2001. Volume II. - Zakopane : Wydawnictwa Naukowo-Techniczne, 2001., ISBN 83-204-2640-5, pg. 277-283
4. Holešovský, F. & Hrala, M., Grinding of Silicon and Nitride Ceramics, In: Production engineering 2004, ročník 3, číslo 2, pg. 21 – 23.
5. Pecháček, F., Charbulová, M. & Javorová, A., Qualitative consequences in finishing process of holes grinding into ceramics with the high power ultrasound application. – paper was published in proceedings of Setkání kateder výrobních strojů a robotiky - SKVS 2008, ISBN 978-80-214-3723-4, ČR, Lednice 9.-10.9.2008, In: MM Science Journal. - ISSN 1803-1269, No 4, 2008, pg. 56-57
6. Charbulová, M. & Pecháček, F., Ultrasonic resonant system parts charakteristics, In: Machine Design. - ISSN 1821-1259. – 2009, 49th anniversary of the Faculty of technical sciences, Novi Sad. May 18th 2009. - Novi Sad : University of Novi Sad, 2009, pg. 319-322
7. Pecháček, F., Charbulová, M. & Charbula, J., Cutting Tools, Manual for exercises. - 1. vyd. - Trnava: AlumniPress, 2008. – pg. 175, E – scriptum, ISBN 978-80-8096-048-3
8. Pecháček, F., Charbulová, M. & Kurajdová, K., Modifications of ultrasonic grinding. In: Annals of Faculty of Engineering Hunedoara - Journal of Engineering. - ISSN 1584-2673. - Tom VI, Fasc 3, 2008, pg. 39-42
9. Pecháček, F. & Javorová, A., Výkonový ultrazvuk - progresívna metóda brúsenia keramiky. In: ITC 2009 : 7th International tools conference. Zlín, ČR, 3.-4.2.2009. - Zlín : Univerzita Tomáše Bati ve Zlíne, 2009. - ISBN 978-80-7318-794-1
10. Pecháček, F. & Javorová, A., Ultrasonic influence to cutting forces intensity at ceramics grinding. In: Machine Design. - ISSN 1821-1259. - 2009 : 49th anniversary of the Faculty of technical sciences, Novi Sad. May 18th 2009. - Novi Sad : University of Novi Sad, 2009, pg. 373-376
11. Javorová, A., Katalinic, B. & Zvolenský, R., Workpiece clamping and its diagnostics. – registrated in ISI Proceedings, In: Annals of DAAAM and Proceedings of DAAAM Symposium. - ISSN 1726-9679. - Vol. 17, No.1. Annals of DAAAM for 2006 & Proceedings of the 17th International DAAAM Symposium "Intelligent Manufacturing & Automation: Focus on Mechatronics and Robotics" : 8-11th November 2006, Vienna, Austria - ISBN 3-901509-57-7. - ISBN 978-3-901509-57-5, pg. 187-188
12. Matúšová, M. & Javorová, A., Analyse der Spannvorrichtungen durch Algorithmus, In: Materials Science and Technology [online]. - ISSN 1335-9053. - Roč. 5, No. 1