QUALITATIVE CONSEQUENCES IN FINISHING PROCESS OF HOLES GRINDING INTO CERAMICS WITH THE HIGH POWER ULTRASOUND APPLICATION

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The paper deals with qualitative changes of machining of holes in ceramic materials applying by finishing conventional grinding and high power grinding. Measured and determined values of surface roughness of machining material definitely indicated the advantages of high power ultrasound application. Ultrasound grinding is the technological method of grinding useful for hard machinable materials.

Keywords
high power ultrasound, ultrasound system, ultrasonic spindle, roughness, technical ceramics, hard machined materials

1. Introduction

The roughness of grinding surface characterised by its microroughness and the quality of surface layer characterised by its state (structure, residual stress) has dominant influence for reliable function of components. Starting faze of wearing depends mainly on surface roughness of machined components. The process of microgeometry creating is a complex physical process of relative mechanical and chemical interaction among involved materials. The common phenomenon of grinding process is characterised by an intersection of trajectories of abrasive grains movement and trajectories of grinding surface.

The mechanism of chip removal process during ceramic materials grinding and steels grinding is different. The chip reduction of ceramic materials is characterised without an extensive plastic deformation because of high hardness, brittleness and low plastic deformation ability of ceramics. The machinability of technical ceramics applying by conventional methods is very low. The problem is the achievement of required quality of machining surface, productivity and economical effectiveness of machining.

2. Finishing conventional grinding of technical ceramics

Applying fine–grained diamond wheels, accuracy and correctness of wheel spindle settings or low feed are the factors that influence ceramics machining and allow chip removal process by plastic deformation. Final cutting force at grinding is the addition of cutting forces that affect grains of a grinding wheel. Radial forces at ceramics machining are bigger than tangential forces. Radial forces at metal machining are lower than tangential forces.

Applying cooling liquid with high cooling and lubricant effect during grinding with low feed application is very important because of decreasing the friction wearing of grains. Contact area of grains and material of grinding component is large. The size of cutting force is significantly influenced by low feed and by the relation of movements between tool and machined component. In spite of lower toughness of grinding machine headstock, contrarotating grinding is more advantageous to obtain higher accuracy to size. It was experimentally proved.

3. Finishing high power ultrasound grinding

Ultrasonic machining technology requires using ultrasound tool resonator, which is one part of ultrasound resonant system. This ultrasound resonant system consists of tools resonator and machining tool, which are fixed together and have one element behaviour. All part of this system has to the same resonant frequency. Ultrasound resonant system task is providing for mechanical oscillations in ultrasound resonator range up 20 kHz. This system caused oscillations end of all system. Tool resonator consists of ultrasound transducer, concentrator and wavequide.

Cutting edges are positioned in loop of longitudinal oscillation resonant ultrasound systems. Acoustic ultrasound energy is transported on grinding place with cooling liquid. This energy has influence on oscillating movement grinding grains kinematics and dynamics effects. Result of this influence is periodical change of orientation and instantaneous value of cutting speed and force.

The using ultrasound major effect in grinding place is dynamical change of grinding process cutting conditions and technological characteristics. Conventional grinding instantaneous value cutting speed vector is constant with stable direction. Ultrasound grinding instantaneous value cutting speed vector and grinding grain direction are periodically varying. This change are described by relation:

$$v = v_K + v_f + v_A, \qquad v_A = A \,.\, \omega \,.\, \cos \omega t$$

High power ultrasound grinding makes use of longitudinal ultrasound oscillation as the additional movement of grinding tool in the cutting rotation process. High power ultrasound grinding of holes makes a use of a join of sinusoidal ultrasound oscillations of grinding tool with classic cinematic scheme of longitudinal grinding. It leads to modified movement of cutting edges of grinding tool what can be seen in Fig. 2. Ultrasound grinding generates less heat than conventional grinding. It leads to the lower probability of microcracks origin, the improvement of the quality of machined surface and almost no wearing of grinding tool was experimentally proved.

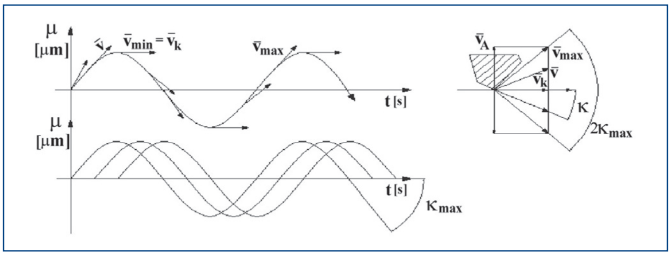

Figure 1. *Kinematics model of grinding grains sinusoid trajectory by using ultrasound grinding process*

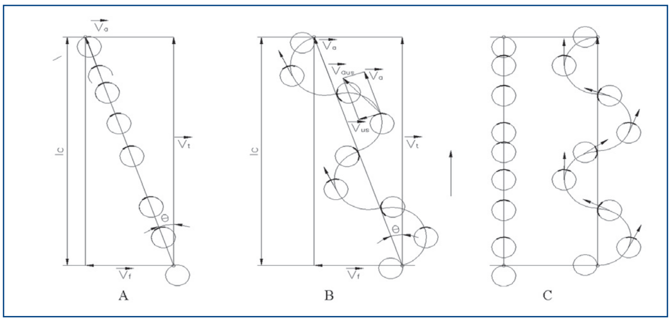

Figure 2. *Kinematic variants of grinding A –longitudinal conventional grinding, B –longitudinal ultrasound grinding, C –transversal ultrasound grinding*

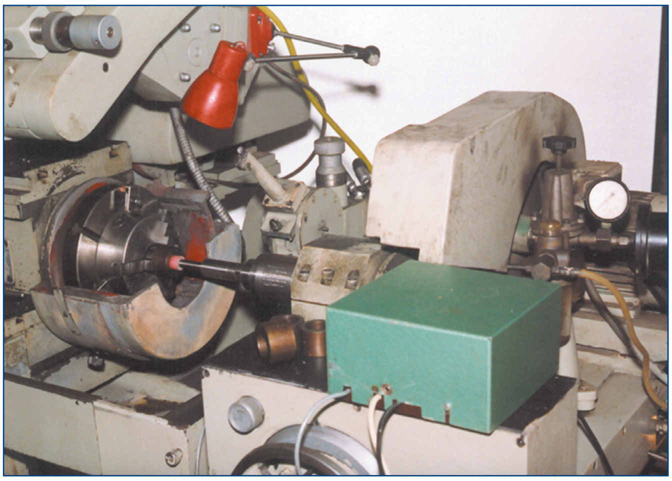

Figure 3. Workstation of SiSiC rings grinding with integrate ultrasound system.

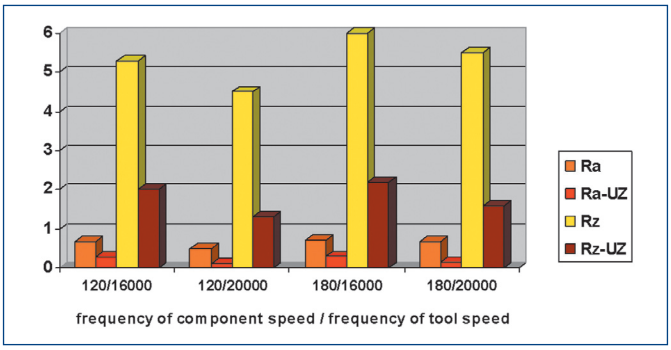

Figure 4. Dependence graph

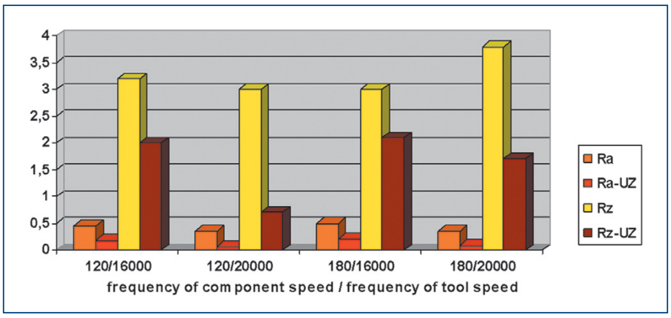

Figure 5. Dependence graph

4. Ceramics – characteristic of silicium carbide infiltrated by silicium (SiSiC)

SiSiC is widely applicable material with special technical properties, mostly with wide temperature range. Technical parameters are the result of the molten silicium implant process. During the process carbides of silicium are infiltrated by molten liquid silicium. The reaction of carbon contained in a component with molten silicium produces new silicium carbides. The reaction is exothermic. Existing grains of silicium carbide make the threedimensional bone structure after the silicium infiltration process and the grains are strengthened.

Better mechanical properties and corrosion protection after the method application was proved. The structure configuration of SiSiC is very tight. The application possibilities of SiSiC are limited by silicium properties. The advantage of infiltrated structure is very low value of thermal expansion coefficient. Large and not easily shaped components with very low measure tolerance can be produced by the method. Silicium carbide is convenient material solution to produce the sealings made of two sealing rings.

Mechanical properties of SiSiC (for example abrasion resistance) are very high because of high hardness, good thermal conductivity and next properties. The special abrasion ability of SiSiC is the common result of complex of the mechanical properties. The strength and the stability of grains is stabile enough to protect the material in conditions of friction load, during grinding with no cooling liquid or no lubricant (time limited self friction ability).

5. Comparing the results of conventional and ultrasound grinding

Values of surface roughness Ra and the hight of undulations Rz of grinding holes were compared for conventional and ultrasound grinding. Equal technological conditions were kept for both grinding methods. The size of machined component was ϕ 55 x ϕ 40 x 5.

All specimens were firstly centred and then fixed in special jigs. The size of diamond wheels was ϕ 30 x 15. Cooling liquid was applied for both methods of grinding.

Technological conditions:

– frequency of component speed	120 – 180 min^{-1}
– frequency of spindle speed	16.000 – 20.000 min^{-1}
– longitudinal feed	0.2 – 1.5 $m.min^{-1}$
– cutting depth	0.02 – 0.04 mm
– amplitude of ultrasound oscillations	6 – 12 μm
– resonance frequency of ultrasound system	22.8 kHz

6. Conclusions

Achieved results of grinding process used ultrasound and compares with conventional grinding process at SiSiC rings grinding leading towards conclusion, that grinding process with ultrasound support is new progressive method of hard machining materials machining. Roughness, grinding process-monitoring parameter, was achieved in IT 1-2.

The best achieved improvement Ra parameter was 82,86 %.
This improvement was achieved with technological conditions:

Table 1. Measured values for conventional grinding and ultrasound grinding, longitudinal feed f = 0.6 $m.min^{-1}$, cutting depth a_p = 0.04 mm

No.	frequency of component speed min^{-1}	Cutting speed $m.min^{-1}$	frequency of tool speed min^{-1}	Ra	Rz	Ultrasound Ra	Ultrasound Rz
1	120	1500	16 000	0.68	5.3	0.28	2.0
2	120	1880	20 000	0.5	4.5	0.12	1.3
3	180	1500	16 000	0.72	6.0	0.3	2.2
4	180	1880	20 000	0.68	5.5	0.15	1.6

Table 2. Measured values for conventional grinding and ultrasound grinding, longitudinal feed f = 0.3 $m.min^{-1}$, cutting depth a_p = 0.02 mm

No.	frequency of component speed min^{-1}	frequency of tool speed min^{-1}	Ra	Rz	Ultrasound Ra	Ultrasound Rz
1	120	16 000	0.45	3.2	0.18	2.0
2	120	20 000	0.35	3.0	0.06	0.7
3	180	16 000	0.5	3.0	0.2	2.1
4	180	20 000	0.35	3.8	0.08	1.7

- longitudinal feed – 0,3m.min $^{-1}$;
- cutting depth – 0,02 mm;
- frequency of component speed – 120 min $^{-1}$;
- frequency of spindle speed – 20 000 min $^{-1}$.

The least significant improvement Ra parameter was 58,34 % with technological conditions:

- longitudinal feed – 0,6m.min $^{-1}$;
- cutting depth – 0,04 mm;
- frequency of component speed – 120 min $^{-1}$;
- frequency of spindle speed – 16 000 min $^{-1}$.

The best achieved improvement Rz parameter was 76,7 %.
This improvement was achieved with technological conditions:

- longitudinal feed – 0,3m.min $^{-1}$;
- cutting depth – 0,02 mm;
- frequency of component speed – 120 min $^{-1}$;
- frequency of spindle speed – 20 000 min $^{-1}$.

The least significant improvement Rz parameter was 60,00 % with technological conditions:

- longitudinal feed – 0,6m.min $^{-1}$;
- cutting depth – 0,02 mm;
- frequency of component speed – 120 min $^{-1}$;
- frequency of spindle speed – 16 000 min $^{-1}$.

In conclusion:

- Positive influence of high power ultrasound on the grinding process of hard and brittle materials (SiSiC);
- Better quality (from two till three times) of machined surface applying by ultrasound grinding at right choice of technological properties of grinding and diamond tools application;
- Ultrasound grinding is more progressive and productive method of ceramics machining than conventional grinding.

Acknowledgements

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