Research On Silicon Carbide Ceramic By Ultrasonic Grinding Processing

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Abstract

Through the research of the silicon carbide ceramic by ultrasonic grinding , the key factors of machining efficiency and surface quality were discussed and the method of impedance control was verified.Finally a conclusion was reached: on the surface of the grinding quality and equivalent impedance values and the grinding force is directly related to;Grinding speed on the machining efficiency and surface quality may also be affected, but the effect is not obvious.

Keywords

silicon carbide;Ultrasonic grinding;Experimental study.

1. Introduction

Engineering ceramics are widely used in automobile manufacturing, precision machinery, oil equipment, engine and aerospace, etc. It has excellent properties, high temperature resistance, corrosion resistance, abrasion resistance, good thermal stability, good thermal conductivity, good oxidation resistance, is extremely superior physical and chemical properties.Belongs to a kind of commonly used engineering ceramics, silicon carbide ceramic can be used for all kinds of bearings, nozzles, sealing rings, motor rotors, turbos, gas turbine rotor blade reflector, the reflective screen, space and rocket combustion chamber liner, etc.Silicon carbide ceramics are widely used for its processing put forward higher request, to seek better and more effective processing method has been a research worker of work to do.Silicon carbide ceramic belongs to hard brittle material, its processing has always been a difficulty and a focus research, commonly used method is given priority to with grinding, the cutting force is an important index of performance evaluation of grinding[1-7]. Liu, M. H., Zhang, F. H., & Lu, G. D. did some research of the silicon carbide ceramic, through orthogonal experiment design and analysis of electroplated diamond bit structure parameters on the machining efficiency and the effect of control variable method is used to analyze the influence of processing parameters on the machining efficiency, device analysis by applying pre-tightening force of pre-tightening force on the influence of hole processing quality [8]. Li, C., Bhat, I. B., Wang, R., & Seiler, J.took the method of the numerical control polishing the surface of the silicon carbide and removal characteristics is studied, and the four variable parameter selection: polishing grinding head speed, polishing, pressure, grinding head offsets and polishing head Angle, analysis on the surface of the silicon carbide material removal trend.The results show that the good combination of above four groups parameters, can achieve a better processing quality [9]. Zhang, C., Zhang, J., & Feng, P. set up a mathematical model for cutting force in rotary ultrasonic face milling of brittle materials[10]. Wang, Y., Lin, B., & Zhang, X. did some research on the system of ultrasonic. They draw the conclutions of the grinding force decreases as the spindle speed, vibration amplitude, and vibration frequency increase. And the grinding force increases as the grinding depth and feed rate increase. the surface

morphology of the workpiece and the change trends of the grinding force can be predicted through the system matching model [11].

This paper mainly studies ultrasonic grinding of silicon carbide ceramic surface, polishing pads, water-based liquid, it is proposed using impedance control method, combining with the size of the grinding speed, select appropriate parameters to get a better surface quality.

2. Ultrasonic grinding mechanism

Ultrasonic grinding the ultrasonic technology, grinding and polishing technology, the combination of is a kind of ultra-precision machining method.Ultrasonic grinding of silicon carbide ceramic processing is shown in Fig.1.

By shown in Fig.1, in the process of ultrasonic grinding, by means of silicon carbide ceramic materials, removing rely mainly on the cutting effect of the workpiece directly grinding and grinding disc for grinding the promoting effect of ultrasonic cavitation.Ultrasonic vibration continuously drive the grinding movement, ensure uniform abrasive contact the workpiece, workpiece with rotary table at the same time also ensure the consistency of the contact surface.Abrasive particle embedded in the polishing pad, in the process of grinding, grinding effect similar Yu Chaosheng spinning processing.A single particle removal volume in a vibration cycle can be represented as:

$$w = \frac{x\omega\,\Delta t}{2\sqrt[2]{2r\delta-\delta^2}}\pi\delta^2\left(r-\frac{\delta}{3}\right) \tag{1}$$

Where w— single diamond grinding grain vibration period remove volume, mm3

ω— the spindle rotation speed, in rad/s

X — abrasive and tool face its center distance, mm

Δt— a period of workpiece and grinding grain contact time, s

δ—the depth of the single abrasive cutting into the workpiece in a vibration cycle, mm

r— particle radius, mm

A differential equation was get：

$$dw = \frac{x\Delta t}{2\sqrt[2]{2r\delta-\delta^2}}\pi\delta^2\left(r-\frac{\delta}{3}\right)d\omega \tag{2}$$

So , the third equation was does derived ,when a large number of grains existing in processing.The ideal equation of material removal rate was obtained.

$$MRR' = \int_0^{\frac{D}{2}} Nf\cdot dx = \frac{\omega DfN\,\Delta t}{4\sqrt[2]{2r\delta-\delta^2}}\pi\delta^2\left(r-\frac{\delta}{3}\right) \tag{3}$$

MRR'— the ideal material removal rate，mm3/s

D— the diameter of tool end face，mm

f — ultrasonic vibration frequency，Hz

N — the number of abrasive particle in processing

In actual processing, the grinding grain number, different abrasive machining area exists inevitably overlap, so the actual processing of the MRR is lower than the theoretical calculation of the MRR '.To make closer to the actual processing of the proposed model, the dynamic coefficient K are introduced to characterize the influence of overlapping area on the material removal rate.By the model assumptions, the abrasive grain is evenly distributed in the end of the tool, so the spindle speed and abrasive projection area and the ratio of the tool face area is a significant factor in influence processing overlap. The equation can be represented as:

$$\lambda = \frac{N\pi r^2}{\pi(\frac{D}{2})^2} = 4\frac{Nr^2}{D^2} \tag{4}$$

So the simplified formula for K

$$K = a_0\omega^{a_1}(N\frac{r^2}{D^2})^{a_2} \tag{5}$$

Including a0 ~ a2 is the model and the unknown coefficients. The calculation of cutting depth and the contact time t .the equation 3 the contact time t can be calculated by abrasive particle trajectory equation.Based on literature [8], a single particle trajectory can be expressed as sine function:

$$z = A\sin\ (2\pi ft) \tag{6}$$

$$\nabla t = 2\ (t_2)\ A\sin\ (2\pi ft) \tag{7}$$

Due to the machining mechanism is very complex, the actual processing of cutting depth is very difficult to calculate.According to the theory of the existing research, in rotary ultrasonic machining, ultrasonic amplitude A, spindle speed, participate in the processing of grinding grain number N, abrasive particle radius r and v spindle feed rate have significant effect on cutting depth.So will cut deep represented as:

$$\delta = b_0A^{b1}\omega^{b2}N^{b3}r^{b4}v^{b5} \tag{8}$$

In the model , the coefficients of b0 ~ b5 are unknown.To sum up, the actual machining process in the MRR:

$$MRR = K\frac{\omega DfN\Delta t}{4\sqrt[2]{2r\delta-\delta^2}}\pi\delta^2\left(r-\frac{\delta}{3}\right) \tag{9}$$

3. Experiment research

Ultrasonic grinding device is shown in Fig.1, the ultrasonic processing system is mainly composed of ultrasonic generator, transducer (35 kHz), the amplitude, tool head.Ultrasonic generator using self-developed constant current power supply, the maximum output power is 250 W, output current peak-to-peak value can be adjusted from 250 mA to 2000 mA, current random error within 2%.Transducer and amplitude vibration system composed of tool head about 35 kHz series resonance frequency, amplitude adjustable range is 2.0 μm ~ 25 μm.

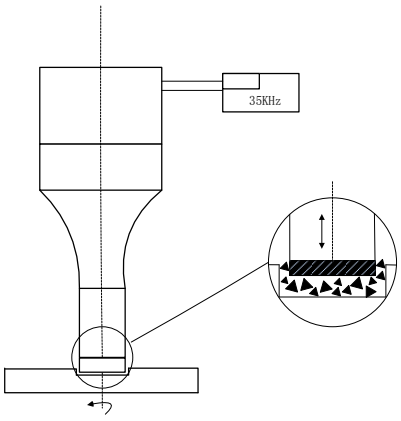

Fig.1 ultrasonic grinding principle diagram

Rotary worktable adopts precision stepper motor drive, 1 mu m face runout, ensure the machining accuracy.Working liquid liquid using grits, uniform workpiece machining area from the external liquid.By sending pulse power supply in the DSP controller, servo feed control.Servo control principle

in the way of equivalent impedance control, and by checking the size of the voltage and current signals on both ends of the transducer, impedance calculation, according to the impedance values for feeding operation, so as to achieve stable processing.

4. Experimental results and analysis

Experiment using the main research of the external load equivalent impedance influence on material removal rate and surface roughness, grinding and rotating velocity on the material removal rate and surface roughness.Experimental results as shown in figure 2-5, when the critical impedance value is less than 300 Ω, material removal rate increases with the equivalent impedance value increases;When critical impedance values greater than 300 Ω, material removal rate is falling.Load equivalent impedance value response is the situation of the machining tools, when improve increase tool stress, material removal rate will gradually increase, when machining force is too large, machining gap smaller, does not favor the chip removal, and material removal rate declines.Critical impedance value on the influence of surface roughness and material removal rate, impedance values set hours, material removal difficult, material surface quality is not provided;Impedance value set is too large, the machining gap smaller, does not favor the chip removal, abrasive particle toughness is insufficient, and the surface quality, but not necessarily good.

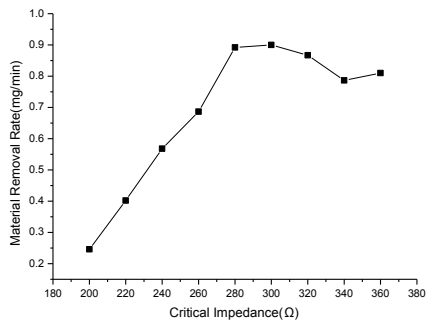

Fig.2. The effect of Critical Impedance on MRR

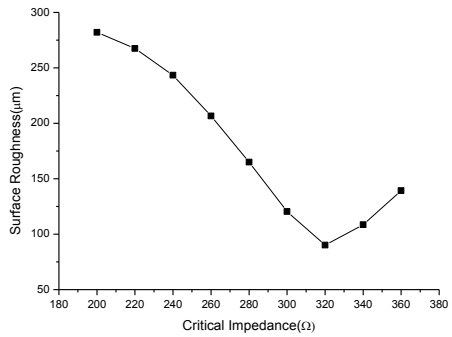

Fig.3. The effect of Critical Impedance on SR

Grinding plate velocity on the material removal rate and the influence of roughness as shown in figure 4, shown in figure 5.Can be seen from the figure 4, the material removal rate increases with abrasive disk rotational speed increases, when the velocity is larger than a critical value, the material removal rate drop, this is because the speed is too high, influence the vibration tool feed, tool head back more often.Grinding speed on the influence of surface roughness as shown in figure 5, when improve the grinding speed, roughness value increases, this is associated with using ultrasonic grinding, grinding speed increase, unstable vibration system, the cutting process is not smooth, the surface quality becomes poor.

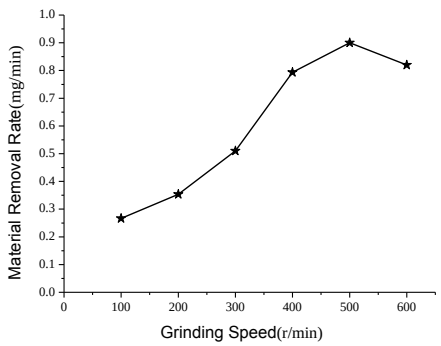

Fig.4. The effect of Ginding Speed on MRR

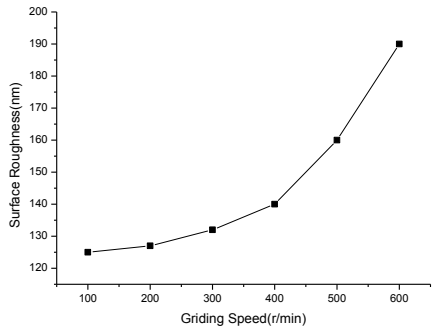

Fig.5. The effect of Ginding Speed on SR

5. Conclusion

Through the study of the ultrasonic grinding of silicon carbide ceramic processing experiment, explore the key factors influencing machining efficiency and surface quality, at the same time to verify the feasibility of the impedance control method.Finally draw the conclusion: the grinding surface quality and the equivalent impedance values and is directly related to the size of the grinding force;Grinding speed also directly affect the machining process, but not decisive.

Acknowledgements

Jiangsu Provincial Prospective Joint Research Foundation for Industry-University-Research of China（BY2016065-57）

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