Research and Application of Engineering Ceramic Material Processing Technology

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Abstract. With the development of the times, the excellent properties of engineering ceramics have gradually emerged. Because engineering ceramics possess many excellent properties such as high hardness, good abrasion resistance, and stable performance, the application of engineering ceramics has become more and more widespread. Therefore, the technology of engineering ceramics processing has been continuously improved, and the hard and brittle characteristics of engineering materials have been continuously overcome. Many new types of processing methods have been gradually developed, and engineering ceramics are continuously processed.

1. Introduction
In recent years, the continuous widening of the application fields of engineering ceramic materials and the inconsistency of low processing efficiency and high cost have become increasingly prominent. The traditional diamond grinding wheel grinding technology not only has high processing costs, but also has less room for improvement in processing efficiency, which greatly limits the Application of engineering ceramics. The common feature of advanced processing technologies such as laser, electric spark, ultrasonic, microwave, plasma [1], and high-pressure water jets is that they can release huge amounts of energy in a very short time. So we apply these high-density energy beams to the local surface of engineering ceramics. Change its organizational structure and deformation characteristics or reduce its hardness and strength, to reduce the cost of engineering ceramics processing, improve processing efficiency or surface integrity [2].

2. Types of machining processes for engineering ceramic materials

2.1. Engineering Ceramics Turning Process
Turning of engineering ceramics is mainly performed with diamond tools. Poly crystalline diamond tools are difficult to produce smooth and sharp cutting edges, generally only used for rough machining. The precision turning of engineering ceramics requires the use of natural single crystal diamond tools, using micro-cutting methods. However, due to the large hardness and brittleness of engineering ceramic materials, turning machining is still difficult to ensure the processing accuracy and processing quality requirements. Currently, the turning mechanism of engineering ceramics and the practical application of turning methods are mainly focused on [3].
2.2. Engineering ceramics drilling process

At present, diamond hollow drills are widely used to process circular holes with a diameter of several millimeters or more. According to the report, when the method is used to drill silicon nitrate at atmospheric pressure, the material removal rate can reach 1600mm³/min or more. However, due to the extremely high hardness of the ceramic, the diamond bit wears severely during the drilling process. In addition, due to the brittleness of the ceramic, the chipping phenomenon occurs at the entrance and exit of the hole, which affects the machining quality of the hole. There are currently additional ultrasonic vibrations on this hollow drill for ceramic drilling, which significantly improves the machining results. There are also diamond grinding wheels used to grind the inner hole and diamond tool scraping holes, but it is only applicable to the case where there are preset holes on the ceramic workpiece. In short, the current machining methods are limited to holes of a few millimeters in diameter, and it is still difficult to obtain the desired economic effects and surface processing quality. Now, we are constantly working hard to develop new drilling methods [4].

2.3. Engineering Ceramic Grinding Process

Grinding is the most important processing method for ceramic materials, including grinding planes, inner and outer circles, and molding surfaces. Although the mechanism of grinding of ceramic materials is not fully understood, brittle fracture is the main mechanism of grinding ceramic materials. The treatment of grinding debris in ceramic grinding is a big problem [5]. Generally, the cooling fluid is used to flush away the wear debris. It can also reduce the grinding temperature, improve the machining quality, and reduce the wear of the grinding wheel. Generally use grinding fluid with good cleaning performance and low viscosity. In addition, the choice of grinding wheel has a great influence on ceramic processing. Cast iron binder is a high-strength grinding wheel binder, with high strength, not easy to block, sharp edge grinding and high processing efficiency. At present, the cast iron binder grinding wheel has been used to grind ceramics in China. The size of the diamond grit is also an important factor affecting the quality of the ceramic processing surface. Generally, the smaller the abrasive particles, the lower the surface roughness, but the grinding ratio of the grinding wheel is reduced. Good overall index, good for ceramic slow-feed grinding.
2.4. Engineering Ceramic Grinding and Polishing Process

Grinding and polishing are important processing methods for engineered ceramic parts and have long been used for the machining of simple molding surfaces such as spherical and cylindrical surfaces. Grinding usually uses harder abrasives such as cast iron to have abrasive grains of several microns or more. Polishing is performed at a lower pressure using a soft polisher and fine powder grit. In recent years, many new advances have been made in the grinding and polishing technology, such as ultrasonic polishing and electrocute-machining compound polishing [6].

3. Types of special processing technology for engineering ceramic materials

The advantage of special processing is that it can perform the processing tasks that traditional processing cannot be completed or is difficult to complete. In recent years, the special processing technology of ceramic materials has achieved considerable development. The current main trend is the combination of processing, such as the introduction of acoustic, optical, electrical, magnetic energy in the cutting zone, can form ultrasonic vibration cutting, laser-assisted cutting, charged Cutting, magnetizing cutting, etc. Combination special cutting processing technology Ceramic processing technology is generally divided into three categories: special processing technology, composite processing technology and machining technology. At present, the mechanical processing technology is the most widely used in engineering ceramics processing, in which the use of diamond grinding wheel grinding technology is more mature. In order to improve the efficiency of hard brittle and hard-to-process materials such as engineering ceramics, many innovative machining concepts and technologies have been proposed at home and abroad. In view of the fact that the process itself is a process of destruction of the material's controlled, the cutting-pushing process technology based on the fracturing of the edge fully exploits the advantages of cracks, edge crushing and other defects. Although in recent ten years, many advanced and special processing technologies have been newly developed at home and abroad, their processes are not perfect and the processing cost is high, and they have not been widely used. However, energy-assisted cutting technology facilitates the improvement of the mach inability of engineering ceramics, which has become a hot topic in domestic research.

3.1. Laser Processing of Engineering Ceramic Materials

Laser processing utilizes a uniform laser beam with a high energy density as the heat source. Instantaneous high temperatures are generated at local points on the surface of the processed ceramic material, and the material is removed by local melting or vaporization. Laser processing is a non-contact, friction less processing technology. There is no need for a mold in the machining process. By controlling the position of the laser beam on the surface of the ceramic material, three-dimensional and complex shape materials can be processed.

Compared with the conventional cutting method, the laser cutting process only needs to be positioned without clamping, no "tool" wear, no "cutting force" acts on the work piece, the processing speed is fast, and the blind groove can be cut through without noise Low and pollution-free, the cutting efficiency of the plate is increased by 8 to 20 times, the cutting of the smallest seam can be realized, the material is saved by 20% to 30%, the production cost can be greatly reduced, and the processing accuracy is high, the product quality is reliable, and also has Can shorten the production cycle, can be selective processing, precision machining and other advantages. For example, a mechanically Q-switched pulsed CO2 laser with a hard and brittle material, and with optimized parameters, a high cutting speed multiple repetitive pass cutting process was used to perform a cutting test on a Si3N4 ceramic test piece, and a fine crack without cracks was obtained. Laser hole drilling research uses high power acoustic QYAG laser with an average power of 400W to cut small holes in the combustion chamber parts of a 0.5mm ceramic thermal insulation coating in engines. The thickness of the recast layer is less than 20μm without micro cracking. Burrs, and processing efficiency increased by 4 to 10 times. Researchers in China have used lasers to punch holes in various non-metallic materials such as synthetic diamonds, ceramics, glass, and human teeth. The aperture can
be as small as 0.03mm, the minimum aperture can be 6μm, and the depth is <10mm. And the roundness of the hole is also ideal.

### 3.2. EDM Process for Engineering Ceramics

EDM EDM, also known as electric erosion machining or electric discharge machining, is a non-contact fine thermal processing technology that uses the electric erosion phenomenon generated during the pulse discharge between the tool electrode and the work piece electrode to process the material. The principle is to first separate the die (cutting) and the processing element as the cathode and anode of the circuit, and separate the two poles with the liquid insulating dielectric. The surface material melts, evaporates or heats through the etching of the high-energy plasma suspended in the dielectric. Peel to achieve the purpose of processing materials. Since the mold is not in direct contact with the work piece during machining, no mechanical stress acts on the surface of the material, and any high-hardness, high-density material can theoretically be processed.

EDM can form, pierce, and cut complex shapes. During machining, the tool does not contact with the work piece, and the force is extremely small. It can process fine structures such as small holes and narrow slits, as well as holes and cavities of various complex shapes. It can also be processed on extremely thin sheets or work pieces. The duration of the pulse discharge is very short, the cooling effect is good, and the thermal effect of the machined surface is minimal. Direct use of electrical energy for processing facilitates automated processing.

It is a processing technology that can produce high-precision high-performance ceramic components with high dimensional accuracy, low surface roughness, and complex shapes. Compared with conventional machining methods, EDM can improve processing efficiency without reducing the surface quality of the material. This technology is particularly suitable for the processing of ceramic shaped parts, and can accomplish the work that is difficult to accomplish with traditional processing technology. In recent years, many new EDM technologies have been developed. Among them, the most widely used ones in ceramic processing are micro-med, micro-med, and mixed powder working fluid EDM mirror processing.

### 3.3. Ultrasonic Processing of Engineering Ceramics

Ultrasonic waves (vibration waves with a vibration frequency exceeding 16,000 times per second) are processed using a tool (mold) that generates ultrasonic vibrations to drive the abrasive suspension between the tool and the ceramic element, and the impact and polishing elements are processed. As the tool advances in three dimensions, the shape of the tool tip is gradually replicated on the ceramic element. Commonly used abrasives are boron carbide, silicon carbide and alumina. The working fluid generally used is water. In order to improve the processing quality of the material surface, kerosene or engine oil may also be used as the liquid medium. The critical pressure (Po) of several common ceramic materials is as follows: SiC (reaction sintering) is 2.4 MPa; Si3N4 (normal pressure cantering) is 4.8 MPa; Al2O3 (92%) is 1.1 MPa; Al2O3 (99.5%) is 1 MPa. At the same time, the removal rate of Al2O3 and SiC by ultrasonic processing is higher than that of Si3N4. However, they are all higher than ordinary machinery cutting, grinding and other processing. Due to the small force acting on the component during the machining process, the material surface generates less mechanical stress, and the damage to the material is small and the surface roughness is good. Compared with laser processing, EDM and other special processing technologies, ultrasonic processing is not dependent on the conductivity of the material, there is no thermal physical effect, the work piece surface after processing has no organizational changes, residual stress and burns, etc.; The medium macro force is small, suitable for a variety of hard and brittle materials that require complex and non-conductive shapes.

### 3.4. Processing technology of edge fracturing effect of engineering ceramic materials

In the conventional grinding process of engineering ceramics, due to thermal stress, mechanical stress, etc., it will produce grinding surface/sub-surface cracks, surface fractures, edge cracks and other brittle
damage, which are difficult to control at random. The localization of stress is formed at the front of the defect, and it is easy to cause the initiation or propagation of cracks in the material, which is a potential source of cracks that damage the quality and strength properties of the ceramic grinding surface. Because engineering ceramics are very sensitive to cracks, residual tensile stress and other defects, the quality of engineering ceramics is generally difficult to control during processing. In fact, the machining process itself is a controllable destruction process for the material. Based on this principle, it is the use of multiple flanges formed by cutting to increase the number of edges and to predict crack defects in the grooves, as well as during processing. The edge crushing effect is very easy to make the cracks expand and form chips, so as to achieve the surface material removal. Under the combined effect of the external three-dimensional tensile stress field and the free edge surface stress field relaxation, the interior of the ceramic material undergoes the rapid expansion of the prefabricated micro-cracks and the fracture process, until the material is broken and removed.

![Diagram](image.png)

**Fig 3.** Engineering ceramic material edge fracturing effect processing principle diagram

The new processing method promotes the transformation of crack defects from "damage" to "benefits" under certain conditions, thereby greatly reducing the constraints of traditional ceramic processing that rely on external input of high energy and can only be processed with ultra-high hardness tools. Harder tools can be processed with less energy consumption. This new technology does not rely on the "cutting" function in the ordinary sense. Therefore, there is no requirement for the sharpness of the cutting edge of the pushing tool, and it can even make scrapped tools very cost-effective. This new processing method will help change the current high cost of ceramic processing, and help promote the extensive use of engineering ceramic materials.

3.5. **Engineering Ceramic Material Abrasive Water Jet Processing Technology**

(1) Water jet cutting technology the development of high-pressure water jets as a new technology has developed rapidly in recent years and applications have become more widespread. The application of high-pressure water jet technology has matured in the cleaning and descaling of ships, pipelines and equipment, and the removal of various coverings. The use of high-pressure water jets to cut various non-metallic materials has also been widely used. In recent years, the application of rock breaking and coal mining has developed rapidly. Compared with ordinary cutting and drilling machines, there are many advantages to using high-pressure water to cut rock and concrete. However, the pressure required for water jet cutting is high, and the requirements for components, equipment, and seals are relatively strict. Therefore, they are limited in use. If high energy water jet cutting of concrete consumes a large amount of energy, the power of the equipment is at least 150kW and the pressure is greater than 300MaP. In addition, when the water jet is cut several times, its maximum notch depth is only 65mm. If the groove depth exceeds 200mm, the notch width must be large, and the water jet...
cutting will do a lot of useless work, and the cutting quality of the notch edge is not ideal. When cutting concrete with a water jet, only the concrete can be cut but it cannot be cut.

(2) The increasing application of engineering ceramics has increasingly higher demands on the processing precision, processing efficiency, and surface quality of its products. Using a single mechanical processing method or a single special processing method, it is difficult to achieve its processing requirements satisfactorily. With the continuous in-depth study of ceramic processing theory and the gradual maturity of new processing technologies, the comprehensive use of machining and advanced laser, EDM, ultrasonic, microwave and other phase-composite processing technologies has enabled high-quality, high-efficiency and low-consumption processing of engineering ceramics. The inevitable trend of the development of engineering ceramic material processing technology. Although the processing technology and processing principles of engineering ceramics have been deeply studied, various processing technologies have some deficiencies. How to overcome these deficiencies and improve the processing efficiency and surface quality of ceramics is the focus of engineering ceramics processing technology research in the future.

4. Conclusion
High efficiency and high precision are the two goals pursued in the grinding of engineering ceramic materials. Domestic engineering ceramics materials need to be strengthened in terms of high-efficiency, precision and ultra-precision grinding. With the deepening of theoretical research and the continuous emergence of new processing technologies, engineering ceramics grinding technology will be further developed and will be more. Field application, promotion, and more technology promotion there are many new technologies.

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