

WATER-JET-GUIDED LASER PROCESS FOR CUTTING OF CBN AND PCD INSERTS

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Cutting Of Diamond And CBN Inserts Difficult Process

PCD and CBN are commonly used as inserts (Photo 1) in machine tools for high-speed cutting, milling or turning machines because of their exceptional tool life. However, because of their hardness, it is difficult to cut the different shapes of the inserts (typically triangles, rectangles or lozenges) from larger discs or plates.

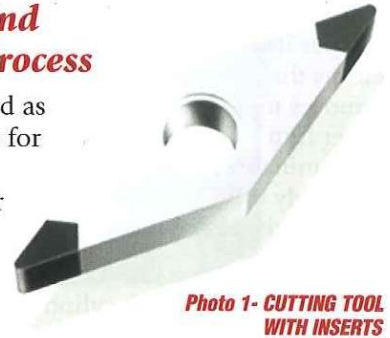
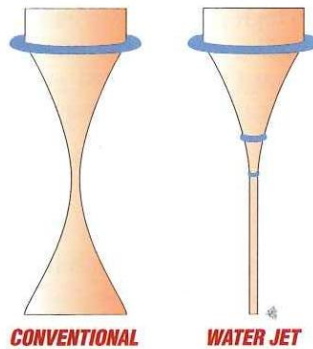


Photo 1- CUTTING TOOL WITH INSERTS

During this manufacturing step, several important requirements should be taken into consideration. The edges have to be smooth and parallel, and the cutting kerfs narrow in order to lose as little material as possible. Burrs should be avoided, as well as material changes due to heating. Speed is also an important criterion as cutting hard materials can be time-consuming, especially for important thicknesses (typically between 1 and 4 mm). Cutting hard materials with diamond saws is problematic because of the important tool wear and the slowness of the process.



Thin gaps cannot be obtained, resulting in costly material loss. Moreover, only straight cuts can be made. EDM cannot be used if the material is not electrically conductive and it is a very slow process. Conventional lasers are a possible solution, but the process generates particles and thermal damages that have to be removed with post-processing steps. Furthermore, conventionally focused lasers produce conical kerfs. If conventional lasers can be used for CBN drilling in some cases, cutting is still very problematic. A new alternative is the use of the water-jet-guided laser technology, a revolutionary technology combining a low-pressure, and hair-thin water jet with a laser beam. So Conventional Water Jet basically, in conventional laser cutting, the laser beam must be focused on the insert, resulting in a conical shape beam and V-shape kerfs. The insert absorbs the laser beam, which heats the material until melting and vaporization occur. The molten material is expelled from the cut using an assist gas, coaxial to the laser beam; the gas is not very efficient due to the low kinetic energy and a significant amount of resolidified materials remain inside the cut. Water-jet-guided laser technology uses a low-pressure water jet to guide the laser beam and generates parallel kerfs by means of total internal reflection at the insert /air interface. During ablation, the water jet expels most of the molten material (high kinetic energy). Only a tiny amount of resolidified materials remain.

INNOVATIVE TECHNOLOGY A MOST PROMISING TOOL FOR HARD-MATERIAL CUTTING

Cutting of hard materials, for example cubic boron nitride (CBN) and polycrystalline diamond (PCD), is a high requirement process; among the existing techniques, very few are efficient. The new water-jet-guided laser technology has been improved over the years to complete such a delicate operation. The reached cutting speeds are higher than for most processes. No post-processing steps are required to clean the inserts after cutting, as the level of contamination directly after cutting is very low and since heat influence is negligible.

Thanks to the particularities of the Laser MicroJet, the cut is parallel and very regular. This innovative technology, able to cut any material, providing that its absorption coefficient at the laser's wavelength is sufficient, is today the most promising tool for hard-material cutting.

Water-Jet-Guided Laser System Best Of Two Worlds

The water-jet-guided laser technology, also called Laser MicroJet, is innovative in the sense that the laser beam is not directly focused on the work piece, as for conventional laser systems, but guided inside a water jet by means of total internal reflection at the water/air interface, similarly to conventional glass fibers (see Figure 1, Photo 3). The use of a low-pressure, hair-thin water jet makes this technology completely different from other laser-based technologies. Indeed, besides its primary guiding function, the water jet has two major effects that are paramount for precision cutting. First, the water jet removes most of the particles generated by laser ablation. As a thin water film is generated on the work-piece surface during cutting, contamination is negligible. In second place, the heat-affected zone is extremely thin, since the continuous water jet cools the work piece between the laser pulses.

Another important effect of the water-jet guiding is to generate parallel kerfs, since the cylindrical water jet guides the laser energy down to the bottom of the cut; the conical effect present in conventional laser cutting is avoided. In addition, very narrow kerf widths are possible due to the use of small nozzles.

For this particular application, a common jet diameter is 36 μm . Powerful lasers near their maximum intensity (high peak powers) are preferably used because of the temperature stability of these materials and the thickness of the inserts; it is also important to use pulsed lasers with high pulse repetition rates, as the edge quality is improved.

Polycrystalline Diamond Structure And Processing

Polycrystalline Diamond (PCD) is a synthetic diamond, exceptionally resistant to wear, used in a wide range of machining operations. Usually, the PCD diamond layer is bonded to a tungsten carbide (WC) substrate, which provides strength and a brazable base for bonding to other metals. During insert production, both layers need to be completely cut. The water-jet-guided laser performs this operation with excellent quality and reasonable cutting speed, considering the thickness of the pieces that have to be cut: Thin samples (1.1 mm WC and 0.5 mm PCD): cutting speed 10.9 mm/min
Thick samples (2.7 mm WC and 0.7 mm PCD): cutting speed 8 mm/min
Using Q-switched lasers (Photo 4) instead of long pulses, the cut quality was greatly improved, as almost no contamination was visible on the surface of the processed samples; furthermore, these frequency-doubled lasers (wavelength: 532 nm) achieve higher cutting speed than infrared lasers. High peak power is advantageous; a good way to increase the beam power per surface unit is to reduce the water jet diameter, that is, the nozzle diameter. With Q-switch lasers, the use of 40- μm nozzles (generating a 36- μm water jet) achieves a good average speed.

The microscope images below (Photo 5a & 5b) show a triangle insert with PCD on the front side and WC on the backside (total thickness: 1.6 mm). A Q-switch green laser (wavelength: 532 nm, average power: 150 W) was coupled into a 72- μm water jet. The WC layer was cut first and is referred to as "front side". For through cut, a total processing speed of 12.8 mm/min was reached in 70 passes. The resulting edge quality is very good; no heat-affected zone can be seen in the area surrounding the cut. The cut is free of burrs and the contamination is very low.

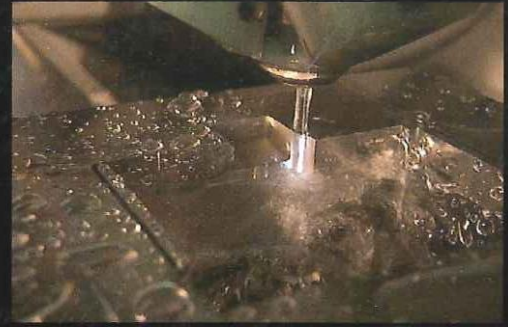


Photo 2 - ELECTRICAL DISCHARGE MACHINING

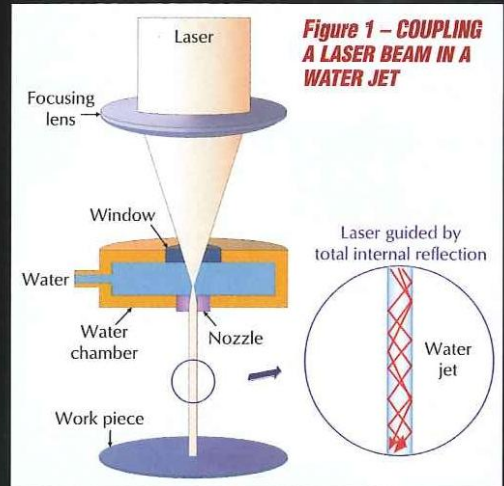


Figure 1 - COUPLING A LASER BEAM IN A WATER JET

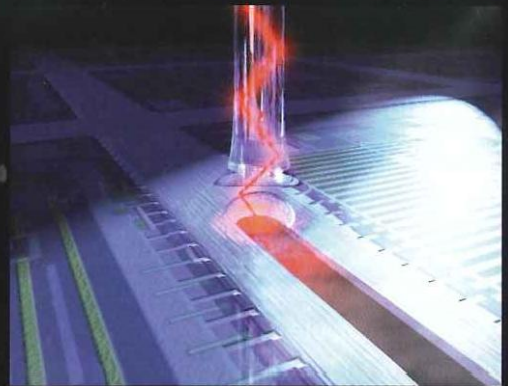


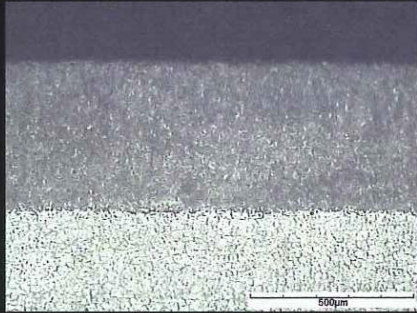
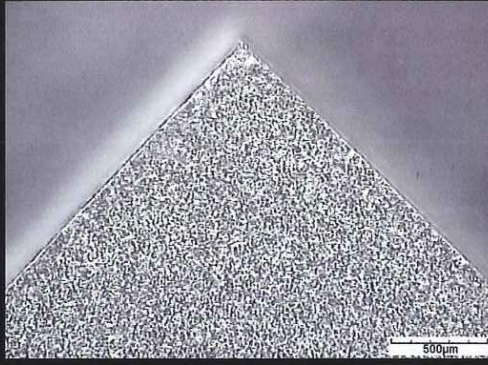
Photo 3 - LASER BEAM IN A WATER JET



Photo 4 - MULTIMODE Q-SWITCHED LASERS

- Wavelengths: 1064 nm (infrared), 532 nm (green) or 366 nm (UV)
- Average power: up to 200 W

Photo 5a & 5b – SAMPLE COMPLETELY CUT WITH THE LASER MICROJET: PCD on front side, corner of the triangle (first picture) and side cut showing PCD on top and WC below (second picture)



Water-jet-guided laser technology has been improved over the years to complete the delicate operation of cutting hard materials.



Photo 6 – EDGE OF A CBN CYLINDER (diameter: 3mm) directly after cutting with the Laser Microjet

Polycrystalline Cubic Boron Nitride Structure And Processing

Cubic boron nitride (CBN) is a synthesized material, stable under conditions of high temperature, which is the second hardest material behind diamond. CBN inserts are used for machining hard materials, providing significant improvement in productivity. The microscope image below (*Photo 6*) shows the edge of a cylinder made in hard CBN on top of a WC-Co layer (total thickness: 1.6 mm) directly after cutting with the water-jet-guided laser (no post-processing). The laser used for this application was also a green laser (wavelength: 532 nm, average power: 60 W) coupled in a 48-µm water jet. The overall cutting speed was 9 mm/min, achieved in 100 passes. The edge is very clean and extremely sharp. Even at high speed, the cut remains smooth. The contamination level on the surface of the insert is minimal. ■

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