New Process for Cutting of CBN and PCD Inserts: Water-Jet-Guided Laser

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Introduction

PCD and CBN are commonly used as inserts 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. 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, hair-thin water jet with a laser beam.

Water-jet-guided laser

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).

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.

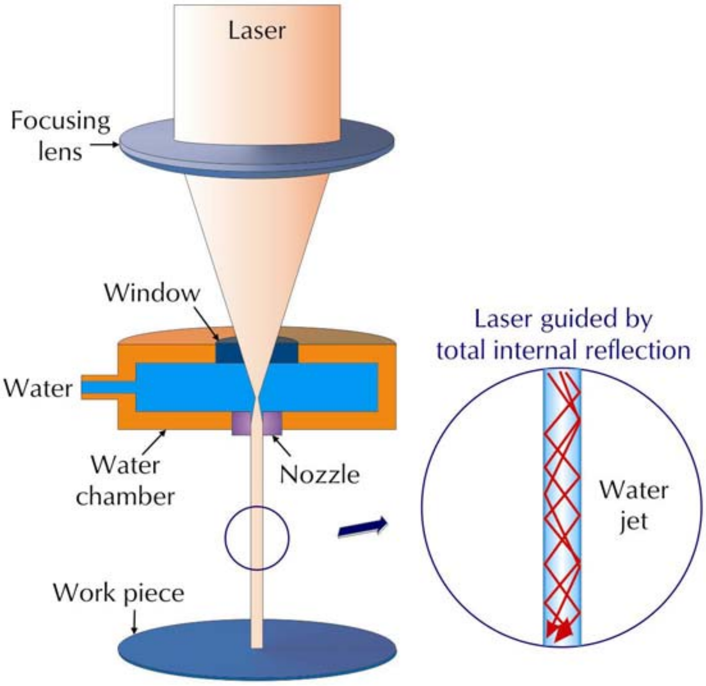

Figure 1 – Coupling a laser beam in a water jet

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

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 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 (Figure 2) 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.

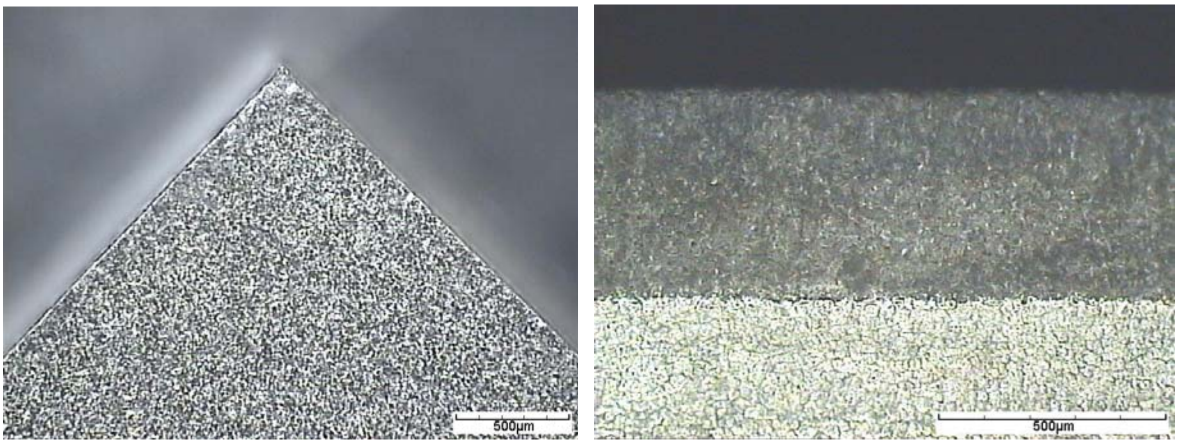

Figure 2 – Sample completely cut with the Laser Microjet: PCD on front side, corner of the triangle (left) and side cut showing PCD on top and WC below (right)

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.

CBN

Cubic boron nitride (CBN) is an artificially 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 (Figure 3) 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.

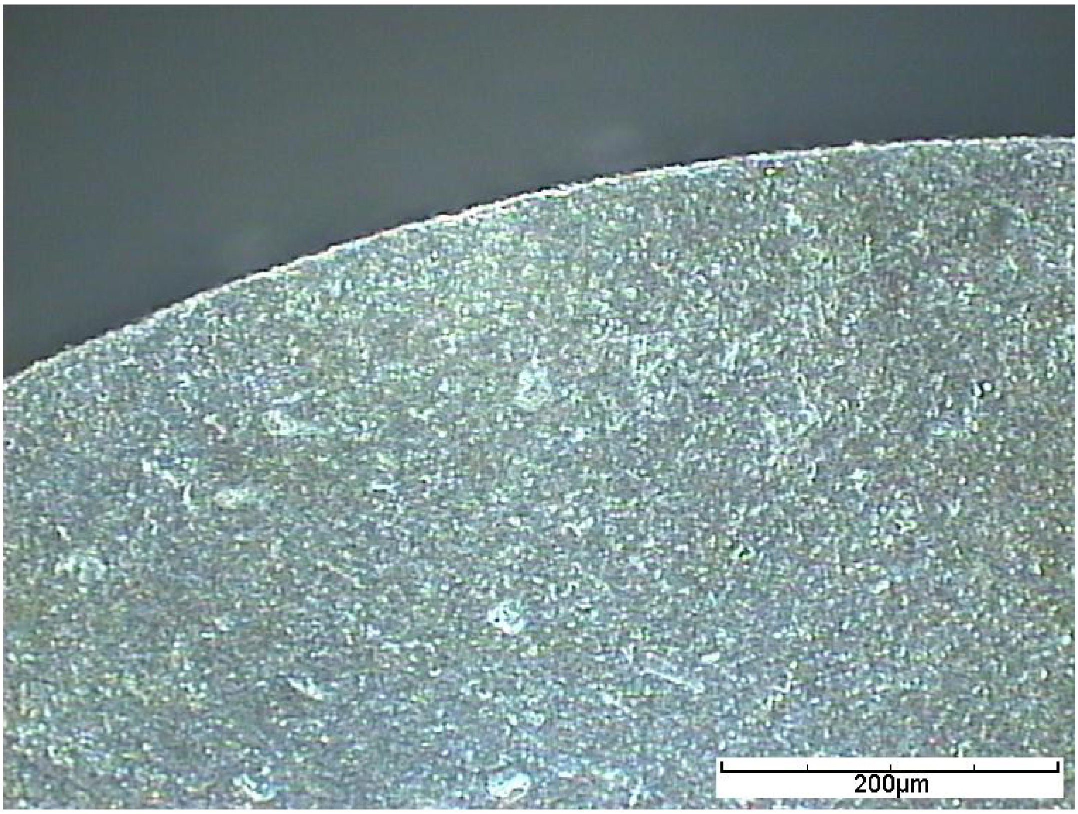

Figure 3 – Edge of a CBN cylinder (diameter: 3mm) directly after cutting with the Laser Microjet

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.

Summary

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.