CUTTING DIAMOND TOOLS BY LASER MICROJET®

New Developments in the Wet Laser Machining of Industrial Diamond Tools

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INTRODUCTION

Artificial diamond materials are replacing tungsten carbide and ceramic composites in cutting tools where high surface finish quality is required. The choice of materials ranges from lower end polycrystalline diamond (PCD) to high-end single crystalline diamond (SCD). SCD tools have proven their capability in the super-finishing of ultra-precision optical grade surfaces. In many cases, the use of SCD tool inserts can eliminate grinding operations and cut process times. They also benefit from a longer tool life.

Only laser technologies are capable of machining such materials, which are just as hard as natural diamonds. Synova's patented Laser MicroJet® (LMJ) technology delivers better results than traditional dry lasers and is especially suited for the machining of diamond materials. This paper shows the results achieved in using Synova's Laser MicroJet process for cutting PCD and SCD tool inserts.

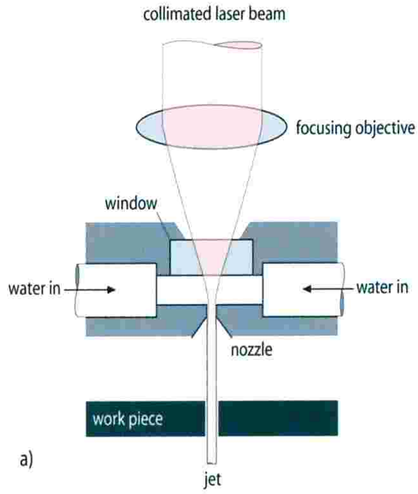
LMJ PROCESS

In the Laser MicroJet system, a laser beam, passing through a pressurized water chamber, is focused into a nozzle.

The low-pressure water jet emitted from the nozzle guides the laser beam by means of total internal reflection at the water/air interface. The water jet diameter is usually 50 microns and the laser power required is between 25 and 30 watts. While the principle looks simple, years of experimentation and optimization were required to fine-tune the process.

The LMJ process works in two stages. The energy of the laser pulses vaporizes the workpiece material by heating while the water cools and cleans the surface in the interval between the pulses. Through a scanning process, a trench is formed that becomes deeper with each pass. As compared to traditional dry lasers, the LMJ 'wet laser' technology has many advantages. The most important advantage is that Laser MicroJet cuts with a parallel beam and the cutting depth can extend up to several centimetres.

This is not the case with conventional lasers where the focused laser beam has a limited working distance of just a few millimetres due to beam divergence. The beam converges at a focal point and then diverges. Therefore, a focus control is required and the working distance is short.



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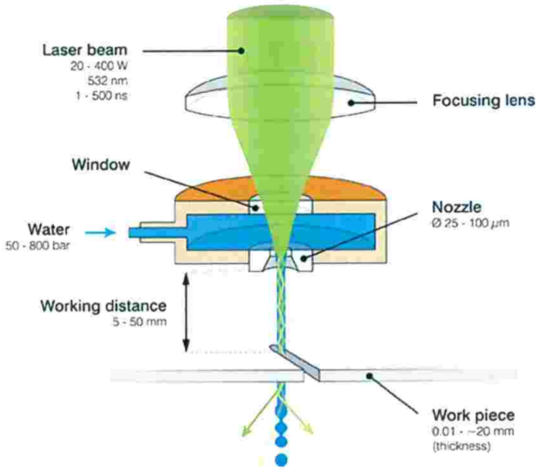
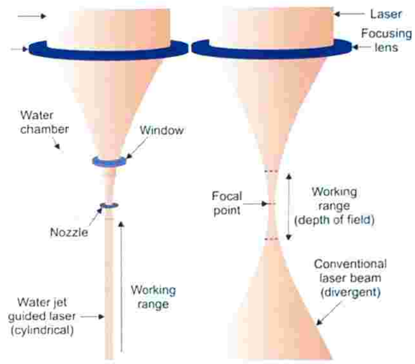




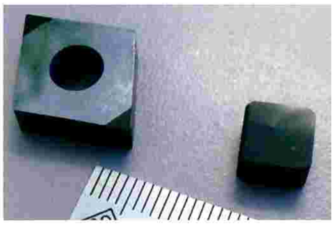
The technology behind the Laser MicroJet is based on creating a laser beam that is completely reflected at the air-water interface, using the difference in the refractive indices of air and water. The laser is, therefore, entirely contained within the water jet as a cylindrical beam, similar in principle to an optical fibre. The LMJ process offers several advantages. There is no need for focal adjustment and one obtains parallel kerf sides. There is a minimum heat affected zone thanks to the cooling effect of the water. Finally, there is a high removal rate with debris washed from the kerf.

SYNOVA LCS 50-5 LASER CUTTING SYSTEM

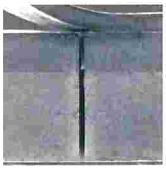
The Synova LCS 50-5 laser cutting system can cut extremely hard materials with high precision. It is a compact machine with 5-axis capability with a user-friendly interface and intuitive CAM software for batch processing of parts such as diamond tools.

The machine's optical head includes an optical fibre cable for laser beam transmission, a camera and a number of lenses. The LCS 50-5 is suited for machining any type of hard material ranging from tungsten carbides and ceramics to CBN, PCD, SCD and natural diamonds.

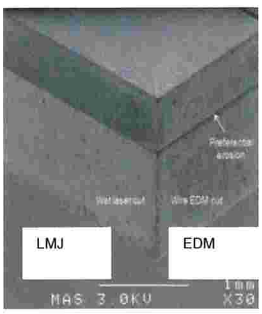
EXAMPLES OF CUTTING RESULTS



The LCS 50-5 can cut PCD or SCD workpieces to a near net shape in just a few minutes. In addition, the excess waste diamond is not ground away but is removed as a piece from which other tools can be made.



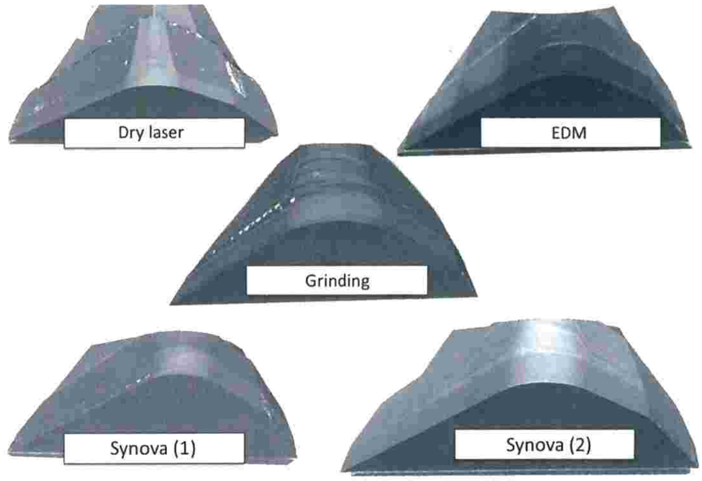
With its LMJ technology, the LCS 50-5 provides better results than traditional processes such as dry lasers or EDM machining.



The LMJ cutting process results in a perfectly parallel cut as demonstrated in the cutting of this PCD workpiece. The advantage is that the water guided-jet has an adequate working range where it is possible to cut to a depth of several centimetres in a single setting. Another result is that the LMJ laser is faster than a dry laser.

Compared to EDM machining, the LMJ process also delivers a more uniform cut surface profile. A spark erosion process was used to cut the right side of the PCD workpiece while the LMJ process was used to cut the left side of the same workpiece. A comparison of the two surfaces shows that the LMJ side has a more uniform cut surface profile. Again, the LMJ process cuts much faster than an EDM machine, resulting in higher productivity and hence cost savings.

A comparison of different machining technologies shows that the Synova LMJ (2) process can provide the best surface quality compared to grinding, EDM and conventional laser.

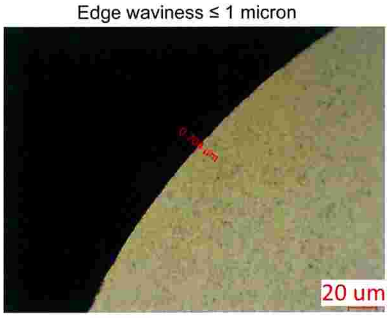


In the above example, the Synova LMJ (1) process took twelve minutes to cut the entire workpiece to final dimension and quality while the Synova LMJ (2) process took 16 minutes. The other machining technologies take similar processing times.

PCD TOOL GEOMETRY

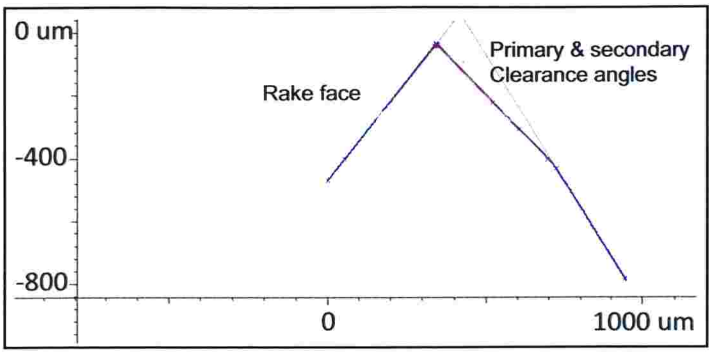
In just thirty years, PCD materials are increasingly being used as super cutting tools for machining non-ferrous metals and it would be impossible to imagine modern production technology without these tools. Synova has focused its development efforts in fine-tuning various parameters for the laser machining of PCD tools. The priority lies in obtaining perfect geometry as well as cutting surface finish so that tool life and performance is optimal.

Edge waviness ≤ 1 micron



0.5 µm PCD grains

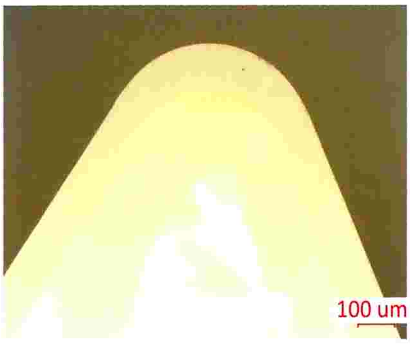
The end cutting edge profile is an important aspect in single point cutting tool geometry. The Synova LCS 50-5 with its 5-axis capability can ensure the correct end and side cutting edge angles. The priority also lies in getting the required surface finish for the end and side cutting edges. Synova's LMJ process achieves an edge waviness of less than one micron with 0.5 PCD grains.



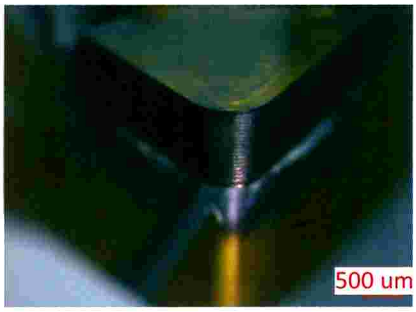
The Synova LCS 50-5 laser machining process delivers an extremely fine surface finish (Ra ≤ 1 micron) for PCD tools, which eliminates the need for a second grinding operation.

In addition, the machine's 5-axis capability is in a position to execute CNC programs with the high degree of precision needed for such cutting tools. The most critical elements are the end cutting edge and side cutting edge primary clearance angle.

SCD TOOL GEOMETRY



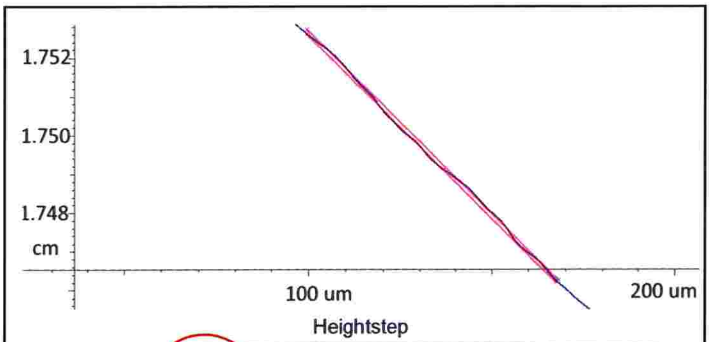
SCD tools represent the wave of the future and Synova's LMJ technology allows single crystalline diamond material to be machined with virtually no heat affected zone. Thus, a standard single point cutting tool retains its material qualities within its geometrical profile.



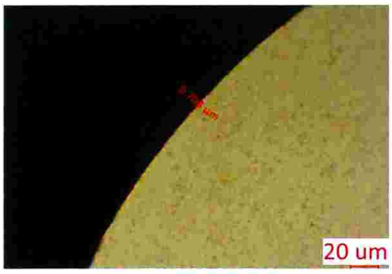
The following three graphics show the edge waviness at the end cutting, nose and side cutting edges. At a magnification of 500, the edge waviness is less than 0.5 microns.

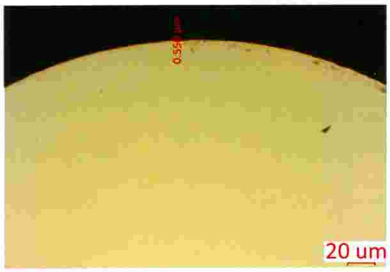
Such a high quality of surface finish is proof that the LMJ technology is best suited for the laser machining of SCD tool inserts. While cutting trenches are visible on the SCD insert, here brazed on to a holder, they have no impact on the surface roughness achieved on the workpiece.

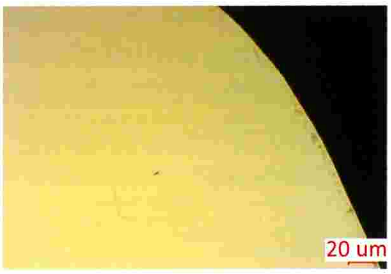
The LCS 50-5 precision machining capability can be gauged by the deviation between a perfectly vertical line and measured points, all within the sub-micron range as shown in the below graphic, proving that the above visible lines have just an optical effect.

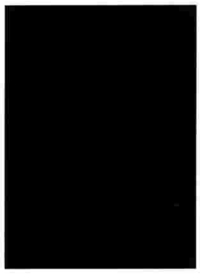


	Angle [°]	Distance [nm]	P1.x [µm]	P1.y [cm]	P2.x [µm]	P2.y [cm]	P3.x [µm]	P3.y [cm]	P4.x [µm]	P4.y [cm]
Heightstep 1	136.609	980.7433	9.1734	1.7528	168.1201	1.7462	167.2750	1.7462	99.1734	1.7526









CONCLUSIONS

The presented results prove that the compact Synova LCS 50-5 (working area 50 x 50 x 50 mm) with its 5-axis capability and intuitive CAM software is ideally suited for the machining of small PCD and SCD cutting tools of different geometries. The LCS 50-5 can deliver a high-quality surface finish for PCD as well as SCD materials. Thanks to its LMJ water jet guided technology, the heat affected zone is less than 2 microns on PCD. Finally, edge microcracking which occurs with dry lasers, has been eliminated. The biggest advantage of the LCS 50-5 lies in its cutting speeds of up to 1.5 mm/min for PCD and 2.6 mm/min for SCD. Faster cutting means that fewer machines are needed and this translates into reduced capital investment.

Synova has developed software functions that enable the batch processing of tool inserts. This allows tool inserts to be loaded in a cassette for automated loading and unloading. It also needs to be mentioned that the LCS 50-5 can also cut natural diamonds and its CAM software enables the faceting of such stones.

In case manufacturers need a high cutting tool edge finish, Synova can offer a hybrid solution which combines the LCS 50-5 with a second operation CNC polisher in the case that sub - 0.1 um Ra roughness is requested. For PCD and SCD tool manufacturers, the question is not whether one can afford to invest in a LCS 50-5. Rather, one needs to ask whether one can afford to be without a LCS 50-5!