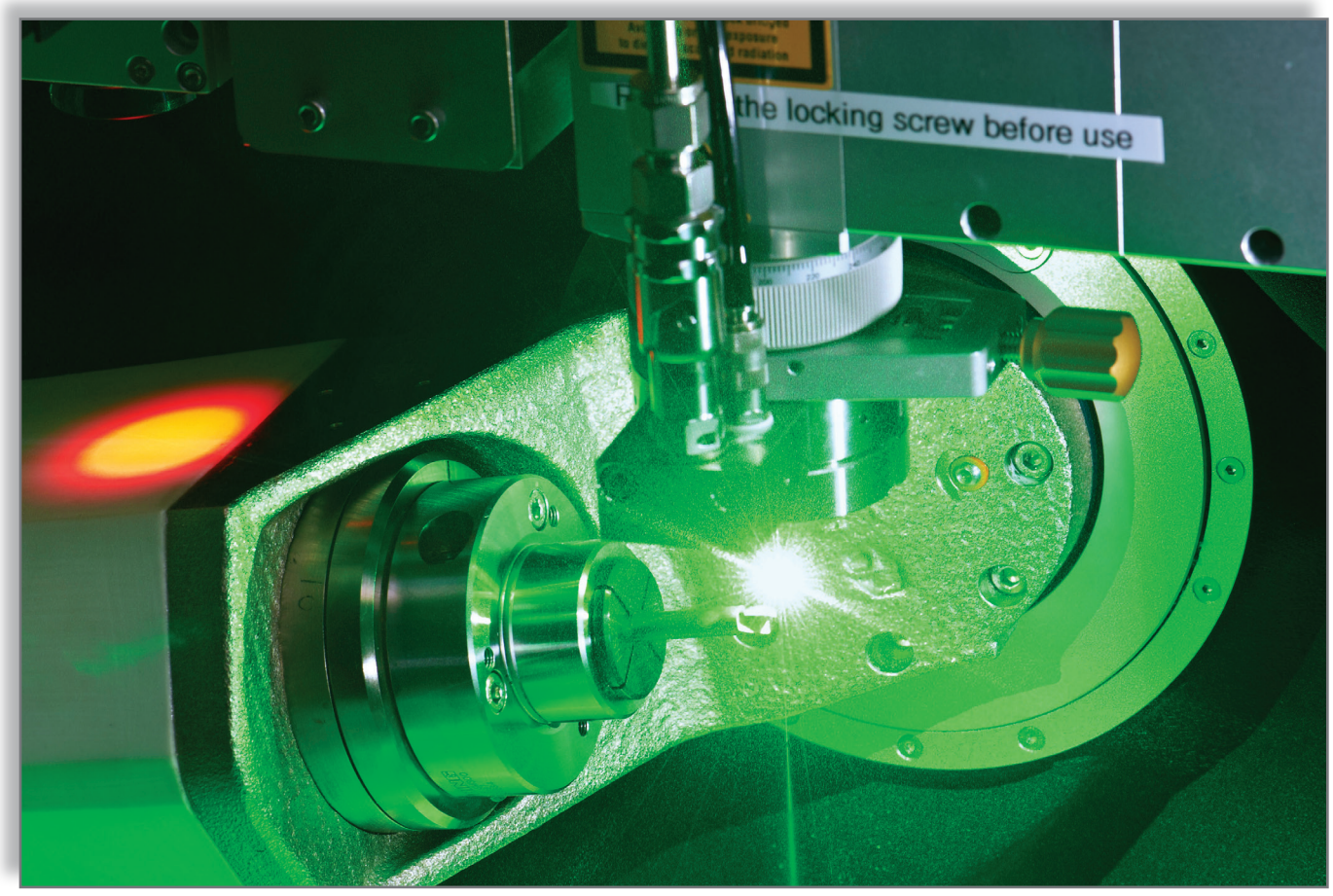


Laser machining of diamond tools

Artificial diamond cutting tools are replacing tungsten carbide and ceramic composites where high quality surface finishes are required. Only laser technologies are capable of machining such materials, which are (like some ceramics) as hard as natural diamonds. The article details on how the Laser MicroJet® (LMJ) technology delivers better performance than traditional dry lasers in machining such materials.

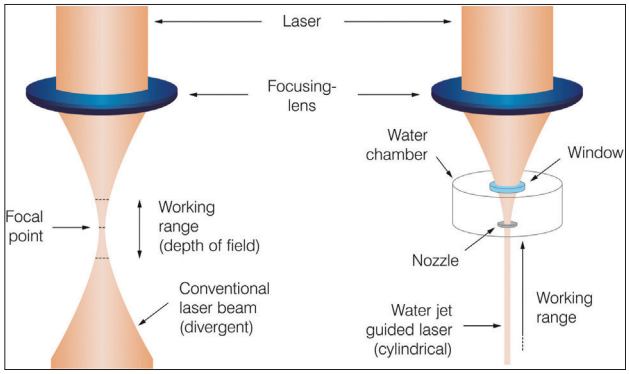
Nitin Shankar
Consultant
Synova SA, Switzerland
nshankar@synova.ch

There is a revolution taking place in the cutting tool industry. Polycrystalline diamond (PCD) and monocrystalline diamond (MCD) cutting tools are finding increasing use in aerospace and automotive applications. For one thing, a PCD tool has a life about 50 to 100 times longer than a ceramic tool. For another, a PCD tool can machine an aluminium alloy piston to a surface finish of within 0.4 µm. A MCD tool has a life about 10 times longer than a PCD tool and can deliver optical grade surface finish to within 0.15 µm. Such performance eliminates the need for grinding and results in manufacturing efficiencies.

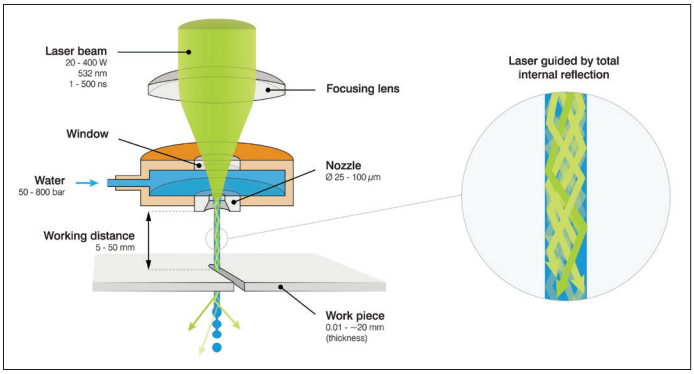
Presently, laser technologies are best suited to machining such ultra-hard materials. Synova's patented LMJ process is capable of precision laser machining without any heat damage from a 10,000°C laser beam.

The fusion of water & light

In the Laser MicroJet system, a laser beam, passing through a pressurised 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



Dry laser vs LMJ wet laser focal length



LMJ Principle

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 optimisation were required to fine-tune the process.

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 works in two stages. The energy of the laser pulses vapourises 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.

In contrast to traditional dry lasers, the LMJ 'wet laser' technology cuts with a parallel beam with a working distance that 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 distance control is required and the working distance is short.

The LMJ process offers several advantages—there is no need for focal adjustment and one obtains parallel kerf sides. There is virtually no heat affected zone, thanks to the cooling effect of the water. Finally, there is a high removal rate with debris washed from the kerf.

5-axis laser machining

The Synova LCS 50-5 laser cutting system (working area: 50 x 50 x 50 mm) can cut extremely hard materials with highest precision. It is a compact machine with 5-axis capability with a user-friendly interface and intuitive CAM software for batch processing of PCD and MCD tools. It can also cut PCD or MCD inserts to a (near or final depending on the application) 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.

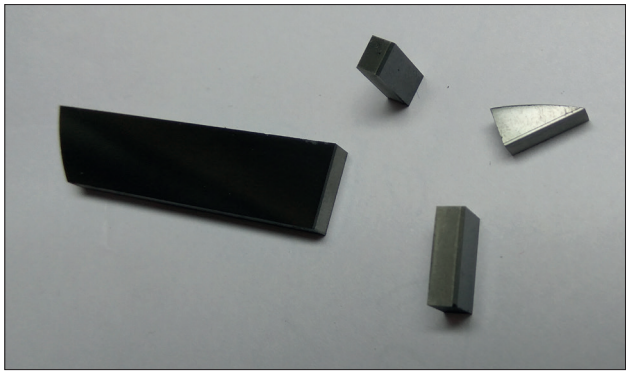
SAI-Impex, Synova's distributor in India, has installed a LCS 50-5 for industrial applications, primarily PCD and MCD tool inserts. L M Van Moppes Diamond Tools India supplied PCD raw material for cutting into tool inserts. The LCS system cut a triangular tool bit in less than 10 minutes. A traditional process such as electro-chemical machining takes three times as long.

According to Mahesh Karger, CEO, SAI-Impex, "The big advantage in Synova's LMJ is the absence of any heat affected zone in the material due to the cooling effect of the water."

Tool insert geometries

The company 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. There are, however, other factors that are essential. PCD and SCD tool edges are either produced as razor-sharp edges or made with a perfect small radius being chip-free.

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. The LMJ



Laser-cut triangular PCD insert

Bakul Limbasiya, CEO, NDE and
Mahesh Karger in front of Synova LCS 150

process achieves an edge waviness of less than 1 µm with 0.5 µm PCD grains.

In addition, the machine's 5-axis capability is able to execute CNC programs with the high degree of precision needed for such cutting tools. The most critical elements are the end cutting and side cutting edges as well as primary clearance angles. MCD tools represent the wave of the future and Synova's LMJ technology allows monocrystalline 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.

At a magnification of 500, the edge waviness is less than 0.5 µm. Such a high quality of surface finish is proof that the LMJ technology is best suited for the laser machining of MCD tool inserts. While cutting trenches are visible on the MCD insert, here brazed on to a holder before the cutting, they have no impact on the surface roughness achieved on the workpiece.

Thanks to its LMJ water jet-guided technology, the heat affected zone is less than 6 microns on diamond materials. Finally, edge micro-cracking and heat affected zone, which occur 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 MCD. Faster cutting means that fewer machines are needed and this translates into reduced capital investment.

The company 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.

In case manufacturers need a high cutting tool edge finish, the company also offers a hybrid solution, which combines the LCS 50-5 with a second operation CNC polisher to achieve a sub-micron (0.1 µm) Ra roughness level.

Local manufacturing

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. It is estimated that the unorganised import of PCD tools from China is around 3 million USD per year.

Sanjay Gupta, Managing Director, Rudrali Hi-Tech Diamond Tools, estimates that the average landed cost of an imported PCD insert is Rs 700 and a MCD insert is Rs 1,200. Although PCD and MCD tool inserts are more expensive, their superior performance and long life justifies the cost. In view of their growing demand, it is important that India develops local manufacturing capacity.

Fortunately, Indian entrepreneurs such as New Diamond Era (NDE) in Surat have invested in reactors to produce monocrystalline laboratory grown diamonds. NDE has installed two Synova laser cutting machines to slice such diamonds before machining the same for industrial applications.

"This process has developed to a point where diamond sizes are getting bigger and raw material prices are going down," observed Gupta. His company has invested in a vacuum brazing furnace as well as grinding facilities to be able to produce high quality diamond tools. "Monocrystalline diamond is the future of the cutting tool business," he further noted. He explained that this wonder material has a longer tool life than PCD, achieves a better surface finish and provides improved dimensional accuracy.

For PCD and MCD tool insert 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! □