Volume Production of Machining Tools Using Laser MicroJet® Technology

Volume production of high precision tools with new 5-axis Laser Machining System LCS 305

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INTRODUCTION:

Industrial 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). As an example, SCD tools have proven their value-add in the super-finishing of ultraprecision optical grade surfaces. In many cases, the use of PCD tool inserts can eliminate grinding operations, thereby improving machining process times. PCD tools have also shown a longer tool life.

Such materials being as hard as natural diamond, lasers are most suitable for machining them. Synova's patented Laser MicroJet® (LMJ) technology delivers better results than conventional dry lasers and has become a benchmark in the processing of diamond materials. In this paper, results achieved in machining diamond inserts are presented. The novel LCS 305 Laser MicroJet system with 5 axes is introduced as a production-ready system to manufacture such tools.

The 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 is simple, years of experimentation and optimization have gone into the industrialization of the process and in the design and manufacturing of advanced machining systems.

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 conventional dry lasers, the LMJ 'wet laser' technology has many advantages. The most important advantage is that the Laser MicroJet cuts with a cylindrical beam (no V-shape) and the cutting depth can reach up to several centimeters. This is not the case with conventional lasers where the focused laser beam has a limited working distance of just a few millimeters 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 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. 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.

The LCS305 Laser Cutting System

The LCS 305 laser cutting system can cut extremely hard materials with high precision and complex shapes. It is a

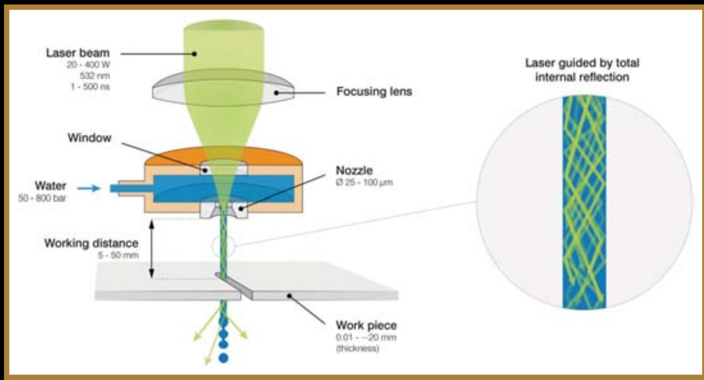

Figure 1: LMJ Technology

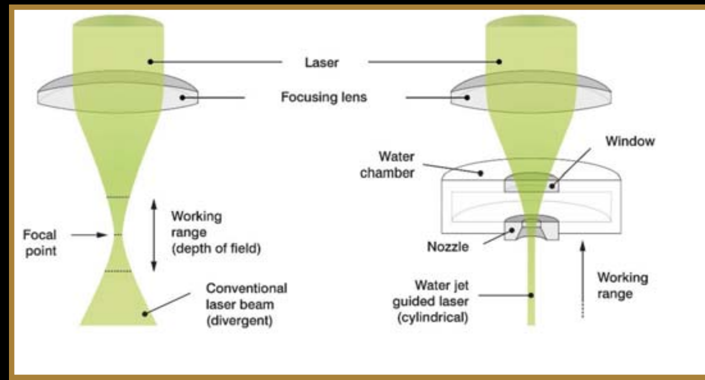

Figure 2: Difference Between Conventional Laser Beam (left) and Water Jet Guided Laser (right)

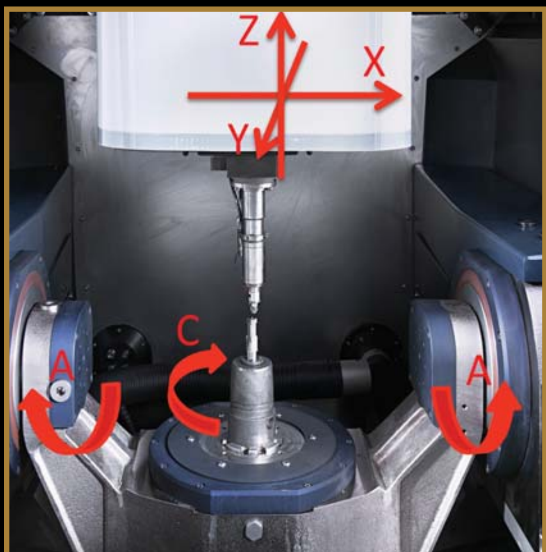

Figure 3: Overview of LCS 305 Axis System

Figure 4: HSK63 Holder

Figure 5: 3D View of Processed Sample

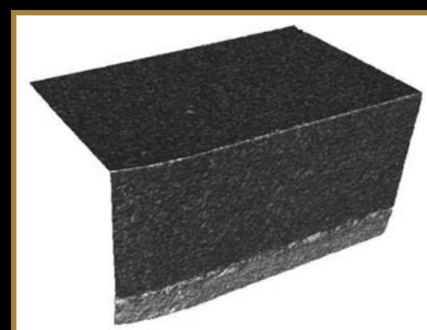

Figure 6: 3D View of Cutting Edge – Alicona Infinite Focus SL

The LCS 305 is designed and manufactured in a way to get the full potential out of the LMJ technology.

5-axis machine with precision components for processing accurate tools. Linear and rotative axes are mounted on separate carrier frames to increase stability at high speed. This results in a dynamic accuracy lower than ± 3 µm and repeatability of ± 1 µm with angular precision of ± 0.9 sec. The LCS 305 is typically configured with an HSK-63 holder, enabling a positioning radial accuracy lower than 3 µm, and an axial accuracy lower than 1µm.

Combined with a unique axis system, it allows a cylindrical working envelope of 130 mm in diameter, with a height of 260 mm. It was designed with highaccuracy machining of hard materials in mind, from small inserts to large rotative tools.

Volume Cutting System

To ensure high-volume manufacturability of hard material tools, the LMJ technology leverages geometrical precision with high-quality finished cutting surfaces, ensuring the manufacturing of a tool that shows a long tool life and optimal performance. The LCS 305 is designed and manufactured in a way to get the full potential out of the LMJ technology, thanks to its axis and holding system. In addition of cutting quality and speed, it is possible to produce parts in volume by eliminating the need for probing or pre-cutting procedures. To generate the data presented in this paper, a production run of 20 samples was done. After one calibration cut, all 20 parts were machined without any additional setup.

Results pertaining to the 20-sample run are presented in the table below. Using the LCS 305, a geometrical tolerance of profile lower than ± 0.1 mm was obtained, versus drawing nominal targets. The achieved surface quality eliminates the need for a subsequent grinding operation.

Edge Radius: 5 µm

Roughness: < 0.300 µm

Overall Cutting Speed: 4.5 mm/min

This test also demonstrated how high precision in primary and secondary clearance angles can be achieved, as shown in the graph and table below. The results are consistent all along the profile path, even if there are

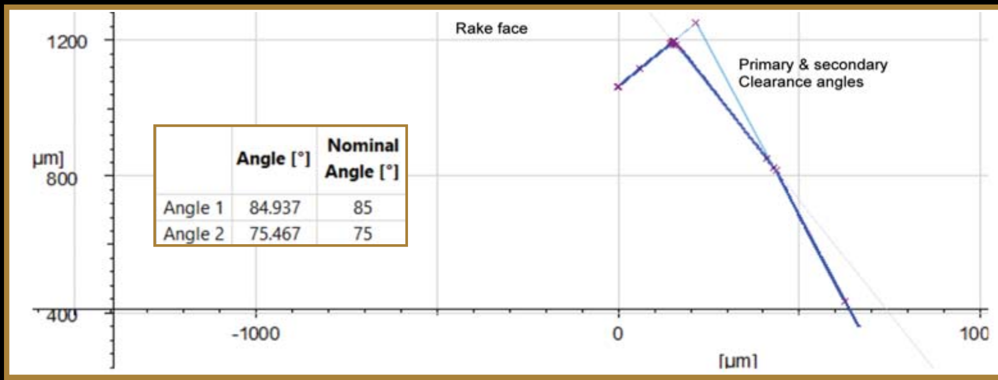

Figure 7: Measure of Cutting Surface (Alicona Infinite Focus SL)

Figure 8: Example of Processed Rotative Tool

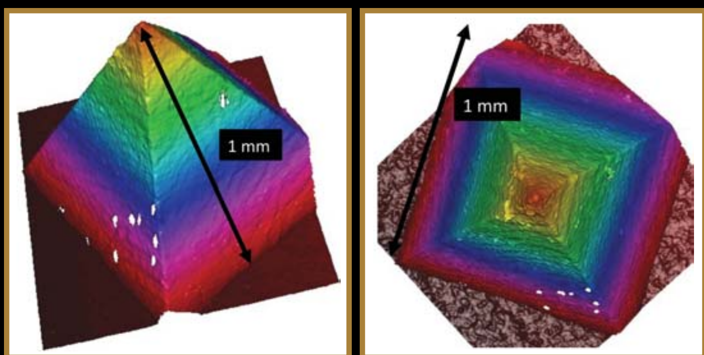

Figure 9: Alicona Measure of Pyramidal 3D Form

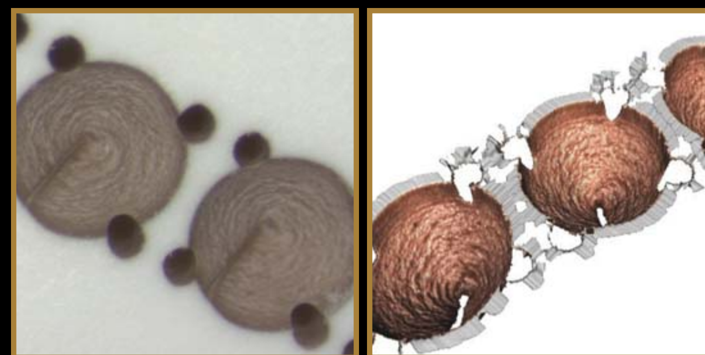

Figure 10: Example of Engraving with LCS 305

CONCLUSION The results shown in this paper highlight the capabilities of the LCS 305. With its 5-axis capability and intuitive CAM software, this advanced system is ideally suited for the machining of super hard materials, able to cut tools of different geometries and size. By using automated setup procedures, a high-precision axis system and holders with high repeatability in positioning, the LCS 305 provides low cost of ownership by reducing the need for operator interventions during volume production. Once calibrated, parts are produced without the need for probing or pre-cutting procedures. The LCS 305 produces parts with high cutting quality that ensure geometrical and surface tolerances. Combined with an overall cutting speed of up to 5 mm/min in PCD, it delivers finished parts at a high rate. In cases where manufacturers need a high cutting-tool edge finish, a hybrid solution can be used whereby an LCS 305 is combined with a CNC polisher. In such cases, a sub - 0.1 um Ra roughness is achievable.

different angles for each face. The same test was performed on rotative tools composed of several inserts. Similar high accuracies were obtained on all inserts of a given tool. The use of an HSK 63 holder guarantees a highly precise positioning. The availability of a fully automated calibration of the LCS 305, along with an optimal repeatability in the process, enables a production with minimum operator coverage and maximum machine availability.

Complex 3D Shaping

The LCS 305 allows complex 3D form-cutting or form-engraving. To demonstrate such capability, small pyramids with a 1 mm square base and 1 mm in height, were cut out of a SiC blank. A production run of 40 pieces was completed in order to demonstrate the repeatability of the process, as well as the uniformity of the cutting profile along the 4 faces. As depicted below, a well-defined peak pyramid, with a roughness of 500 nm on all the faces, was achieved. In addition to 3D cutting, 3D engraving trials were conducted, where blind holes (diameter 0.25 and depth 0.9) and conic shapes (diameter 1.20 and depth 0.85) were ablated (see Figure 11). First, the ablation rate per pass is determined. The number of repeated passes is then adjusted to achieve the desired depth. Repeatability and shape control of this test demonstrate the ability to produce a wide range of high-precision forms by using the LCS 305. ■