REPORT: 5-axis PCD/WC insert cutting by Laser MicroJet ®

For Anonymous

by KURZEN Sébastien, Synova SA

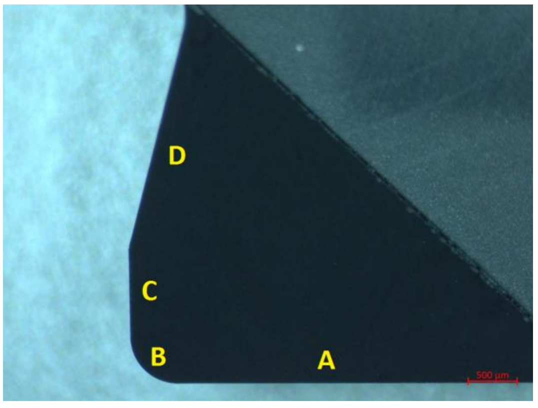
1. TASK

The Laser MicroJet® technology has been used for cutting in simultaneous 5 axes PCD/WC inserts. The aim of these tests was to investigate the possibilities of such a machining technology on 1.52 mm thick cutting tools consisting in two conical clearances.

2. SAMPLE DESCRIPTION

The composition of the inserts is the following:

Material	Polycrystalline diamond (PCD)	Tungsten carbide (WC)	
Thickness	0.51	1.01	*mm*



Picture 1. Macro view from the top of the tool.

Release of application report			
Project Leader		Responsible Application Group	
Name:	KURZEN Sébastien	Name:	Dr Benjamin Carron
Date:	29.01.2016	Date:	29.01.2016
Visum:	SEK	Visum:	BC

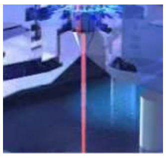
3. PROCESS: INSTRUMENT & TEST PARAMETERS

For these experiments, a 5-axis LCS 50 equipped with a frequency-doubled Nd:YAG laser has been selected as the appropriate machine configuration. This machine allows 3D shaping and 3D finishing of all kinds of hard materials (SCD, PCD, PcBN, carbides, ceramics, etc).

Major advantages of the Laser MicroJet® technology with regards to the tooling industry are:

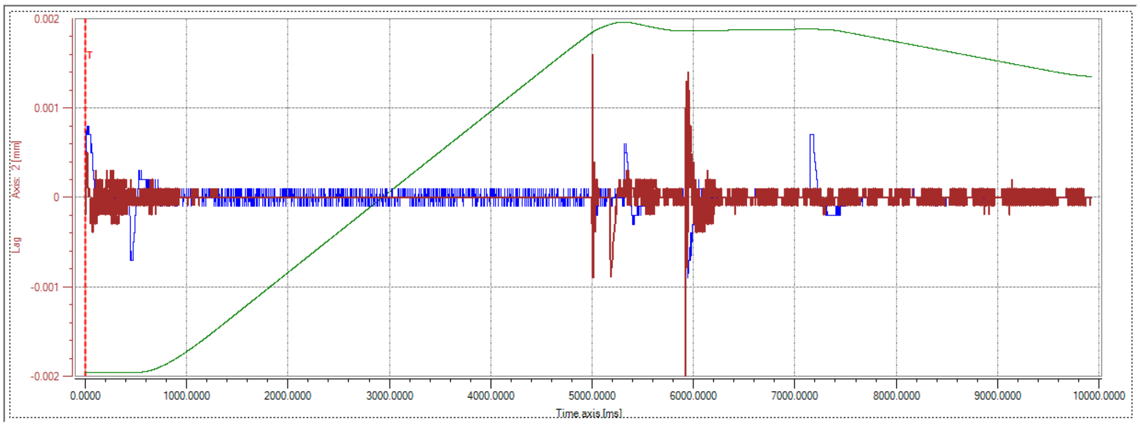
- Ability to cut non-conductive materials (SCD, CVD diamond);
- Low heat damage;
- Homogeneous cut between the diamond layer and the carbide.

The table below summarizes the optimized processing parameters used in the experiments. More details follow in the result section.

	**SYSTEM**	Machine type	5-axis LCS 50	
	**MICROJET® PARAMETERS**	Nozzle diameter	40	*µm*
		Water pressure	400	*bar*
		Working distance	10	*mm*
	**LASER PARAMETERS**	Wavelength	532	*nm*
		Power in jet	7.5	*W*
		Pulse frequency	6	*kHz*
		Pulse width	120	*ns*

4. OPTIMIZATION OF THE CONTROLER PARAMETERS

The CNC parameters have been optimized for the primary clearance cut at a scanning speed of 2 mm/s. As depicted in the graph below, only two oscillations on the Y-axis of the machine go over a 1 µm amplitude, during less than 0.2 second each. For the rest of the program, the lag measurement on X and Y axes exceeds only twice the noise of the measuring instrument.



Picture 2: lag measurement on X (in blue) and Y (in red) axes during the cut of the primary clearance. The green curve is the evolution of X and is used as reference.

5. RESULTS

During this development, the attention was focused on the following criteria:

- Cut flank homogeneity on PCD and WC;
- Cut flank roughness (*Ra* and *Rz*) on PCD;
- Cutting edge radius;
- Primary and secondary clearance angles values;
- Primary clearance depth;
- Straightness of the cutting edge;
- Geometry (length, radius, angles) on the surface;

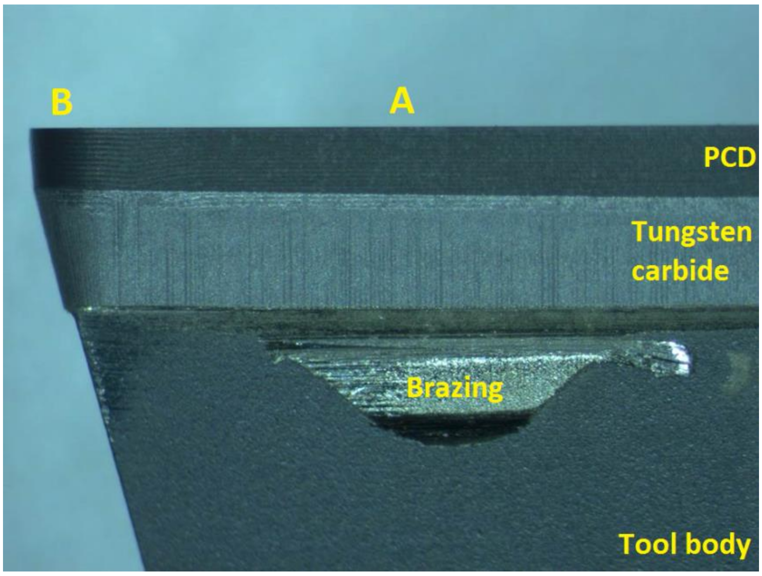
For the different parts of the insert, these criteria were targeted to the following values:

	A	B	C	D
Cut flank homogeneity on PCD and WC (visual)	Best possible			
Cut flank roughness *Ra* on PCD	< 0.4 µm			
Cut flank roughness *Rz* on PCD	< 2 µm			
Cutting edge radius	< 7 µm			
Primary clearance angle	10°	c.c.* 7.5°	5°	5°
Secondary clearance angle	15°	c.c.* 15°	15°	15°
Primary clearance depth	0.51 mm			
Straightness of the cutting edge	Chipping < 3 µm			
Geometry	In tolerances			

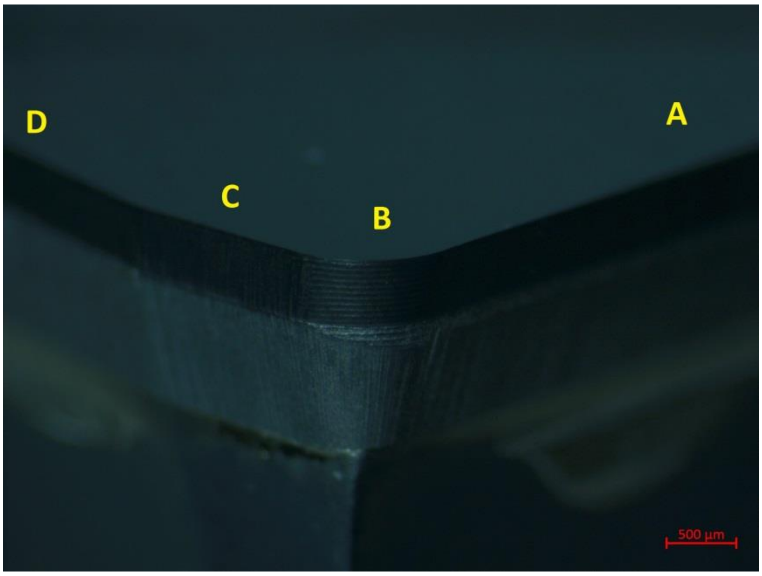
* Conical clearance.

5.1. CUT FLANK HOMOGENEITY

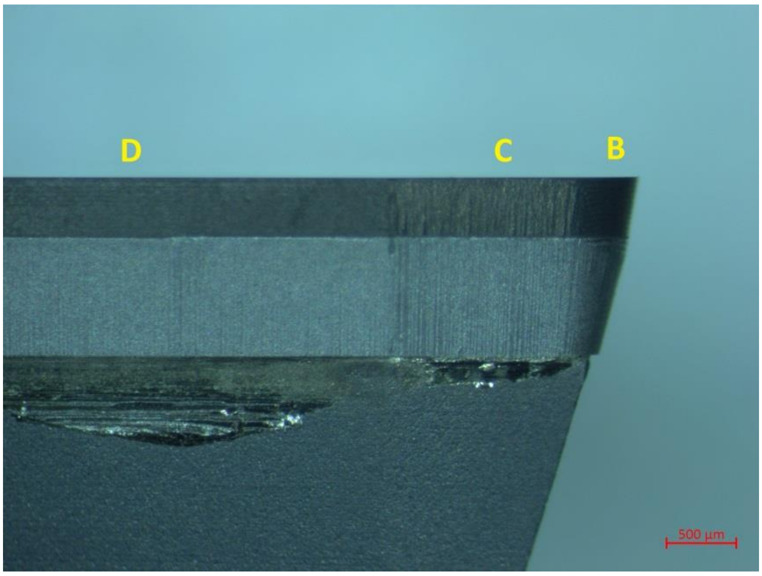
The results presented below are qualitatively focused on the visual aspect of the cut.



Picture 3: Part A and B visual result.



Picture 4: Focus on part B.



Picture 5: Part B, C and D visual result.

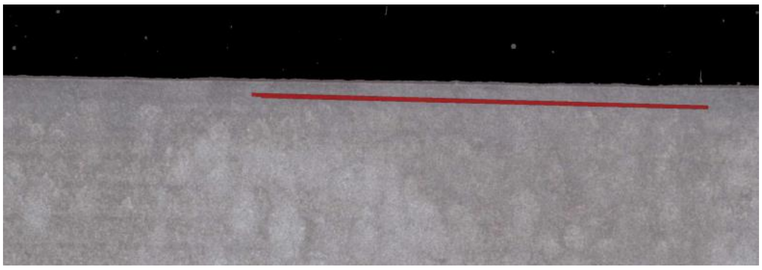
Picture 3 shows vertical lines on the tungsten carbide. We will see in the following that these lines have a very slow depth. Some horizontal lines can also be seen. These are due to the brazing beneath, which requires a higher laser power in this region.

On picture 4, we can easily see the primary and secondary conical clearance angles.

Picture 5 shows the difficulty that induces the brazing in the C region. Nevertheless, a more homogeneous brazing in region D enabled a very good cut quality, as demonstrated in the next section.

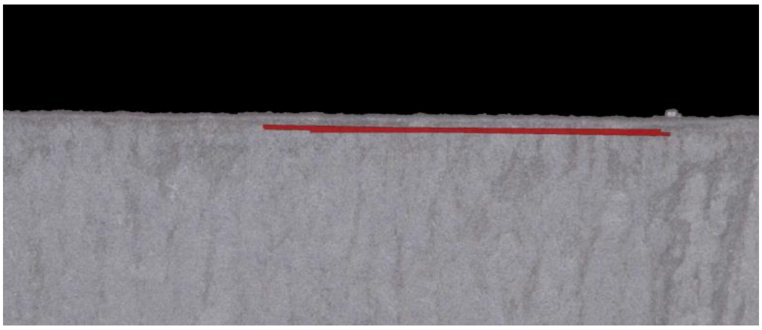
5.2. CUT FLANK ROUGHNESS ON PCD

The roughness is measured with an Alicona microscope equipped with a 20x lens. Measurements are proceeded following the ISO 4288 norm, right below the cutting edge – since this region is the more exposed during the use of the final cutting tool. Only one measurement is done at the center of the PCD thickness to show the homogeneity of the result. Finally, we also present the roughness on the vertical lines in the tungsten carbide.



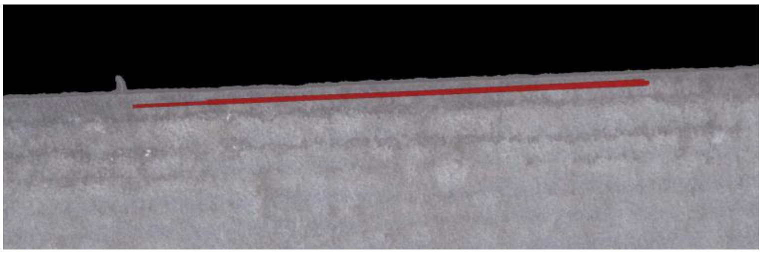
Picture 6: roughness measurement on part A.

Ra	0.18 µm
Rz	1.20 µm



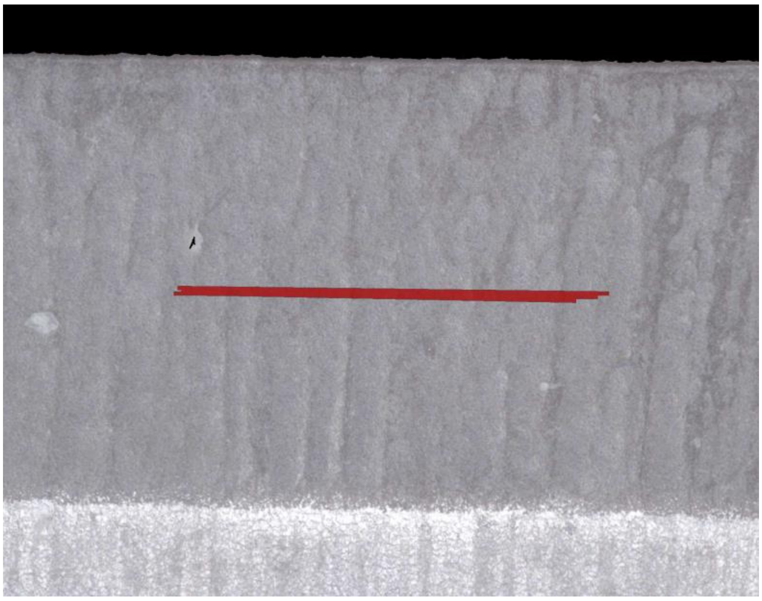
Picture 7: roughness measurement on part C.

Ra	0.33 µm
Rz	1.65 µm



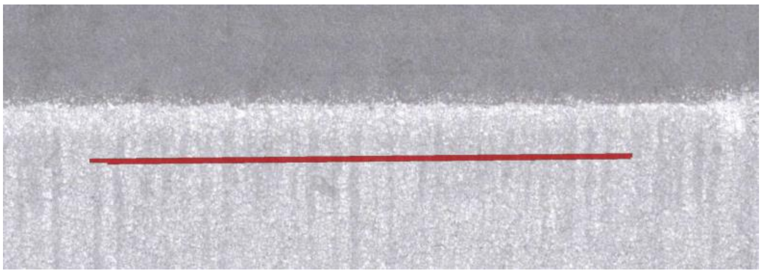
Picture 8: roughness measurement on part D.

Ra	0.14 µm
Rz	0.96 µm



Picture 9: roughness measurement at the center of the PCD thickness, on part C.

Ra	0.32 µm
Rz	1.83 µm



Picture 10: roughness measurement on the tungsten carbide, part D.

Ra	0.24 µm
Rz	1.42 µm

Pictures 6 and 8 show an excellent roughness beneath the cutting edge on parts A and D, with an *Rz* even below 1 µm for the latter.

Despite a visual aspect slightly poorer on part C, pictures 7 and 9 demonstrate that even when irregularities can be seen, the *Ra* and the *Rz* results are still clearly in the target.

Finally, picture 10 shows that the waviness in the tungsten carbide should not be considered as problematic, since the roughness measurements are also in the tolerances. Furthermore, we can notice that the transition between the PCD and the WC is visually very smooth.

5.3. CUTTING EDGE RADIUS

The cutting edge radius of each part of the geometry is presented in the table below.

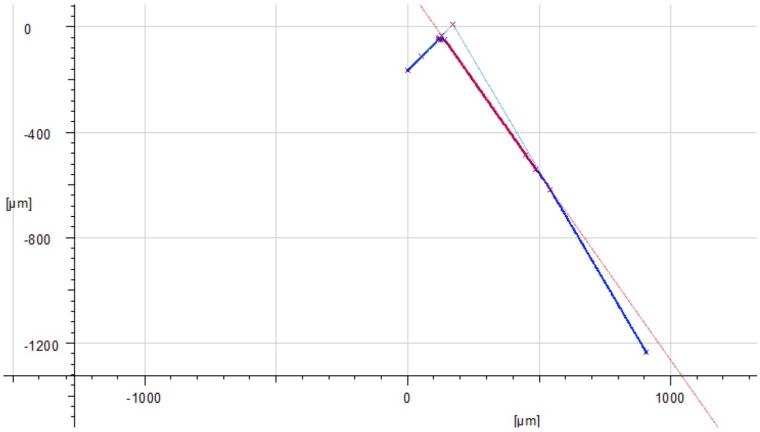
A	B	C	D
8 µm	8 µm	13 µm	8 µm

Except for part C, the cutting edge radius is only 1 µm too big regarding the target value. This is easily explained by the cutting strategy used to solve the brazing issue. With less brazing material to remove beneath the tungsten carbide, the cutting strategy can be adapted and the cutting edge radius can be reduced and reach the target.

This phenomenon is accentuated on part C. The solution is to look for in the same direction: the decrease of the amount of brazing material.

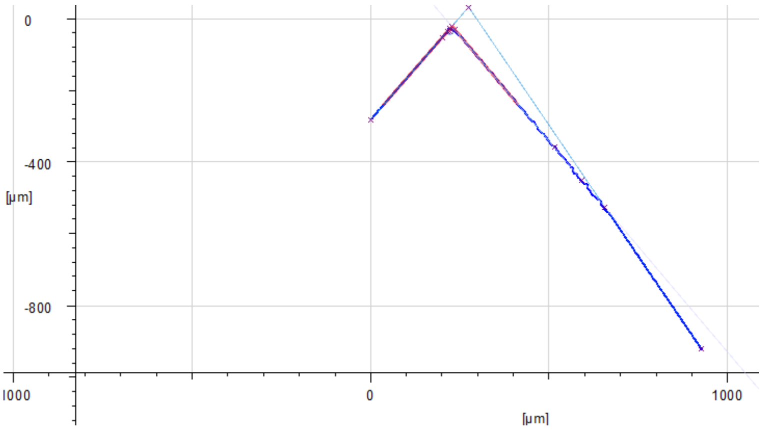
5.4. PRIMARY AND SECONDARY CLEARANCES

In this section, the primary and secondary clearances are presented separately for each part of the geometry.



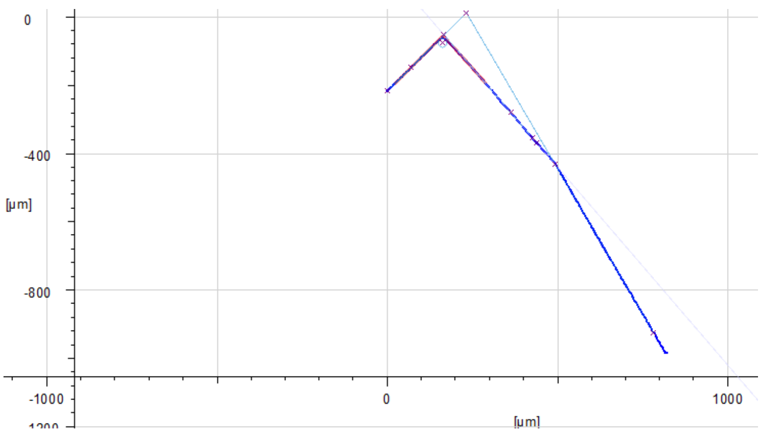
Picture 11: clearances measurement on part A.

	Measured	Wanted
Primary clearance angle	10.4°	10.0 ± 1°
Primary clearance length	0.60 mm	0.51 ± 0.03 mm
Secondary clearance angle	15.2°	15 ± 1°



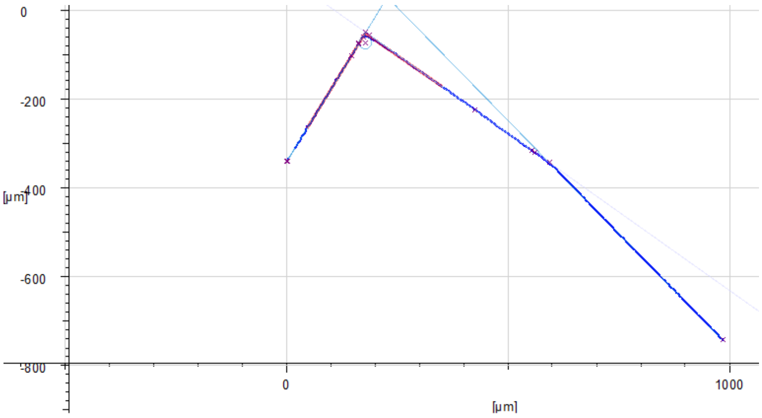
Picture 12: clearances measurement on part B.

	Measured	Wanted
Primary clearance angle	8.7°	Transition between 10° & 5°
Primary clearance length	0.55 mm	0.51 ± 0.03 mm
Secondary clearance angle	14.7°	15 ± 1°



Picture 13: clearances measurement on part C.

	Measured	Wanted
Primary clearance angle	4.1°	5 ± 1°
Primary clearance length	0.42 mm	0.51 ± 0.03 mm
Secondary clearance angle	14.3°	15 ± 1°



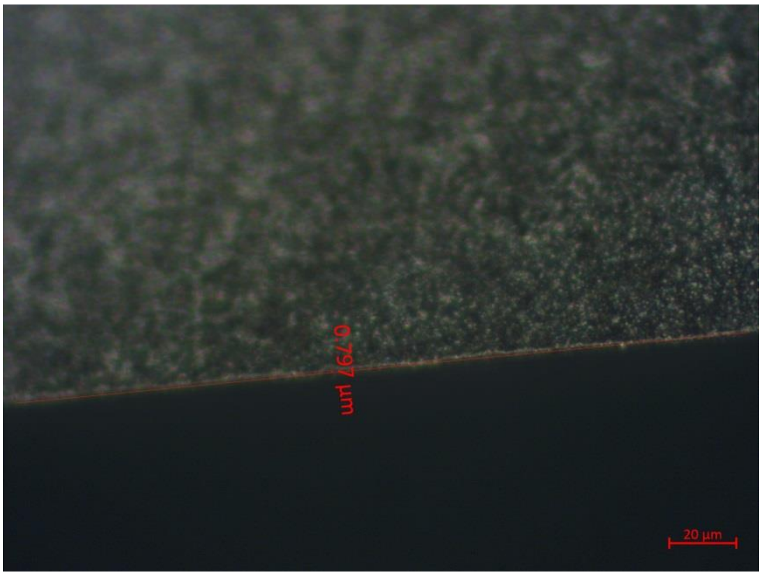
Picture 14: clearances measurement on part D.

	Measured	Wanted
Primary clearance angle	3.9°	5 ± 1°
Primary clearance length	0.45 mm	0.51 ± 0.03 mm
Secondary clearance angle	14.2°	15 ± 1°

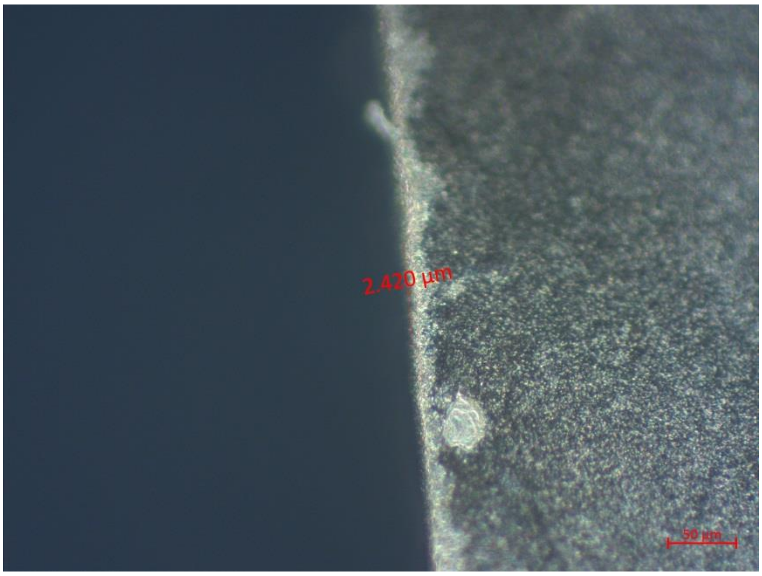
Globally, we can see that the clearance angle values – except for the primary clearance on part D – hit the target everywhere. On the other hand, we observe a varying gap between the wanted value for the primary clearance depth and the measured one on each part of the geometry. This is explained by the complex interaction between the laser light and the tungsten carbide for different inclinations of the sample, when the cutting angle is close. This can be corrected by tuning the machine configuration.

5.5. STRAIGHTNESS OF THE CUTTING EDGE

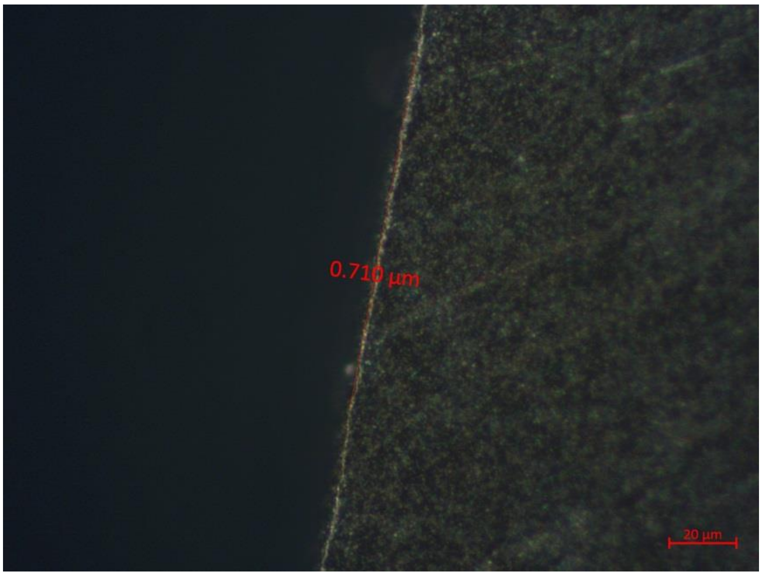
The straightness of the cutting edge is analyzed below for parts A, C and D. Being circular, part B will be discussed in the next section.



Picture 15: straightness analyze on part A.



Picture 16: straightness analyze on part C.

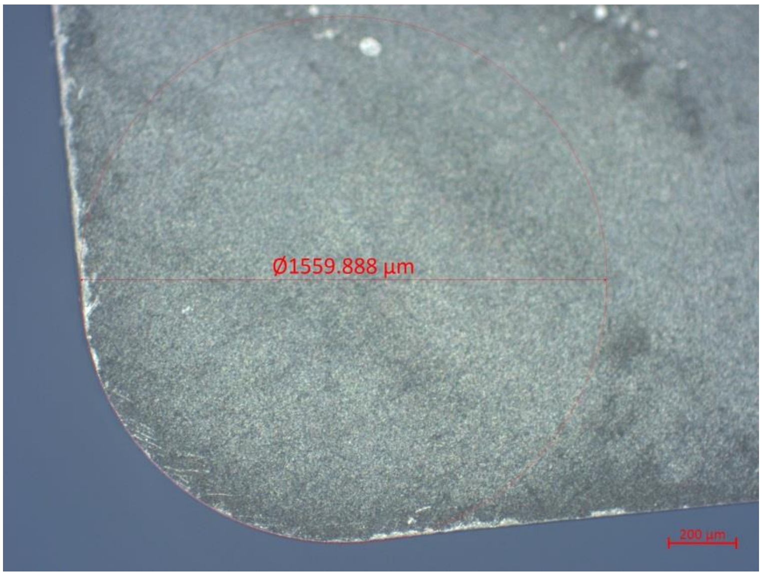


Picture 17: straightness analyze on part D.

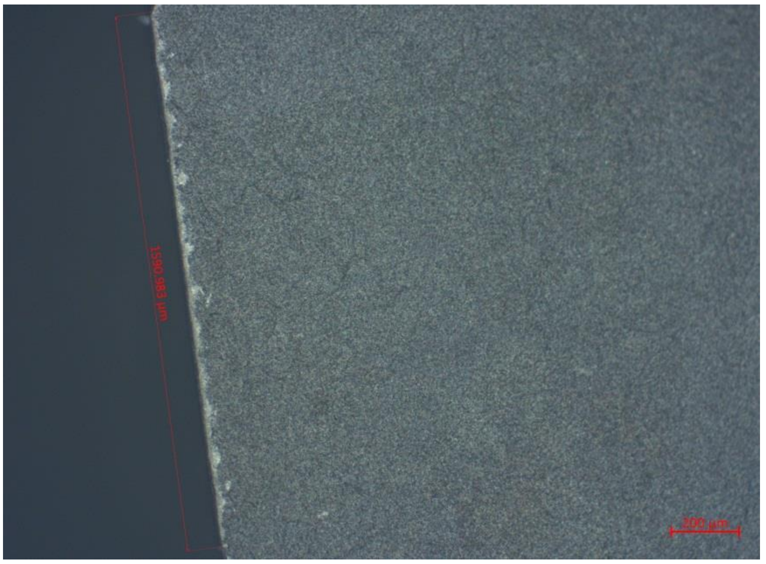
Picture 15, 16 and 17 show that especially on parts A and D, the straightness is excellent with a chipping lower than 1 µm. Part C is a bit more deteriorated as already noticed in pictures 7 and 9 due to the brazing. Nevertheless, the waviness in this region does not exceed 3 µm, which was the objective. Finally, picture 16 can explain the cutting edge radius a bit higher on part C by the white discoloration. The latter is currently under investigation and we have good reasons to believe that, again, with the brazing issue solved, the water jet stability will be optimized as well as the laser parameters and this edge problem should disappear.

5.6. GEOMETRY

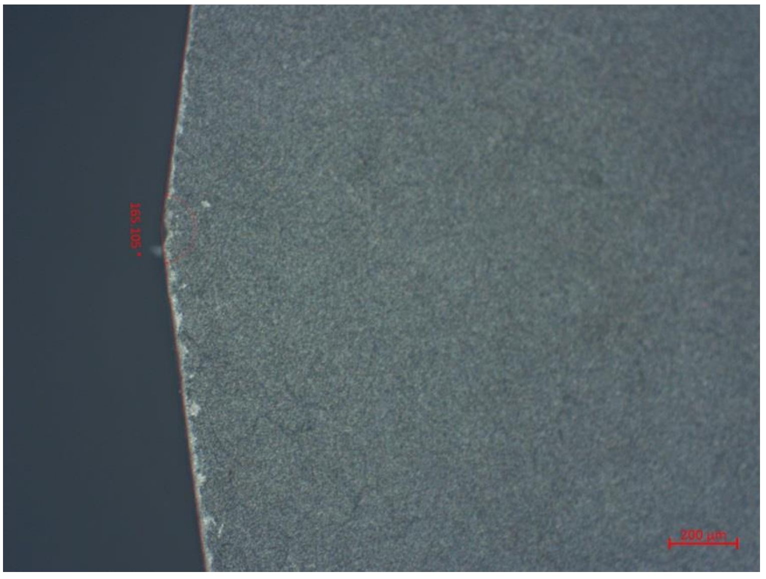
In this last section, we focus our attention on the cut geometry itself. In particular, the diameter of the round corner, the length of part C and the angle between part C and D is measured.



Picture 18: analyze of the part B diameter.



Picture 19: analyze of part C length.



Picture 20: analyze of the angle between parts C and D.

	Measured	Wanted
Diameter of part B	1.56 mm	1.58 ± 0.1 mm
Length of part C	1.59 mm	1.52* mm
Angle between parts C and D	165.1°	165.0° *

*: tolerance not found.

Based on these 3 criteria, we can see that the simultaneous 5-axis machining on an LCS-50 respects the programmed geometry. In such machining conditions, this demonstrates the accuracy of the sample positioning inside the machine by touch probing.

CONCLUSION

The cutting of PCD/WC brazed on a carbide substrate was investigated on a Synova 5-axis LCS 50. This machine is based on the Laser MicroJet® technology and combines the advantages of a high-energy pulsed laser with a hair-thin water jet. While the laser is used for material ablation, the water jet is used for guiding the laser light, cooling the edges and preventing the sample from particle contamination.

These tests have shown that:

- It is possible to get a good visual aspect on the whole cutting flank for both PCD and WC layer;
- The roughness obtained meets the target value;
- The clearance angle values are controlled within 1° accuracy;
- The geometry requirements are respected;
- The cutting edge radius is very close to the wanted value; the latter can be reached as soon as the brazing issue is solved;
- Chipping can be reduced below 1 µm.

Nevertheless, the white discoloration has to be solved but we are confident that it is a problem also related to the well-known brazing problem. We are currently focusing our investigations on that matter and should be able to propose a solution very soon.

We thank you for your interest in our technology and we hope that our results meet your requirements.