REPORT: Nickel superalloy drilling by Laser MicroJet®

for Anonymous

by Ronan Martin, Synova SA

TASK

The Laser MicroJet® technology has been tested for drilling Inconel plates. The two aims of these tests were to drill a 0.8mm hole as fast as possible and to drill the smallest possible hole.

SAMPLE DESCRIPTION

Two small Inconel plates were provided. One plate was used for optimization, and the other one was drilled with the optimized parameters. The plates were held at an angle of 30°.

PLATES	Material	Inconel
	Thickness	4 *mm*

Release of application report			
Project Leader		Responsible Application Group	
Name:	Ronan Martin	Name:	Dr Benjamin Carron
Date:	10.02.2016	Date:	10.02.2016
Visum:	ROM	Visum:	BC

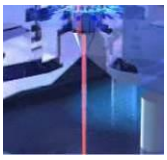
PROCESS: INSTRUMENT & TEST PARAMETERS

For these experiments, an LCS 150 equipped with a dual-cavity frequency-doubled Nd:YAG laser has been used as the machine configuration in our lab. This machine allows cutting most ceramics and any kind of metal.

Major advantages of the Laser MicroJet® technology with regards to your application are:

- Ability to cut non-conductive materials
- Low heat damage
- Advantageous process rate

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

	**SYSTEM**	Machine type	LCS 150
		Head type	Slim
		Diaphragm type	Brass 0.1mm
	**MICROJET® PARAMETERS**	Nozzle diameter	70 *µm*
		MicroJet® diameter	58 *µm*
		Water pressure	0.8mm holes: 400 *bar* 0.5mm holes: 200 *bar*
		Assist gas	He, 0.7 *L/min*
		Working distance	10 *mm*
	**LASER PARAMETERS**	Laser type	L202G
		Wavelength	532 *nm*
		Pulse frequency	8 *kHz*
		Internal power	2 x45 *W*
		Power in jet	64 *W*
		Pulse widths	180 *ns*
		Inter-pulse delay	300 *ns*

A diaphragm (small metal plate put below the nozzle) was used in order to protect the nozzle from particle contamination and from water-jet instabilities due to feedback.

A spiral path is necessary to drill deep holes with a high aspect ratio. In this case, the hole begins to be cut through in the center, and gets progressively wider on the backside, minimizing the taper.

The 0.8mm holes were drilled in three steps in order to optimize the process time:

1) The first step was a full double spiral, as shown in Figure 1A. This step was used to drill through all the central part of the hole.
2) The second step was a modified spiral path, where the central part was omitted in order to optimize the process time, as shown in Figure 1B. This step was used to reduce the taper of the hole.
3) The third step was simply ac circular path, used for the finishing.

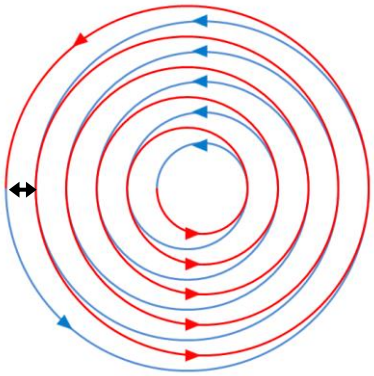


FIGURE 1A: Illustration of the spiral path used for drilling, following first the blue arrows, then the red ones.

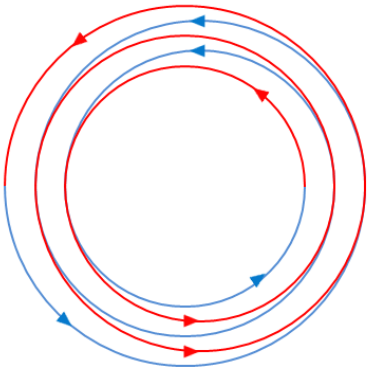
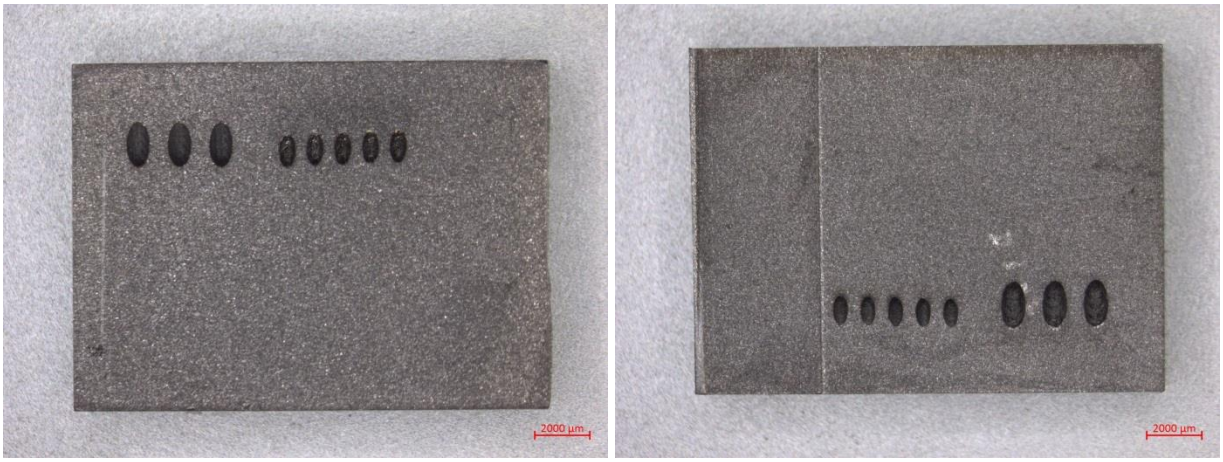


FIGURE 1B: Illustration of the spiral path used for finishing, where the central part of the hole is omitted.

RESULTS - GENERAL

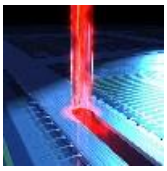
As shown below, three holes were drilled with a diameter of about 0.8mm, and five with a diameter of about 0.5mm. The actual diameters we measured were a bit higher than expected: 0.83mm and 0.53mm.



FIGURES 2A & 2B : Overview of all the holes (left: front side; right: back side)

RESULTS – 0.8mm HOLES

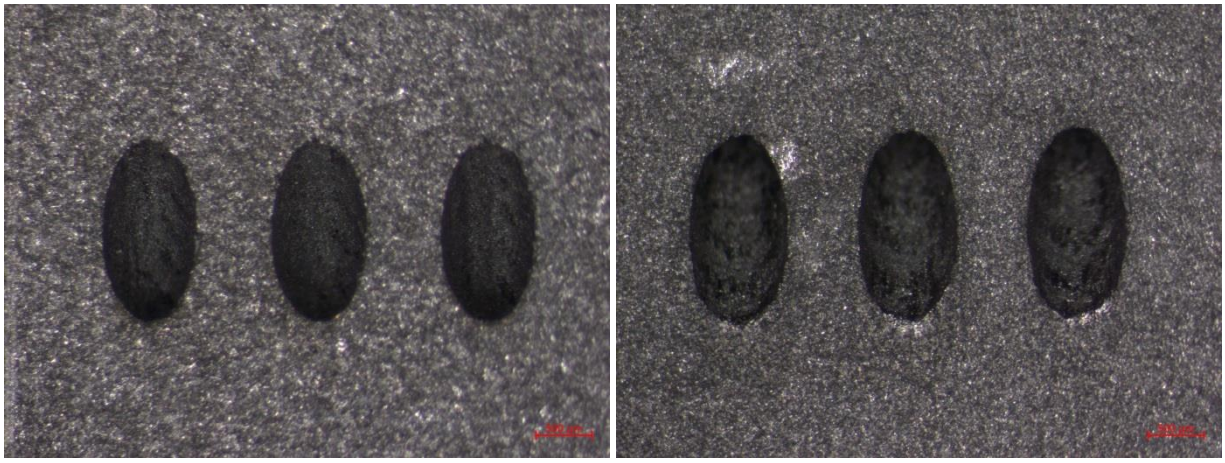
The cutting parameters are presented in the table below. As explained above, three steps were used to optimize the process time.



CUTTING PARAMETERS		**Step 1**	**Step 2**	**Step 3**
	Strategy	Full spiral	Partial spiral	Circle
	Spiral steps	4 x 80 *µm*	2 x 80 *µm*	-
	Motion speed	8 *mm/s*	8 *mm/s*	2 *mm/s*
	Repetitions	28	5	8
	Process time	48 *s*	9 *s*	13 *s*
	Total time	**70 *s***		

The process time has been significantly reduced compared to the previous results. It takes 70 seconds to drill these holes.

The pictures below show in more detail the quality that was obtained. Although we focused on the process speed, the hole shape is well defined, and recast seems negligible.

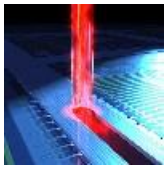


FIGURES 3A & 3B : Overview of the 0.8mm holes (left: front side; right: back side)

RESULTS – 0.5mm HOLES

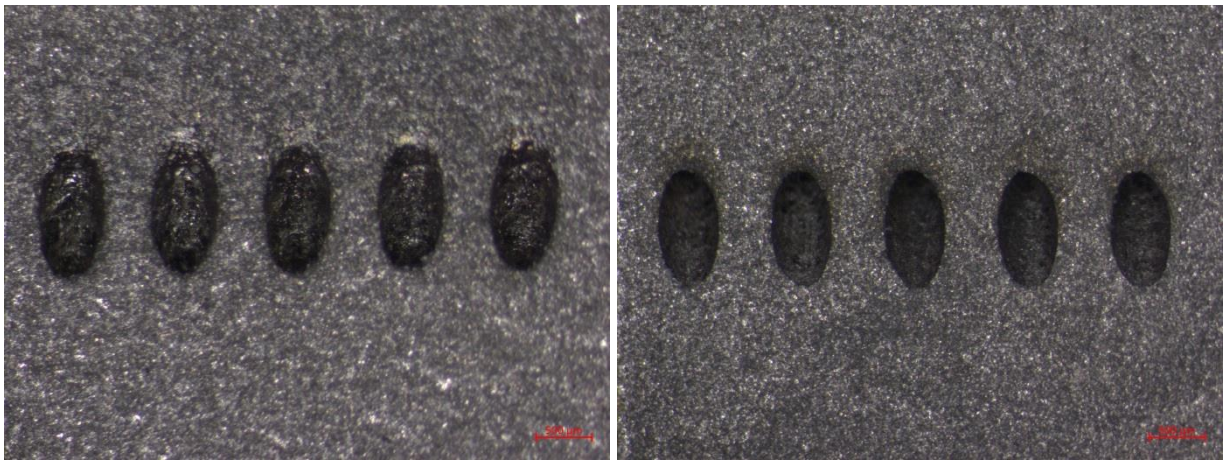
The cutting parameters are presented in the table below. Since optimizing the process time was not the aim of these tests, we just used a full spiral path.

In order to reach smaller diameters, we had to decrease the water pressure. The most efficient way would be to use smaller nozzle diameter, but such nozzles were not available yet for the optical head we used.



CUTTING PARAMETERS		
	Strategy	Full spiral
	Spiral steps	5 x 40 *µm*
	Motion speed	4 *mm/s*
	Repetitions	~ 100
	Breakthrough time	130 – 150 *s*
	Total time	**~ 4 *min***

The pictures below show in more detail the quality that was obtained. The quality is similar to the previous results.



FIGURES 4A & 4B : Overview of the 0.5mm holes (left: front side; right: back side)

CONCLUSION

The drilling of Inconel plates was investigated on a Synova LCS 150. 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, performed in a 4mm-thick plate held at 30°, have shown that:

- It is possible to drill and finish a 0.8mm hole in 70s,
- The process time is significantly decreased compared to the previous results,
- A diameter of about 0.5mm can be reached with the same setup.

Drilling even smaller holes (down to 0.3mm) would be possible using a smaller nozzle diameter.

We thank you for your interest in our technology and we hope that our results meet your requirements. We will contact you soon to obtain a feedback about the analysis of these results and to discuss with you the further steps