SYNOVA
Ch. Dent-d'Oche
CH-1024 Ecublens
Switzerland
www.synova.ch

APPLICATION REPORT

Report No: 1210-14
Sample No: 2.2.1182

CONFIDENTIAL

REPORT: Inconel drilling by Laser MicroJet®

for attention of Anonymous

by Ronan Martin, Synova SA

TASK

The Laser MicroJet® technology has been tested for drilling inconel plates of two different thicknesses: 1.2mm and 3mm. The holes were drilled with an incidence angle of 30° (which doubles the effective thickness). After the tests, the samples were taken back by the customer for evaluation, so the purpose of the present report is essentially to give a summary of the parameters used during the various tests for future reference.

PROCESS: INSTRUMENT & TEST PARAMETERS

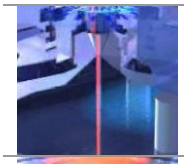
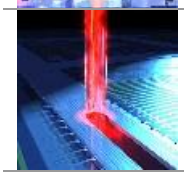
For these experiments, an LCS 300 equipped with a frequency-doubled Q-switched Nd:YAG laser with dual cavity has been used as the machine configuration in our lab. It is a manually loaded machine, allowing cutting and drilling any kind of metal part.

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

- Cutting of non-conductive materials
- Cutting of arbitrary shapes
- Low heat damage to the material
- Low contamination

In the table below, the usual processing parameters used in the experiments are summarized. More details concerning each sample are given in their respective sections.

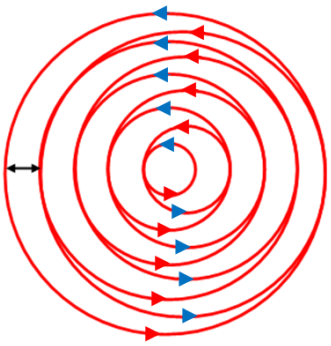
Release of application report			
	Project Leader		Responsible Application Group
Name:	Ronan Martin	Name:	Benjamin Carron
Date:	31.10.2012	Date:	31.10.2012
Visum:	ROM	Visum:	BC

	**SYSTEM**	Machine type	LCS 300	
	**MICROJET® PARAMETERS**	Nozzle diameter	60	*µm*
		MicroJet® diameter	50	*µm*
		Water pressure	180 / 200	*bar*
		Assist gas	He	
	**LASER PARAMETERS**	Laser type	L202G	
		Wavelength	532	*nm*
		Pulse frequency	14	*kHz*
		Average power	60 — 120	*W*
	**CUTTING PARAMETERS**	Working distance	10	*mm*
		Motion speed	0.5 — 3	*mm/s*
		Step for spiral drilling	30	*µm*

The 120W power was obtained by combining pulses of both cavities, with a peak-to-peak delay of about 230ns.

All the holes in the thinner plate were drilled using a circular path (trepanning).

On the other hand, a spiral path, as illustrated in the picture below, was found to be more efficient in the thicker plate. In that case, the path first follows the red arrows (inwards) and then blue arrows (outwards). The 30µm step value given in the table above corresponds to the distance indicated by the black double arrow. It corresponds to half of the nozzle diameter. In this case, the hole begins to be cut through in the center, and gets progressively wider on the backside, minimizing the taper. An advantage of the spiral drilling is that it produces no waste part that could fall.



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

In order to protect the nozzle from contamination and waterjet instabilities, a diaphragm was used. This is a small metal sheet that is fixed under the coupling unit and where a small hole is drilled by the Laser MicroJet®.

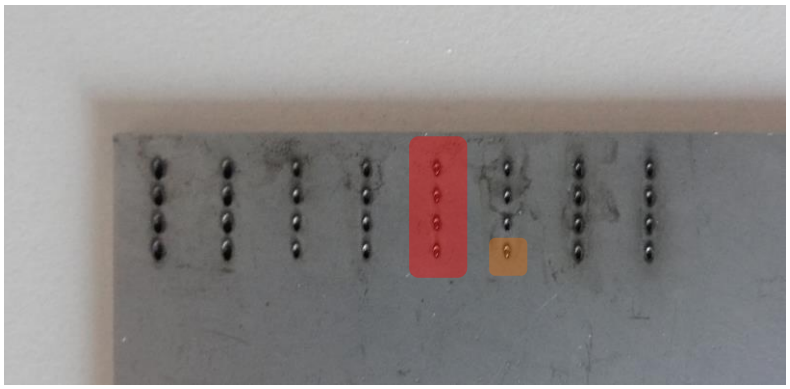
RESULTS

- **1.2mm plate**

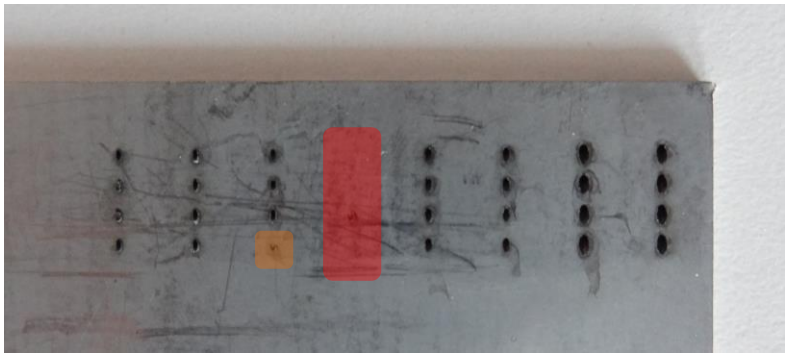
Eight columns of four identical holes were processed in the thinner plate. The parameters for each column are given in the table below. The columns are numbered from the left to the right as seen on picture 2A. As seen in picture 2B, the holes in column 5 (highlighted in red) were not drilled through due to an insufficient number of passes. The number of passes was therefore increased in column 6, but one hole (highlighted in orange) was still not perfectly drilled through. The power was therefore increased for the last two columns.

Please notice that the radius values given below are the input ones. The effective radii should be about 40µm larger.

The quality was good, with limited heat damage. Heat damaged could be further limited by using a lower power for the first few scans. (This strategy is particularly useful when there is a ceramic coating.)



PICTURE 2A: Close-up on the frontside of the thinner plate.



PICTURE 2B: Close-up on the backside of the thinner plate

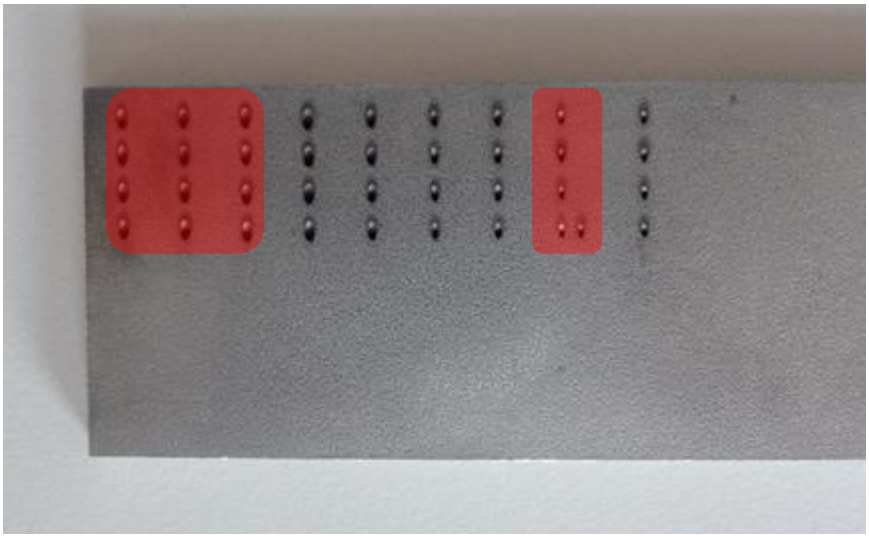
Column	Radius (mm)	Pressure (bar)	Power (W)	Speed (mm/s)	Passes	Time per hole (s)	All holes through?
1	0.30	180	60	1	12	27	Yes
2	0.30	180	60	1	10	23	Yes
3	0.20	180	60	1	20	28	Yes
4	0.20	180	60	1	18	26	Yes
5	0.15	180	60	0.5	28	57	None
6	0.15	180	60	0.5	32	66	Not perfectly
7	0.15	180	120	0.5	18	39	Yes
8	0.15	180	120	0.5	16	35	Yes

- **3mm plate**

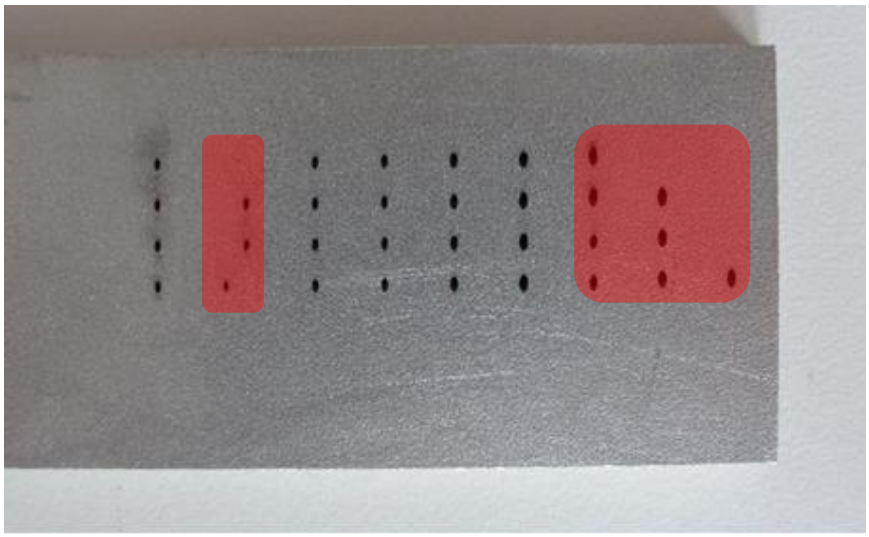
Nine columns, numbered from the left to the right as seen on picture 3A, were processed in the thicker plate. All rows consist of four holes, except for column 8 which has five of them. Columns 1, 2, 3 and 8 (highlighted in red in the pictures and the table below) were used for optimization. The parameters are therefore not the same for all the holes, and a few holes are not cut through, as seen in picture 3B. The parameters for each column (and each hole if relevant) are given in the table below.

Please notice that the radius values given below are the input ones. The effective radii should be about 40µm larger on the frontside. However, the diameters on the backside are smaller than on the frontside. The difference can be minimized by increasing the number of passes or the power. (With a 5-axis machine, one could even imagine to modify the spiral path in order to get perfectly cylindrical holes.)

The nozzle had to be replaced after the second hole of column 3 for optimal performances (probably because of the prototype objective we used in the tests). Using a 80µm nozzle could certainly help to decrease the process time.



PICTURE 3A: Close-up on the frontside of the thicker plate.



PICTURE 3B: Close-up on the backside of the thicker plate

Column	Radius (mm)	Pressure (bar)	Power (W)	Speed (mm/s)	Passes	Time per hole (s)	All holes through?
1	0.35	180	60	3	10/10/10/20		No
2	0.35	180	70	3	12/20/15/15		No
3	0.35	200	70	3	15/15/10/10		Yes
4	0.35	200	70	3	10	90	Yes
5	0.30	200	70	3	12	81	Yes
6	0.25	200	70	3	18	85	Yes
7	0.25	200	70	3	15	71	Yes
8	0.20	200	70	3/1/1/2/2	30/20/15/25/30		No
9	0.20	200	70	1	18	159	Yes

CONCLUSION

The feasibility of drilling holes in inconel with a 30° incidence angle was investigated for different hole diameters and material thicknesses in a series of tests in the presence of the customer.

- In the thinner plate (1.2mm), the smallest holes were processed with an input radius of 0.15mm (in 35s), and the lowest process time was 23s (for a radius of 0.30mm).
- In the thicker plate (3mm), the smallest holes were processed with an input radius of 0.20mm (in 159s), and the lowest process time was 71s (for a radius of 0.25mm).

We thank you for your interest in our technology. Our sales manager will contact you soon to receive your feedback and the analysis of these results and to discuss the further steps.