REPORT: Hole drilling in nickel superalloy by Laser MicroJet®

for attention of Anonymous

by Ronan Martin, Synova SA

TASK

The Laser MicroJet® technology has been tested on nickel-superalloy turbine blades. The aim was to drill holes without backstrike, i.e. without damaging the inner walls of the blades.

SAMPLE DESCRIPTION AND PREPARATION

Five parts were provided. We decided to drill one column of 0.4mm diameter holes on the edge of each one. The cut edge was cut off so that we could see the wall opposite to the holes.

BLADE	Material	nickel superalloy
	Wall thickness	1–1.5 *mm*
	Quantity	5 *pcs*

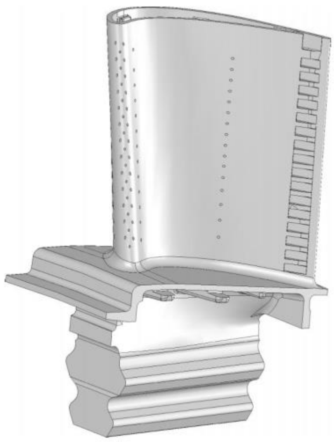

FIGURE A: Drawing of the blade with processed holes

Release of application report			
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PROCESS: INSTRUMENT & TEST PARAMETERS

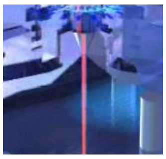
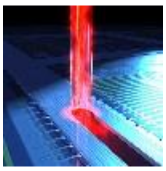
For these experiments, a DCS 300 equipped with a frequency-doubled Q-switched Nd:YAG laser has been used as the machine configuration in our lab. It is a manually loaded machine, allowing cutting and drilling any kind of metal piece.

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

- Cutting of non-conductive materials (such as ceramic coating)
- Advantageous process rates
- Cutting of arbitrary shapes
- Low heat damage to the material

In the table below, the optimized processing parameters used in the experiments are summarized. Specific details about each sample are given further in the result section.

The initial test were done with a rather standard setup, while the following tests were performed with a setup as close as possible as with a compact head (see Figure B): we used an adaptor to put the same nozzle nut and diaphragm nut, used a different collimator lens in order to get a similar spot size and used a 50µm nozzle.

	**SYSTEM**	Machine type	DCS300	
		Collimator	250 *mm*	150 *mm*
		Coupling unit	Thin ("hat-shape")	Thin, with nozzle nut from compact head
		Diaphragm	Yes	Yes, with diaphragm nut from compact head
	**MICROJET PARAMETERS**	Nozzle diameter	30 *µm*	50 *µm*
		MicroJet diameter	25 *µm*	42 *µm*
		Water pressure	300 *Bar*	140 *bar*
		Working distance	8 *mm*	9 *mm*
		Assist gas	Helium, 0.9 *L/min*	Air, 0.9 *L/min*
	**LASER PARAMETERS**	Laser type	L101G	
		Wavelength	532 *nm*	
		Frequency	10 *kHz*	
		Power in jet	15 *W*	19 *W*
		Pulse widths	335 *ns*	315 *ns*
	**CUTTING PARAMETERS**	Motion speed	2 *mm/s*	2 *mm/s*
		Step for spiral drilling	15 *µm*	25 *µm*
		Number of double spiral per drilling cycle	10	20
		Time per drilling cycle	76 *s*	84 *s*

The samples were glued on a goniometer, and the holes were positioned visually and therefore rather imprecisely. Moreover, because of the geometrical limitations of the machine, we could not drill all the holes in one column.

FIGURE B: Coupling unit setups used with the 30µm nozzle (left) and the 50µm nozzle (right)

Because of the imprecise positioning, we had to move at a position above the sample, execute a first drilling cycle, and then if the cycle was not enough, decrease the working distance by 0.5mm and repeat, and so on.

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. This is a standard procedure in this type of application.

Like previously, all the holes were drilled using a spiral path, as illustrated in the picture below, where the path first follows the blue arrows (inwards) and then red arrows (outwards). The 15µm or 25µm 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.

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

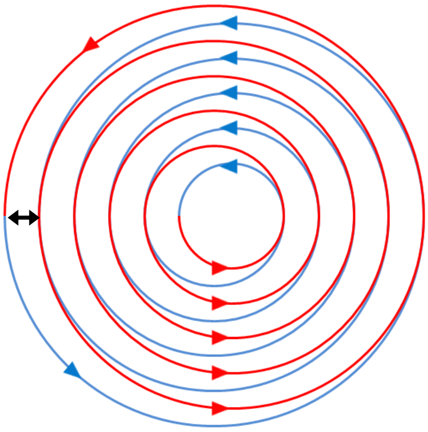


FIGURE C: Illustration of the path used for spiral drilling, following first the blue arrows, then the red ones.

RESULTS

- **BLADE 1**

Five holes were drilled in Blade 1, with a 30µm nozzle as detailed in the parameter table above. This first try provided good results, since no backstrike could be observed inside the blade. The Raman light indicated that the water jet had a rather sudden break-up.

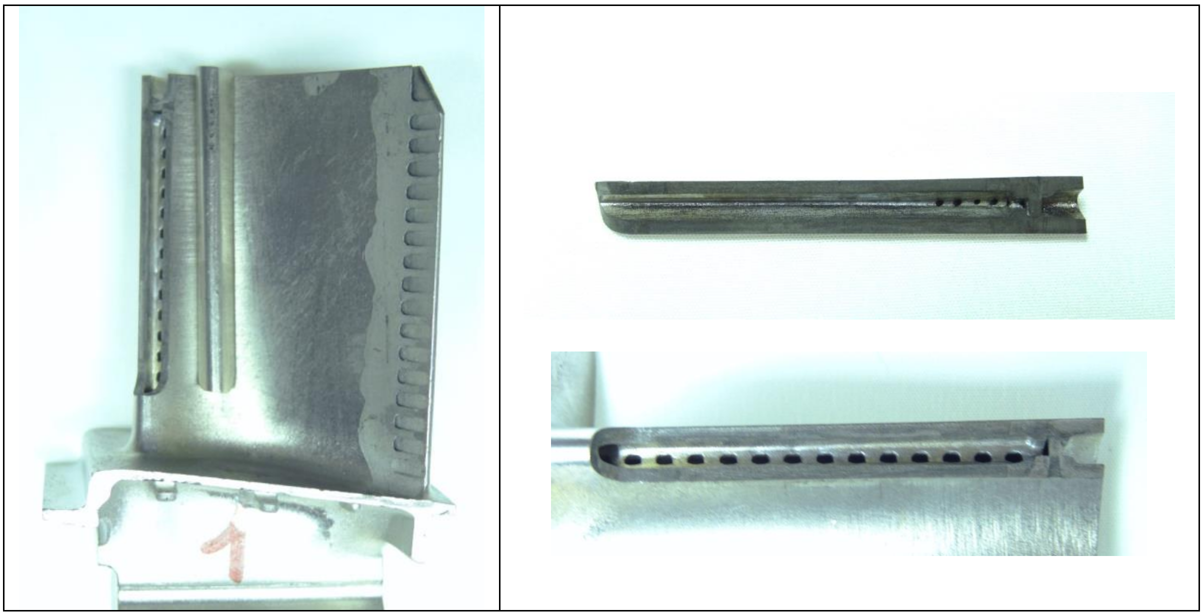


FIGURE 1: Five holes drilled in Blade 1 with a 30µm nozzle, showing no sign of backstrike.

The 30µm nozzle provided good results, but the water jet was short. This worked well in this experimental setup, because we used a coupling unit with a very small dead zone below the nozzle, and because we drilled holes only at the top of the blade. But in production, we would need to be further away from the nozzle in order to be able to drill all the holes. That is why we changed the setup for the following tests.

- **BLADE 2**

In order to get closer to what can be used in the final machine, we used a 50µm nozzle and adapted a nozzle nut and diaphragm nut from the compact optical head on the coupling unit. We also changed the collimator lens in order to get the same spot dimension as in the optical head.

Thirteen holes were drilled in Blade 2 using this new setup. In this case helium was used as assist gas. As seen below, there was some slight sign of backstrike.

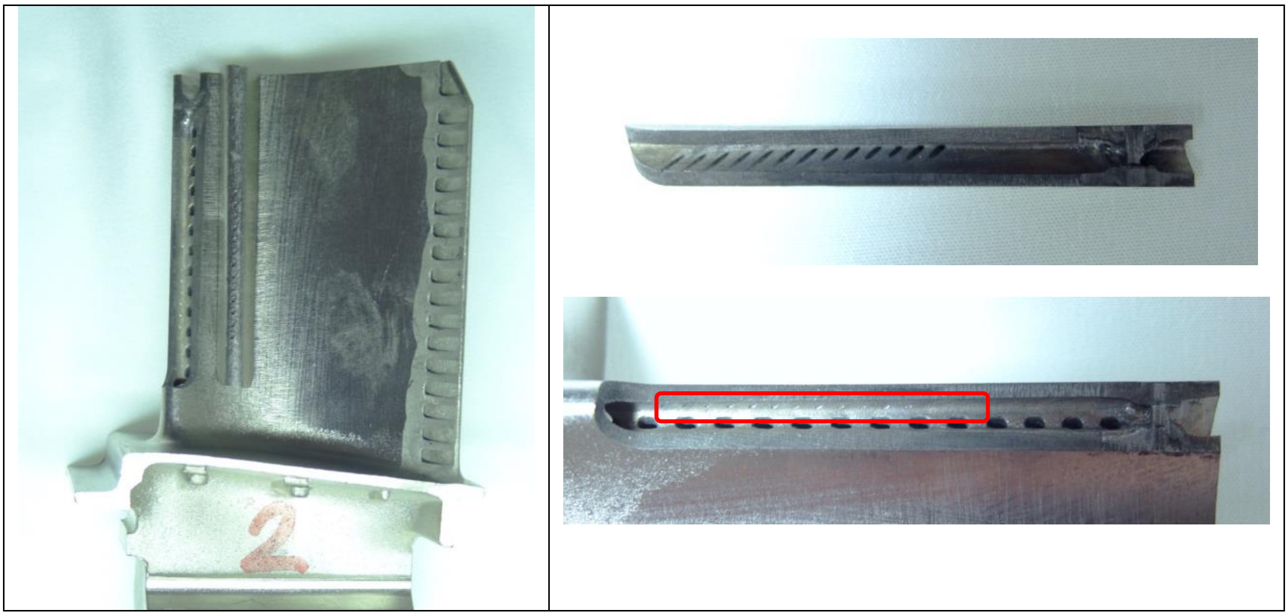


FIGURE 2: Thirteen holes drilled in Blade 2 with a 50µm nozzle and helium as assist gas, showing some very limited backstrike, as outlined in red.

After checking the Raman light, we observed that the water jet break-up was not so well defined as previously. But by switching from helium to air, it looked better. That is why we used air in the following tests.

- **BLADE 3**

Using the same setup as for Blade 2, but with air instead of helium, we drilled twelve holes in Blade 3. This time, no backstrike could be observed at all.

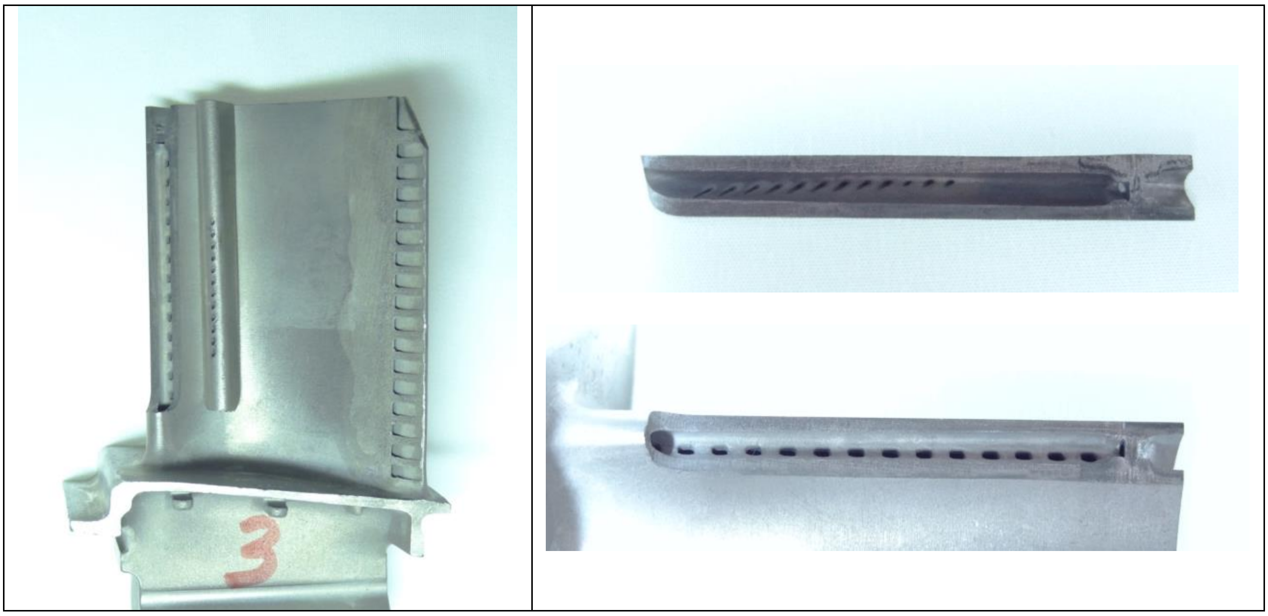


FIGURE 3: Twelve holes drilled in Blade 3 with a 50µm nozzle and air as assist gas, showing no sign of backstrike.

- **BLADE 4**

We tried to repeat the previous results with a better positioning of the holes, but it was unfortunately worse. Still, after drilling nine holes in Blade 4, no backstrike could be seen.

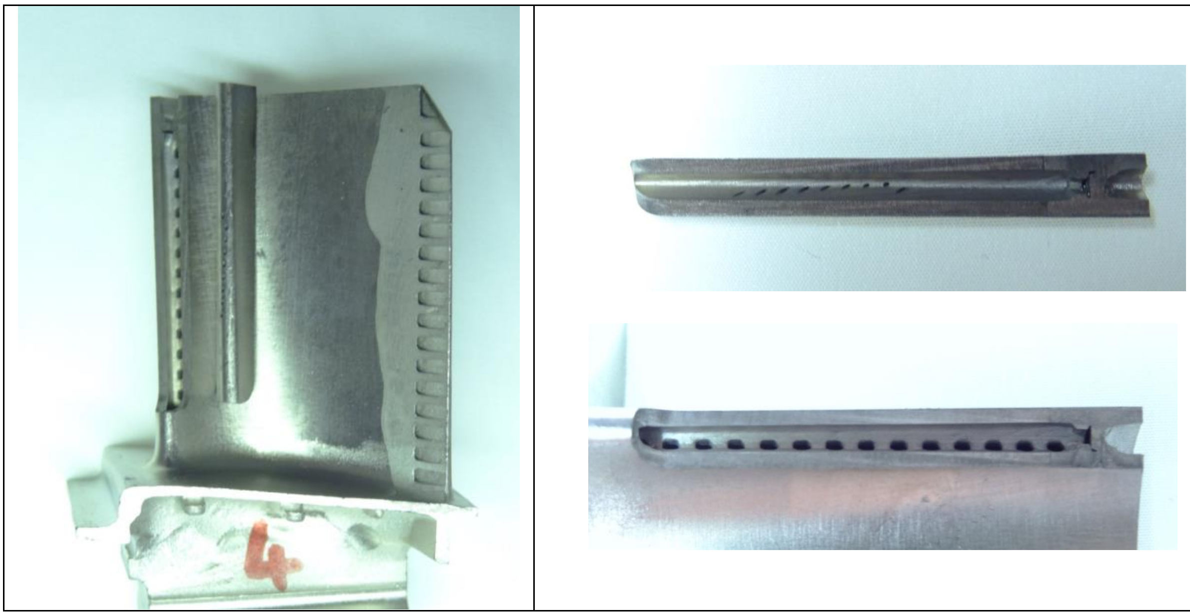


FIGURE 4: Nine holes drilled in Blade 4 with a 50µm nozzle and air as assist gas.
The holes are very poorly positioned, but there is no sign of backstrike.

- **BLADE 5**

We tried again to repeat the previous results with a better positioning of the holes, but it was again unsuccessful in that regard. (It appeared that the water jet angle in our setup should have been adjusted.) Fourteen holes were drilled in Blade 5, the first one having been drilled using helium as assist gas instead air. No backstrike could be seen, except for the first hole.

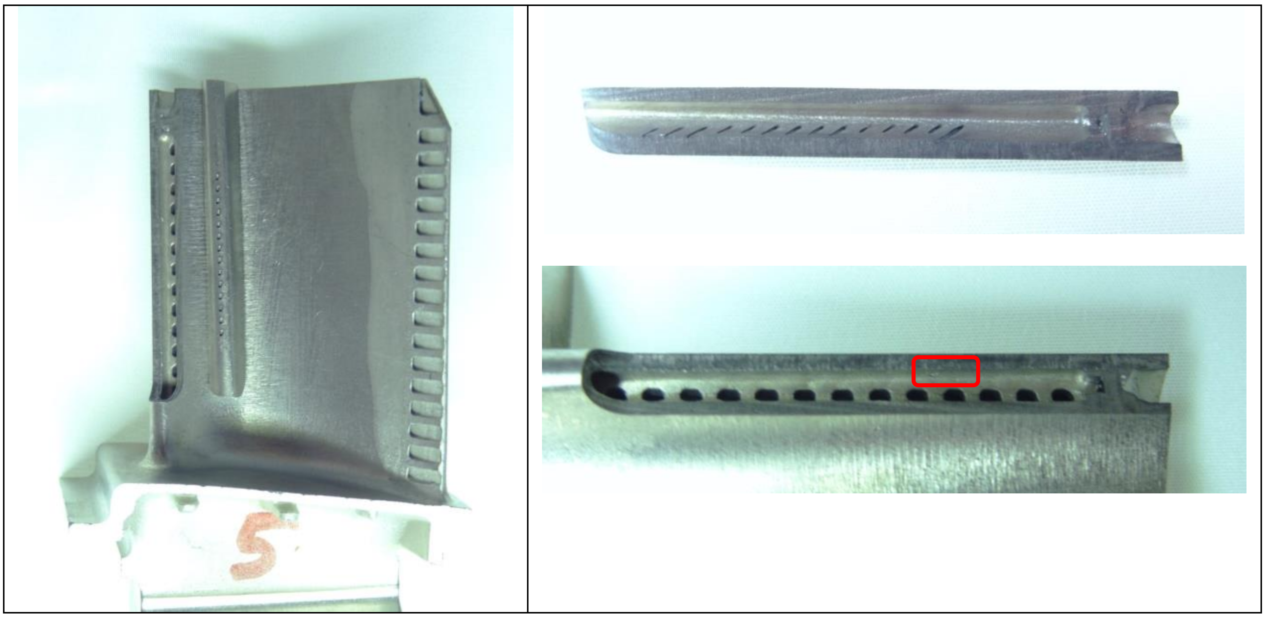


FIGURE 7: Fourteen holes drilled in Blade 4 with a 50µm nozzle and air as assist gas.
The holes are again poorly positioned, but there is no sign of backstrike, except on the first hole, where helium was used instead of air as assist gas.

CONCLUSION

The drilling of holes in nickel superalloy was investigated on a Synova DCS300. 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, advantages that are essential for cutting and grooving metals with high quality.

In these tests, we showed that it is possible to avoid backstrike by controlling the water jet length and breakup. The best samples are Blade 1, which was drilled using a 30µm nozzle, and Blade 3, which was drilled using a 50µm nozzle.

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