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REPORT: Hole drilling and grooving in nickel superalloy by Laser MicroJet®

for attention of Anonymous

by Ronan Martin, Synova SA

TASK

The Laser MicroJet® technology has been tested on a nickel-superalloy turbine bucket that was provided by the customer during their visit. In order to assess the feasibility of using the Laser MicroJet® in production, several holes were drilled and two shapes were grooved in the bucket.

SAMPLE DESCRIPTION AND PREPARATION

SAMPLE	Material	nickel superalloy
	Length	105 *mm*
	Wall thickness	1–2 *mm*
	Quantity	1 *pcs*

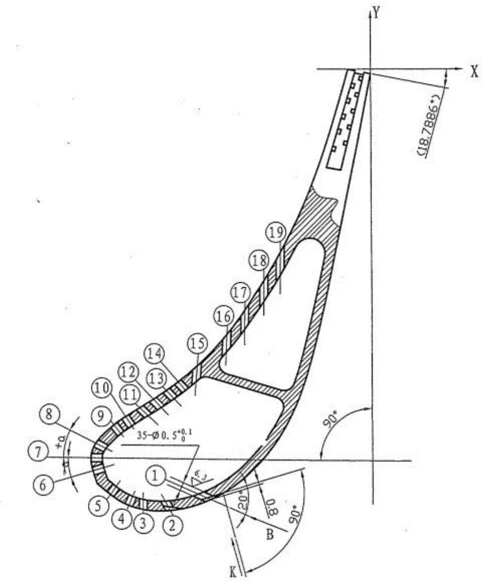

FIGURE 1: Position of some holes in the finished product

Release of application report			
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Date:	08.07.2013	Date:	08.07.2013
Visum:	ROM	Visum:	BC

In order to avoid backstrike damage (i.e. unwanted damage below the drilled holes), several ideas can be considered. However, since we had only on part for these tests, and since the part had already been sawn and was therefore not representative of the real product, we avoided backstrike damage simply by putting some teflon pieces inside the bucket. Teflon is indeed an excellent protection.

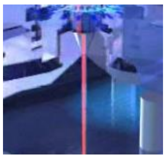
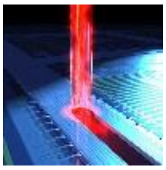
PROCESS: INSTRUMENT & TEST PARAMETERS

For these experiments, an LSS 800 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
- 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. More details concerning each sample are given in their respective sections.

	**SYSTEM**	Machine type	LSS 800	
	**MICROJET® PARAMETERS**	Nozzle diameter	60	*µm*
		MicroJet® diameter	50	*µm*
		Water pressure	200	*bar*
		Assist gas	He	
	**LASER PARAMETERS**	Laser type	L101G	
		Wavelength	532	*nm*
		Pulse frequency	14	*kHz*
		Average power	Drilling: 60 Grooving: 30	*W* *W*
	**CUTTING PARAMETERS**	Working distance	12–16	*mm*
		Motion speed	Drilling: 1 – 3 Grooving: 10	*mm/s* *mm/s*
		Step for spiral drilling	30	*µm*

All the holes were drilled using a spiral path, as illustrated in the picture below, where 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.

Such a spiral path is necessary to cut 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. Another advantage of this method is that it produces no waste part, which could fall inside the bucket. A similar method can be used to drill holes of any shape.

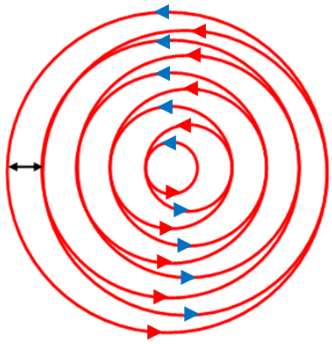


FIGURE 2: Illustration of the path used for spiral drilling, following first the red arrows, then the blue ones.

The sample was fixed by clamping. Some holes were drilled with an angle of about 90° between the water jet and the surface, and while some other were drilled with an angle of about 30°.

A diaphragm (small metal plate put below the nozzle) was used in order to prevent nozzle damage. The protection chamber and diaphragm protects both from particle contamination and from water jet instabilities due to feedback.

RESULTS

The picture below presents all the different holes and patterns that were processed in the sample.

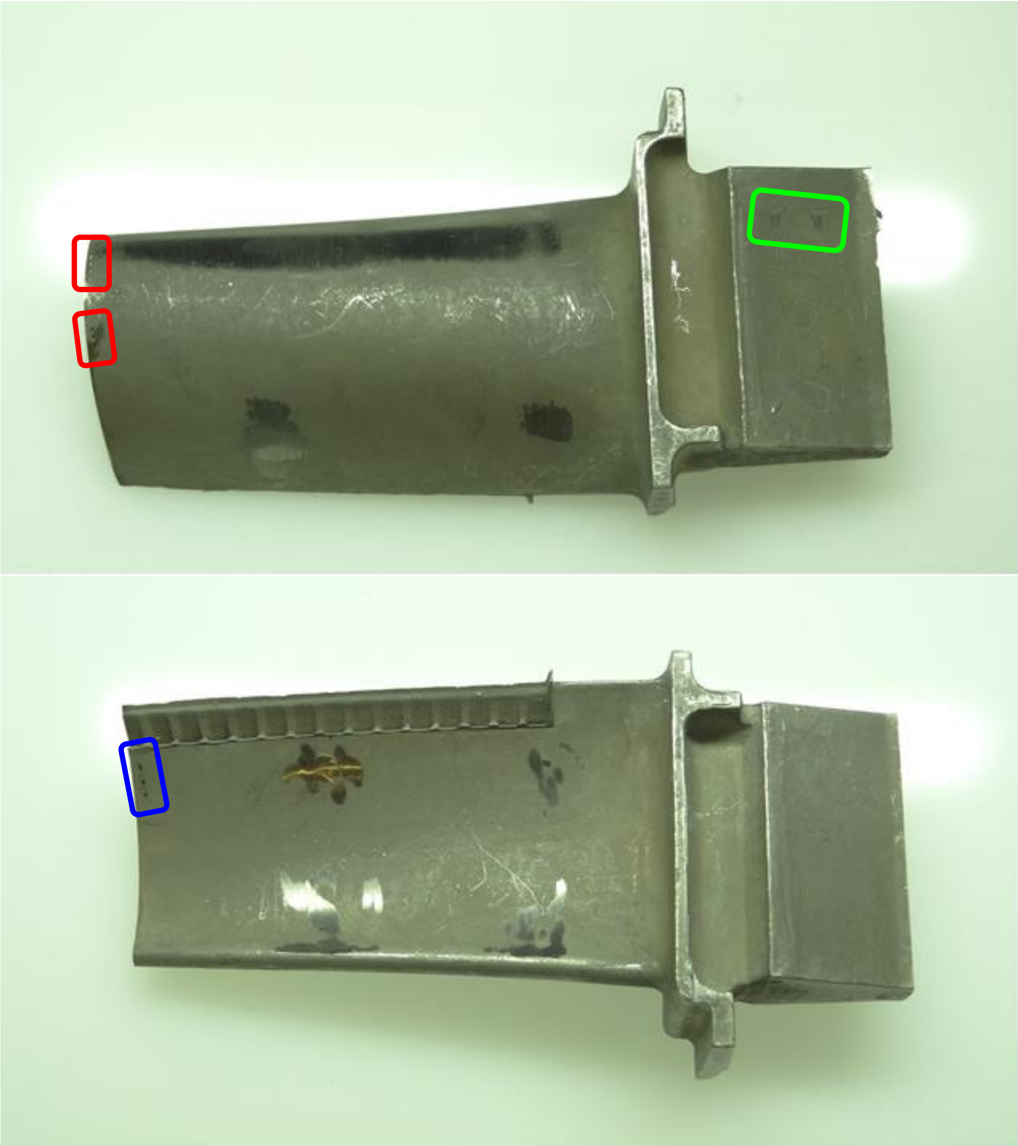
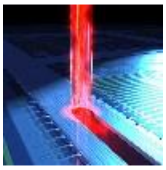


FIGURE 3: Overall view of both sides of the sample. Holes outlined in red were drilled almost perpendicularly, while the ones outlined in blue were drilled with an angle of about 30° between the surface and the water jet. The two grooved trapezoidal shapes are outlined in green.

- **HOLES DRILLED PERPENDICULARLY**

Six holes were drilled about perpendicularly to the surface. The first drilled hole has a diameter of 0.5mm, while all the following ones have a diameter of 0.4mm. Also, all the 0.4mm holes underwent a finishing process, where the motion speed was decreased in order to ensure that the holes have a good cylindrical shape. The thickness varied between about 1mm and 2mm. For safety's sake, more passes than necessary were done. The drilling times are therefore not very representative.

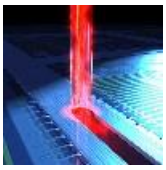
The quality is comparable to what was shown to the customer during their visit. The holes have a nice cylindrical shape, and heat damage is very limited.

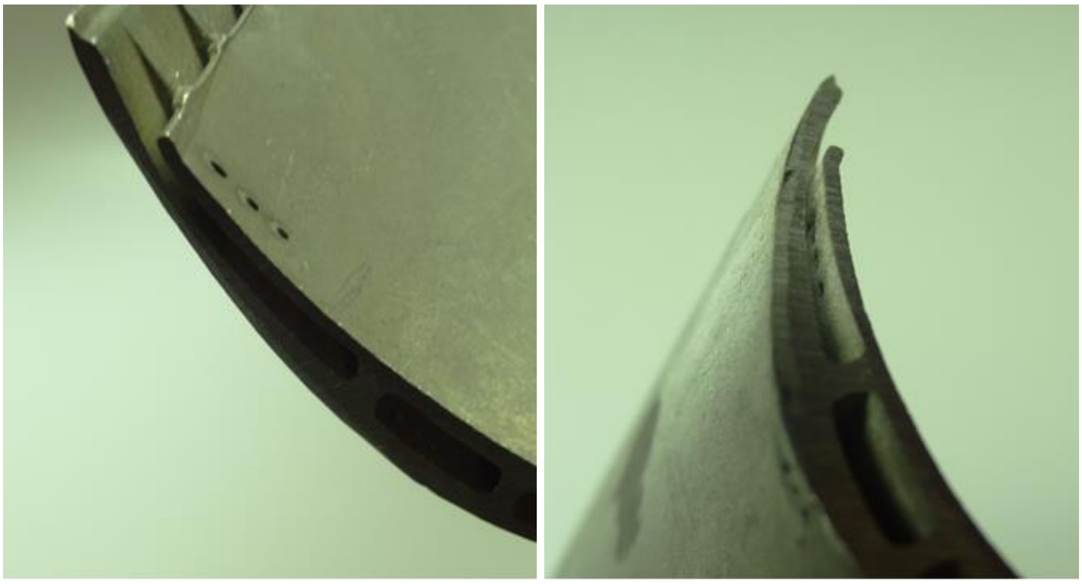
	CUTTING PARAMETERS	Motion speed	Main drilling: 3 Finishing: 1	*mm/s* *mm/s*
		Number of passes	Main drilling: 9 – 48 Finishing: 3 – 38	
		Processing time per hole	39 – 140	*s*

PICTURE 4: Front view and back view of the holes

- **HOLES DRILLED AT 30° COMPARED TO THE SURFACE**

Six holes were drilled with an angle of about 30° between the water jet and the surface. The diameter was always kept at 0.4mm. The good quality is similar to that of the previous holes. The motion speed was varied between holes for experimental purposes, but it did not show any big difference.

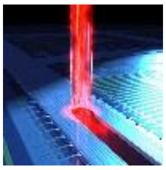
	CUTTING PARAMETERS	Motion speed	Main drilling: 1 – 3 Finishing: 1	*mm/s*
		Processing time per hole	107 – 117	*s*



PICTURE 5: Front view and back view of the holes

- **TRAPEZE GROOVING**

Trapezoidal shapes were grooved in order to demonstrate the feasibility of processing more complex shapes, which could for instance be useful for diffusers. The trapezes were processed by cutting parallel lines in successive layers.

	CUTTING PARAMETERS	Motion speed	10	*mm/s*
		Number of layers	5	
		Number of lines per layer	40	
		Grooving time per shape	76	*s*

PICTURE 5: Top view of the two grooved trapezes

CONCLUSION

The feasibility of drilling holes in turbine buckets was demonstrated on a sample provided by the customer.

Holes with a diameter of 0.4mm were processed at various incidence angles. Depending on the holes, the process time varied between 39s and 140s. However, in order to ensure a good quality for all holes, more passes than necessary were done. The drilling time could therefore be greatly decreased in a real production (especially with an optimized strategy that avoids drilling in the middle of the hole when it is already through).

In order to illustrate the variety of shapes that are possible to process with the Laser MicroJet® technology, trapezes were also grooved in the sample. Such shapes could be needed for instance for diffusers. But this also opens the possibility to use square holes (as shown to the customer during their visit) or even to slotted holes.

Although the provided bucket was not coated with ceramic, the customers were shown during their visit such a coated sample, and could appreciate the good quality. The Laser MicroJet® technology can indeed process ceramic-coated buckets with minimal damage to the coating.

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.