REPORT: Aluminum and steel cutting and engraving by Laser MicroJet®

for attention of Anonymous

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TASK

The Laser MicroJet® technology has been tested in three samples made of aluminium and steel, referred to as L1T1, L1T2 and L1T3. Since the tests results have already been well documented (see report *Loop1_AnalysisReport_SYNOVA_v2.pdf*), the present report only aims to list the used process parameters, the strategies, and the process times.

Release of application report			
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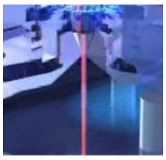
INSTRUMENT & TEST PARAMETERS

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.

The table below summarizes the parameters used in the experiments. More details will follow in the next sections.

	**SYSTEM**	Machine type	LCS 150
		Optical head type	Standard
		Coupling unit type	Thin
		Diaphragm	Brass, 0.1mm
	**MICROJET PARAMETERS**	Nozzle diameter	60 *µm*
		MicroJet® diameter	50 *µm*
		Water pressure	L1T1, L1T3: 300 *bar* L1T2: 350 *bar*
		Working distance	L1T1, L1T3: 10 *mm* L1T2: 20 *mm*
		Assist gas	He, 0.9 *L/min*
	**LASER PARAMETERS**	Laser type	L202G
		Wavelength	532 *nm*
		Pulse frequency	L1T1, L1T2: 10 *kHz* L1T3: 14 *kHz*
		Internal power	L1T1, L1T2: 60 *W* L1T3: 2x45 *W*
		Transmission in jet	70 *%*
		Pulse width	L1T1, L1T2: 150 *ns* L1T3: 200 *ns* (with delay of: 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.

STRATEGIES

- **L1T1:**

  - **Ref 6, 7, 7bis, 9**

The shapes were processed by one pass of horizontal hatching and then of vertical hatching, with a step of 20µm.

  - **Ref 10**

The shape was also processed by hatching with a step of 20µm, but the directions were chosen to be parallel to the outline: one pass of horizontal hatching and then of tilted hatching.

  - **Ref 100**

The biggest hole was processed by trepanning. All the other holes were processed by double-spiral drilling (spiralling inwards then outwards), with a step of 55µm.

  - **Ref 200**

The thinnest slot was ablated by using a multipass strategy along a simple line, without any offset. The width is thus controlled by the nozzle diameter and laser parameters. The other slots were ablated by offsetting the path in one direction between each pass. Since the offset was done in one direction, the width of the slots is not constant. The offset values and number of steps were chosen in order to get the proper dimensions. However, since the parameters were entered manually each time, it is possible that some errors were made, which can explain the discrepancies that were observed. Here are the offset values that we noted:

- 0.06mm slot: 0 step
- 0.08mm slot: 1 step with a 20µm offset
- 0.10mm slot: 1 step with a 40µm offset
- 0.15mm slot: 2 steps with a 45µm offset
- 0.20mm slot: 3 steps with a 46.7µm offset
- 0.40mm slot: 6 steps with a 56.7µm offset
- 0.60mm slot: 10 steps with a 54µm offset

When the ablation was completed, a finishing process was then performed on the outline, using a multipass strategy.

- **L1T2:**

The slots were processed by offset-filling, from inside to outside. The offset was about 30µm.

Because of the part geometry, the working distance had to be increase to 20mm, which is not ideal for the jet stability.

The pressure was increased to 350bar to make the jet longer. One of the slots was badly processed because the part was not properly fixed. Another slot was processed at a wrong angle because of a simple mistake.

- **L1T3**:

Once again, the slots were processed by offset-filling, from inside to outside. The offset ranged between 30 µm to 32µm, in order to get the get the proper slot width with a constant offset.

Because steel is more difficult to ablate than aluminum, the average power and pulse width were increased to get a more efficient process.

Two things should be noted:

- Since our technology does not have a control of a focal point, if we ablate a porous material, all the porosity present in the ablated thickness will show on the surface, kind of like accumulated. However, we are working on a technology that could map the actual ablated depth.

- All the hatching was performed by opening and closing the shutter when the axes were stopped. (We had to do that because the mechanical laser shutter is too slow to be opened or closed on the fly.) This led to slightly longer process times, but also to a deeper ablation on the edges of the shapes. Again, we are working to get a better control of the laser that would allow us to start and stop lasing on the fly at a precise position.

PROCESS PARAMETERS

The tables below present the process parameters as well as the process times.

- **L1T1:**

Reference		Motion speed	Passes	Time
#6		22mm/s	1x2	39min56s
#7		22mm/s	10x2	18min28s per hexagon
#7bis		20mm/s	1x2	2min07s per hexagon
#9		22mm/s	1x2	56min27s
#10		30mm/s	1x2	17min35s
#100	**Ø0.6**	10mm/s	90x2	87s
	Ø0.8		40x2	68s
	Ø1.0		30x2	83s
	Ø2.0		140	94s
#200	**0.06mm**	50mm/s then 10mm/s	300+10	148+48s
	0.08mm		300+10	243+48s
	0.10mm		300+10	243+48s
	0.15mm		200+10	290+49s
	0.20mm		200+10	384+54s
	0.40mm		200+20	670+110s
	0.60mm		150+20	787+112s

- **L1T2:**

Reference	Motion speed	Passes	Time
#2	30mm/s	36	7min51s
#3			
#4			
#5		28	6min14s
#6			
#7			
#8		30	6min36s
#10		29	12min12s

- **L1T3:**

Reference	Motion speed	Passes	Time
#2	30mm/s	70	28min45s
#3			19min24s
#5			17min44s
#6			27min29s
#8			22min21s
#10			12min27s
#11			14min18s
#12			10min01s

CONCLUSION

The cutting and engraving of aluminium and steel was investigated on a Synova LCS150. 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.

In these tests, we have given an overview of what the technology can currently offer. It is easily possible to get a high quality and precision when cutting a metal. (And depending on the application, we have room to significantly optimize the quality or the process speed.) On the other hand, engraving is currently more challenging, but some current hardware and process development should allow us to better control the depth in the near future.

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.