Industrial Applications of Laser Engraving: Influence of the Process Parameters on Machined Surface Quality

F.Agalianos, S.Patelis , P. Kyratsis, E. Maravelakis, E.Vasarmidis, A.Antoniadis

Abstract**—**Laser engraving is a manufacturing method for those applications where previously Electrical Discharge Machining (EDM) was the only choice. Laser engraving technology removes material layer-by-layer and the thickness of layers is usually in the range of few microns. The aim of the present work is to investigate the influence of the process parameters on the surface quality when machined by laser engraving. The examined parameters were: the pulse frequency, the beam speed and the layer thickness. The surface quality was determined by the surface roughness for every set of parameters. Experimental results on Al7075 material showed that the surface roughness strictly depends on the process parameters used.

Keywords**—**Laser engraving, Al7075, Yb:YAG Laser, Laser process parameters, Material Roughness

I. Introduction

LASER engraving is one of the most promising technologies to be used in rapid prototyping in order to engrave or mark an object. In this method, a laser beam is used to ablate a solid bulk, following predetermined patterns. The desired pattern is created by repeating this process on each successive thin layer. There are many advantages of this method compared to traditional machining, such as: no mechanical contact with the surface, reduction in industrial effluents, a fine accuracy of machining and an excellent quality and detail on the final product [1], [2]. The laser engraving method has many applications in industry, such as: creation of molds and dies, engraving information i.e. names and serial numbers in the silicon chips, direct engraving of the expiry date on food package, engraving of an image beneath the surface of a solid material (usually glass), direct engraving of flexographic plates and cylinders.

The main research areas on the laser engraving are the process parameters and the resulted surface roughness. Genna et al. aimed in studying the process parameters affecting the material removal rate and surface roughness on C45 steel [2]. A research which was developed by Qi et al. aimed to find the relationship between the frequency of the laser and the quality characteristics on stainless steel [3]. Another research developed by Leone et al. had as its purpose to investigate how the process parameters are affecting the material removal rate in different types of wood [4]. The research which was conducted by Leone et al. had as its purpose to determine the correlation between process parameters and their visual outcome [5].

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II. Experiments

A. Equipment

The engraving tests were performed by using a Q-Switched 100 W Yb:YAG laser, with fundamental length $\lambda = 1064$ nm. The beam is moved through two galvanometer mirrors onto the workpiece and the final focused beam diameter is about 50 μm. The range of the frequency that can be used by the laser is between 4–50 kHz, the corresponding range in speed is between 50-1000 mm/s and the removal material thickness per layer can be between 1-15μm depending on the material. The laser system is controlled via a PC, which allows the generation of the geometric patterns and the setting of the process parameters: the beam power, the pulse frequency (f), the scan speed (v) and the removal material thickness per layer (Figure 1).

B. Process Parameters

In order to perform the engraving tests an Al7075 plate was used. Cycle areas of 12 mm diameter and 200 μm depth were obtained on the samples by engraving circles with the same dimensions and different parameters (Figure 2). The pulse frequency was fixed at 20, 30, 40, 50 kHz, the scan speed was varied in the range 200-1000 mm/s and the layer thickness was fixed at 2, 4, 6, 8 μm (Figure 3). The surfaces of the engraved cavities were measured by a Surface Roughness Measurement Diavite Compact. Five measurements were performed in the same direction for each circle and the average value was calculated.

C. Results and Discussion

The influence of the process parameters on the laser engraving are depicted in the following two figures. Figure 4 presents four diagrams showing the surface roughness as a

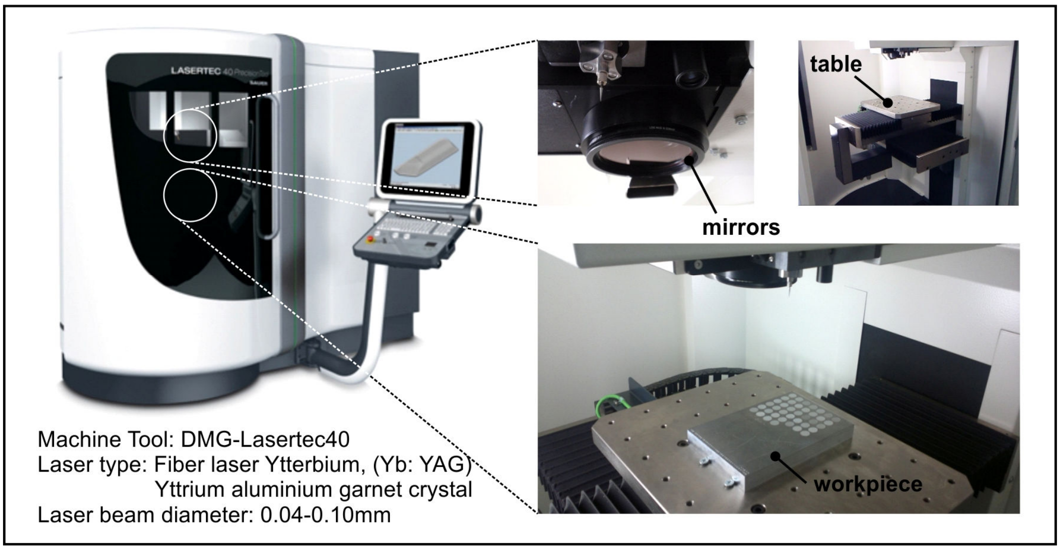

Fig. 1 The Q-Switched 100 W Yb:YAG laser

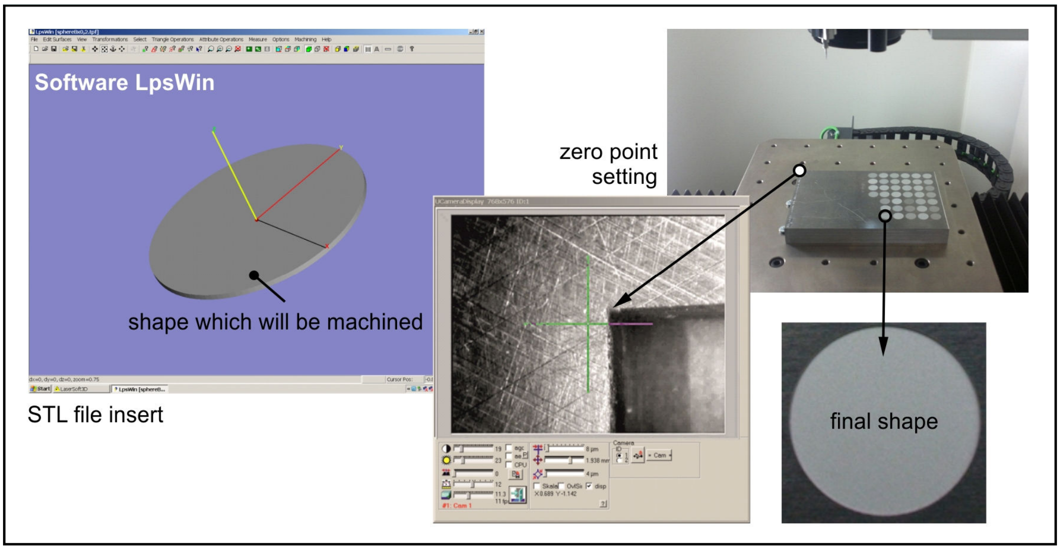

Fig. 2 The engraving tests on Al7075 plate

function of scan speed for different frequencies, for layer thickness 2, 4, 6 and 8 μm.

It's obvious from all the cases of figure 4, that surface roughness has in general its smallest values for a frequency of 20 kHz. More specifically in the diagram with a layer thickness of 2 μm and for a frequency equal to 30 kHz, the surface roughness decreases continuously with the increase of the scan speed. When the frequency is 20 kHz the surface roughness increases for all increased values of the scan speed and when a frequency of 40 kHz is used, the surface roughness fluctuates throughout the range of all scan speed values.

In the diagram with a layer thickness of 4 μm, when a frequency of 30 kHz is used, the resulted surface roughness decreases until the scan speed reaches 500 mm/s and then increases with the scan speed. In the case of using a frequency of 20 kHz the roughness slightly increases with the increase of scan speed and for a frequency of 40 kHz it slightly decreases for the same conditions. A similar behavior is depicted in the diagram for the layer thickness of 6 μm, with the difference that for a frequency of 20 kHz the surface roughness decreases with the increase of the scan speed. As expected in the diagram for the layer thickness of 8 μm, there are not impressive differences in the resulted roughness trends, except in the case of 20 kHz where surface roughness is almost constant.

Figure 5 presents three diagrams showing the surface roughness as a function of the layer thickness for different scan speeds (starting from 400 up to 1000mm/s) and for frequencies of 20, 30 and 40 kHz respectively. The three scan speeds used for each diagram were selected because they have resulted the smallest values of surface roughness.

	f [kHz]	v[mm/s]	L.th. [μm]
1	20	500	2
2	20	500	4
3	20	500	6
4	30	600	6
5	40	400	6
6	50	400	6
7	40	500	6
8	50	500	6
9	30	500	2
10	20	500	8
11	40	500	2
12	30	400	2
13	30	400	4
14	30	400	6
15	30	400	8
16	30	500	4
17	30	500	6
18	30	500	8
19	30	200	2
20	30	200	4
21	30	200	6
22	30	200	8
23	40	500	4
24	40	500	8

	f [kHz]	v[mm/s]	L.th. [μm]
25	30	600	2
26	30	600	4
27	30	600	8
28	20	400	6
29	20	600	6
30	30	600	6
31	20	300	6
32	20	700	6
33	20	800	6
34	20	600	2
35	20	600	4
36	20	600	8
37	20	700	2
38	20	700	4
39	20	700	8

	f [kHz]	v[mm/s]	L.th. [μm]
40	20	800	2
41	20	800	4
42	20	800	8
43	40	400	6
44	40	600	6
45	40	700	6
46	40	800	6
47	40	900	6
48	40	1000	6
49	40	1000	2
50	40	1000	4
51	40	1000	8
52	40	900	2
53	40	900	4
54	40	900	8
55	40	700	2
56	40	700	4
57	40	700	8
58	40	600	2
59	40	600	4
60	40	600	8
61	40	800	2
62	40	800	4
63	40	800	8

f: Frequency [kHz], v: Velocity [mm/s], L.th.: Layer thickness [μm]

Fig. 3 The experimental parameters used

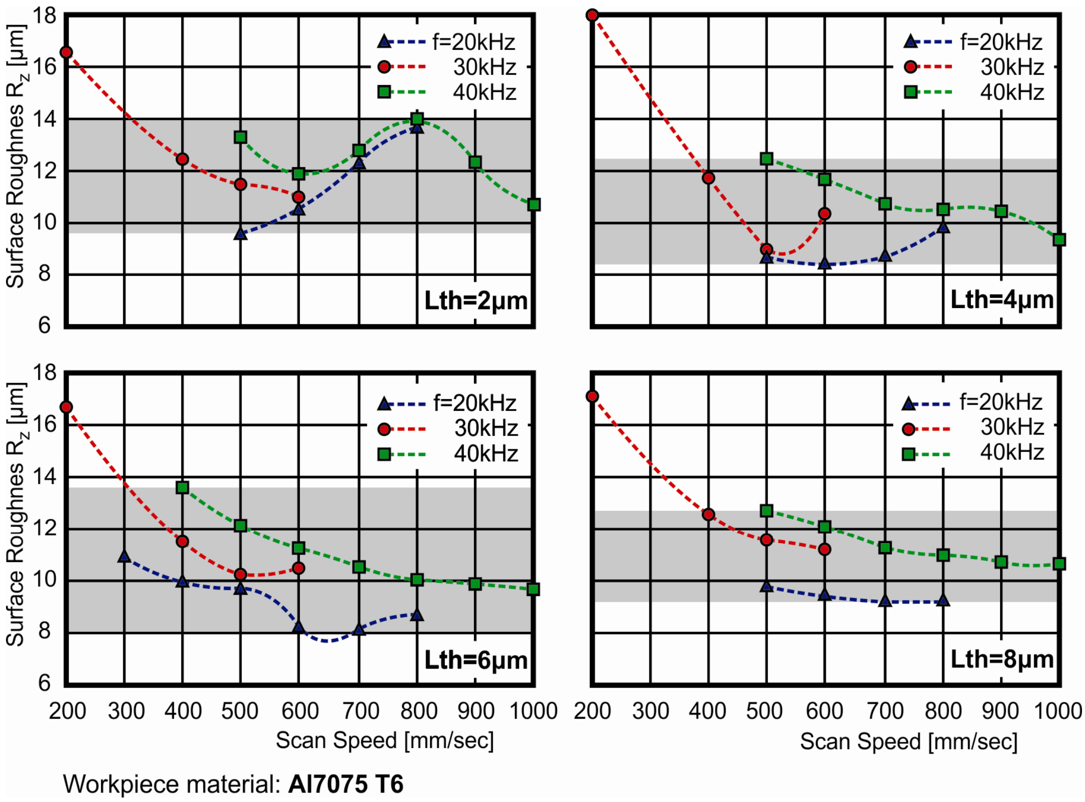

Fig. 4 Surface roughness as a function of scan speed for different frequencies (20-30-40 kHz)

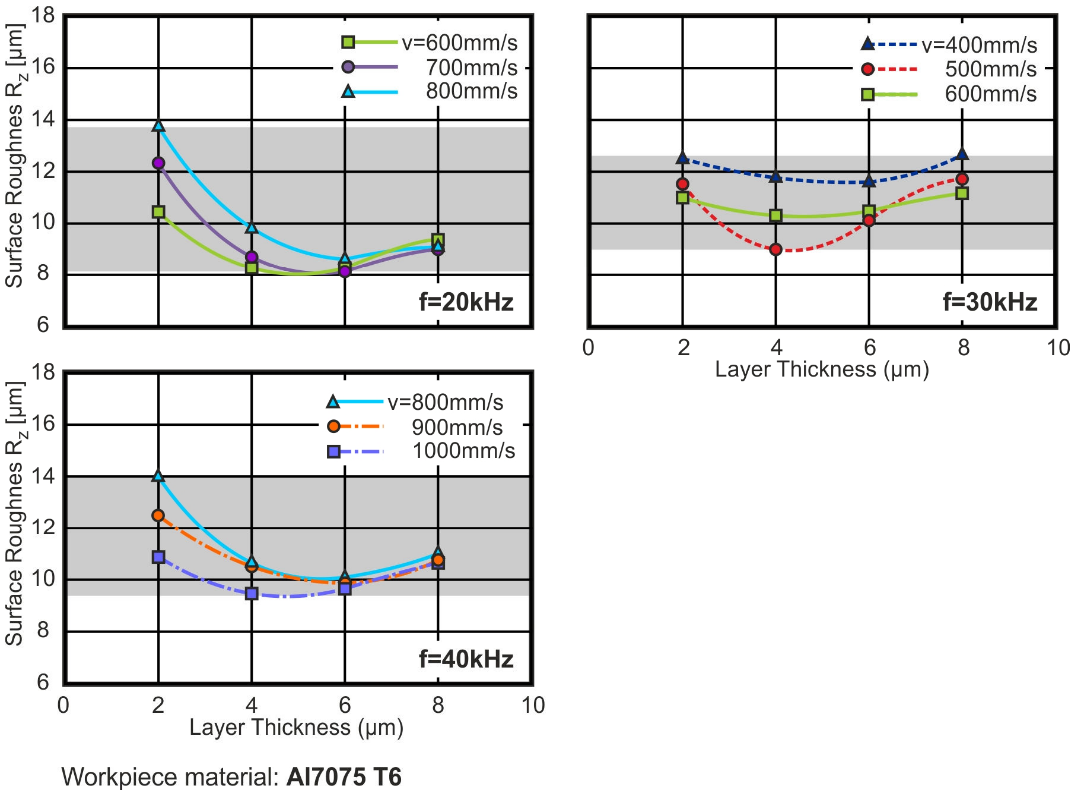

Fig. 5 Surface roughness as a function of layer thickness for different scan speed values

For the frequencies of 20 and 40 kHz the surface roughness: a)decreases when the layer thickness receives a value of 2 or 4 μm, b)remains almost stable for a layer thickness of 6 μm and c)increases for a layer thickness of 8 μm. It worth mentioning that the resulted surface roughness converges to the same value as the layer thickness increases, when the three scan speeds are used.

For the frequency of 30 kHz and scan speeds of 400 mm/s and 600 mm/s, the surface roughness a)decreases for layer thickness of 2 μm to 4μm, b)is almost stable for layer thickness of 4 μm and 6 μm and c)increases for a layer thickness of 8 μm. In the case that the scan speed is 500 mm/s the surface roughness decreases for layer thickness 4 μm and then increases until the layer thickness reaches 8 μm.

III. Conclusions

Based on the experimental work of the present paper in laser engraving of Al7075 using a Q-switched Yb:YAG fibre laser, it can be summarized that the surface roughness strongly depends on the frequency and the scan speed used. In addition it was proven that the resulted roughness depends less by the layer thickness. When considering all the experimental data of the current experimental plan, the best surface roughness was achieved when using a frequency of 20kHz, a scan speed in the range of 600-700mm/s and a layer thickness of 4 and 6μm.

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