INVESTIGATION OF THE INFLUENCE OF POWER AND SPEED IN CO2 LASER ENGRAVING ON GLASS

JAUDAS UN ĀTRUMA IETEKME CO2 LĀZERA GRAVĒJUMĀ UZ STIKLA

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Abstract. *Laser technologies are a major priority in the development of our economy and society in the 21st century. One of the main applications of lasers is laser marking / engraving. The laser engraving method is widely used in many industries, including the glass industry. There are many ways to engrave glass, for example sandblasting, but it is time consuming, expensive and not as precise as laser engraving. The report contains glass engraving quality with CO2 laser, using different power and speed values.*

Keywords: *CO2 laser, glass engraving, surface roughness, engraving depth.*

Introduction

Engraving glass with CO2 laser isn't as simple as it may seem, because of the glass structure. A CO2 laser marks the glass by creating small cracks in or on the glass. To understand how lasers interact with glass, it is necessary to know how glass is made.

Basically glass is made by heating silica (sand). When it reaches a certain temperature silica melts and becomes liquid. At this point it can be poured in mold and while cooling down it becomes transparent.

CO2 laser engraves wood, acryl and other materials by burning and removing some material from the surface. It is a little bit different when we talk about glass engraving. Because in this case a laser doesn't remove any material. When glass is made sand is heated up to 2000 degrees Celsius or more until it becomes molten. After it is removed from the oven and cools down, while cooling glass obtains air and moisture.

It is the air and moisture that makes laser marking on glass possible with CO2 laser. As the laser beam strikes the glass, it heats up the glass elements, like silica and any metal content. None of these elements react to the relatively low heat and frequency of a CO2 laser. There are 2 elements that react to low heat, that is air and moisture. When heated both of these elements expand, this results in microscopic fractures inside the glass or on its surface. It is these small fractures that we see as engraving.

1. Materials and methods

In this experiment was used a CO2 laser with a wavelength of $\lambda = 10.6$ µm. Synchronous control of the on / off laser generation and the movement of the laser beam focusing system along a given contour along the X, Y axes, as well as the change in the laser radiation parameters, is carried out using a special computer program.

The main technical parameters of the CO2 laser system, which was used in the experiments, are listed in table 1.1.

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Table 1.1

Technical parameters of CO2 laser system

Laser type	CO2 laser
Operation mode	CW
Laser wavelength	10.6 µm
Max. laser power	90 W
Process size	500 x 800 mm
Scanning speed	0 – 250 mm/s

For this experiment was also used Normal (Annealed) sheet glass. Sheet glass has a slight distortion. Properties are listed in table 1.2.

Table 1.2[1]

Normal (Annealed) sheet glass parameters

High light transmission	
Optical Clarity	
Density (approximate)	2.42 – 2.52 g/cm^3
Tensile strength	40 N/mm^2
Compressive strength	1000 N/mm^2
Modulus of elasticity	70 GPa
Coefficient of linear expansion	9x10^{-6} m /(m K)
Thickness	4 mm
Color	Clear

For measurements LEXT 3D Measuring Laser Microscope OLYMPUS OLS5000 was used. This type of laser microscope is able to determine the surface relief and create a topographic 3D model of the surface. Microscope parameters are given in Table 1.3.

Table 1.3

Laser scanning microscope parameters

Error in X, Y direction measurements with MPLAPON X10 LEXT lens	0.0027 mm
Error in the Z direction in measurements with MPLAPON X10 LEXT lens	0.0023 mm
Lens magnification error	<1.5%

2. Results

This is investigation into the possibility of engraving glass with CO2 laser. Applying two variable parameters, the speed and laser beam power, matrix-type gradients for engraving are obtained. A matrix of 42 squares was created. Power range from 10% to 40% in 5% increments. The speed range from 125 mm/s to 250 mm/s in steps of 25 mm/s and scan gap was constant - 0.1 mm . The scheme of the matrix is shown in Fig.2.1.

Fig. 2.1 **The scheme of the matrix**

Variable parameters have been selected for the experiments. The study parameters and their values in different experiments are shown in table 2.1.

Table 2.1

Parameters of laser engraving on glass experiments

Experiment number	***Laser power, %***	***Laser beam transfer rate - v, [mm / s]***	***Engraving depth, [μm]***	***Surface roughness, Sq,[μm]***
1	10	125	3,949	8,433
2	10	150	2,168	7,759
3	10	175	1,214	7,396
4	10	200	1,468	7,209
5	10	225	0,75	7,791
6	10	250	7,127	4,218
7	15	125	8,591	7,86
8	15	150	7,783	7,354
9	15	175	10,89	7,933
10	15	200	6,534	9,718
11	15	225	5,873	9,757
12	15	250	18,503	10,643
13	20	125	14,754	6,106
14	20	150	11,555	7,285

15	20	175	11,027	7,271
16	20	200	4,741	8,773
17	20	225	6,436	8,153
18	20	250	11,109	8,514
19	25	125	22,543	5,416
20	25	150	27,837	6,205
21	25	175	18,477	7,158
22	25	200	16,092	10,509
23	25	225	32,638	15,626
24	25	250	26,138	13,023
25	30	125	36,875	8,204
26	30	150	34,606	8,594
27	30	175	29,947	11,654
28	30	200	26,412	10,825
29	30	225	30,552	12,73
30	30	250	33,237	14,112
31	35	125	49,12	9,667
32	35	150	35,049	8,918
33	35	175	38,724	8,756
34	35	200	39,475	17,214
35	35	225	28,605	8,92
36	35	250	41,833	14,764
37	40	125	55,132	7,047
38	40	150	50,632	9,898
39	40	175	48,041	8,82
40	40	200	38,928	10,404
41	40	225	36,569	18,84
42	40	250	47,711	15,092

3. Results and discussion

3.1 Engraving depth

As seven experiments were performed with different laser powers – 10, 15, 20, 25, 30, 35, 40 % and constant laser transmission speeds of - 125 mm/s, 150 mm/s, 175 mm/s, 200 mm/s,225 mm/s, 250 mm/s transfer rate, then in Figure 3.1.1, Figure 3.1.2 and Figure 3.1.3. The dependence of the engraving depth on the power and constant speed of movement is studied.

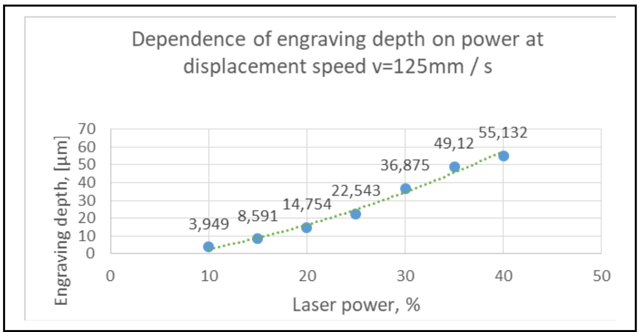

Fig. 3.1.1 **Dependence of engraving depth on power at displacement speed v=125mm / s**

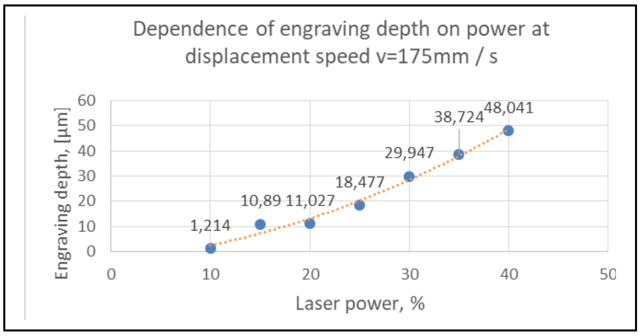

Fig. 3.1.2 **Dependence of engraving depth on power at displacement speed v=175mm / s**

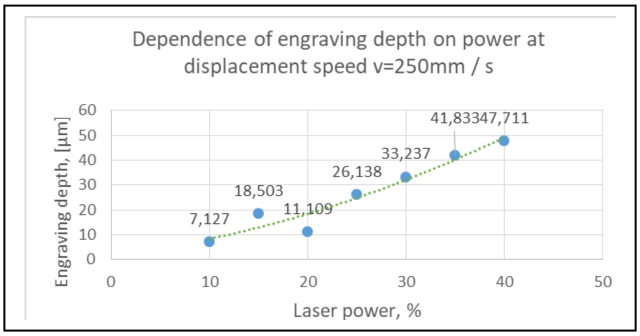

Fig. 3.1.3 **Dependence of engraving depth on power at displacement speed v=250mm / s**

In all of the above mentioned cases, as the laser power increases, the engraving depth increases exponentially at a constant speed.

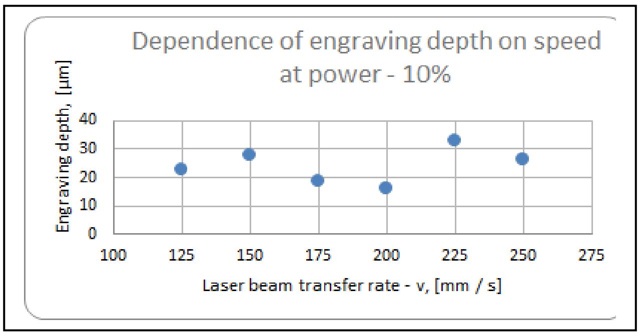

Fig. 3.1.4 **Dependence of engraving depth on speed at power - 10%**

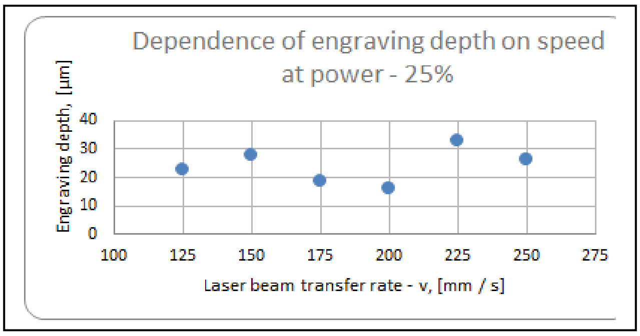

Fig. 3.1.5 **Dependence of engraving depth on speed at power - 25%**

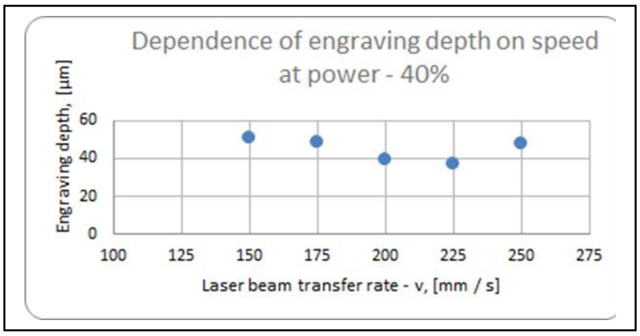

Fig. 3.1.6 **Dependence of engraving depth on speed at power - 40%**

From the graphs it can be concluded that at constant powers, as the speed increases in the range from 125 mm/s to 150 mm s, the depth of engraving increases, but in the range from 150 mm/s to 200 mm/s decreases, from 200 mm/s to 225 mm/s increases again.

In the range from 225 mm/s to 250 mm/s, this relation does not apply, because at all powers, the depth either increases, for example, in Figure 3.1.6, or decreases, in Figures 3.1.4 and 3.1.5.

3.2 Surface roughness

Roughness of engraved surfaces was also measured. Figure 3.2.1 and figure 3.2.2 shows surface roughness depending on power and speed.

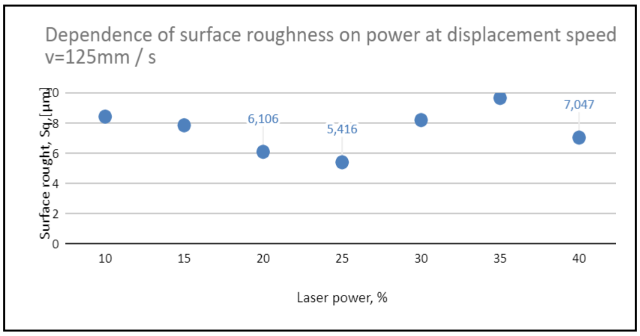

Fig. 3.2.1 **Dependence of surface roughness on power at displacement speed v=125mm/s**

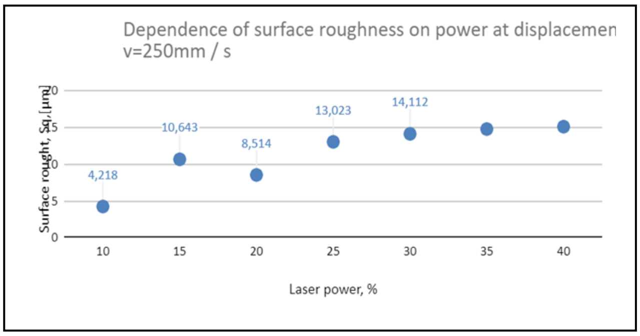

Fig. 3.2.2 **Dependence of surface roughness on power at displacement speed v=250mm/s**

It can be seen from the graphs that as the power increases, the surface roughness also increases.

3.3 Cracks depending on engraving power and speed

Figure 3.3.1 shows a qualitative engraving of the material at a power of 30 % and a speed of 250 mm/s, in contrast, at low power and speed, such as 10% power and speed of 125 mm/s, many cracks form.

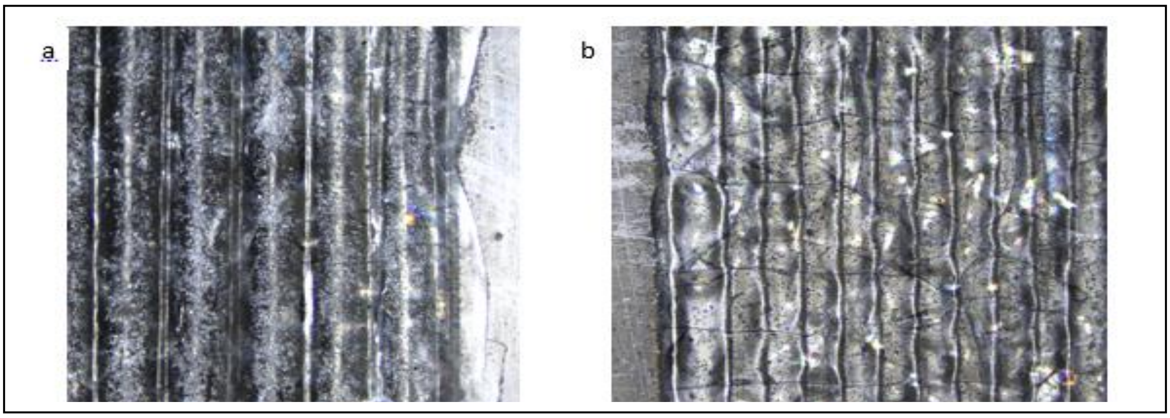

Fig. 3.3.1 **a) engraving quality of the material at a power of 30 % and a speed of 250 mm/s; b) engraving quality of the material at a power of 10 % and a speed of 125 mm/s.**

Summary

1. *The cheaper cast glass is easier to engrave due to its low lead content. The result is a more uniform structure.*
2. *As the laser power increases, the engraving depth increases exponentially at a constant speed.*
3. *At constant powers, as the speed increases in the range from 125 mm/s to 150 mm s, the depth of engraving increases, but in the range from 150 mm/s to 200 mm/s decreases, from 200 mm/s to 225 mm/s increases again.*
4. *When engraving power increases, the surface roughness also increases.*
5. *At low engraving speeds, more cracks form on the glass surface.*

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