

LASER MARKING OF METAL MATERIALS

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The contribution deals with the implementation of new information from the area of laser marking processing. The marking of various types of metal and non-metal materials are very actual topic of these days. The focus is on the production technical aspects of laser engraving and the introduction of processing strategies. Less attention is paid to the complex chemical process that can be observed when using laser as a tool chance the visible material appearance. The aim is to identify the parameters and guidelines that can be used to control the laser engraving process in the production environment. The problem of engraved metal material surface is discussed in solved experiments. The aim of the contribution is visual and microscope evaluation, how by changing of laser parameters can change the influence on the final visage of tested metallic materials.

KEYWORDS
laser technology, marking system, material

1. INTRODUCTION

Laser technologies belong to progressive methods of material treatment. These methods deals with the processing of work-piece material with a high-energy laser beam on solid (or liquid or diode) base. The laser marking systems using different lasers and optical delivery systems may be used to mark an almost endless list of materials including metals, plastics, ceramics, glass, wood and leather as well as painted surfaces and photographic emulsions. The contribution was prepared together with cooperation of TU of Košice and training center of Trumpf Slovakia, s.r.o..

2. MARKING CHARACTERISTICS

There are many methods of part or product marking, including labels, ink systems, mechanical engraving, and embossing, chemical and dry etching. Each has its use, but laser marking is growing more and more popular. The utilisation of laser engraving of metals is shown in the Figure 1, where we can compare it with other marking systems in the part production.

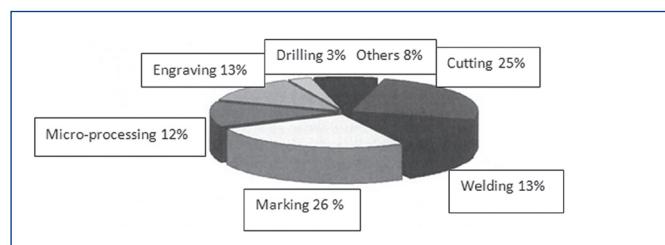


Figure 1. Percentage of Laser used technologies [Lintech 2014]

Reversible interaction between the laser beam and the work-piece, product or tool form is the basis for each process. The Figure 2 shows the interaction of laser radiation with the workpiece, where is shown the incoming laser energy, reflection, absorption, transmission of laser beam into processed material [Hani 2008, Pajak 2005, Meijer 2004b, Trumpf Slovakia 2014]. The absorptivity is the most important material parameter

of workpiece in laser material interaction. For each configuration is the absorptivity given by combination of laser parameters – wavelength, angle of incidence, polarization of the laser radiation and of the material radiative properties – state, geometry of the surface and temperature. The higher value of the resulting absorptivity means that the more laser radiation is used for the processing [Sobotová 2014].

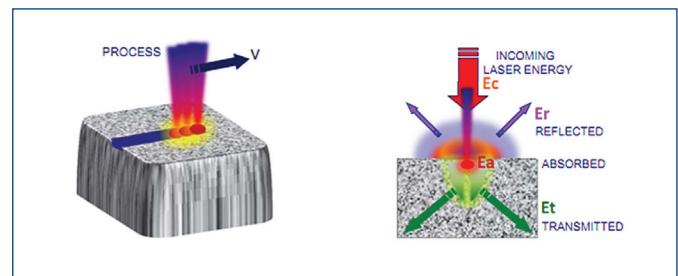


Figure 2. The interaction of laser radiation with the workpiece material and workpiece laser marking processing [Pajak 2005]

In the Table 1 we can compare the reflectivity properties of chosen materials.

Metal	REFLECTIVITY R [%]	
	Wavelength [μm]	Wavelength [μm]
	0,9 – 1,1	9–11
Gold	94,7	97,7
Silver	96,4	99
Aluminium	73,3	96,9
Copper	90,1	98,9
Iron	65	93,8
Nickel	72	95,6
Zinc	49	98,1
Chrome	57	93
Silicon	28	28
Steel (1 % carbon)	61,1	93-96
Carbon	26,8	59

Table 1. Reflectivity of materials [Trumpf Slovakia 2014]

Energy density and relative time of exposure (interaction) to determine which path will be the energy delivered to the provider, and the resulting phenomena that impact the workpiece are shown in Table 2.

When selecting a laser marking system for a particular application there are many factors to consider [Meijer 2004a]:

- power density,
- thermal: thermal conductivity, heat capacity, melting point, heat of vaporisation,
- reflectivity: material, wavelength, temperature.

According to new laser possibilities, it is possible to mark all materials such as hardened and non-hardened steel and cast iron, titanium, brass, bronze, aluminium and its alloys, cemented carbide, gold, ceramics, precious stones, plastics, wood, glass, rubber, paper, leather etc. The described surface can be polished, sandblasted, painted, blacken, enamel coating provided with chromium, zinc, titanium carbide, titanium nitride, a ceramic coating and the like. Also it is possible to describe with laser planar, cylindrical and other curved surfaces and to create variable description (text string, 2D, symbols, barcode, logos and more difficult graphic subjects, even on low-reach places [Rasa 2008]. The Figure 3 and Figure 4 show the examples of tool laser marking.

Main effect	Heating	Melting	Melting and sublimation	Sublimation	Sublimation and ionization	Sublimation
Initial energy density	30 W/m²	1 kW/mm²	10 kW/mm²	1 MW/mm²	10 MW/mm²	10 GW/mm²
Interaction	s	ms	ms	ms	ns	ps
Process examples	Hardening	Welding by heat conduction	Deep welding	Drilling	Marking	Forming

Table 2. Accompanying phenomena in metalworking by laser beam [Trumpf 2014]

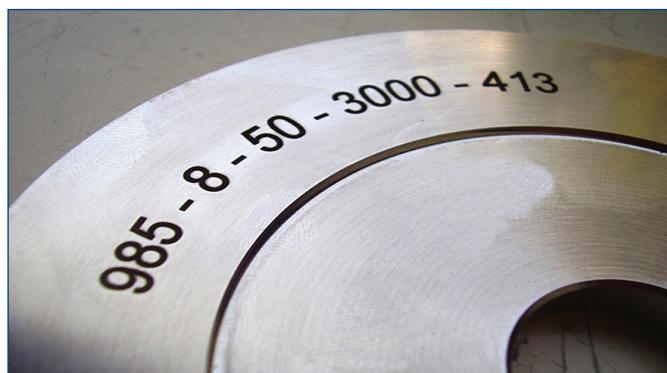


Figure 3. Marking of workpiece



Figure 4. Marking of shaft

The common advantages of all laser marking techniques are [Hani 2008, Pajak 2005, Meijer 2004b, Trumpf Slovakia 2014, Rasa 2008] as:

- Hi-tech technology;
- permanent, high quality marks;
- high efficiency and low operation cost;
- good accessibility, even to irregular surface;
- non-contact marking and no special working environmental needed;
- the minimized metallurgical and mechanical damage
- easy to automate and integrate (direct writing of patterns can be established using computer-controlled movement of the beam or sample);
- precise beam positioning and a beam highly localised energy transfer to the workpiece;
- high reproducibility and high speed, effectiveness;
- minimal heat load,
- contamination – free.

3. MARKING METHODS IN LASER MARKING TECHNOLOGIES

There are two basic methods for laser marking:

- mask marking,
- beam deflected marking.

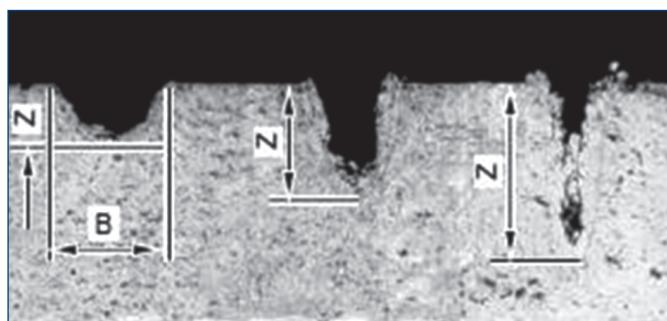


Figure 5. The cross section grained material [Pajak 2005]

Both methods also use optical techniques to enhance the power densities to levels sufficient to etch the surface of the material to be marked. The laser beam focuses for writing on the material and changes its surface. According to this change, the following types of description: can be divided as [Lintech 2014, Pajak 2005]:

- ablation–evaporation layer–withdrawal, removal,
- annealing – tempering,
- colour change–carbonization (darkening), bleaching, fading,
- foaming,
- engraving.

The laser beam is used to remove material in engraving, which gives quick etching of the workpiece. Almost all materials can be engraved or marked. During the engraving, any direct contact of the tool with the material is absent – this effect ensures only contact laser beam [Trumpf Slovakia 2014]. The following Figure 5 shows a cross-section grained material.

4. EXPERIMENTAL PROCEDURE

The experimental methods and testing of engraving of materials were prepared in laboratories of training centre of Trumpf Slovakia, s. r. o. in Košice and Technical University of Kosice, Faculty of Mechanical Engineering, in Department of Process and Environmental Engineering and Department of Production machines.

The laser engraving machine TruMark 6020 and software TruTop Mark were used for the experimental testing of three types of materials at various parameters. The laser machine parameters are shown in the Table 3.

During the proposal of the experiment we used the Trumpf navigator system to find right laser setting for tested materials. The Figure 6 shows the navigator tested engraved matrix fields. In each field was chosen testing parameters.

In the proposed experiment were chosen laser parameters and testing materials. After visual evaluation of the first prepared sample, Figure 7 and

Laser medium	Nd: YAG
mode of work	pulse
wavelength	1064 nm
Pulse repetition frequency	1–120 kHz
Min. focal diameter	42/45 μm
Max. marking field size	120 x 120 mm
Max. power	20 kW
Caliber accuracy—scanner	$\pm 50 \mu\text{m}$
Max. power consumption	230 V; 115 V
Frequency consumption	50,Hz; 60 Hz

Table 3. Technical parameters of TruMark 6020

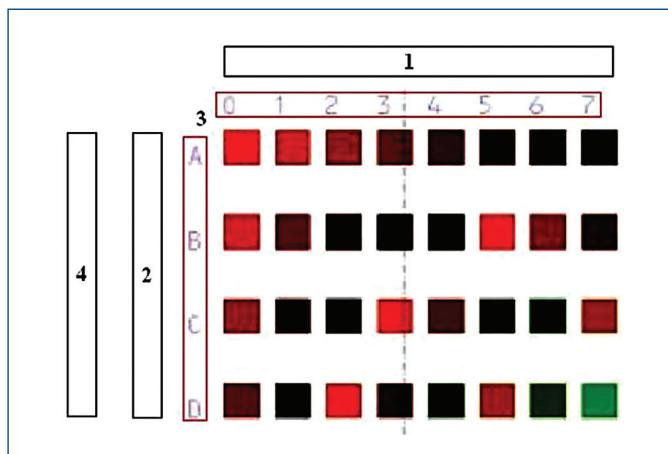


Figure 6. The example of the engraved samples: 1—pulse frequency, 2—speed engraving, 3—description of the field, 4—number of repetitions

according to the most different visual fields from the testing sample, (the darkest one and the lightened one) there were chosen the samples for microstructure testing.

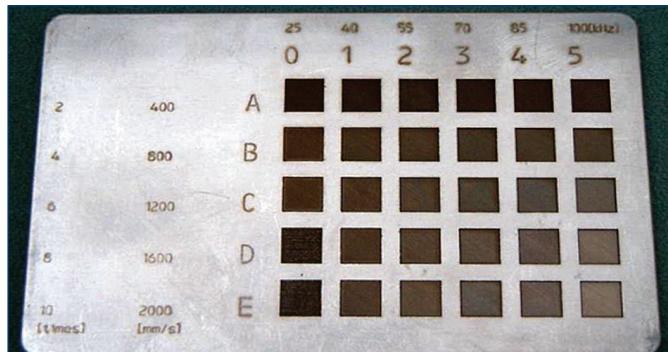


Figure 7. The sample from the stainless steel material with defined parameters

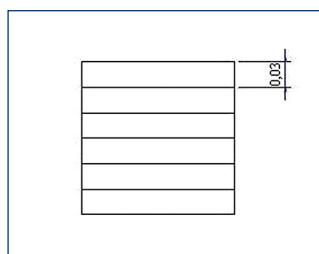


Figure 8. The tracks of pitch at the engraving

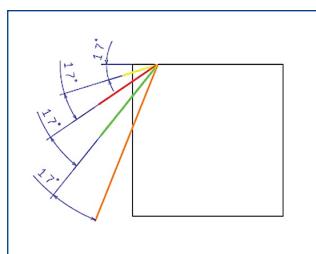


Figure 9. Rotating angle of beam

In the experiment were suggested also the laser beam ways/run through the testing field and how the laser beam will run through the sample considering to the first setting. During the engraving by laser beam, the pattern of engraving determines:

- what is the overlap of ways/runs and lines (visible under the microscope),
- the angle of the incident beam at engraving is 90 degrees,
- number of repetitions—determined number of times the laser beam passes over a given quadrant,
- sample lines pitch 0.03 mm, see Figure 8,
- rotation angle of 17 degrees of the next repetition, see Figure 9.

During the experiment was used material – stainless steel 17 020, chemical properties are shown in the Table 4.

steel	C	Mn	Si	P	S	Cr
17 020	0,08	0,9	0,7	0,04	0,035	12,14

Table 4. Chemical structure of stainless steel 17 020 (%)

The shape and magnitude of testing samples are shown in the Figure 7.

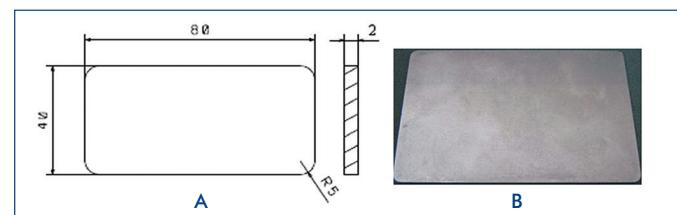


Figure 10. Samples: A – The sample for engraving with geometrical parameters, B – example of the real sample from bras

RESULTS AND DISCUSSION

After preparing of testing samples, they were evaluated as following:

- visually, the colour and lines of samples were evaluated, after run of laser beam,
- the melting and morphology of sample surface were evaluated with help of microscope Olympus and measurement roughness apparatus Mitutoyo.

In the Figure 11 is shown the engraved sample from the stainless steel material. The changes of the line structure are seen in the morphology of the material fields in dependence of the number of crossings of laser beam, from chosen fields A0 (frequency 25 kHz, 400 mm.s⁻¹, 2x

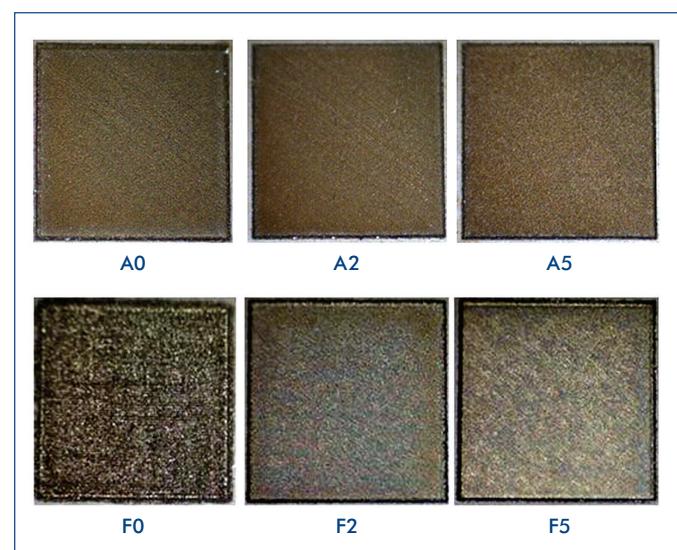


Figure 11. Visual evaluation of the stainless steel testing samples, fields A and F

crossing), A2 (frequency 55 kHz, 400 mm.s⁻¹, 2 x crossing), A5 (frequency 100 kHz, 400 mm.s⁻¹, 2 x crossing), and from E0 (frequency 25 kHz, 2000 mm.s⁻¹, 10x crossing), E2 (frequency 55 kHz, 2000 mm.s⁻¹, 10x crossing), E5 (frequency 100 kHz, 2000 mm.s⁻¹, 10x crossing).

After preparing of tested microstructures of tested samples with microscope Olympus, the changing of morphology of testing samples is visible as it was supposed. The testing samples A0 to A5 shows the lines and featureless morphology, more flat peaks after laser beam run more than the testing samples E0 to E5. It can be seen from the Figure 12 and Figure 13.

There is not visible a significant change of material morphology, in despite of increasing of pulse frequency. The quadrates were traversed by laser beam 2 times, we do not observe oriented structure of this patterns (A2 and A5).

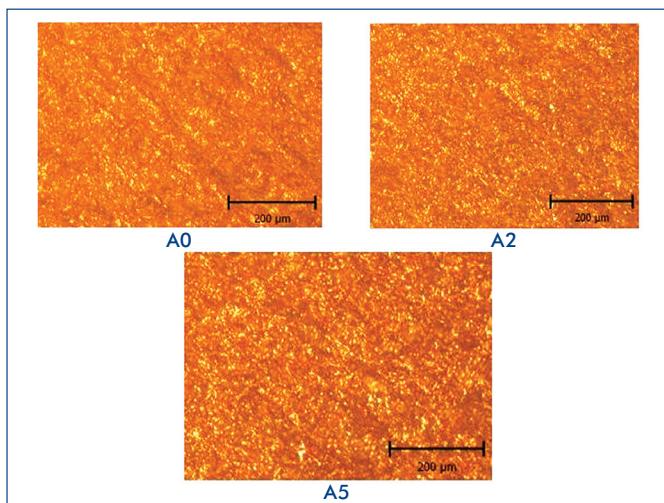


Figure 12. The microstructure of samples A0, A2, A5 from stainless steel

After preparing of fields E0, E2, E5 were used permanent engraving speed 2000 mm.s⁻¹. In Figure 13 are not seen a significant changes in microstructure despite of increasing of pulse frequency, but compared with fields A0, A2, A5, they are more re-melting. We observed non-oriented structure, because the laser beam passed one quadrate 10 times.

For the observing of the roughness of tested samples there were used Surftest SJ-301 (Mitutoyo, Japan) In the Table 4 is shown the results from the measuring of roughness of material fields.

Stainless Steel						
Roughness	Ra [μm]			Rz [μm]		
Marking of the field	0	3	7	0	3	7
A	9,77	3,64	5,65	33,2	15,88	25,84
B	1,35	2,81	3,48	6,77	12,47	14,82
C	0,99	3	3,54	5,46	14,98	17,93
D	0,81	1,94	4,14	4,57	8,78	17,55
E	0,68	2,02	2,78	3,57	10,3	12,04
F	0,82	2,27	3,91	4,27	11,86	16,59

Table 4. The measured parameters of surface roughness of material stainless steel

After evaluated of roughness of chosen tested fields, it was found that the quadrate A0 has the largest roughness. The sample has the highest roughness Ra = 9,77 [μm], Rz = 33,2 [μm], because the laser beam started to engrave these material quadrates.

CONCLUSIONS

The laser engraving is the best and the most applied technique to make such permanent marks on a wide range of material. The contribution is the contribution to database of laser marking of materials.

From the experimental results of testing of material marking at various laser parameters, it can be make the conclusions:

- At the visual evaluation of colour scale of engraved surface samples, it was found that with increasing of the pulse frequency and speed, the colour of engraving square passes to a lighter colour shade.
- When we observed the microstructure of metals under the microscope OLYMPUS, we found that with the increasing of pulse frequency and speed, after engraving, the stainless steel samples observed oriented structure – lines.

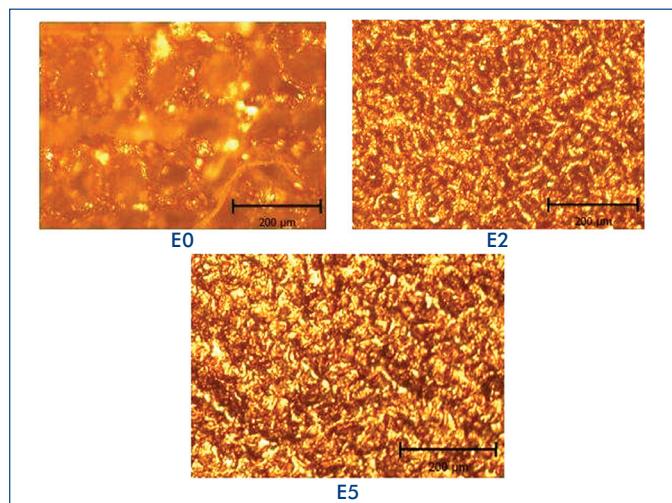


Figure 13. The microstructure of samples E0, E2, E5 from stainless steel

- During the engraving also the highest quality of the cutting edge was reached at the stainless steel, which is strong and sharp.
- When the samples were observed with microscope, it was confirmed that the microstructure is changed due to technological parameters and pulse rate, engraving speed, number of repetitions. The impact of increasing of the pulse frequency of the structure is more translating into a laser beam. With an increasing of the speed of engraving, the structure did not change significantly. At an elevated number of run times (from 2x to 10x), it can be seen larger thermal effect caused by re-melting of he structure by the laser beam.

Success of the engraving can be obtained by changing of the process parameters. Engraving laser beam belongs to the new technology, which is used for describing different types of materials. The major advantages of this technology include a description of permanent good quality, low operating cost, non-contact process (no tools required), and business process, there is no need clamped workpieces, to alter the description entered in the software description of the different materials and redundant special working environment.

The advantage of laser marking is that it is a non-contact and non-waste treatment. The description is resistant to wear and it is also durable. With simple programming we can be done the descriptions of serial numbers, texts, barcodes, matrix codes, logos, brands and various symbols. For the change of the theme, you can just change the program, thus there are no any preparatory works. By the action of the laser there can be aimed different effects as removing layers of material, colors, engraving, and more.

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