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NUMBER OF LASER BEAM PASSES INFLUENCE ON SURFACE COLOR TO WOOD MARKING

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ABSTRACT: For burning wood surface with laser beam darkening of the surface is obtained by burning.Traditional wood burning is done by burning it with a hot metal. Pirogravure with traditional means of wood is widely used in some cases the result is appreciated as a work of art. Studies on the use of laser for pyrography of wood are few in number by comparison with laser applications for cutting materials, including wood. By successive passes is being pursued getting dark colors.A maple wood surface was irradiated by successive passes of laser beam. Colorimetric measurements for the color obtained were performed. These were correlated with the number of passes. A physical and technological investigation of the machining process was carried out.By setting an optimal number of passes, the processing time is reduced.
KEY WORDS: laser pyrography, wood, CO2 laser, colorimetry

1. INTRODUCTION

Studies on the use of laser for pyrography of wood are few in number by comparison with other studies of laser machining applications for wood.

This was also noticed by [1]. Laser beam irradiation of wood surfaces has been studied in several papers. The type of laser used predominantly for pyrography is CO_2 laser and the type of wood varies. In the paper [2] it was studied irradiation for maple (*Acer pseudoplatanus* L.) by a CO_2 laser beam at different values of exposure energy. The CO_2 laser is inducing chemical and structural modifications, which were studied by [3] on Scots Pine, who concluded that the laser is causing modifications most intense at the treated surface.In the paper [4] was investigated the effect of feed speed ratio and CO_2 laser power on the engraved depth and colour difference of Moso bamboo lamina. In the paper [5] using a CO_2 laser, studied effects of the laser power on wood coloration of beech wood. In the paper [6] was analised the posibility to reproduce the wood texture on MDF.

Laser use for wood pirogravings are numerous. In the paper [7] was explored the option to treat wood surfaces with laser beams to develop new aesthetic possibilities and found an application in ski design. In the paper [8] was observed that used for wood decoration with laser was being a popular method for producing artistic items from wood. In the paper In the paper [9] was used laser engraving wood veneer for mass production.

In this paper we were made laser irradiation on wood Norway maple (*Acer platanoides* L.). The aesthetic qualities that recommend the use of this woody species for pyrography are the open color and the pale drawing**.** Before processing the support material was dried until the moisture content 12% and conditioned at atmospheric temperature of 20 ° C and relative air humidity of 65%. These parameters, for normal conditions, are recommended by [10]. The material was cut to size 300x55x12 mm. The surface which will be irradiated was calibrated with P60, and finally manual sanding with P100 grit size. Several successive passes of laser beam were made on a given surface. The color darkened with the number of passes. A color measurement system was used.

2. EXPERIMENTS

The experiment consisted of laser irradiation using CO2 laser on a square surface of 20×20 mm. The industrial laser used in the experiments is shown in Figure 1.

Figure 1 Marking Laser

The blackening of these areas on the wood surface was achieved. The following parameters were used:

- scan speed $v = 500$ [mm/s];

- Distance between the irradiated lines (step)

$$scan\ lines\ gap = 0.0254\ [\text{mm}]$$

- Laser beam pulse frequency

$$PWM = 2000\ [\text{Hz}]$$

- Laser beam average power

$$P = 6.76 [\text{W}]$$

The number of passes on the irradiated surface varied in the experiment. Thus, under the same experimental conditions, between 1 and 11 passes were made.The surfaces irradiated on wood for these are shown in Figure 2. The color was measured with the proposed method of [11]. This method of measurement can be used for small surfaces.

The color was expressed in the CIEL*a*b*, tricromatic system, according to [12] or [13]:

- L* represents luminance;
- a * represents the red color, if it is positive and the green color, if it is negative;
- b * represents the yellow color, if it is positive and the blue color, if it is negative.

For nonirradiated wood these parameters have the following values:

$$L_0^* = 84.32$$

$$a_0^* = 1.84$$

$$b_0^* = 23.42$$

This was used as references to appreciate the measured values.These are shown in Table 1. Table 1 also shows the processing time for each sample.

Table 1 Measured sizes

Number of passes [-]	**L* [-]**	**a* [-]**	**b* [-]**	**Processing time [s]**
1	64.6	6.9	34	174
2	64.4	6.1	33.4	349
3	63	5.6	32.4	522
4	62.4	5.2	31.1	696
5	58.4	6	31.8	870
6	55.8	6.2	31	1044
7	59.4	5	29.4	1219
8	60.7	5.5	30.9	1393
9	58.1	5.8	30.8	1567
10	53.6	6.4	30.3	1741
11	53.9	6.5	31.1	1916

Based on these values, we calculated:

$$\Delta L^* = L^* - L_0^*$$

$$\Delta a^* = a^* - a_0^*$$

$$\Delta b^* = b^* - b_0^*$$

Comform [14] or [15] the color difference was characterized by the size:

$$\Delta Eab^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

1 2 3 4 5 6 7 8 9 10 11

Figure 2 Dark surfaces by laser irradiation

3. ANALYSIS OF EXPERIMENTAL RESULTS

In the following will be analyzed the variation of sizes measured directly. Figure 3 shows the luminance L* variation with the number of passes. There is a logarithmic decrease in luminance with the number of passes. This shows that the irradiated surface it's getting dark.

Figure 4 shows the variation of the red color of a* with the number of passes. Its variation has several maximums and minimums. These are, however, in a relatively narrow field. This parameter has increased about 3 times for irradiated surfaces relative to the unirradiated surface. It shows a reaction to irradiation of the material which increases the red tint. It can not be associated with the number of laser beam passes. Practically values of this parameter stabilize after the first pass.This is shown by the ratio between standard deviation and average that is 9.37%.

Figure 5 shows the variation of the yellow tint with the number of passes.For this, a logarithmic decrease was obtained. It is obvious that as the burning of the wood occurs and it becomes dark decreases its natural yellow color.

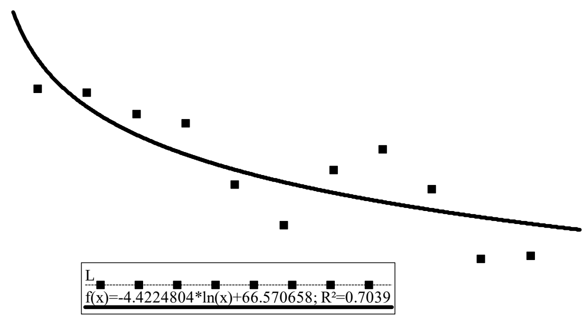

Figure 3 Variation of the luminance of the irradiated surface with the number of laser beam passes.

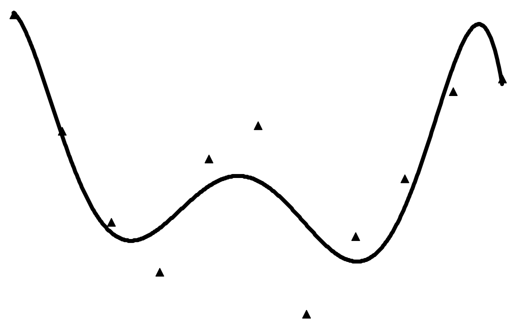

Figure 4 Variation of the red color of a* with the number of laser beam passes

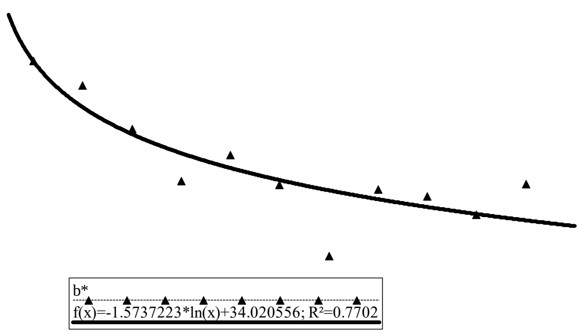

Figure 5 Variation of the yellow color of b* with the number of laser beam passes

In the following, calculated sizes will be analyzed to characterize the color of the irradiated surface.

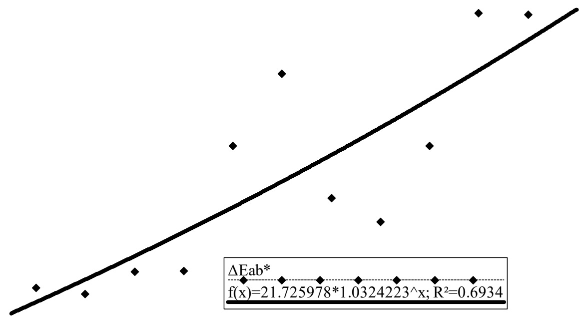

Figure 6 Variation $\Delta Eab*$ with the number of laser beam passes.

By increase size $\Delta Eab*$ it is shown that the surface color intensity increase.Thus, this size indicates the increase in the degree of darkening of the surface. Figure 6 shows that the surface darkens with increasing with number of laser beam passes. It is noted that there is an exponential increase with a high correlation coefficient.

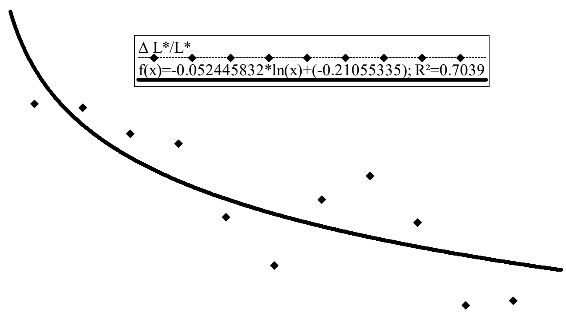

Figure 7 Relative luminance $\Delta L*/L_0^*$ variations

From the measured parameters, the luminance best presents the darkening phenomenon of the wood surface.

Figure 7 shows a logarithmic decrease for relative luminance. This type of decrease indicates that luminance tends to stabilize with the number of laser beam passes. The negative sign indicates that the surface darkens.

From the color measurements analysis showed increase color intensity and decrease of luminance. This means a darkening of the irradiated surface. It has been shown that after several laser beam passes there is a stabilization of the degree of darkening that can be obtained under the given irradiation conditions.

4. CONCLUSIONS

Following the experiments it was observed that the factor that is most affected by laser irradiation is luminance L*. Color does not change but just darkens.The other parameters to characterize the color were also presented. The color obtained is a yellow tint, this tint being defined by the natural color of the wood. After 8 passes of laser beam a steady tint of the irradiated area is obtained so that no further passage is justified. This observation can be applied to reduce processing time. It can be seen from Table 1 that the processing time is proportional to the number of laser beam passes. Thus reducing the number of passes to obtain a degree of darkening of the surface useful in laser marking becomes an important objective. Reducing processing time becomes the more important because in addition to the actual processing time, processing time includes a series of dead times used to reposition the work head in its original position and to restart the work. Sometimes it is also necessary to provide a pause time between the passes of laser beam necessary to cool the work equipment.

5. REFERENCES

1. Gurău L., Petru A., Varodi A. ,Timar M. C., The Influence of CO2 Laser Beam Power Output and Scanning Speed on Surface Roughness and Colour Changes of Beech (Fagus sylvatica)," *Bioresources*, vol. 12(4), pp. 7395-7412, 2017.
2. I. Kubovský F. Kačík, „FT-IR study of maple wood changes due to CO2 laser irradiation," *Cellulose Chemistry and Technology*, vol. 43, pp. 235-240, 08 2009.
3. S. Barcikowski, G. Koch, J. Odermatt, „Characterisation and modification of the heat affected zone during laser material processing of wood and wood composites," *Holz als Roh- und Werkstoff*, vol. 64, nr. 2, pp. 94-103, Apr 2006.
4. C.-J. Lin, Y.-C. Wang, L.-D. Lin, C.-R. Chiou, Y.-N. Wang M.-J. Tsai, „Effects of feed speed ratio and laser power on engraved depth and color difference of Moso bamboo lamina," *Journal of Materials Processing Technology*, vol. 198, nr. 1, pp. 419-425, 2008.
5. A. Petru, A. Lunguleasa, „Effects of the laser power on wood coloration," în *International Conference of Scientific Paper AFASES*, Braşov, 2015.
6. Z. Howard, K. Young P. Dunn, *Laser treatment transforms MDF producing startling image of rare wood grains*, 2014.
7. A. Petutschnigg, M. Stöckler, F. Steinwendner, J. Schnepps, H. Gütler, J. Blinzer, H. Holzer T. Schnabel, „Laser Treatment of Wood Surfaces for Ski Cores: An Experimental Parameter Study," *Advances in Materials Science and Engineering*, vol. 2013, pp. 1-7, 09 2013.
8. B. Yakimovich, M. Chernykh, A. I. Stepanova M. Siklienka, „Influence of selected laser parameters on quality of images engraved on the wood" *Acta Facultatis Xylologiae Zvolen res Publica Slovaca,* vol. 58, nr. 2, pp. 45-50, 2016.
9. M. Chernykh, E. Kargashina V. Stollmann, „The use of wood veneer for laser engraving production," *Acta Facultatis Xylologiae Zvolen res Publica Slovaca*, vol. 60, nr. 1, pp. 121-127, 2018.
10. M. Cismaru, *Fizica lemnului şi a materialelor pe bază de lemn,* Braşov, Editura Universităţii Transilvania, 2003.
11. A. Petru şi A. Lunguleasa, „Colour measurement using digital image analysis," în *International Conference of Scientific Paper AFASES*, Braşov, 2014.
12. S. 6880/1-88, *Colorimetrie. Colorimetrie de reflexie. Noţiuni generale.,* Bucureşti, 1988.
13. B. E. I. 105-B01:2014, *Textiles. Tests for colour fastness. Colour fastness to light: Daylight*, 2014.
14. S. 6880/3-88, Colorimetrie. Colorimetrie de reflexie. Calculul diferenţelor de culoare, Bucureşti, 1988.
15. B. E. I. 105-J03:2009, *Textiles. Tests for colour fastness. Calculation of colour differences,* 2009.