ACTA FACULTATIS XYLOLOGIAE ZVOLEN, 58(2): 45−50, 2016
Zvolen, Technická univerzita vo Zvolene
DOI: 10.17423/afx.2016.58.2.05

INFLUENCE OF SELECTED LASER PARAMETERS ON QALITY OF IMAGES ENGRAVED ON THE WOOD

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ABSTRACT

The paper demonstrates the method for defining the power and speed of laser engraving of tone raster images on wood. The method is based on expert evaluation of aesthetic perception of engravings on wood produced with various engraving power and speed, defining the range of their favorable values and further application of these values in technological process of engraving different items. The results obtained make it possible to recommend the proposed method to define the rational mode of laser engraving of tone images on other wood species.

Keywords: laser, engraving, wood, power, speed, black color percentage.

INTRODUCTION

Laser processing technology is unique, it is applied for different materials, it allows obtaining raster and vector images, cutting material, producing 3D images in transparent material, as well as combining the foregoing possibilities in one item (ARAI *et al*. 1979).

Laser decoration is popular for producing artistic items from wood. Laser engraving is applied for producing images (engravings) of 3 types: linear vector, whose patter in formed from the lines of the same tone; contour vector in the form of a spot or spots, each of which has its own tone; and tone raster, in which the tone gradient is used (BARCIKOWSKI *et al*. 2004. BARCIKOWSKI *et al*. 2006. DULEY 1976.). Due to light-and-shade tone images are perceived as volumetric and have greater aesthetic value in comparison with linear and contour ones.

A tone image engraved on wood always differs from black-and-white or color original – photograph or drawing produced by offset printing or means of image graphics. If the color of black-and-white original can change from white in the lightest regions to black in the darkest ones, and intensity of black color in CMYK palette – from zero to 100%, the engraving color changes from light to dark brown, and intensity of black color of engraving K_r – from natural, i.e. from the background intensity of the image engraved K_b to maximum possible for the particular wood species under laser processing – tone limit K_t (FRUHWALD 2007, CHERNYKH 2014).

The aesthetic perception of the item with engraved image depends both on the image color (i.e. tone as the image has one color – brown) and its facture (different from the primary blank facture), as well as the image background, i.e. natural color, facture and texture of wood. Currently there is no method of designing technological processes of laser engraving

of wood (as well as other materials) taking into account the combination of the item aesthetic perception and process technological factors – power P of radiation source and its traveling speed V, which complicates the production of items of high aesthetic value and decreases their competitiveness. In practice the problem is solved either using test prototypes or the engraving is performed based on the variant of computer pattern selected by the customer (CHERNYKH 2015, PHOTOGRAV). The first method is connected with additional material and time consumption and results in the item appreciation, and the second one does not provide high aesthetic value of the item, as selecting the pattern it is difficult to take into account the difference in color, texture and facture of computer pattern and the wood of actual blank, as well as the difference in facture and tone of computer pattern and the one produced by engraving.

Based on the foregoing, it is topical to develop the formalized method for defining the modes of laser engraving of tone images on wood improving the aesthetic value and competitiveness of items.

MATERIAL AND METHODS

The investigation was carried out on beechwood. The blank size – 70 × 95 mm. The engraving was performed by laser GCC Laser Pro Mercury II carries the fine tradition of the Mercury series to provide stable engraving quality. The servo motor enables fast movement of lens carriage while maintaining accuracy over time, giving you reliable and dependable results. Mercury II is reinforced with new features, including key switch, user-friendly control panel, and SmartCENTER. Virtually any materials such as acrylic, wood, fabrics, glass, leather, marble, stone, rubber stamps, paper products, coated metals, plastics (especially micro plastic developed by IPI, Spectrum and Rowmark etc.) other hard-surface materials blended with polyester and fibers (Corian™, Fountainhead™, and Avonite™ etc.) or laserable simulated products of stone, wood and metal etc. The GCC Laser Pro Mercury II with the maximum power P_{max} equaled to 25 W and the highest head movement speed V_{max} equaled to 1000 mm/sec. Factors P and V varied in the range from 0.125 up to 1.0 P_{max} and from 0.125 up to 1.0 V_{max}, respectively. Portrait No 12 (YSTO GROUP) was selected as the image. The image contained the wide range of gray gradations from white to intensive black.

The values of parameters K_b, K_r and K_T were defined by twenty five sample scans processed in Photoshop. The aesthetic perception of the engravings was evaluated by experts (NEWSINPHOTO). The image faximility i.e. the distinguishability of minor elements of the portrait: hairs, wrinkles, face details, overtones, eye shine, etc. was accepted as the evaluation criterion. A five-grade scale was used: high quality of engravings was given 5 grades, good – 4 grades, satisfactory – 3 grades, unsatisfactory – 2 grades and very low – 1 grade. 24 experts were involved in the evaluation.

The change in the area of the charred region and tone of the engravings depending on the absorbed power W was studied with the help of digital microscope Dino-Lite, and the tone wedge as the original (CHERNYKH *et al*. 2013, GOST 1984) (Fig. 1,a).

RESULTS AND DISCUSSION

The table contains the values of engraving speed V for each sample, arithmetic mean value of its aesthetic perception, black color percentage Kr_{max} in the darkest region and engraving power P in this region. In lighter regions the engraving power P_i was

automatically decreased by the laser executive program proportionally to the percentage of black color K_i in the original region to zero when K_i equals zero.

When observing the laser engraved raster image under the microscope (as the tone wedge (Fig. 1,b), and as the portrait), the dark charred spots are seen on the light background formed as a result of laser radiation pulse concentration in the center of half-tone cell of the linear raster. Due to small spot sizes (0.2–0.3 mm), distances between them, and blur of their contours the tone of raster engravings is perceived as homogeneous with a naked eye.

When power *P* increases and engraving speed *V* goes down, the absorbed laser radiation power W goes up, the heating temperature of wood surface around the areas of pulse concentration is elevated, the engraving charred area, tone intensity and black color percentage increase (KUBOVSKÝ 2016, OLSSON 2014). At some value of absorbed power W the intervals between spots become completely charred, and engraving tone intensity and black color percentage Kr reach their maximum values, i.e. the tone limit K_T (Fig. 2). The further increase in the absorbed power leads to peeling the charred wood layer in the regions of pulse concentration, resin extraction and, as a result, to surface lightening in these regions (Fig. 1,c), the engraving tone intensity and black color percentage decrease. With further growth of absorbed power the peeling, resin extraction and lightening are spreading to the regions between the spots, and the carbon deposit is formed in the background regions adjoining the boundaries of the engraving darkest areas, thus impairing the item aesthetic perception.

Tab. Research results

Sample No	P, W	V, m/sec	Expert evaluation, mean score	Kr_{max}, %
1	3.12	0.37	2.5	58
2	6.25	0.25	2.37	67
3	9.38	0.12	1.0	88
4	3.12	0.87	1.3	48
5	6.25	0.75	3.87	53
6	9.38	0.62	3.66	60
7	12.50	0.50	3.2	69
8	15.62	0.37	1.2	82
9	18.75	0.25	1.0	87
10	25.00	1.00	2.6	63
11	15.62	0.87	2.9	61
12	18.75	0.75	2.9	72
13	21.88	0.62	1.0	76
14	21.88	0.12	1.0	88
Note: K_b = 37%				

The expert evaluation demonstrated that the engravings have the highest aesthetic value at Kr_{max} equaled to 0.7–0.9 K_T (see Table). Such values in coordinates *P*–*V* correspond to region A in Fig. 3 located approximately in the ranges $5<P<10$ W and $0.6<V<0.8$ m/sec. The engravings produced at the values of *P* and *V* located either to the left from or above region A are perceived as overlighted, and those produced at *P* and *V* located either to the right from or under region A – as overdarkened. The defined power and speed ranges can be recommended for working out technological processes of laser engraving on beechwood. When operating in these ranges, the highest aesthetic value of engravings is achieved without the computer pattern adjustment; in other cases the adjustment is required the results of which are unknown in advance.

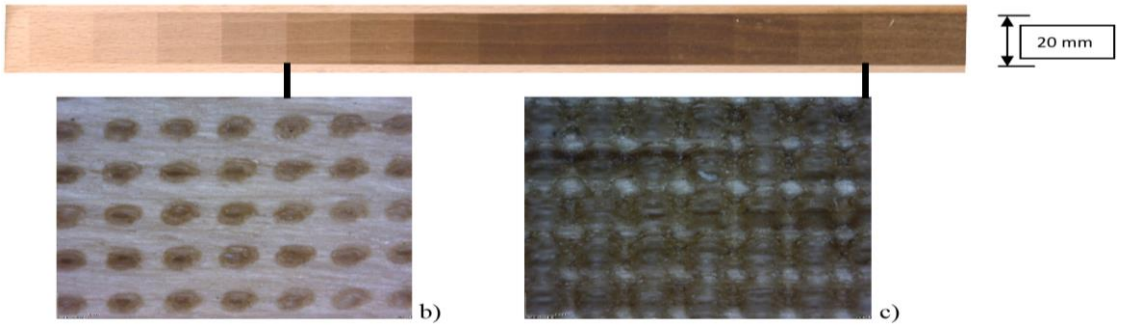

Fig. 1 Tone wedge engraved on beechwood [11] with engraving power *P* = 9.6 W, speed *V* = 0.18 m/sec (a) and its regions 4 (b) and 13 (c) of steps (× 180); resolution 500 dpi.

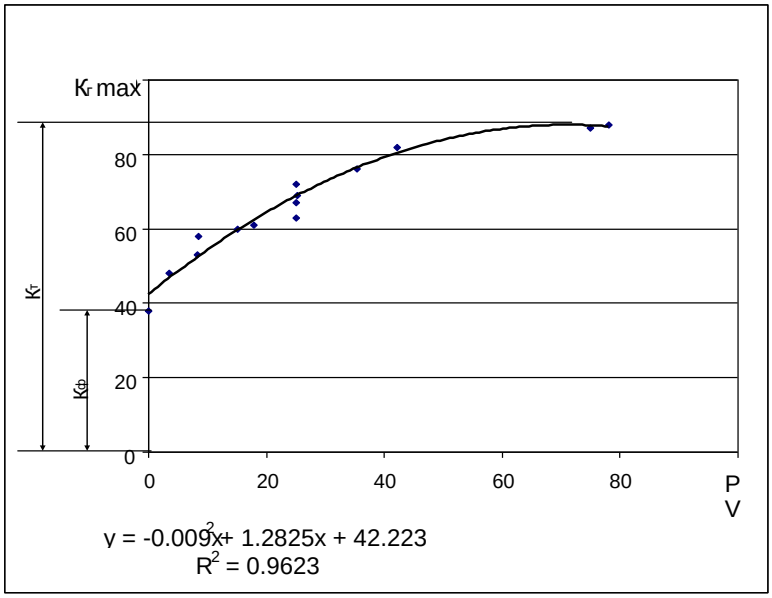

Fig. 2 Dependence of maximum percentage of black color Kr_{max} in the darkest regions of engravings on the ratio of technological factors *P/V*.

The results obtained make it possible to recommend the proposed method to define the rational mode of laser engraving of tone images on other wood species.

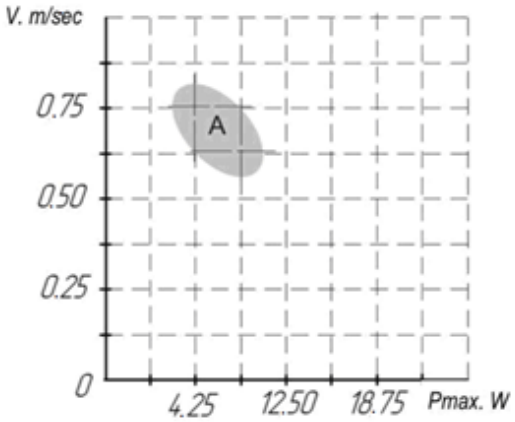

Fig. 3 Region of values *P* and *V* providing the highest aesthetic properties of engravings on beechwood.

CONCLUSION

The proposed method allows selecting the power and speed values of laser engraving on wood providing the highest aesthetic properties of items multiply applying the results once obtained. The expert evaluation demonstrated that the engravings have the highest aesthetic value at Kr_{max} equaled to 0.7–0.9 Kт. The defined power and speed ranges can be recommended for working out technological processes of laser engraving on beechwood. When operating in these ranges, the highest aesthetic value of engravings is achieved without the computer pattern adjustment; in other cases the adjustment is required the results of which are unknown in advance. The results obtained make it possible to recommend the proposed method to define the rational mode of laser engraving of tone images on other wood species.

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