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METHOD OF COMPUTER TEMPLATE ADJUSTMENT FOR WOOD LASER ENGRAVING

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ABSTRACT

To achieve the identity of wood-engraved replicas with a pseudo-volume original, it is necessary to adjust the computer model. The method of selecting the model tone range ensuring the reproduction of the original light-and-dark transitions in the replica is introduced in the paper. The method is based on the selection of boundary values of the model black color saturation, taking into account the brightness threshold value perceptible to a human eye. Two methods for determining the boundary values of the model tone saturation were compared – visual by expert assessments and instrumental by scanning replicas and processing scans in Photoshop. The model black color saturation recommended for beech wood in CMYK color space was 2% (lower boundary value) up to 33% (upper boundary value).

Key words: beech wood, computer model, laser engraving, perception.

INTRODUCTION

Changing the color by thermal exposure (thermodification) expands the possibility of using wood in design, decorative arts, production of interior items and furniture, carpentry (DZURENDA 2013, 2018, GEFFERT *et al*. 2017).

The thermal effect can be carried out by different technologies with different types of energy. Engraving and cutting are performed applying a laser beam to the wood. Laser engraving of wood and wood materials (BAKCIKOWSKI *et al*. 2004, 2006, YAKIMOVICH *et al*. 2016, CHERNYKH *et al*. 2018) allows obtaining a variety of images of high aesthetic value.

The color of wood in the laser beam action area changes from natural to brown depending on the heating temperature, which, in turn, depends on the pulse power of radiation P, movement speed of laser head V, saturation of tone R of the computer model developed from the original image (photo, drawing). Pseudo-volume images with light-and-dark transitions created by the tone gradient are the most difficult for identity reproduction on wood. The identity of engraved images determines their aesthetic perception and value for a consumer. The most approximation of the replica to the original is achieved when displaying both the lightest and darkest areas of it, which allows providing volume to the engraved image to show small elements.

When developing the model, the original is transformed into black-and-white format. The saturation of its color in CMYK color space can vary from 0 up to 100%, and the black color saturation of the engraved image – from the lower threshold value K_f (equal to the natural saturation of wood black color) to the upper threshold value K_t (the tone limit), significantly less than the maximum possible saturation of the original black color, i.e. one hundred percent. The correct display of the original light-and-dark transitions in the replica is possible only in the narrow range of the power-to-speed ratios of engraving without adjusting the model (YAKIMOVICH *et al*. 2016). The determination of these ratios requires the production of a series of prototypes in the range of possible values of P and V. Therefore, in most cases, the model adjustment is required.

The simplest and quickest is the adjustment (and simultaneous approval by the customer) using a computer template attached to the software of some laser units (PHOTOGRAPHV, YSTO CROUP). However, when using this method, high aesthetic properties of replicas are not achieved due to the difference between the computer template and the real work piece in color and texture due to the inevitable fluctuation of these properties from work piece to work piece within the tree species.

It seems more promising to use the method of model adjustment based on threshold values of K_f and K_t (CHERNYKH *et al*. 2015, YAKIMOVICH *et al*. 2016), which can be found in two ways: using a spectrophotometer and scanning a halftone wedge engraved on the work piece (GOST 24930-84 (State Standard), followed by the scan computer processing in Photoshop.

However, even in these cases, the task of the model adjustment cannot be considered completely solved. A consumer visually evaluates the aesthetic value of the engraved product and the desire to purchase it. Perception of one tone brightness by a human eye is limited by a so-called threshold brightness value (MIKOV 2007), so the visually perceived range of black color saturation can differ from the one measured instrumentally, and the range of black color saturation set by the model values of K_f and K_t may need to be clarified.

To test the hypothesis, the study was conducted.

MATERIALS AND METHODS

The study was carried out using replicas of geometric ornaments of the same pattern engraved on beech wood. Sixteen replicas were engraved from sixteen black-and-white originals. The size of each replica was 20 × 20 mm. For the study convenience, all replicas were concentrated in 100 × 100-mm field on the sample with dimensions in the plan of 130 × 130 mm. The moisture content of the wood was 12%, the front surface of the sample was grinded before engraving.

The drawing of each original contained an internal element in the form of a circle, a middle element in the form of a square with four rays radiating from the middle of the square sides, and four external elements in the form of angles (Fig. 1). The originals were made on white paper using laser printer and had the same black saturation of the external elements equal to 100% in CMYK color space, the same saturation of the internal elements equal to 0% and different black saturation of the middle elements. The latter was changed as follows: 3, 5, 7 and 10% in the area of light tones and then up to 70% in increments of 5%. The selected pattern was convenient for comparing the consistently changing tone saturation of the middle elements with the constant tone saturation of the internal and external elements.

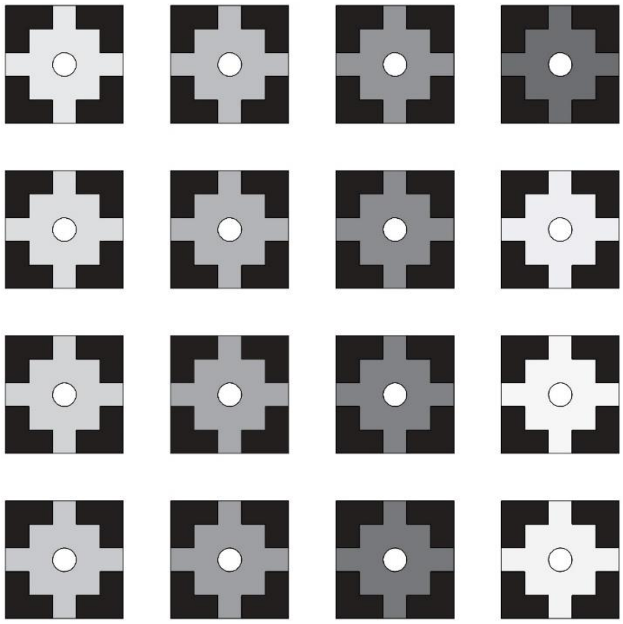

Fig. 1 Image original.

The engraving was performed with Trotec Speedy 100R laser engraver with the power of P = 25 W, speed V of up to 2.85 m/s and resolution R = 125-1000 dpi. All replicas were engraved in the same mode P = 14 W, V = 0.7 m/s and R = 500 dpi.

To process the results, two methods were used – instrumental measurement of the black saturation of elements on replica scans in Photoshop and method of expert assessments using the method similar to the one in paper (CHERNYH *et al*. 2012).

The difference between the tone of middle elements from lighter internal elements, on the one hand, and darker external elements, on the other, was compared by the method of expert assessments. If an expert believed that the tone of the middle engraved element of the replica in question seemed darker than the tone of the internal (non-graved) element, i.e. answered in the affirmative to the first question of the table, then the expert entered one into the survey table. If the expert thought that the middle element of the replica did not darken as a result of engraving, and was perceived as equal to the tone of the internal element, the expert entered zero into the table. In case of doubt, the expert entered 0.5 into the table. Similarly, the tone of the middle element of the replica was compared with the tone of the external ones.

All experts had a high level of color perception, passed or are currently undergoing art training at universities. Two groups of fifteen experts were interviewed at different times. The results of each group were averaged.

Comparing the instrumental and visual assessments of the replicas, it can be concluded that it is necessary to take into account the threshold value of a human eye brightness when designing a computer model of the engraved value.

RESULTS AND DISCUSSION

The replicas obtained by engraving are shown in Figure 2. The numbers on the left of the replicas indicate the black color percentages of the model middle element corresponding to the replica.

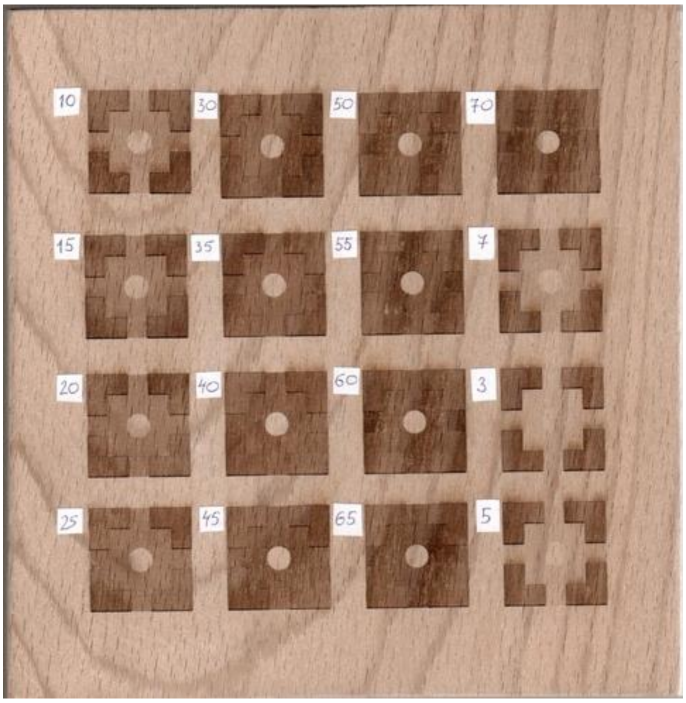

Fig. 2 Replicas laser-engraved on beech wood.

The results of expert assessment of the replicas are presented on the graphs in the coordinates "black color percentage of the model middle element K_m – perception W" (Fig. 3). In table 1 line 1 demonstrates the comparison of the middle element tone of the replicas with the tone of their external elements, line 2 – the middle element tone of the replicas with the internal element tone.

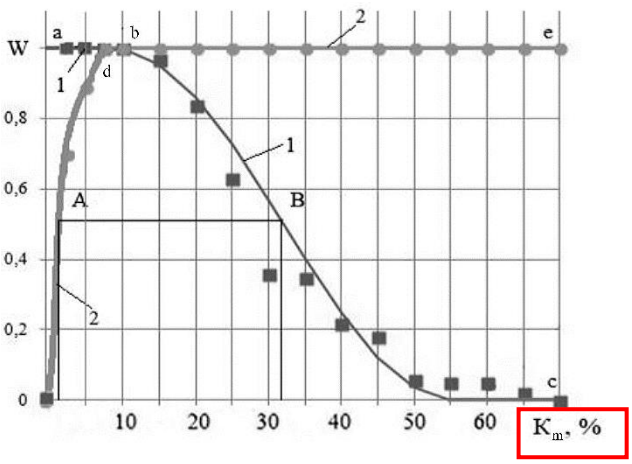

Fig. 3. Results of expert assessment of the tone of replica element: 1 – comparison of the tone of middle and external elements, 2 – comparison of the tone of middle and internal elements.

Line 1 can be divided into 2 specific sections – *ab* and *bc*. With low saturation of the middle element tone of the model ($0 \leq K_m \leq 10\%$), corresponding to the section *ab*, all the interviewed experts, as expected, noted that the middle element tone of the replica was lighter than the tone of its external elements. At the same time, the value of perception W – the ratio of the number of affirmative answers to the number of interviewed experts – equaled one. With further increase in the black color percentage of the middle element of the models, the number of experts who gave an affirmative answer and the perception of W decreased, and at $K_m \approx 33\%$ (in point B of the graph) the perception became equally probable (W=0.5), when the number of experts who gave an affirmative answer equaled the number of those who gave a negative answer. Even with the growth of K_m, the perception decreased, approaching zero at $K_m \approx 50\%$ or more.

Tab. 1 The perception of the tone contrast of the elements of the replicas by experts

No	Perception option of the replica middle element tone	Replica number															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		K_m, %															
		3	5	7	10	15	20	25	30	35	40	45	50	55	60	65	70
1	Darker than ligh	0.7	0.89	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Lighter than dark	1	1	1	1	0.97	0.84	0.63	0.35	0.36	0.22	0.18	0.06	0.05	0.05	0.02	0

In the instrumental assessment, the tones of the middle and external elements also converged with the growth of K_m (Fig. 4). But their equality in the zone of dark tones occurred at higher values of K_m (approximately 50-60%) than in the visual assessment. The discrepancy was caused by the influence of the threshold value of human eye brightness. A human eye, unlike the instrument, does not distinguish tones similar in brightness K_n, K_s, K_v, %.

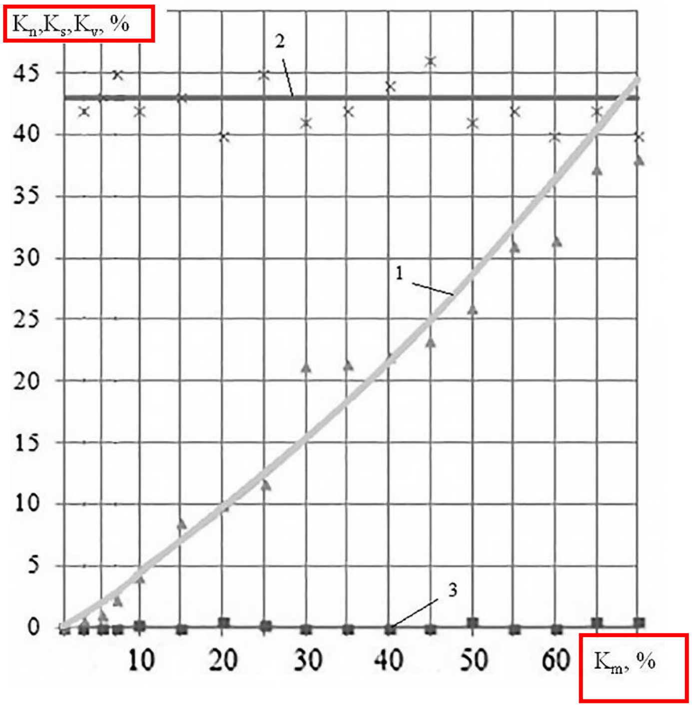

Fig. 4 Black color percentage of replica elements: 1 – middle, 2 – external, 3 – internal.

In the graph of comparison of the middle element tone with the internal element one (line 2 in Fig. 3) two sections – *od* and *de* can also be distinguished. When the tone saturation of the model middle element corresponded to K_m values of 7% or more, all experts noted that the middle element looked darker than the internal one, therefore, the perception of W in *de* section equaled one. The left branch *od* of graph 2 proceeded from the origin of coordinates. In point 0 the perception equaled zero because the replica middle part with zero saturation of its tone in the model cannot look darker than the internal one. At 3% of the model black color, the average perception value W was 0.62, at 5% – 0 .85, at 7% – 1. Point A of the equally probable perception (W=0.5) in section *od* corresponded to $K_m \approx 2\%$.

The black color percentage of the internal element of the replicas measured using Photoshop varied from 0 up to 3%, the fluctuation of values can be explained by the texture influence. Thus, the discrepancy in the results of visual and instrumental assessments in the area of light tones was insignificant and within the experiment error margin. Nevertheless, even in the area of light tones, we can talk about the influence of the brightness threshold value perceived by a human eye, since only at 7% of the model tone saturation all experts noted the difference between the replica tone and the natural tone of wood.

The availability of the brightness threshold perceived by a human eye is essential in the design of wood-engraved pseudo-volume images for their identity. For beech wood, the rational black color gradient range of the model is from 2 to 33%. The obtained data are consistent with the results of previous work (CHERNYKH *et al*. 2018). In this case, the light-and-dark transitions of the original are distinguishable in the replica by most consumers, and the image on the replica is perceived as three-dimensional.

CONCLUSION

When engraving pseudo-volume images on wood with a laser, it is necessary to adjust the model to display light-and-dark transitions of the original in the replica in order to achieve identity.

The highest aesthetic value of products with engraved images is achieved when the model is adjusted according to the threshold values of black color percentage in CMYK system of the natural tone of wood, on the one hand, and the tonal limit for laser processing, on the other. This method allows taking into account the tone and texture features of the real workpiece.

Visual perception of light-and-dark transitions engraved on beech wood is limited by the brightness threshold value perceived by a human eye. A visually perceivable brightness range of a human is narrower than the range determined using replica scanning and processing in Photoshop. In the zone of light tones on beech wood, the difference in ranges, determined visually and instrumentally, is insignificant and within the experiment error margin. In the zone of dark tones on laser-treated wood, the difference reaches 20-30% of black color.

When designing the model of pseudo-volume laser-engraved images on wood, the model black color range should be $2 \leq K_m \leq 33\%$.

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