

## IMAGE CONVERSION FOR LASER PYROGRAPHY

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### **Abstract**

*All previous studies of pyrography have been focussed on colour obtained through modifying the work parameters. This paper analyses colour nuances obtained by laser woodworking by measuring colour changes digitally. The investigated parameter is colour reproduction by laser technology, using different image conversion methods (Halftone Round, Jarvis, and so on). The changes of image reproduction are analysed globally and colour by colour. The results show that the colour nuances are represented to a more and less degree, according to the conversion method selected. To evaluate the aesthetic changes, CIEL\*a\*b\* colour measurements were applied. The results show that laser burning on wood surfaces has a great influence on wood colour. These findings will be useful to develop innovative design possibilities for wood surfaces for furniture and other products.*

**Key words:** *pyrography; wood burning; laser technology; colour.*

### **INTRODUCTION**

Usually, in laser technology, an unconverted image contains just two colours, black and natural wood colour. When using a converted image, it can contain about 10 nuances between natural wood and black. Demand for wood products is growing despite the fact that wood is more difficult to obtain and more expensive. Petutschnigg et al. (2013) has used laser technology to increase the aesthetic value of skis.

Drawing preparation for pyrography is a challenge for artists because the model must represent an artistic emotion through a plain image with just two colours and their tonal values. In the case of classical pyrography, the shades are made by varying the heat temperature of the device nib. Varying heat temperature of the material is made in several ways: varying the tool nib temperature, varying work speed, or by varying other work parameters. Sometimes the management of these parameters is difficult.

Because wood is a complex material, it is difficult to obtain the same colour with the same work parameters. Irish (2012) proposed a template with more filled squares using different working parameters. Because wood is a heterogeneous material, it is recommended to use this template for each masterpiece. As regards to obtained colour, Millis (2013) used samples which were 'scorched' in a controlled manner at a range of temperatures to produce different shades from light to dark.

In the particular case of laser processing, the work parameters which influence the colour are: laser power, feed speed, and scan gap. These parameters can be set globally for each image, but not for image parts. Of these parameters, scan gap value and laser power have the most influence on the colour obtained (Petutschnigg et al. 2013). Kacik and Kubovsky (2011) deal with colour changes by laser beam irradiation. Donțu (1985) noted that using a laser to achieve decoration is an application based on local vaporisation or material burning. One of these applications is wood burning by laser. Dumitraș (1982) considered that the frequency of calls for applications in gas lasers is due to the advantages that they have: high gain, continuous wave operation capability, power levels of extremely high potential, high yield, high spectral purity, simplicity of design, a spectral area lying between far ultraviolet emission and millimetre waves, and lower cost. Leone et al. (2008) observed that lasers are widely used in cutting and welding operations. In recent years, thanks to laser sources characterised by pulse duration variable from nanosecond to femtosecond, lasers have been applied in other machining like marking, scribing, selective ablations and engraving on metallic, ceramic and polymeric materials. Kacik and Kubovsky (2011) observed that use of CO<sub>2</sub> laser irradiation on wood has several advantages. Unlike conventional methods of dyeing, lasers can change colour (from wood colour to black) only by delivering energy in the form of electromagnetic radiation. In the case of the use of the industrial CO<sub>2</sub> laser, the amount of input energy can easily be changed – either by changing the distance from the irradiated surface from the output focus lens or by change of the feed speed of the laser head. By measuring the intensity of irradiation, it can precisely define the quantity of energy supplied. Compared with other technological procedures used to change the colour of wood (steaming, and drying), lasers are usually quite difficult.

In order to provide a support for works, Irish (2012) proposed more materials used for pyrography. These materials are: leather, gourds, cloth, paper, and wood. Researchers from the University of Warwick have established a new way of using lasers that transforms the aesthetic appearance of MDF, giving it a surface finish that looks like some of the most expensive wood grains. They proposed MDF as a support material for laser pyrography. It can imitate a wide range of real wood structures, can produce logos, decoration, decorative surfaces or even shapes using the latest version of this new laser technology (Howard 2014). Petutschnigg et al. (2013) observed a global trend in the use of lasers for fast growing wood species. These species are considered inferior by other researchers from the point of view of physical and mechanical properties, as well as aesthetic qualities. Another possibility to increase the aesthetic value of these materials is by aesthetic burning. In contrast to other decorating techniques, pyrography has the advantage of being an inexpensive technique, ecological, and available.

The parameters which were investigated by Petutschnigg et al. (2013) were laser beam intensity and the number of laser points on the surface. To evaluate the aesthetic changes, CIEL\*a\*b\* (1976) colour measurements were applied. This measurement system consists of three parts: L\*, a\*, and b\*. L\* represents lightness and it is on scale of 100, where L\*=100 is white and L\*=0 is black. The a\* parameter characterises the green (negative values), and red (positive values). The b\* parameter characterises the blue (negative values), and yellow (positive values). The results show that the laser treatments on wood surfaces have a great influence on wood colour and the chemical composition. The intensity of laser beams especially affects the colour changes in different patterns for the analysed parameters. These findings will be useful to develop innovative design possibilities for wood surfaces for ski cores as well as for further product design applications.

## OBJECTIVE

The aim of this study was to find the image conversion method which had the nearest colour nuances to the original image prepared for the laser machine. The study proposed to obtain a burned image with the most numerous colour nuances.

## MATERIAL, METHOD, AND EQUIPMENT

The methodology consists of tests using the same image converted in to more black and white images, using Corel Photo Paint software, and keeping the same work parameters. For this study, beech (*Fagus Sylvatica* L.) plywood was used. This species is one of the most used species, recommended as a support for pyrography by Filipovici (1965), Bucur (1978), Dogaru (1985), Hinescu (1989), Năstase (1991), Haller et al. (2001), Kacik and Kubovsky (2011), Petutschnigg et al. (2013). Beech is a species with a uniform structure and light natural colour. The pale colour provides the possibility of obtaining a large colour gradient after burning. The experiments were made on specimens formatted to 45 mm wide and 35 mm depth. In order to analyse the colour of wood, the tangential surface of samples was used.

The specimens were dried at 12% moisture content and conditioned at 20°C temperature and 65% relative humidity as considered by Cismaru (2003). Before laser processing, the wood specimens were sanded with 80 grit sand paper and then sanded with 120 grit sand paper. The equipment used was: Laser Engraving Machine 4030lsct, HP LaserJet 3055 all-in-one printer for image scanning, PC for image processing and measurement. The specimens were processed by laser. The technical characteristics of the Laser Engraving Machine 4030lsct equipment, were:

- Scanning speed (maximum): 500 mm/s raster engraving;
- Material Size (maximum): 400 x 300 mm;
- Material Types: Metal, Plastics, Wood, Paper, Composites, Fabric, Rubber;
- Spot Size (at working distance): 0.0254 mm;
- Laser Wavelength: 10.6 µm.

The laser system was controlled through a PC by means of customized CAD-CAM software, which allows the generation of the geometric patterns to be used and the control of the working parameters.

The original image was a graphical product processed by computer. This image contained 20 squares, each filled with different colours. The colours chosen started from primary colours (yellow, red, and blue for artists' primary colours and cyan, yellow, magenta for printing). This image was converted to grey-scale colour nuances to reduce differences between reference image and pyrographed images. Each image was converted using the conversion methods provided by Corel PhotoPaint software. Each specimen was burned with a different converted image. The studied conversion methods for images were: Ordered, Jarvis, Stucki, Cardinality-Distribution, Floyd-

Steinberg, Halftone cross, Halftone square, Halftone fixed 4x4, Halftone fixed 8x8, Halftone line, Halftone round.

The work parameters were:

- Laser Power: 6 W;
- Focused distance: 73 mm;
- Scanning speed: 500 mm/s.

In order to measure colour, the processed samples were scanned using a common desktop scanner. The technical characteristics of the HP LaserJet 3055 all-in-one printer, fax, copier, scanner type for scanning HP (2014) were:

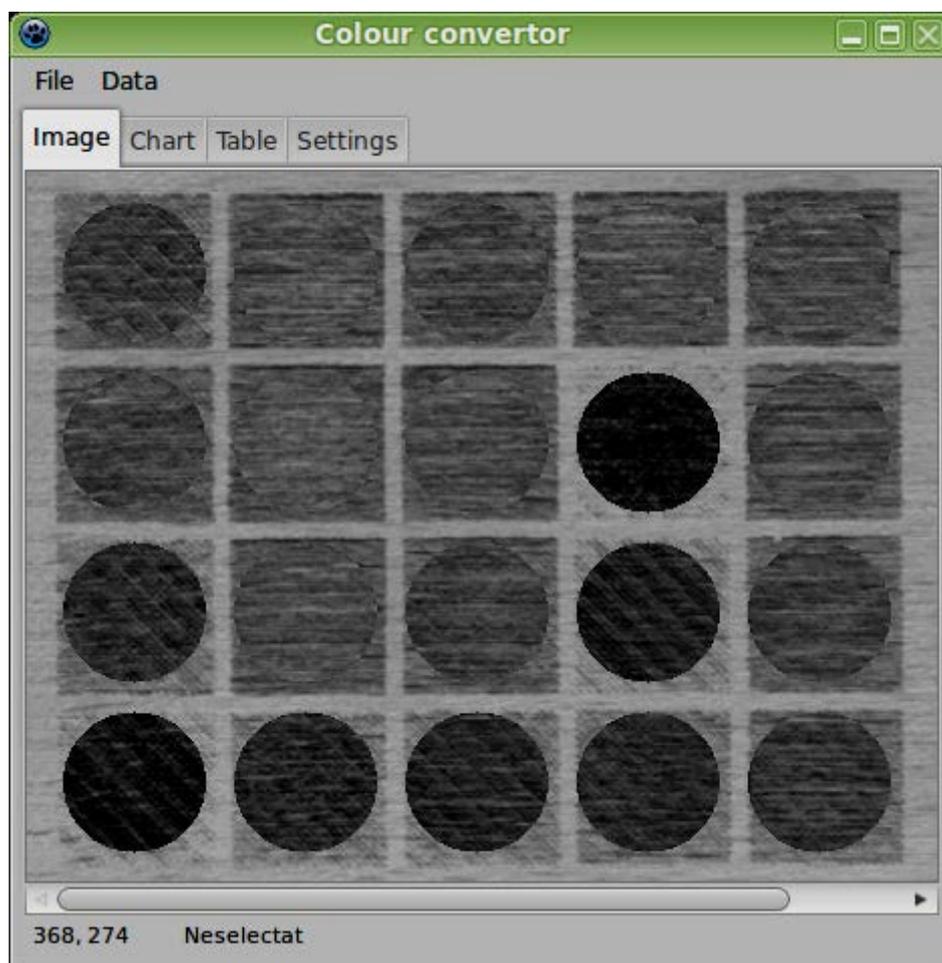
- Resolution: 1200 ppi, 24-bit full-colour scanning from letter/A4-size scanner glass;

Engraved surfaces were scanned with HP LaserJet 3055 all-in-one scanner with 600 dpi resolution in bitmap format. The colour was measured using the method presented by Petru and Lunguleasa (2014). The used parameters for this study were:

- Colour mode;
- Scan scale 1:1.

In order to analyse all images, the scanned image files were transferred to a computer.

Before loading the measurement software, all images were scaled in order to have the same dimensions. To correlate the colour measured values, each pyrographed image was converted to large-scale nuances.



**Fig. 1.**  
***The template with measuring points***

Inside of each filled square, the colour was measured with a 70 pixels for a circular surface. It resulted 3905 pixels for each square and 78100 measured pixels for each image. To simplify all measurements, an electronic template was made using all the measuring pixels. Each image, original

and pyrographed, was measured using this template (Fig. 1). Measured values were saved and exported to LibreOffice Calc software (Libre Office 2015). For each measured round surface, the average value was calculated. The average value for each measured round surface from the pyrographed image was compared with the corresponding value from the reference image. The value which is nearest to the reference value is considered the optimal value. The next step was to count the conversion methods which were closest to the reference value. The conversion method which occurred most often to the closest value was considered the best one.

## RESULTS AND DISCUSSION

From the trichromatic colour analysis it was observed that the L\* component, which defines the lightness of colour, had the highest percentage. The other two components, a\* and b\*, have a much smaller magnitude (Table 1). Therefore it can be concluded that the simplified analysis of differences in colour nuances need only consider the L\* factor. At first glance it might be thought that this difference is because the images are grey-scale, but the same differences in terms of size, were recorded in the case of measurements on coloured images.

Colour differences were calculated by using the following equation as defined in BS EN ISO 105-J03:1997:

$$\Delta E_{ab}^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

where

$$\Delta L^* = L_p^* - L_R^*$$

$$\Delta a^* = a_p^* - a_R^*$$

$$\Delta b^* = b_p^* - b_R^*$$

P= Pyrographed image

R= Reference image

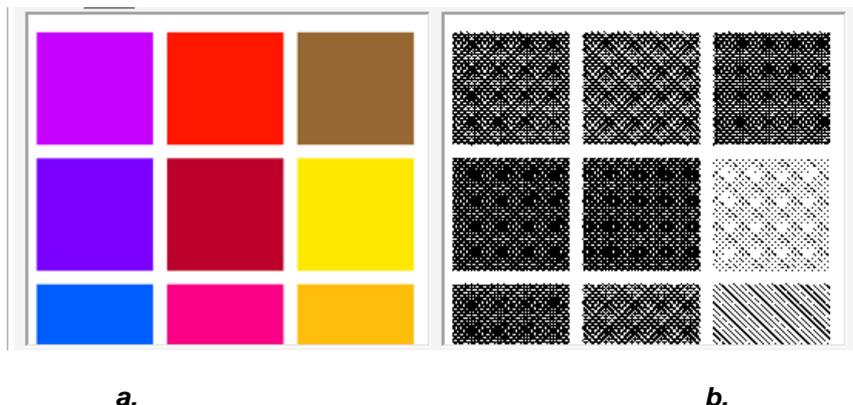
**Table 1**  
**Average values trichromatic measured in CIEL\*a\*b\* system for all colours in different conversion methods**

| Conversion method        | L* average | a* average | b* average | ΔE*ab | Rank |
|--------------------------|------------|------------|------------|-------|------|
| Photo                    | 52.27      | -0.0031    | 0.0062     |       |      |
| Halftone Line            | 40.55      | -0.0026    | 0.0051     | 11.73 | 11   |
| Halftone Fixed4x4        | 44.36      | -0.0028    | 0.0054     | 7.91  | 10   |
| Halftone Fixed8x8        | 45.11      | -0.0028    | 0.0055     | 7.16  | 9    |
| Cardinality-Distribution | 50.23      | -0.0030    | 0.0059     | 2.04  | 7    |
| Floyd-Steinberg          | 51.46      | -0.0031    | 0.0060     | 0.81  | 4    |
| Stucki                   | 51.82      | -0.0031    | 0.0061     | 0.45  | 2    |
| Halftone Round           | 51.95      | -0.0031    | 0.0061     | 0.32  | 1    |
| Halftone Cross           | 53.08      | -0.0031    | 0.0062     | 0.81  | 3    |
| Jarvis                   | 53.62      | -0.0032    | 0.0063     | 1.34  | 5    |
| Ordered                  | 54.18      | -0.0031    | 0.0063     | 1.91  | 6    |
| Halftone Square          | 59.36      | -0.0034    | 0.0068     | 7.09  | 8    |

From the data presented in Table 1, the conversion method which most closely matches the colours is the Halftone Round method (Fig. 2). This method best approached the colour tones of the original image. This approach is not surprising if it is considered that the principle of the method consists in transforming the image into circular surfaces. These surface fillings are similar to the technological principle which usually operates with laser technology.

To determine the differences between colours, each filled square obtained through different conversion methods was compared with the corresponding area on the reference image.

Colour names are the usual ones (Color converter 2015). The best conversions are shown in Table 2. In this table the conversion method observed, which had the most colours that were closest to the reference colours, was the Halftone square.



**Fig. 2.**  
**Differences between original image and image converted by Halftone Round conversion method:**  
**a - Original image; b - Converted image**

Efficiency of conversion methods was made related to the number of colours that were closest to the reference nuance. In Table 2 it is observed that some conversion methods do not approach the reference colour even with any nuance in the paper conditions.

**Table 2**

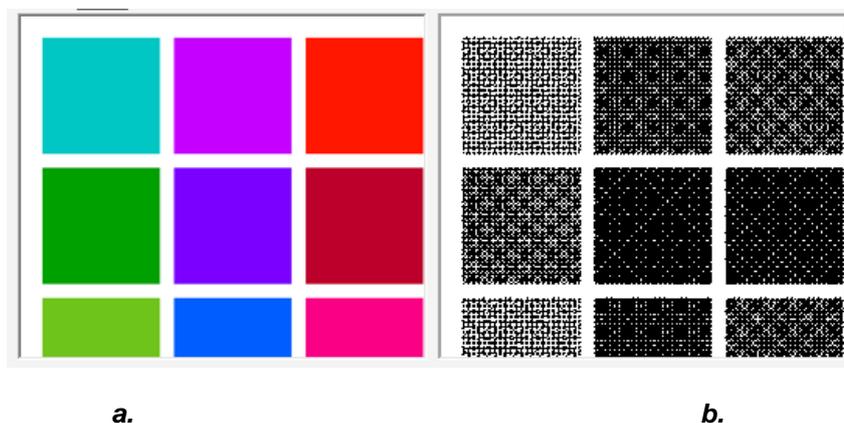
**The colours which are represented the best in different conversion methods**

| Conversion method | Colour           | Photo L* | Pyrography L* | Difference $\Delta L^*$ |
|-------------------|------------------|----------|---------------|-------------------------|
| Halftone Line     | Fuchsia          | 25.32    | 37.71         | 12.40                   |
|                   | Blue             | 36.15    | 33.40         | -2.75                   |
|                   | Deep Pink        | 26.65    | 35.22         | 8.57                    |
| Halftone Fixed4x4 | Sienna           | 46.44    | 42.24         | -4.19                   |
|                   | Dark Violet      | 18.47    | 35.50         | 17.03                   |
|                   | Fire Brick       | 17.53    | 32.66         | 15.13                   |
| Halftone Fixed8x8 | Red              | 30.16    | 37.44         | 7.28                    |
| Stucki            | Green            | 48.04    | 48.87         | 0.83                    |
| Floyd-Steinberg   | SlateGray        | 50.43    | 49.86         | -0.57                   |
| Ordered           | Gray             | 58.25    | 56.23         | -2.02                   |
|                   | Light Slate Gray | 55.93    | 54.80         | -1.13                   |
|                   | Dark Orange      | 58.64    | 55.67         | -2.97                   |
| Halftone Square   | Dark Turquoise   | 64.36    | 59.02         | -5.34                   |
|                   | Olive Drab       | 68.12    | 63.66         | -4.45                   |
|                   | Orange           | 76.98    | 67.26         | -9.71                   |
|                   | Deep Sky Blue    | 65.49    | 65.17         | -0.32                   |
|                   | Gold             | 81.69    | 71.77         | -9.92                   |
|                   | Violet           | 68.12    | 65.22         | -2.90                   |
|                   | Light Gray       | 60.94    | 60.17         | -0.77                   |
|                   | Yellow           | 87.76    | 73.11         | -14.65                  |

The sign "-" before difference value means more intense colouring and decreased lightness by burning, more intense staining of the area, respectively. It was also observed that some areas were dark, others were lightened. Therefore it is difficult to define a mathematical correlation between the original and the reproduced colours.

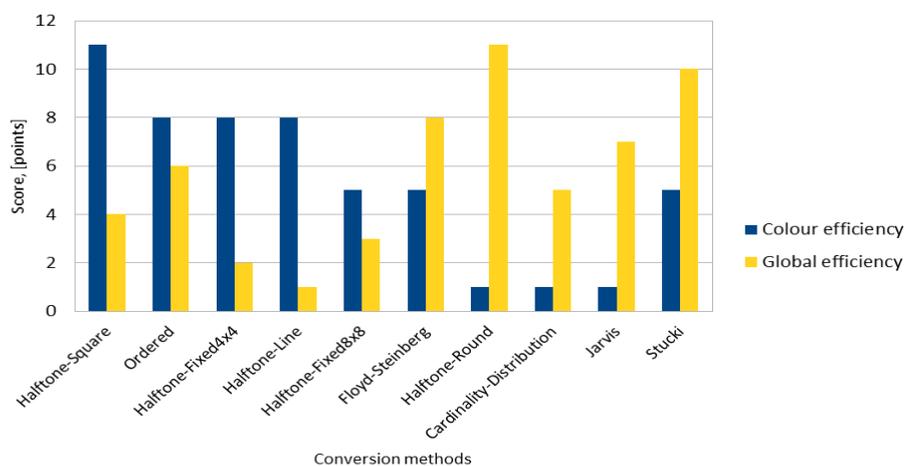
Because a comparison between different methods of conversion is desired, it was necessary to keep a benchmark image. For that, the values obtained using different conversion methods were compared with measured values only in grey-scale image. To simplify the calculations, the average global analysis of all colour nuance differences for each method was made using measured values.

The results show that different colours may not all perform the same according to the method of conversion. Some are closer to the base nuance, others away from it. Therefore care must be taken in order to choose the colours that make up the image, depending on the colour conversion method. If the image is composed of colour which behaves differently when the conversion method is used, then it is necessary to find a compromise solution. In this case either by changing the colours of the original image with some that behave similarly with the chosen conversion method, or to choose another conversion method. Fig. 3 shows the original colours (Fig. 3a), and converted image using Halftone Square conversion method (Fig. 3b).



**Fig. 3.**  
**Differences between original image and image converted by Halftone Square conversion method:**  
**a - Original image; b - Converted image**

By comparing Fig. 2 and Fig. 3, the differences between these two conversion methods can be observed. Similar differences were recorded between all conversion methods used.



**Fig. 4.**  
**Comparative representation between colour efficiency and global efficiency using different conversion methods**

On the basis of the above considerations, a method of comparison of the two value series was sought. Each method got a score determined by the next aspects: the overall effectiveness and efficiency of the colours. Depending on the score it generated a hierarchy: in which the method of the colour that was the closest to the reference got full marks. The results are shown in Fig. 4. In this figure it can be observed that the most efficient conversion methods were Halftone round for global efficiency and Halftone square for efficiency on separated colour. These results are to be expected if

the operating mode of these conversion methods is considered. The operating mode consists of transforming the image surface into an area filled with round or square dots.

The engraving process on the wood surface involves complex phenomena from a changing of the wood colour (darkening) to ablation and then to burning, depending on the laser parameters and the wood structure. Theoretically Halftone round is the best conversion method for image preparation for laser processing, but this conversion method is not clearly differentiated from other conversion methods. Some colours can be reproduced better by other conversion methods. It is necessary to carefully choose the colour and conversion method used. A varied colour palette cannot be reproduced by laser technology and the resulting image will be unclear despite the fact that the image is converted in black and white mode. Even if the picture has the most detailed model, it cannot be used for a pyrographed image because there is a small difference between colour nuances. The transformation from coloured image into monochrome image can lose some important details. The image has to transform into a monochrome image (grey-scale or sepia) but in this case the colour gradient cannot be followed by the laser resolution parameters.

The pyrographed samples resulted from processing of the converted images using Halftone Round and Halftone Square conversion methods are shown in Fig. 5.



**Fig. 5.**  
**Images converted by Halftone Round and Halftone Square conversion methods:**  
**a – Halftone Round; b - Halftone Square**

## CONCLUSIONS

This study confirms the theoretical suppositions which consider Halftone round the best conversion method in order to obtain a good image for laser pyrography. That conversion method is based on image transformation to a surface filled with circular areas. One of that circular surface contains the colour provided by the square surface where it comes from. The laser spot has a round area. Having regard to the above, the laser spot shape is similar with circular areas which compose the image.

The differences between reference image and pyrographed image are caused by different aspects as: differences between shape of filling dots and shape of the laser spot, differences between support materials and the representation mode.

Even if various methods of image analysis have been used (global analysis and colour analysis), it cannot indicate with certainty which is the best conversion method, because certain colours are very good for a certain conversion and others not. That is why great care should be taken primarily when choosing colours, and then choosing the conversion method that will be used.

Because pyrography is considered as an art, it is necessary to modify the reference image so that it can be reproduced faithfully by burning even if the image cannot be reproduced on screen as well.

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