"HENRI COANDA"
AIR FORCE ACADEMY
ROMANIA

"GENERAL M.R. STEFANIK"
ARMED FORCES ACADEMY
SLOVAK REPUBLIC

INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2014
Brasov, 22-24 May 2014

WOOD PROCESSING BY LASER TOOLS

Adrian PETRU, Aurel LUNGULEASA

Faculty of Wood Engineering, Transilvania University, Brasov, Romania

Abstract: *Nowadays the laser is used more and more in industrial application. This gains more and more uses in wood industry. Operations which cannot makes with traditional technology can be made by laser technology. This paper is a study about laser using in the wood industry. The paper is a synthesis about scientific literature and papers from this domain. It shows an approach of the processing as wood cutting, burning and engraving. This study brings together all processing parameters found in literature. Some particular characteristics of the wood processing by laser are also presented. Advantages and disadvantages of the laser working are presented, as well. The most used woody species are presented, too.*

Keywords: *laser, wood processing, cutting, pyrography, engraving*

1. INTRODUCTION

Wood processing by laser is less developed than other similar areas. The laser machining for metal working has developed enhanced because of high power lasers which can cut high density materials. High costs of producing laser effect are offset by the reduced costs due to premature wear of the tool.

In the medical field the laser has imposed, because it has high accuracy than conventional processes, but also due to the fact that the side effects are greatly diminishes. Lasers have very precise control of the working parameters.

The advantages listed above do not have shown interest in woodworking because this material does not have a density comparable to metals. The species with the highest density wood is Lignum-vitae wood (*Guajacum officinale* L.). The density of this is 1400kg/m^3 [12]. Metals can reach to 22570kg/m^3 densities [7], which is the osmium density.

Regarding to the woodworking precision, it should not be very high due to swelling and shrinkage by varying moisture content. These natural phenomena are permanent.

Laser beam machining has several advantages over conventional methods.

Because it is a non-contact process, laser beam machining it well suited for advanced cutting of engineering materials such as difficult to be cut, brittle materials, electric and non-electric conductors, and soft and thin materials [2].

Laser beam machining is a thermal process and materials with favourable thermal properties can be successfully processed, regardless of their mechanical properties. Laser beam machining is a flexible process [15].

Other advantages include narrow slot width (minimum material lost), straight cut edges,

low roughness of cut surfaces, easy integration with computer numerically controlled (CNC) machines for cutting complex profiles [18].

By combining the laser beam and the machine providing motion, in addition to the applied numerically controlled system, it is possible to provide for a continual sheet cutting along the pre-determined contour.

A laser beam is a high intensity beam of light that can be tightly focused onto a spot only 0.1...0.2mm in diameter [17].

About researches in this domain, there were studied more articles about CO_2 laser cut quality from year 1996 till 2011 [17]. This paper confirm the great interest about laser using in metal domain and low interest about other domains that including the wood engineering.

The laser is use to cutting, etching, pyrography in the woodworking.

2. WOOD CUTTING BY LASER

The main reason that laser are used in the wood industry is the technological flexibility and speed with which good results are obtained. Wood processing industry puts particular emphasis on design. Repeating an ornament or a shape decreases the value of the item.

An example of wood cutting by laser beam is shown in Figure 1.

As a particularity, in the case of the wood behaves differently depending on the direction of the cutting plane.

This operation is suitable for intarsia jobs, where it needs precision cutting for decorative veneers. This technology is preferred because of the relatively small thickness of the veneer, and its low density, it does not require high-power lasers, all thus reducing the processing costs. The second reason for preferring this technology is that it presents great flexibility, being virtually eliminated costs of production patterns and dies and the processing time, while increasing the accuracy of execution. Execution time decreases by eliminating design and implementation templates and moulds. The preparation time of manufacture is not eliminated because execution patterns and dies is replaced with achieving control programs, but this time is much less than the time required for preparing the classical technology. It done and saves material by using the laser cutting for intarsia veneers because it is not necessary that the veneers to be cut in package.

Cutting photonics is based on the wood influence of light rays with high power ($10^6...10^9$ W/cm^2) [5], which it heats the material to the burning temperatures.

The most common lasers, both as applications and as manufacturing, are that with gas. The advantage is that the emitted wavelengths can be determined with precision, are set up and remain independent of environmental conditions. These lasers use a gas mixture of CO_2, He and H_2 [5].

Figure 1: Wood cutting by laser [1].

CO_2 lasers dominate this application due to their good-quality beam combined to high output power [19].

When using high power lasers, the feed rate is closer to the industrial speed, this depends essentially by thickness of wood pieces, density, moisture content and adhesives.

Feed rate for beech and spruce is 0.31...0.43m/min and laser power range is from 150 to 500W [5].

The cut width is 0.1mm, the distance of the timber from the slot 1.5mm, and the lens focal length of 12.7cm [5].

About quality of surfaces obtained by laser cutting there have made a series of photographs of surfaces by electron microscopy and then were compared with photographs of the surfaces cut by conventional methods. It was thus evident that

laser cut surfaces are smoother than the sawing. By sawing, it results cut surface of beams tracheid. It also results deep traces of tooth setting, especially of its unevenness. At the laser cutting, it was observed small damage of the wood cutting area.

The roughness of the cut surface can be compared to the milled surface.

The laser cut is a narrow, accurate and right cut. The edges are straight and sharp. The width cut decreases with increasing cutting feed rate and it is higher at the entrance than at the exit to the material, the difference being visible to increase the feed rate. By increasing the density of the wood, the cutting width is reduced.

Using laser for the wood cutting offers a number of advantages over conventional machining process: does not produce sawdust; provides the ability to cut complex profiles; surfaces are cut very fine; not cutting forces acting on the parts clipped; very small width of cut; no tool wear occurs and there is no question of their maintenance; the noise is reduced.

With respect to various other cutting processes (such as oxy-fuel cutting, plasma cutting, sawing and punching), its advantages are numerous, namely, minimal area subjected to heat, a proper cut profile, minimal deformation of a work piece, the possibility of applying high cutting speed and fast adaptation to changes in manufacturing programs.

The disadvantages using laser for cutting wood are: cut surfaces are burned, it is difficult to know the density for calculating the laser power for cutting because wood is a heterogeneous material.

Evaluation of laser cut quality bases on: geometry of cut, surface of cut, burr formation and characteristics of material in zone of cut.

The cut geometry comprises the following: kerf (kerf profile and kerf width), perpendicularity and slant tolerance, and rounding out of the cut edges.

Kerf is an important characteristic of the laser cutting. That ensures the advantage in regard to other contour cutting processes. Kerf profile by laser cutting has form of taper. The channel effect of a focused beam minimizes taper of the kerf.

The perpendicularity and slant tolerance determine the cut quality also.

The side inclination of cut angle increases along with the sheet thickness, but it decreases with increasing of the laser power.

The cut edges at the laser beam entrance side are rounded out due to the Gauss distribution of radiation intensity over the laser beam cross-section. The rounding-out of the edges is very small [17].

About woody species which can be cut by laser there is no ban. However have to an attention about the wood density. A low laser power cannot cut all material thickness and a high-power of the laser burns the wood.
Studied woody species cut by laser are shown in Table 2.

3. WOOD COLOURING BY LASER (PYROGRAPHY)

Wood surfaces treatment has two goals:

- increases wood resistance (especially resistance against the pest attacks) and dimensional stability;
- obtaining the decorations.

These two goals cannot be separate because they are complementary.

Wood treatment by laser darks the colour surface. This is one of the reasons that the laser did not developed in the woodworking.

This drawback will be minimized if the colouring makes through artistic pyrography.

In a short action at a constant and relatively low energy laser on wood a charring of the material decorative shapes occurs.

An example of wood burning by laser is shown in Figure 2.

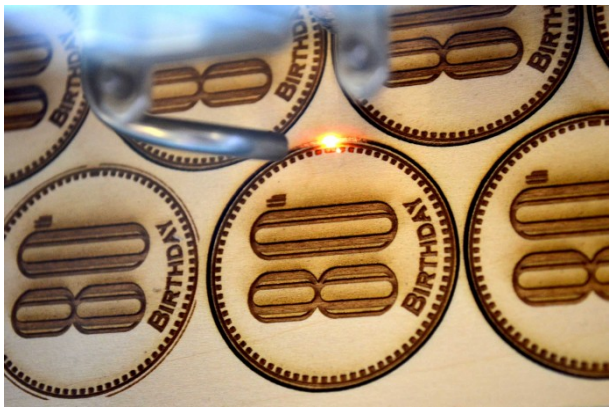

Figure 2: Wood burning by laser [6].

For decoration it uses especially CO_2 [4] [14,21] He [4], oxygen and nitrogen [3] lasers.

Colouring of the wood surface is influenced by the species of wood burned, by the laser power, the feed rate, the material thickness and the energy flow density. The colour varies from pale brown to black. The colour changes will be more pronounced if feed rate is reduced.

The carbonized depth of the wood is equal to the width of tracheid or fibres, i.e. 30...60μm [5].

By decreasing the feed rate, the wood has more time to carbonize itself, it increases the energy expended per unit length of cut, also. Increasing the moisture content decreases the carbonization effect; the excess energy is used for evaporation of water from the wood.

Wood treating by laser technology is in laboratory stage due to high costs of implementation at industrial scale. However this technology even in the laboratory opens new perspectives in research phenomena occurring in wood.

The advantages of wood colouring by laser are: surfaces can be differently coloured; it can be obtained images with high resolution.

The disadvantages are: uneven colouring due to heterogeneity of wood, increases the surface roughness, the lines are drawn too strict. The last one will be a disadvantage just if it wants to make an artistic pyrography.

A criteria for choosing of the material is its homogeneity. A homogeneous wood will be treated uniform; the colour will be without hue sudden change and properties will be uniformly distributed.

Woody species funded in literature are shown in Table 2.

4. WOOD ENGRAVING BY LASERS

The laser beam is used to detach a large proportion of wood, following pre-set patterns.

Sculpture is obtained through repeating this process for each thin layer successively.

An example of wood engraving is shown in Figure 3.

It has already shown that the laser treatment the wood areas are burned, but the laser can also be used for making ornaments in relief.

The free carbon formed on the surface can easily be removed with a jet of air or light brushing, only faint brown remaining.

MDF is the most used wood material for engraving. This has the advantage that consisting of wood fibres (small anatomical elements), the surface is cleaned against free carbon very well.

The Q-switched diode-pumped frequency-doubled Nd:YAG green laser can be successfully used to machine different types of wood, obtaining decorative drawing and 3D engraved geometries without burning [10].

The advantages of engraving by laser are: high work precision, it is eliminated the risk of fibre pull-out.

The disadvantages are: surfaces are burned, that will be removed it is necessary; it increases the number of passes because the power decreases.

Another aspect is about heterogeneity of the wood; the laser should be variable power or a high enough power to cut the maximum density of the material but, sufficiently low to does not burn the minimum density area.

Studied woody species engraved by laser are shown in Table 2.

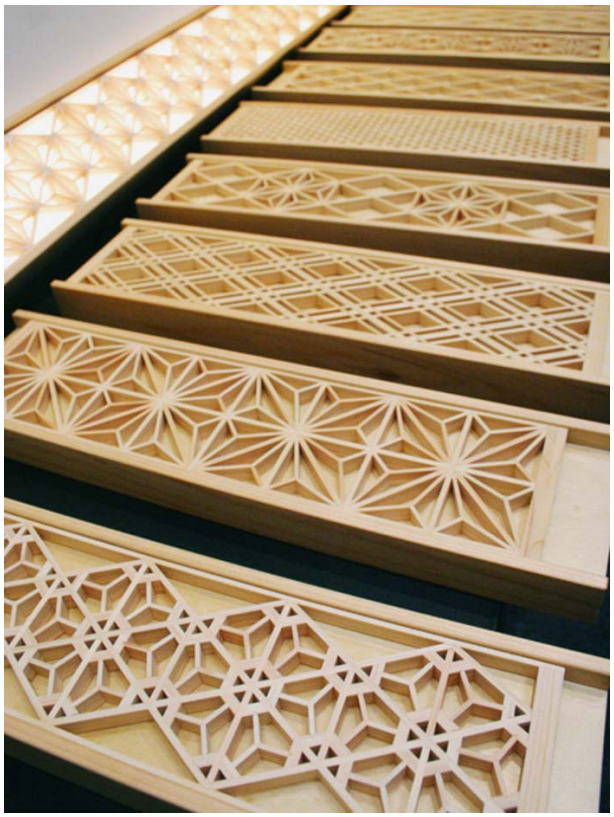

Figure 3: Wood engraving by laser [20].

5. CONCLUSIONS & ACKNOWLEDGMENT

Woodworking by laser is a domain unexploited at the maximum in this moment and it has some aspects unknown.

Because the relatively costs of production are high, especially for lasers pumping, they are very little used in the wood industry.

The woodworking by lasers creates new prospects in terms of phenomena research that occur during and after wood processing.

Wood surfaces treatments by laser can be controlled in small details. It is possible to study wood burning mechanisms (especially chemical wood degradation). Also it is possible to isolate insoluble wood components.

Usually just a single machine can do all these three operations.

Generally, woodworking by lasers has a number of advantages over the conventional processing: decreases working time, increases working precision, can be make complex operations, for all these operations it is need just one machine, the operations are automates.

Generally, the disadvantages are: high costs of the equipments, high cost for production of the laser effect.

The production costs can be reduced using other lasers instead lasers with gas. Q-switched diode-pumped frequency-doubled Nd:YAG green laser reduces the cost but increase the working time. It is possible because wood density is low and a high laser power is not necessary. The material with high density can be processed trough more passes.

The parameters for lasers used in wood industry are shown in Table 1.

Table 1. Main parameters for woodworking by laser.

	Cutting	Pyro-graphy	Engraving
Laser type	Gas CO_2, He and H_2 [5]	Gas CO_2, He [4], O_2 and N_2 [3]	Q-switched diode-pumped frequency-doubled Nd:YAG [10]
Power	10^6...10^9 W/cm^2 [5]		
Speed	50800 mm/min	91500 mm/min	

In wood industry the lasers are not used just for woodworking. They are used for:

dimensional and roughness measuring, marking etc. Among these, the lasers are used the most at the timber working, where it is difficult to determine the volume of log. That because the log shape is irregular.

Table 2. The woody species and materials processed by lasers, found in literature.

Cutting	Beech, Spruce, Douglas, Particleboards [4]
Pyrography	Black locust [3], Beech [8,14,16,21,13], Lime [14], Spruce [14,16,21], Ash [14,16], Scots pine [16], Pine [13], Maple [9], Sapelli [21], Moso bamboo [11]
Engraving	MDF, Walnut, Mahogany, Chestnut Oak, Poplar, Pine [10]

ACKNOWLEDGEMENT: This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), ID134378 financed from the European Social Fund and by the Romanian Government.

REFERENCES

1. American woodworker, *Tool Talk - Epilog CNC Lasers*. [online]. Available: http://www.americanwoodworker.com/blogs/tools/archive/2010/07/13/tool-talk-epilog-cnc-lasers.aspx (March, 2014)

2. Chen, M., Ho, Y., Hsiao, W., Wu, T., Tseng, S., Huang, K., *Optimized laser cutting on light guide plates using grey relational analysis*. Optics and Lasers in Engineering. 49 (2011)

3. Chen, Y. , Gao, J. , Fan, Y. , Tshabalala, M. A. , Stark, N. M., *Heat-induced chemical and color changes of extractive-free Black Locust (Robinia Pseudoacacia) wood*. BioResources. 7(2) (2012)

4. Dogaru V., *Aşchierea lemnului şi scule aşchietoare*. Bucureşti: Editura Didactică şi Pedagogică (1981)

5. Dogaru, V., *Bazele tăierii lemnului şi a materialelor lemnoase*. Bucureşti: Editura Tehnică (1985)

6. Grathio Labs, *Making Wooden Nickels. With Lasers*. [online]. Available: http://grathio.com/2011/06/making-wooden-nickles-with-lasers/ (March, 2014)

7. Gugnin, A. A. , L'vov, S. N. , Mal'ko, P. I., Nemchenko, V. F., Starodubov, I. P., *Electrical and thermal conductivities of rhenium, osmium, and iridium and some of their alloys with thorium and lanthanum in a wide temperature range*. Soviet Powder Metallurgy and Metal Ceramics. 11 (1972)

8. Kacík, F. , Kubovsky, I., *Chemical changes of beech wood due to CO2 laser irradiation*. Journal of Photochemistry and Photobiology A: Chemistry. 222 (2011)

9. Kubovsky, I. , Kacík, F., *FT-IR study of maple wood changes due to CO2 laser irradiation*. Cellulose Chemistry and Technology. 43 (2009)

10. Leone, C. , Lopresto, V., De Iorio, I. , *Wood engraving by Q-switched diode-pumped frequency-doubled Nd:YAG green laser*. Optics and Lasers in Engineering. 47 (2009)

11. Lin, C.-J. , Wang, Y.-C. , Lin, L.-D. , Chiou, C.-R. , Wang, Y.-N. and Tsai M.-J., *Effects of feed speed ratio and laser power on engraved depth and color difference of Moso bamboo lamina*. Journal of Materials Processing Technology. 198, no. 1-3 (2008)

12. Lunguleasa, A., *Wood physics and mechanics*. Braşov: Editura Universităţii Transilvania (2007)

An Experimental Parameter Study. Advances in Materials Science and Engineering. 2013 (2013)

15. Prasad, G., Siores, E., Wong, W.,, *Laser cutting of metallic coated sheet steels*. Journal of Materials Processing Technology. 74 (1998)

16. Preklet, E. , Papp, G. , Barta, E. , Tolvaj, L. , Berkesi, O. , Bohus, J. , Szatmári, S. , *Changes in DRIFT spectra of wood irradiated by lasers of different wavelength*. Journal of Photochemistry and Photobiology B: Biology. 112 (2012)

17. Radovanovic, M. , Madic, M., *Experimental investigations of CO2 laser cut quality: a review*. Nonconventional Technologies Review. 4 (2011)

18. Rao, T. , Kaul, R. , Tiwari, P. , Nath, A., *Inert gas cutting of titanium sheet with pulsed mode CO2 laser*. Optics and Lasers in Engineering. 43 (2005)

19. Riveiro, A. , Quintero, F. , Lusquinos, F. , Comesana, R. , Pou J., *Parametric investigation of CO2 laser cutting of 2024-T3 alloy*. Journal of Materials Processing Technology. 210 (2010)

20. Thompson, J., *Kumiko Pattern*. [online]. Available: http://www.jeffreythompson.org/blog/tag/wood/ (March, 2014)

21. Wust, H. , Haller, P. and Wiedemann, G., *Experimental study of the effect of a Laser beam on the morphology of wood surfaces*. In Proceedings of the 3rd International Symposium on Wood Machining, Lausanne, Switzerland: (2007)