Application of the laser cutting of wood-containing materials in construction

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Abstract. One of the popular materials in the construction is plywood. Experimental studies of the laser cutting of plywood of various thicknesses (4, 6, 8 and 10 mm) under different cutting conditions are presented in this paper. In the experiments, the focal length, cutting speed and power were varied. The aim of the work is to study the samples and select the optimal cutting mode.

1. Introduction

Valuable building properties of wood determine areas for its effective use. The low density of dry wood with relatively high strength and rigidity (along of a fibers) makes it appropriate to use of wooden structures in the coverings of public, industrial and agricultural buildings; it is easiest to implement constructive measures against the decay with the most complete using of the best structural properties of dry wood. Ecological purity makes the wood particularly useful for the construction of housing, particularly of cottage type. In the enclosing parts of heated buildings well used small thermal conductivity of dry wood across of the fibers. The chemical resistance of dry wood justifies the predominant using of metal-free and especially glued wooden structures for coatings of chemical workshops and warehouses.

One of the popular materials in the construction is plywood. It is a wood-layered plate, which is made on the basis of thin sheets of veneer. Each layer is laid with different directions of fibers to give strength.

The laser cutting of wood and plywood is the most economical, fast and convenient way of cutting these materials, because it is made without mechanical contact with the material itself, with the absence of waste and consumables [1-18].

The cutting of plywood is possible on any, the most complex contours with a petty detail, by using sample instruments (saws and mills) easy not cope, because there is no mechanical contact.

Veneer sheets (from 0.6 mm) are also easy to laser-treat, allowing to cut out the most original subjects from different breeds, which gives great opportunities for decorators, furniture manufacturers and other interior items. When laser cutting veneer edges are not torn, are not break and are not burn. Due to the minimum thickness of the cut (the thickness of the laser beam), the gaps between the parts are very small, which makes it possible to interchange the cut elements while preserving valuable material.

Experimental studies of the laser cutting of plywood GOST 3916.1-96 of various thicknesses (4, 6, 8 and 10 mm) under different cutting conditions are presented in this paper. In the experiments, the
focal length, cutting speed ($V$) and power were varied ($P$). The aim of the work is to study the samples and select the optimal cutting mode.

2. Experimental studies
Specific energy of cutting, i.e. what energy it is necessary to spend on the destruction of a unit of mass of a substance is determined by the formula:

$$ S_p = c \cdot T_p, $$

where $c$ is thermal capacity; $T_p$ is the temperature of cut material.

For plywood, the value of $S_p = 5.4 \cdot 10^{-6}$ J/kg.

Optical parameters, such as focusing of laser radiation - the size of the focusing spot, the focal length of the optical focusing system, the displacement of the focal plane relative to the surface the processed materials, the degree of the polarization radiation and distribution of power density over the beam section have a significant effect on the profile of the cut, its depth and width [19-20].

The technological laser AUTOM 150 was used for cutting the plywood. AUTOM Laser 150 is a portal-type laser cutting and engraving machine. It is effective in the processing of non-metals - for cutting sheet material: leather, cloth, paper, cardboard, rubber, wood, organic glass, plastic. Technical characteristics of this laser technological complex are presented in table 1.

| Table 1. Characteristics of laser AVTOM 150. |
|--------------------------------------------|
| Parameter                                | Value                      |
| The size of treated surface              | 1300x2600 mm               |
| Laser power                              | 150 W                     |
| Laser emitter                            | CO$_2$ glass tube, water cooling |
| Engraving, speed                         | 1000 mm / sec             |
| Engraving depth                          | 0-25mm (depending on material) |
| Maximum speed the movement of machine    | 25000 mm / sec            |
| Positioning accuracy                     | <0.01 mm                  |
| Graphic format                           | DST, PLT, BMP, DXF        |
| Support software                         | LASERCUT 5.x software     |
| Power supply                             | 220V ± 10% / 50 Hz        |

The results of experimental studies are presented in figures 1-6.

![Figure 1](image1.png)

**Figure 1.** $P = 25$W; $V = 0.6$ m/min; gas flow rate 5 m$^3$/h (air), $h = 4$ mm; a) type of cut; b) type of cut in the profile; c) type of cut from above.

Figure 1 shows the most effective cutting mode for plywood thickness of 4 mm, cutting is carried out to the full depth, it can be cut parts of almost any shape. When the cutting speed is increased by a factor of 3 (Fig. 2), it is necessary to increase the laser radiation power by 4.8 times, and in this mode it is not impossible to cut the details of the complex shape. When it is necessary to cut out small parts or curvature less than 4 mm, it is need to reduce the speed by 2 times (Figure 3).
Figure 2. $P = 120\, \text{W}; \, V = 1.8\, \text{m/min}; \, \text{gas flow rate } 5\, \text{m}^3/\text{h} \, (\text{air}), \, h = 4\, \text{mm}$; a) type of cut; b) type of cut in the profile; c) type of cut from above.

Figure 3. $P = 25\, \text{W}; \, V = 0.3\, \text{m/min}; \, \text{gas flow rate } 5\, \text{m}^3/\text{h} \, (\text{air}), \, h = 4\, \text{mm}$; a) type of cut; b) type of cut in the profile; c) type of cut from above.

Figures 4-6 show photos of the cut in the most effective modes for plywood thickness of 6, 8, 10 mm.

Figure 4. $P = 30\, \text{W}; \, V = 0.6\, \text{m/min}; \, \text{gas flow rate } 5\, \text{m}^3/\text{h} \, (\text{air}), \, h = 6\, \text{mm}$; a) type of cut; b) type of cut in the profile; c) type of cut from above.

Figure 5. $P = 35\, \text{W}; \, V = 0.6\, \text{m/min}; \, \text{gas flow rate } 5\, \text{m}^3/\text{hour} \, (\text{air}), \, h = 8\, \text{mm}$; a) type of cut; b) type of cut in the profile; c) type of cut from above.
Figure 6. $P = 40\text{W}; V = 0.6 \text{m/min};$ gas flow rate $5\text{m}^3/\text{h}$ (air), $h = 10 \text{mm}$; a) type of cut; b) type of cut in the profile; c) type of cut from above.

In case of increasing the thickness of the material, a higher laser radiation power requires. The maximum speed decreases sharply with increasing the thickness, because a continuously increasing power is required for cutting. The edge of the cut becomes darker with increasing the thickness and power of the radiation.

3. The conclusion
The wood and veneer are well cut to a thickness of 9-10 mm, depending on the type of wood. Pine, spruce, aspen, poplar are better than other types of wood suitable for laser cutting. Birch, beech, or oak have much less suitable properties. The hardness and density of wood complicate the process of laser cutting, make it more time-consuming. The nature of cutting along and across of fibers is different. The general problem - twigs in the presence of excellent quality the cut it is very difficult to achieve. The cut edge is light brown to almost black, slightly charred. The cutting edges are darker and so the wood is thicker and harder.

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References
[1] Kobayashi A 1974 Processing of plastics cutting (Moscow: Engineering) 192 p
[2] State Industry Standard Plastic 12020-72 (ST SEV428-89). Methods for Determination of Resistance to Chemical Environments
[3] Granovsky G I 1982 Processing of the results of experimental studies of metal cutting (Moscow: Engineering) 112 p
[4] Zharin D E, Gumerov A F, Zagidullin A J, and Shafigullin L N 2012 The development of mathematical models of the cutting-purpose thermoset composites Journal of International Scientific Publications 6(3) p 200-214
[5] Hemdi A and Taha 2007 Simplex method Introduction to Operations Research – operations Research: An Introduction (Moscow: Williams) p 95-141
[6] Ehrgott M and Gandibleux X 2004 Approximative Solution Methods for Multiobjective Combinatorial Optimization Sociedad de Estadistica e Investigacion Operativa 12(1)
[7] Petrosyan L A, Zenkevich N A and Shevkoplyas E V 2012 Game Theory St. Petersburg:BHV-Petersburg p 432
[8] Trifonov A G 2000 Multi-criteria optimization. Optimization Toolbox 2.2 User's Guide. http://matlab.exponenta.ru/optimiz/book_1/16.php
[9] Khisamutdinov R M, Zvezdin V V, Saubanov Ruz R, Israfilov I H, Rakhimov R R, Spirin A A 2016 Study of processes of steels surfaces modification with highly concentrated energy flows IOP Conf. Ser.: Mater. Sci. Eng. Volume 669 Issue 1 Article number 012024
[10] Israfilov I H, Saubanov R R, Rakhimov R R 2011 Prospective application of highly concentrated energy for the surface heat treatment products Socio-economic and technical systems: research, design, optimization № 1 p 25-30

[11] Grigoryants A G, Shiganov I N, Misyurov A I 2006 Processes of laser processing (Moskow: MGTU im. N. Uh. Bauman) 664 p

[12] Kostecki V V, Lisovsky A L 2013 Increasing the absorption capacity of the surface layer of metal during laser exposure by using absorbing coatings Bulletin of Polotsk state University. Series: Industry. Applied science No. 3. p 97-101

[13] Stepanov A A 1987 Cutting of High-Strength Polymer Composites (Leningrad: Mashinostroenie) 176 p

[14] Stuchnyi BP 1974 Cutting Plastics: A Handbook (Moscow: Mashinostroenie) 144 p

[15] Mikul’skii V G 2000 Structural Materials (Moscow: Izdatelstvo ASV) 536 p

[16] Komar AG 1983 Structural materials and Components (Moscow: Vysshaya Shkola) p 487

[17] Yashcheritsyi P I, Fel’dshtein E E, Kornievich M A 2006 Theory of Cutting (Minsk: Novoe Znanie) 512 p

[18] Zharin D E, Yurasov S Y, Gumerov M I, Shafigullin L N 2009 Optimal machining of loosely filled polymer composites Russian Engineering Research 29 (10) pp 1007-1009

[19] Bashmakov A D, Gabdrakhmanov A T, Israfilov I H, Galiakbarov A T 2013 Electrostatic field as factor of increase of stability of quality of laser processing of metals MNTK "IMTOM-2013" Part 1 p 325-328

[20] Gabdrakhmanov A T, Israfilov I H, Galiakbarov A T 2017 Preparation of metal surfaces for application of functional coatings IOP Conf. Series: Journal of Physics: Conf. Series. Volume 789 Article number 012009