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THE EFFECT OF TRADITIONAL AND LASER CUTTING ON SURFACE ROUGHNESS OF WOOD MATERIALS USED IN FURNITURE INDUSTRY

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Abstract

One of the most important problems in the use of solid wood in the furniture industry is the surface roughness of the furniture elements depending on the cutting conditions. The required processes and efforts to obtain a smooth surface are too much, and besides the loss of time and raw materials in the production line, there are great costs in the creation of the machine park.

In this study, the surface roughness of the materials obtained from some wood species processed with CNC laser and circular saw machine was investigated. Poplar (*Populus canadensis*), scotch pine (*Pinus sylvestres*) and fir (*Abies cilicica*) samples were used as raw material in the study. Cutting processes were applied parallel and perpendicular to the fibers of the samples. In the cutting power of the CNC laser machine was kept constant as 130 watts and two different speeds were used at 10 mm/s and 20 mm/s. The rotation speed of the circular saw machine was adjusted as 4300 rpm without loading and the roughness rates of the traditional circular saw and CNC laser cut surfaces were compared.

As a result, it has been determined that the laser cutting speed is directly proportional to the surface roughness. In addition, compared to traditional cutting, rougher surfaces were obtained in parallel cutting to fibers with CNC laser and smoother surfaces were obtained in perpendicular cutting to fibers. In the results: In laser cutting with CNC, smoother surfaces have been obtained in parallel to the fibers.

Keywords: CNC, laser cutting, surface roughness, wood material

1. Introduction

As time progressed, the understanding of aesthetics in consumers began to show sensitivity by changing compared to previous periods. This change started to meet the expectations of design and consumers. Issues such as surface roughness in production, first of all, metal, steel, etc. became important in material engineering. Factors such as final quality, competition, aesthetics have made the surface roughness return in the wooden material used in furniture production.

The smooth surface of the wooden material to be used increases the preference of the furniture. In addition, it is very important to obtain a good surface quality during the processing of wood material and to solve this with the least cost. In order to obtain smooth surfaces in wood material, an appropriate combination of processing conditions must be applied. Correct processing of wood in the furniture industry and minimizing surface roughness are very important for the national economy (Peker and Ulusoy 2019).

Measuring the surface roughness of wooden products used in the furniture and decoration industry is very important in determining the quality of the final product. Surface roughness significantly affects the aesthetics of wood products and customer demand at the marketing stage. However, the surface roughness of wood needs to be determined in the application of wood surface treatments as it has a significant effect on the adhesion resistance (Tiryaki, 2014).

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Surface roughness poses a problem for both manufacturers and users. Although this defect can be removed with a little over sanding, the loss increases and the production time is prolonged. Therefore, surface roughness measurements should be among the quality control tests that should be applied in the woodworking industry in order to reduce production losses and costs (Aydın and Çolakoğlu, 2003)

Laser was discovered in the world in the 1960s. Laser technology in developed countries steel, metal, fiber, plastic and so on. It has found wide application areas in industries. Although it entered the wood industry later, it has spread rapidly and only laser machines for wood processing have been produced. These developments made the studies for wood processing with laser a necessity.

In recent years, laser technology has been at the forefront of material processing. In the near future it will probably be considered to replace traditional techniques such as sawing (Gaff, M. et al. 2020). In recent years, we see that the use of laser cutting machines has increased rapidly depending on the economic development. Among these areas of use, the wood industry has also taken its place. As it is known, laser has two main functions: cutting and engraving.

In general, cutting theory in woodworking examines the factors in traditional cutting such as metal or steel cutter types, cutter teeth types, cutter diameters, chip cutting and cutting methods, chipless cutting or peeling methods, feed rate. There have been many studies on the effects of traditional cutting factors on the surface roughness of wood.

In this study, the surface roughness of massive materials obtained from some wood species cut by CNC laser and circular saw machine was investigated. The effects of laser cutting speed and surface roughness were compared to traditional cutting and laser cut surface roughness, and recommendations were made to manufacturers.

2. Materials and Methods

2.1. Materials

In the research, Canada poplar (*Populus canadensis*), scotch pine (*Pinus sylvestres*) and fir (*Abies cilicica*) trees purchased by random selection method from Kahramanmaraş industry were used. Samples obtained from sapwood of smooth tree trunks with a diameter of about 25-30 cm and a length of 100 cm were used. While preparing the test samples, care has been taken to ensure that the wood material used is without knots, backs, no growth defects and has smooth fibers.

2.2. Preparation of Experimental Samples

Experimental samples for measuring the surface roughness of wood massive materials were prepared in 4x20x20 mm dimensions. Later, laser cutting was performed on the vertical (max) and parallel (bay window) surfaces of the 4x20 mm^2 sectioned fibers in a 130-watt carbon dioxide tube laser cutting machine with 100% power at 20mm/s and 10 mm/s speeds. In addition, conventional cutting was performed on a circular saw machine rotating at 4300 rpm without loading (dv/min), with a blade diameter of 26 cm including the teeth, 40 teeth number, and 1.5 cm tooth height. As shown in Figure 1 below, surface roughness measurements were made by making a total of six different cuts for each massive type, with three different cutting variables in two different fiber directions. Four measuring surfaces were prepared for each different cut. However, the closest three sample values from some sample groups that gave very different results after measurement were included in the average**.**

Figure 1: Surface roughness experiments of poplar massif in different cuts

2.3. Methods

Surface roughness measurements were made in accordance with ISO 4287 standard. It was applied with 0.5 mm / sec speed, λc = 2.5 mm limit wavelength and 12.5 mm scan length. Test samples were carried out at 12% humidity, ambient temperature 22 ºC, relative humidity 65% normal air conditions. Due to the function of the measuring device, measurement values were determined in three different parameters. In measurement;

Ra = General surface roughness,

Rz = The arithmetic mean of the highest five points and the least five points, a total of ten points,

Rmax = The distance between the highest and least points in micrometers (μm). The findings of the study were evaluated based on the general surface roughness (Ra) data in terms of compatibility with literature studies.

3. Results

The findings of the surface roughness of the cutting surfaces parallel to the fibers of wood massive materials obtained from Canada poplar *(Populus canadensis*), scotch pine (*Pinus sylvestres*) and fir (*Abies cilicica*) tree species are given in Table 1.

Table 1: Surface roughness values of solid wood materials cut parallel to the fibers (μm)

Wood Type	Cutting Type	Laser		Laser		Conventional	
	Cutting speed	20 mm / sec		10 mm / sec		4300 dv / min	
	Surface Roughness	X	SD	X	SD	X	SD
Poplar	Ra	3,49	0,53	3,42	0,95	3,30	0,67
	Rz	18,1	1,7	17,86	4,47	17,76	4,65
	Rmax	26,53	6,65	29,53	5,06	28,76	10,58
Scotch Pine	Ra	3,77	0,42	3,74	0,43	3,28	0,77
	Rz	18,7	1,15	19,86	1,92	19,93	1,30
	Rmax	22,7	2,68	25,8	2,69	27,23	6,87
Fır	Ra	3,53	0,39	2,66	0,59	2,48	0,45
	Rz	19,46	3,91	15	3,25	14,68	3,38
	Rmax	23,96	5,68	17,53	3,95	24,94	13,72

SD: standard deviation

When Table 1 above is examined, the general roughness values (Ra) of laser cutting surfaces at a speed of 20 mm / s were obtained as 3.77 μm in the highest scotch pine massif and 3.49 μm in the poplar massif the least. The general roughness values (Ra) of laser cutting surfaces at a speed of 10 mm / s were obtained as 3.74 μm in the highest scotch pine massif and 2.66 μm in the fir massif. The general roughness values (Ra) of traditional cutting surfaces were obtained as 3.30 μm in the highest poplar massif and 2.48 μm in the fir massif. In Figure 2, the surface roughness (Ra) values of each type of massive parallel to the fibers, at different laser cutting speeds and in conventional cutting are shown.

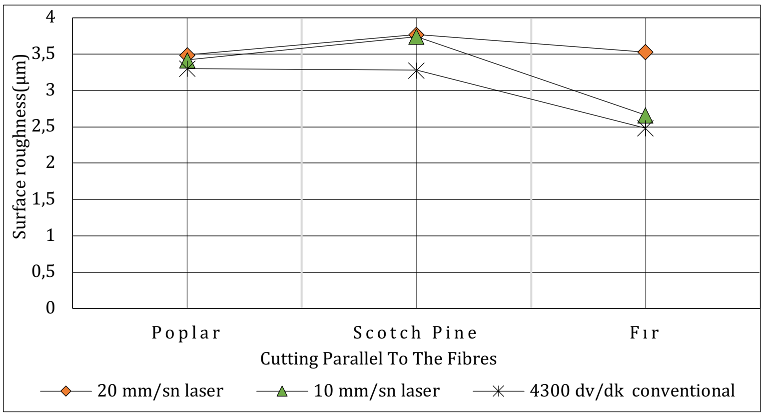

Figure 2: Surface roughness in cutting solid materials with different methods parallel to the fibers

When Figure 2 is examined, it is seen that the laser cut surface roughness of all massive materials parallel to the fibers is directly proportional to the cutting speed. It was determined that the difference in proportionality of laser cut surface roughness values according to speeds is insignificant in poplar and scotch pine massif, and significant value in fir.

Compared to traditional cutting of solid materials with laser cutting parallel to the fibers, smoother surfaces have been obtained in conventional cutting. It has been determined that this difference is significant in scotch pine. It has been determined that in poplar and fir massif, when laser cutting is performed at low speed (10mm/s), surfaces with roughness of approximately the same value as conventional cutting surfaces can be obtained. Findings of the surface roughness of the cutting surfaces of solid materials perpendicular to the fibers are given in Table 2.

Table 2: Values of cut surface roughness of solid wood materials perpendicular to the fibers (µm)

Wood Type	Cutting Type	Laser		Laser		Conventional	
	Cutting speed	20 mm / sec		10 mm / sec		4300 dv / min	
	Surface Roughness	X	SD	X	SD	X	SD
Poplar	Ra	6,27	0,53	6,26	0,36	6,69	3,24
	Rz	39,63	3,15	37,73	1,91	38,76	16,82
	Rmax	47,56	2,27	44,2	1,60	54,63	23,01
Scotch Pine	Ra	5,67	1,25	4,86	0,14	6,91	0,98
	Rz	33,26	7,29	27,4	0,72	43,4	6,35
	Rmax	4,7	15,37	34,66	1,77	68,63	25,15
Fır	Ra	3,63	0,20	3,26	0,29	4,30	1,01
	Rz	22,96	0,56	17,1	45,5	26,59	4,68
	Rmax	38,63	4,39	29,2	8,84	48,46	20,80

SD: standard deviation

When Table 2 is examined, the general roughness values (Ra) of laser cutting surfaces perpendicular to the fibers with a speed of 20 mm / s were obtained as 6.27 µm in the highest poplar massif and 3.63 µm in the fir massif. The general roughness values (Ra) of laser cutting surfaces at a speed of 10 mm/s were obtained as 6.26 µm in the highest poplar massif and 3.26 µm in the fir massif. The general roughness values (Ra) of traditional cutting surfaces were measured as 4.30 µm in the least fir massif and 6.91 µm in the scotch pine massif.

In another study, the surface roughness was measured as 6.87 µm at a value close to the determination in this study (6.91 µm) in a cut made in the radial direction of the scotch pine massif at a feed speed of 9 m / min with 40 toothed circular saw (Kılıç and Demirci, 2003). A roughness value of 6.66 µm on a planed surface in the radial direction of the scotch pine massif was reported to be 6.91 µm (Örs and Baykan, 1999).

In Figure 3, the surface roughness (Ra) values of each massive type at different laser cutting speeds perpendicular to the fibers and in conventional cutting are shown.

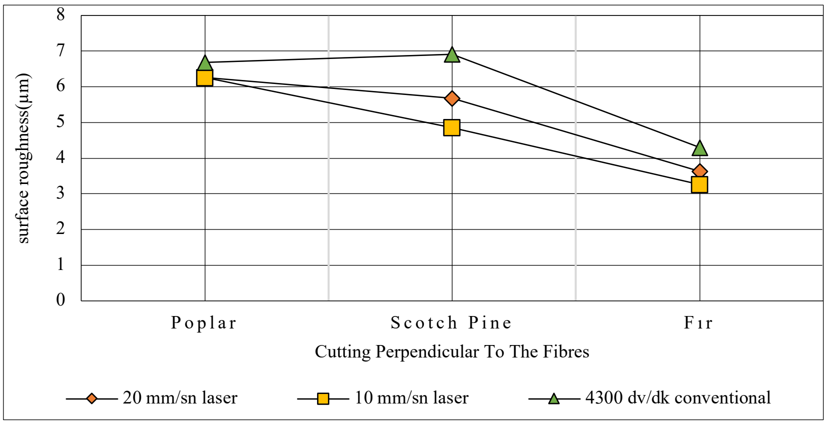

Figure 3: Surface roughness in cutting solid materials perpendicular to the fibers with different methods

When Figure 3 is examined, it is seen that the laser cut surface roughness of all solid materials perpendicular to the fibers is directly proportional to the cutting speed. The difference in the proportion of laser cut surface roughness according to the speeds was insignificant in poplar and fir massif, and significant in scotch pine massif. Compared to laser cutting perpendicular to the fibers and conventional cutting of solid materials, rougher surfaces have been obtained in conventional cutting in all massive types. In addition, this difference is insignificant in the poplar and fir massifs, and more in the scotch pine massif.

Although the poplar massif has a higher value in terms of surface roughness than the average of all cutting parameters, it showed a more stable behavior. It is considered that the cellular structure of poplar tree with large trachea may cause more roughness, and scattered trachea may cause a uniform distribution of the roughness on the entire surface. In addition, it is considered that the wall thickness of the tracheid found in the spring and summer wood in scotch pine and fir and the amount of lumen space are in contrast, giving different values in terms of surface roughness in different sections.

In another study, it was stated that one of the biggest contributors to surface roughness is the size and distribution of the pores in the wood cell. It was stated that the roughness values of the laser cut oak wood samples were 20% higher than the roughness values of the beech wood samples. It has been reported that the surface roughness of saw-cut beech wood is lower than that of oak, due to the wood texture of beech wood, which is thinner than oak. By comparing the two cutting methods, it was explained that the surface cut with laser has a lower roughness than the surface cut with a saw. It has been reported that the reduction in surface roughness due to laser cutting is more pronounced in oak (36%), which is a thin-textured tree than beech (24%) (Gaff, M. et al. 2020).

The average of laser cutting and conventional cutting surface roughness (µm) of three massive materials parallel to and perpendicular to the fibers at speeds of 20 mm/s and 10 mm/s are shown in Figure 4.

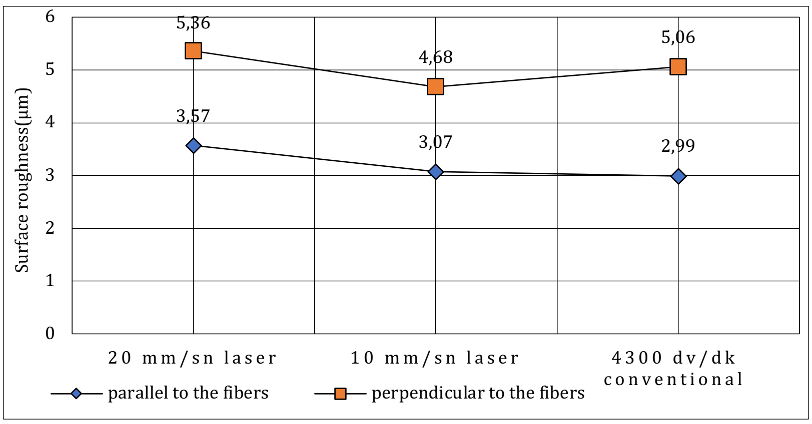

Figure 4: Average surface roughness values of solid materials in different cuts (µm)

When Figure 4 is examined, a 100% speed increase (from 10 mm/s to 20 mm / s) in laser cutting increases the surface roughness parallel to the fibers by 16.2% and the surface roughness perpendicular to the fibers by 14.5% caused. Considering these values, it can be said that a 100% speed increase in laser cutting in all fiber directions in massive materials generally causes surface roughness of approximately 15%. The reason for this may be that the surface roughness values at low speed are also low, the number of passes of laser beams from the process point per unit time increased, and the amount of material per unit cutting decreased.

Conventional cutting surfaces were found to be 16.2% smoother than laser cutting at a speed of 20 mm/s with a surface roughness parallel to the fibers. It was determined that they have roughness values approximately the same (difference 2.6%) with laser cutting at 10 mm/s speed. In addition, it has been determined that conventional cutting surfaces are 7.5% rougher than laser cutting perpendicular to the fibers at a speed of 10 mm/s, and 5.5% smoother surfaces can be obtained from laser cutting perpendicular to the fibers at 20 mm/s.

According to the average of all cutting parameters, the surface roughness of the cutting perpendicular to the fibers is 41% higher than the cutting parallel to the fibers. Generally, in the literature, it has been stated that by processing the wood material perpendicular to the fibers in traditional cuts, rougher surfaces are obtained compared to processing parallel to the fibers.

4. Conclusion

In laser cutting, the overall cutting speed has increased the surface roughness. This result is consistent with other studies on laser cutting of wood materials and wood composites (Barnekov et al. 1989; Eltawahni et al. 2011). Since laser cutting speed increases the roughness significantly, the cutting speed should be kept as low as possible in order to obtain smooth surfaces. However, it should not be forgotten that laser cutting at very slow speeds can cause burns in wood material.

In industrial wood product designs where surface roughness is important in laser cutting, it is recommended to make the production plan in vertical cutting at low speeds, preferring traditional cutting. However, it is not recommended to prefer laser cutting in both fiber directions at high speeds.

In terms of surface roughness in laser cutting, scattered wood species such as poplar massif are recommended when a uniform surface is desired. However, it should not be forgotten that these trees have rougher cut surfaces on average than coniferous tree species whose difference in spring and summer wood is more pronounced, such as scotch pine and cedar, since they are generally large trachea. In general, wood types with high density are recommended when roughness is important.

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