Ağaç ve Orman
Tree and Forest
https://dergipark.org.tr/tr/pub/agacorman

ISSN: 2757-5349
2024, 5(1): 42-50

Araştırma Makalesi

Analyze the effects of CNC machining parameters on the surface roughness (*Rz*) of Anatolian chestnut

CNC işleme parametrelerinin Anadolu kestanesinin yüzey pürüzlülüğü (*Rz*) üzerindeki etkilerinin incelenmesi

Oruç ARAS[1], Sait Dündar SOFUOĞLU[2]

[1]Kütahya Dumlupınar Üniversitesi, Lisansüstü Eğitim Enstitüsü, Kütahya, Türkiye
[2]Kütahya Dumlupınar Üniversitesi, Simav Teknoloji Fakültesi, Ağaç İşleri Endüstri Mühendisliği Bölümü, Simav/Kütahya, Türkiye

Sorumlu yazar:
Sait Dündar SOFUOĞLU

E-mail:
sdundar.sofuoglu@dpu.edu.tr

Gönderim Tarihi:
09/04/2024

Kabul Tarihi:
24/05/2024

Atıf:
Aras, O., Sofuoğlu, S. D. 2024. Analyze the effects of CNC machining parameters on the surface roughness (*Rz*) of Anatolian chestnut. Ağaç ve Orman, 5(1). 42-50.
DOI:10.59751/agacorman.1467058

Abstract
The effect of processing parameters on the surface roughness parameter *Rz* (mean peak-to-valley height) in CNC machining of Anatolian chestnut (*Castenia sativa* Mill.) wood species used in the woodworking and furniture industry was investigated. The machining conditions were determined to obtain the lowest *Rz* value. The experiments were carried out at the speeds of 8000, 12000, and 16000 rpm and the feed rates of 1000, 1500, and 2000 mm/min with 3 and 4 machining layers by using two different cutters with a diameter of 8 mm. *Rz* measurements were made on the obtained surfaces using the needle scanning method according to TS EN ISO 21920-2 (2021). In the measurements perpendicular to the fibers, the lowest *Rz* values were obtained with cutter type 2 (the cutter of the three cutting edge straight end mill), at 16000 rpm speed, 1000/2000 mm/min feed rate, and four machining layers. In the measurements made parallel to the fibers, the lowest *Rz* values were obtained at the cutter type 2 (the cutter of the three cutting edge straight end mill), at the speed of 16000 rpm and the feed rate of 1000/2000 mm/min and 4th step-down. A smooth surface (lower *Rz* value) was obtained with fourth cuts (step down, cut layer) instead of third cuts.

Keywords: Anatolian chestnut CNC, machining, surface roughness, *Rz*.

Özet
Mobilya ve ağaç işleme sanayiisinde kullanılan yerli ağaç türlerinden Anadolu kestanesi (*Castenia sativa* Mill.)'nin CNC ile işlenmesinde işleme parametrelerinin *Rz* yüzey pürüzlülük parametresi üzerine etkisi incelenmiştir. En düşük *Rz* değerinin elde edilebilmesi için işleme koşulları belirlenmiştir. Denemeler iki farklı kesici kullanılarak (çap=8 mm) 8000, 12000 ve 16000 devir/dakika devir sayılarında ve 1000, 1500 ve 2000 mm/dak ilerleme hızlarında 3 ve 4 olmak üzere farklı iki işleme katman sayısında yapılmıştır. İşleme sonucu meydana gelen yüzeylerin zeminlerinde dokunmalı iğne taramalı yöntem kullanılarak TS 6956 EN ISO 4287' e göre *Rz* (ortalama tepe-vadi yüksekliği) tespiti yapılmıştır. Liflere dik yapılan ölçümlerde en düşük *Rz* değerleri 2 no'lu (3 kesici kenarlı düz parmak freze) kesici tipinde, 16000 dev/dak devir sayısında, 1000/2000 mm/dak ilerleme hızında ve 4 işleme katman sayısında elde edilmiştir. Liflere paralel yapılan ölçümlerde en düşük *Rz* değerleri 2 no'lu kesici (3 kesici kenarlı düz parmak freze) tipinde, 16000 dev/dak devir sayısında, 1000/2000 mm/dak ilerleme hızında ve 4 işleme katman sayısında elde edilmiştir. 3 kesiş ile alan boşaltma yerine 4 kesiş ile yapılan alan boşaltma da düzgün yüzey (daha düşük *Rz* değeri) elde edilmiştir.

Anahtar kelimeler: Anadolu kestanesi, CNC, işleme, yüzey pürüzlülüğü, *Rz*.

1. Introductions

In products with wood and wood-based materials, high surface quality is a desired feature during and after production. Surface quality is one of the most critical factors determining the quality in the furniture and woodworking sector. The machining technique is a critical factor that forms the surface quality of wood material. The use of CNC machines in the Turkish furniture industry started in the 1990s (Koç and Koç, 2005). Nowadays, CNC machines in the furniture industry fulfill customer demands and enable the application of various designs. Low labor costs and the ability to produce quality products increase competitiveness (Karagöz, 2010). The machining strategy and parameters, and cutting tool must be correctly selected (Karagöz, 2011). Settings such as the number of revolutions used in machining, feed speed, depth of cut, machining strategy, depth of cut, *etc*., are determined with the CNC programs (Bal and Akçakaya, 2018). These factors change the surface roughness of the processed surface. With the decrease in forest assets worldwide, both producers and users should process the wood material more efficiently, evaluate it, and use it for a more extended period. Non-smooth surfaces in one of the processing stages of wood material causes additional processes, such as sanding in the next production stage (Aykaç, 2018). Wood materials generally give higher roughness values than similar materials where surface smoothness is essential. Wood materials should be processed with appropriate tools, cutters, and machines. Otherwise, undesirable defective surfaces may occur. Surface quality can be related to surface roughness in the joints of wood materials, adhesion strength at joints and surfaces, and the success of finishes (Jakub and Martino, 2005). It is significant to know and apply the machining properties of the wood species and the machining properties appropriate for them (Sofuoğlu, 2008). As a rule, the feed rate, number of cutter marks per unit distance, and depth of cut must be kept small when the density of the workpiece being processed increases (iron, steel, etc.). Low-density and easy-to-process materials such as wood are kept large, and these settings vary according to the material density (Bal, 2018). There are studies on the determination of surface quality in CNC machining of wood and wood-based materials by changing various machining parameters (Kilic et al., 2006; Karagöz, 2010; Sütcü and Karagöz, 2012; Kacal and Sofuoglu, 2013; Sofuoglu and Kaçal, 2013; Sofuoglu, 2015a; Sofuoglu, 2015b; Sofuoglu, 2016; Koç et al., 2017; Bal, 2018; İşleyen and Karamanoğlu, 2019, Kaba and Bal, 2024). Heat-treated (Ergin and Sofuoglu, 2023), surface densified (Tosun and Sofuoglu, 2023a, Tosun and Sofuoglu, 2023a, Sofuoglu et al., 2023) studies were also carried out to determine the optimum parameters in CNC hole drilling process. Machining time (Dumanoglu and Bal, 2022) and energy consumption (Bal et al., 2022) are also investigated. There are also review articles on the subject (Khorasani et al., 2012; Gurau and Irle, 2017). Different results may occur in each wood species due to its heterogeneous structure. This study aimed to investigate the relationship between machining parameters and *Rz* surface roughness in CNC machining of Anatolian chestnut wood species and determine the optimum conditions for obtaining the lowest *Rz* value.

2. Material and Method

2.2. Material

The study used an Anatolian chestnut (*Castenia sativa* Mill.) wood sample as the experiment material. The wood was randomly selected from the sawmill in Simav, Kutahya. The air dry density was determined as 0.56 g/cm³.

The specimens were machined using the SKILLED 2040 three-axis CNC vertical machining machine located in Kutahya Dumlupinar University Simav Technology Faculty Woodworking Industrial Engineering Departmen.

As the cutter type, straight-end mills with 8 mm diameter and a different number of cutting edges (2 and 3) made of high-speed steel (HSS) supplied by Netmak company were used (Figure 1). The roughness was measured using a Time TR-200 needle-scanning surface roughness measuring instrument.

2.2. Method

The timbers determined for the test specimen were left to natural drying for six months under room conditions. Then, they were cut to dimensions of approximately 55x6x2 cm. The specimens prepared for the experiments were kept in an air conditioning cabinet at a temperature of 20 ± 2°C and a relative humidity of 65 ± 5% until they reached a stable weight and the relative humidity reached 12 ± 2%. Using the software, L-shaped zigzag machining was carried out with long sides of 5 cm and short sides of 2 cm, with a machining depth of 10 mm. The machining parameters and levels determined in the creation of the experimental design are given in Table 1. A schematic representation of the experimental design is given in Figure 1.

The parameter *Rz* (arithmetic mean of the highest and lowest five points, a total of ten points) was used to obtain roughness data. The *Rz* parameter is a valuable complement to the *Ra* parameter as it defines the height of individual irregularities. *Rz* defines the gradual removal of protruding fibers from the surface andthe reduction of deep grooves created on the surface simultaneously. In the direction perpendicular to the fibers, the parameter is also an indicator of the decrease in the differences between earlywood and latewood (Adamcik et al., 2024). The test was conducted according to ISO 21920-2 (2021) standard. The wood surface roughness parameter *Rz* was evaluated in two directions: parallel and perpendicular to fibers. The measurement step (cut-off) was taken at 0.8 mm. The device was used to determine the surface roughness values of the specimens, which were placed parallel to the ground with five repetitions. During the measurement process, the calibration of the device was checked at specific intervals.

Table 1. Parameters used in the face milling of Anatolian chestnut (Aras, 2019).

Machining parameters	**Coded levels**		
Number of stepdown	3	4	
Spindle speed (rpm)	8000	12000	16000
Feed (mm/min)	1000	1500	2000
Cutter type	1 (The cutter with the two cutting-edge straight end mills)	2 (with the three cutting edge straight end mills)	

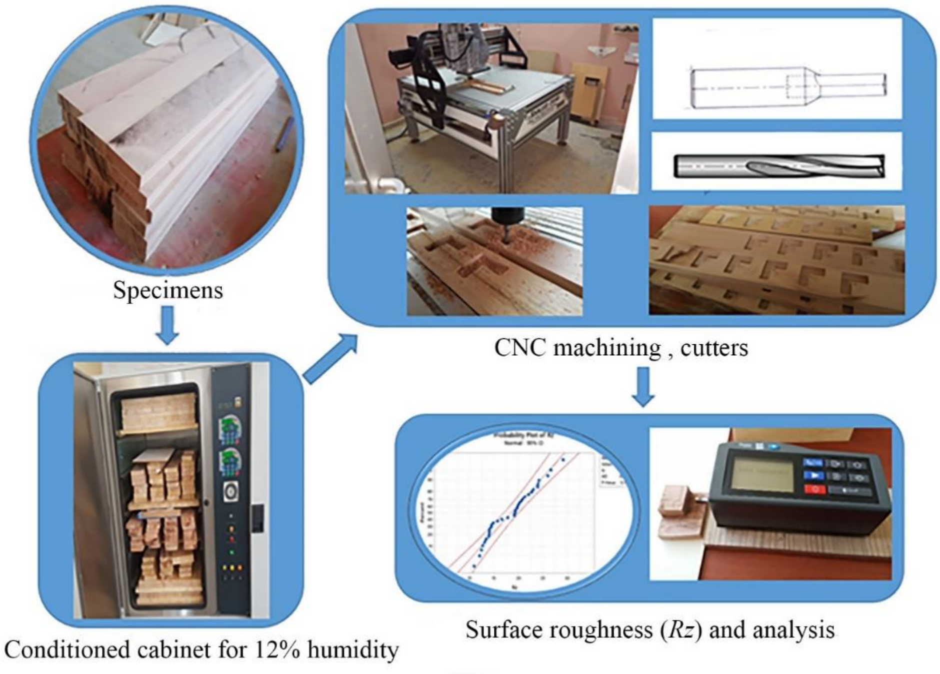

Figure 1. Schematic representation of the experimental design.

2.3. Statistical analysis

Using Minitab software, a normality test was performed on the obtained data at a 95% confidence level. Analysis of variance (ANOVA) was applied to the data, and evaluations were made with main effect and interaction graphs between factors. The results are given in tables and graphs.

3. Results and Discussion

Roughness measurements perpendicular and parallel to the fibers on the machined ground surfaces were carried out and evaluated using statistical methods to determine the effect of cutter type, speed, feed rate, and number of cut layers on *Rz* on the machined ground surfaces. *Rz* values obtained are given in Table 2.

In Figure 2, the normality test was performed on the *Rz* values obtained from the measurements perpendicular to the fibers. The p-value is more significant than 0.05 (P=0.753), so the *Rz* values are normally distributed at a 95% confidence level.

The results of the analysis of variance for *Rz* in measurements perpendicular to the fibers are given in Table 3.

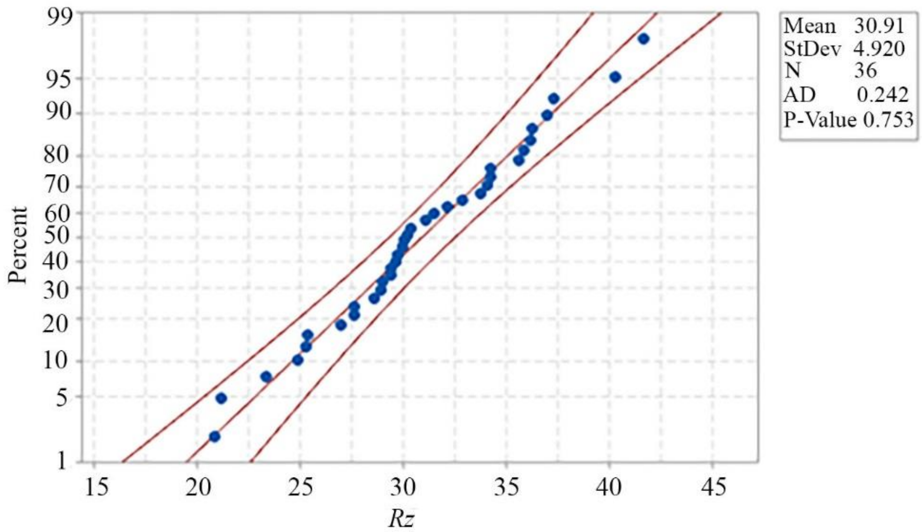

Figure 2. Normality plot for *Rz* for measurements perpendicular to the fibers.

Table 2. *Rz* values obtained from measurements perpendicular and parallel to the fibers on the ground surfaces (Aras, 2019).

Cutter type	Spindle speed (rpm)	Feed (mm/min)	Number of stepdown	*Rz* (µm)	
				Perpendicular to the fibers	Parallel to the fibers
1	8000	1000	3	32.167	23.048
1	8000	1000	4	29.367	12.387
1	8000	1500	3	35.918	13.950
1	8000	1500	4	34.090	24.187
1	8000	2000	3	21.150	19.130
1	8000	2000	4	30.200	15.690
1	12000	1000	3	28.610	13.873
1	12000	1000	4	36.167	19.750
1	12000	1500	3	36.247	14.457
1	12000	1500	4	37.014	11.990
1	12000	2000	3	41.680	26.017
1	12000	2000	4	29.028	14.473
1	16000	1000	3	29.763	13.043
1	16000	1000	4	28.920	29.223
1	16000	1500	3	34.220	24.013
1	16000	1500	4	29.417	21.260
1	16000	2000	3	29.640	20.033
1	16000	2000	4	37.313	19.200
2	8000	1000	3	30.388	20.830
2	8000	1000	4	26.950	22.110
2	8000	1500	3	34.268	19.350
2	8000	1500	4	29.983	19.727
2	8000	2000	3	33.780	16.583
2	8000	2000	4	20.823	14.030
2	12000	1000	3	32.896	19.357
2	12000	1000	4	27.628	13.330
2	12000	1500	3	31.073	20.573
2	12000	1500	4	27.593	23.970
2	12000	2000	3	24.900	14.840
2	12000	2000	4	31.536	17.807
2	16000	1000	3	25.347	20.167
2	16000	1000	4	25.297	14.043
2	16000	1500	3	40.347	22.717
2	16000	1500	4	23.564	12.640
2	16000	2000	3	23.287	26.723
2	16000	2000	4	30.070	10.855

Table 3. Analysis of variance results for *Rz* in measurements perpendicular to the fibers.

Source	Degree of freedom	*Rz*			
		Sum of squares	Mean squares	F	P
Cutter type	1	183.06	183.06	4.52	0.042
Spindle speed (rpm)	2	92.94	46.47	1.15	0.331
Feed (mm/min)	2	22.85	11.43	0.28	0.756
Number of stepdown	1	71.46	71.46	1.77	0.194
Error	29	1173.69	40.47		
Total	35	1544.00			

According to the results of the analysis of variance at 95% confidence level, there is a statistically significant difference for *Rz* since P=0.042<0.05 for cutter type. There is no significant difference for all other factors due to p-value>0.05. Figure 3 shows the main effect plot for *Rz* for measurements perpendicular to the fibers on the surface.

According to the main effect plot in Figure 4, lower *Rz* values were obtained on the surfaces machined with the cutter of the three cutting-edge straight-end mills. The roughness value increased when the number of revolutions increased from 8000 rpm to 12000 rpm. In the case of increasing to 16000 rpm, the

Rz value decreased, and the lowest roughness value was obtained at this speed. The lowest roughness value was obtained at 1000 mm/min feed, while the roughness value increased when the feed increased to 1500. The highest roughness value occurred at 1500 mm/min. The values were nearly identical at 1000 and 2000 mm/min feed rates. The lowest *Rz* values were obtained with the three cutting-edge straight-end mills, 16000 rpm, 1000/2000 mm/min feed, and the fourth cut layers.

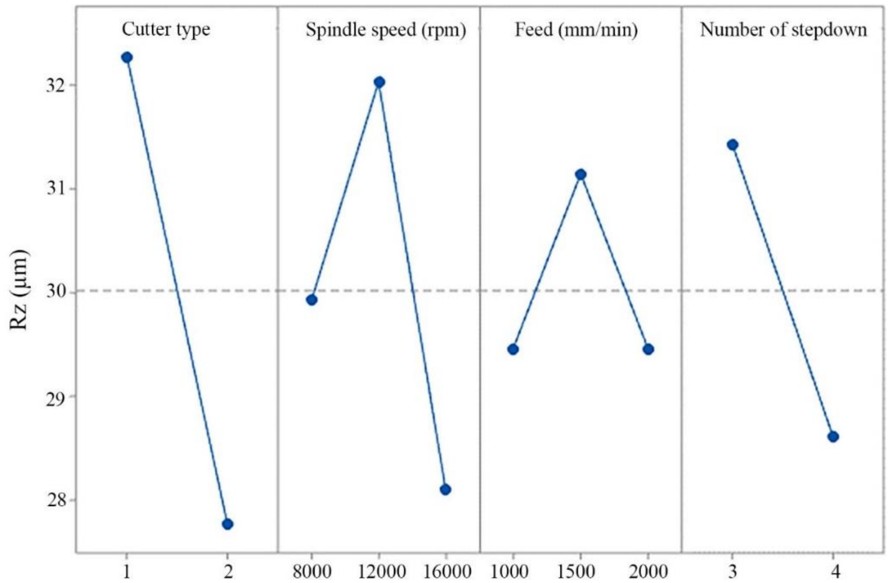

Figure 3. Effect of cutter type, speed, feed rate, and number of cut layers on *Rz* in measurements perpendicular to the fibers.

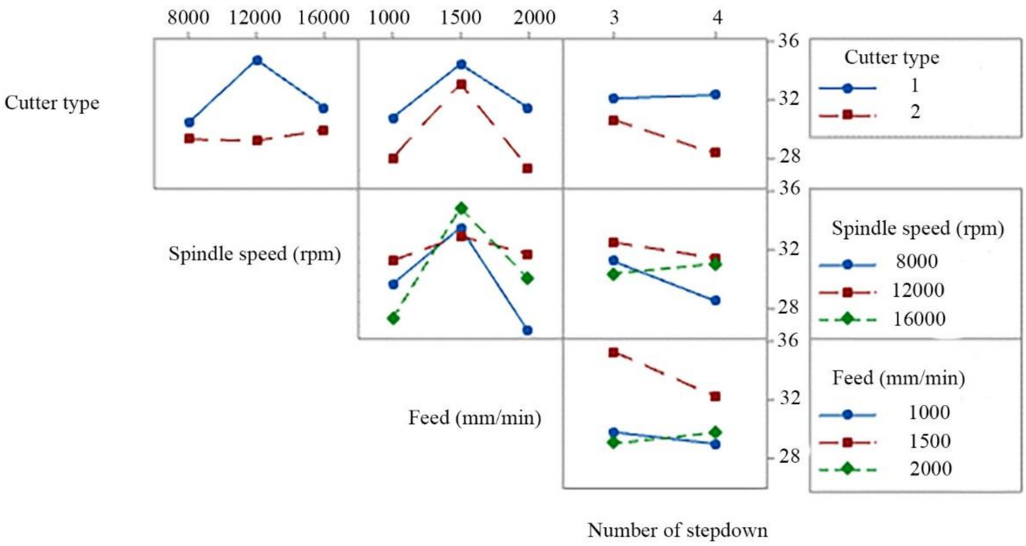

Figure 4. Interactions of processing factors in terms of *Rz* in measurements perpendicular to the fibers.

As can be seen in the interaction plot, the cutter of the two cutting-edge straight-end mills gives *Rz* values close to each other at both machining layer numbers. In comparison, the cutter of the three cutting edge straight end mills gives a lower *Rz* value at the fourth step-downs. At 8000 and 12000 rpm, the lowest *Rz* value was obtained at the fourth machining layers, while at 16000 rpm, the lowest *Rz* value was obtained at the third step-downs. At 1000 and 2000 mm/min feed rates, close *Rz* values were obtained between the number of machining layers, while a lower Rz value was obtained at 1500 mm/min feed rate with the fourth step-downs. The highest *Rz* values were obtained at 1500 mm/min feed rate in both cutters and each speed. The highest *Rz* value was obtained at 1500 mm/min feed rate at all three speeds. The cutter with the three cutting-edge straight-end mills gave lower *Rz* values at both machining layer numbers, all feeds, and all speeds.

The normality plot of *Rz* values obtained in surface roughness measurements parallel to the fibers is given in Figure 5.

Since p-value=0.119>0.05 was obtained according to the normality plot, it is obvious that the average *Rz* values obtained in the average roughness measurement are normally distributed at a 95% confidence level.

Table 4 gives the results of the variance analysis for the surface roughness parameters in the measurements made parallel to the fibers on the surface.

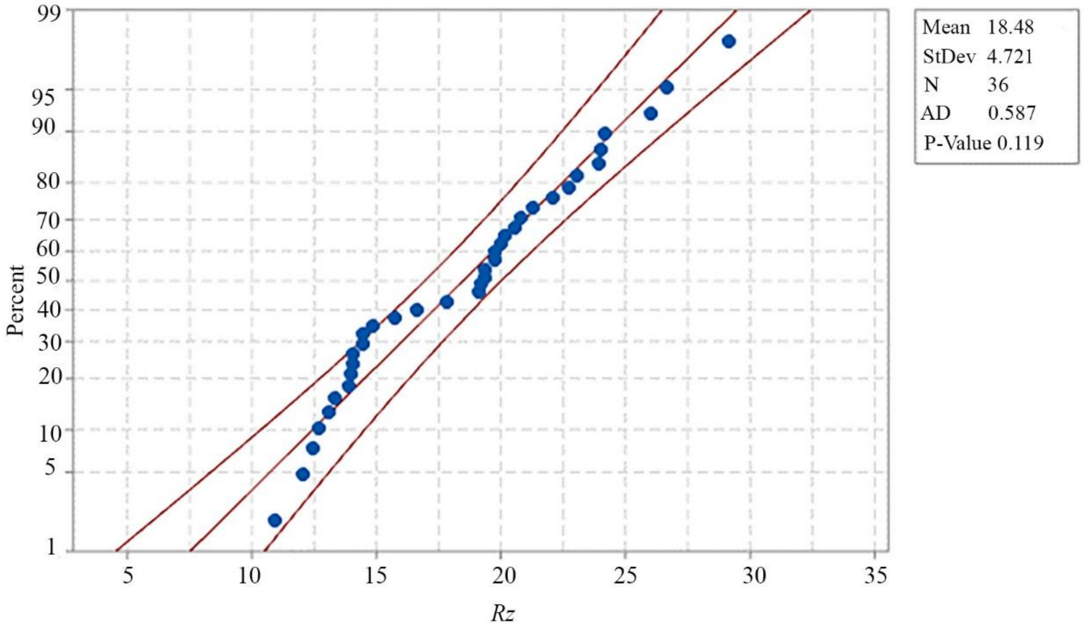

Figure 5. Normality plot for *Rz* for measurements parallel to the fibers.

Table 4. Analysis of variance results for *Rz* in measurements parallel to the fibers.

Source	Degree of freedom	*Rz*			
		Sum of squares	Mean squares	F	P
Cutter type	1	1.024	1.024	0.04	0.840
Spindle speed (rpm)	2	23.047	11.524	0.46	0.633
Feed (mm/min)	2	7.590	3.795	0.15	0.859
Number of stepdown	1	28.501	28.501	1.15	0.293
Error	29	719.973	24.827		
Total	35	780.135			

According to the variance analysis results for *Rz* at a 95% confidence level, there is no significant difference in all factors since P>0.05. Figure 9 shows the main effect plot for *Rz* in the measurements made parallel to the fibers on the surface.

As can be seen in the main effect plot for *Rz* in the measurementsparallel to the fibers (Figure 6), smoother surfaces were obtained on the surfaces machined with the cutter of the three cutting-edge straight-end mills- However, closer values were obtained compared to the measurement perpendicular to these fibers. When the spindle speed was increased from 8000 rpm to 12000 rpm, a decrease occurred in the roughness value. When increased to 16000 rpm, the *Rz* value increased again, and the lowest *Rz* value was obtained at 12000 rpm. While the highest *Rz* value occurred at 12000 rpm in the measurement perpendicular to the fibers, the lowest *Rz* value was obtained in the measurement parallel to the fibers. When the feed was increased from 1000 mm/min to 1500, an increase in the roughness value occurred, and when the feed was increased to 2000 mm/min, the *Rz* value close to the *Rz* value obtained at 1000 mm/min was obtained again. The lowest *Rz* values were obtained with the cutter of the three cutting-edge straight-end mills, 16000 rpm, 1000 or 2000 mm/min feed, and the fourth step-down.

According to Figure 7, when the interaction graph of the measurements made parallel to the fibers is evaluated in general, it can be said that lower roughness values are obtained with cutter type 2 (the cutter of the three cutting-edge straight-end mill). Similar to the measurements perpendicular to the fibers, in the measurements parallel to the fibers, at a feed of 1000 mm/min, cutter types 1 and 2 gave similar *Rz* values.

With the increase in the number of revolutions in rotary cutters, roughness values decrease, and smoother surfaces can be obtained (Karagoz, 2010; Sutcu and Karagoz, 2012; Sofuoglu, 2015a; Sofuoglu, 2015b; Koç, et al., 2017; Hazır, et al., 2018; Aykac and Sofuoglu, 2021; Tosun, 2021). When evaluated in general, it is seen that the values obtained in the study show similar trends to those in the literature. It can be considered that the differences that occur in some cases may be due to the increase in vibration at some speeds in CNC and the anatomical structure of the wood material due to its heterogeneous structure. As a result, a linear graph may not appear. Smoother surfaces can be achieved by increasing the number of cutting marks per unit distance on the material surface of the cutters. (Malkocoglu and Özdemir, 2006; Usta et al., 2007; Sofuoglu, 2008; Sofuoglu and Kurtoglu, 2014; Tiryaki, 2014). In this case, the fact that cutter No. 2 has three blades and its side surfaces have helical, beveled cutting edges provided smoother surfaces in the machining of the surfaces and similar results to the literature were obtained. It is also known that softwood is resinous. The surface roughness parameter *Rz* is slightly influenced by the presence of resin canals in wood macrostructure (Vitosytė, et al., 2015).

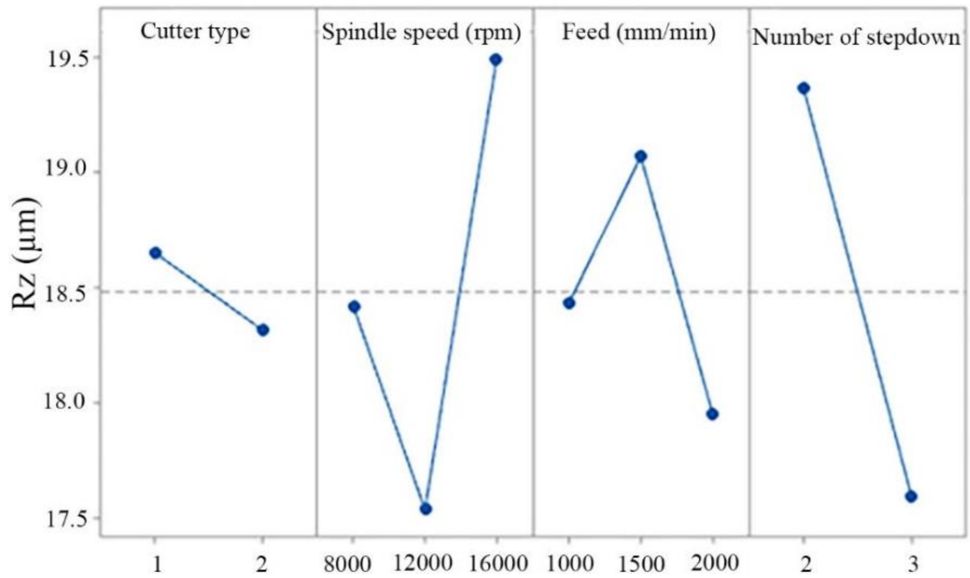

Figure 6. Effect of cutter type, spindle speed, feed, and number of stepdown on *Rz* in measurements parallel to the fibers.

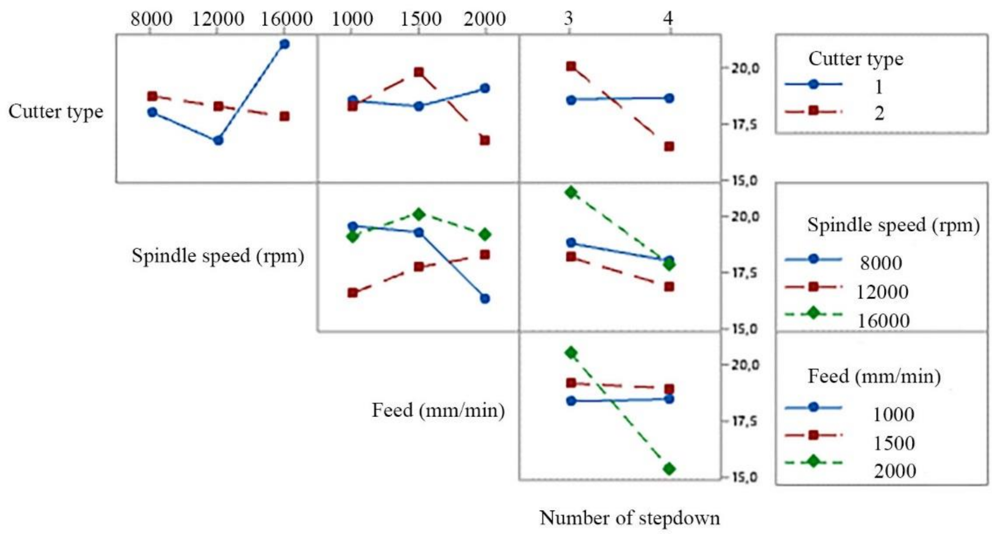

Figure 7. Interactions of processing factors in terms of *Rz* in measurements parallel to the fibers.

4. Conclusions

In this study, machining was carried out on a CNC machine by changing various parameters to determine the optimum machining conditions by obtaining the lowest *Rz* roughness value of the samples prepared from Anatolian chestnut (*Castenia sativa* Mill.) wood species. When the roughness values obtained are analyzed,

- Increasing the feed rate had different, independent effects on the roughness parallel and perpendicular to the fibers. The lowest value occurred in *Rz* perpendicular to the fibers, and the highest value occurred in *Rz* parallel to the fibers at the highest spindle speed (16000 rpm). It is obvious that the effect of measurement direction on Rz was different.
- Feed rate variations, the number of machining layers, and the cutter type had similar effect on *Rz* in both measurement directions. The lowest *Rz* values were obtained with cutter type 2 (with the three cutting-edge straight-end mills), 16000 rpm, 1000/2000 mm/min feed rate, and four

machining layers in the measurements perpendicular to the fibers.

- The lowest *Rz* values were obtained at the cutter type 2 (the cutter of the three cutting edge straight end mill), at a speed of 16000 rpm, at a feed rate of 1000/2000 mm/min and the fourth machining layers in the measurements parallel to the fibers.
- A smoother surface (lower *Rz* value) was obtained with four cuts (step-down) compare to those of three cuts.
- The data should be evaluated, and machining should be performed using the optimum parameters to obtain minimum roughness values.
- Since CNC machining characteristics will differ for each wood type, optimum points can be determined by changing the parameters such as cutter type, wood type, moisture content, etc.

Acknowledgment

This article is based on Oruç ARAS's master thesis entitled "Investigation of the relationship between machining parameters in different massive wood sections at CNC milling operations ".

Author contributions

Concept: O.A., S.D.S.; Design: O.A., S.D.S.; Supervision: S.D.S.; Data Collection: O.A.; Analysis: O.A., S.D.S.; Literature Search: O.A., S.D.S.; Writing Manuscript: O.A.; Critical Review: S.D.S

References

Aras, O., 2019. Investigation of the Relationship Between Machining Parameters in Different Massive Wood Sections at CNC Milling Operations, Kutahya Dumlupinar University, Graduate School of Sciences, Master Thesis, Kutahya, Turkiye.

Aykaç, E., 2018. Investigation of the effect of machining parameters on surface quality in Bamboo, Kutahya Dumlupinar University, Graduate School of Sciences, Master thesis, Kutahya, Turkiye.

Aykac, E., Sofuoglu, S.D., 2021. Investigation of the effect of machining parameters on surface quality in bamboo. *Tehnicki Vjesnik-Technical Gazette,* 28(2): 684-689. https://doi.org/10.17559/TV-20200102202928

Bal, B.C., 2018. The effects of some tool paths adjustments of CNC machines on surface roughness and processing time of fiberboards, *Furniture and Wooden Material Research Journal*, 1(1): 21-30. https://doi.org/10.33725/mamad.427588

Bal, B.C., Akçakaya, E., 2018. The effects of step over, feed rate and finish depth on the surface roughness of fiberboard processed with CNC machine, *Furniture and Wooden Material Research Journal*, 1(2): 86-93. https://doi.org/10.33725/mamad.481278

Bal, B. C., Mengeloglu, F., Akcakaya, E., Gündes, Z., 2022. Effects of cutter parameters on surface roughness of fiberboard and energy consumption of CNC machine. *Kastamonu University Journal of Forestry Faculty*, 22(3): 264-272. https://doi.org/10.17475/kastorman.1215347

Dumanoglu, F., Bal, B.C., 2022. Effects of machining parameters on the processing time and surface roughness of fiberboards formed by CNC machine. *Kahramanmaras Sutcu Imam University Journal of Engineering Sciences*, 25(4) 615-621. https://doi.org/10.17780/ksujes.1144224

Ergin, U., Sofuoglu, S. D., 2023. Determination of machining characteristics of heat-treated Siberian pine (*Pinus sibirica*). *Drvna Industrija*, 74(2): 139-152. https://doi.org/10.5552/drvind.2023.0003

Gurau, L., Irle, M., 2017, Surface roughness evaluation methods for wood products: A review, *Current Forestry Reports*, 3: 119-131. https://doi.org/0.1007/s40725-017-0053-4

Hazir, E., Erdinler, E.S., Koc, K.H., 2018. Optimization of CNC cutting parameters using design of experiment (DOE) and desirability function. *Journal of Forestry Research*, 29(5): 1423-1434. https://doi.org/10.1007/s11676-017-0555-8

Isleyen, U.K., Karamanoglu, M., 2019. The influence of machining parameters on surface roughness of MDF in milling operation. *BioResources*, 14(2): 3266-3277. https://doi.org/10.15376/biores.14.2.3266-3277

Jakub, S., Martino, N., 2005. Wood surface roughness-What is it, Rosenheim Workshop, 29–30 September 2005, Boku University of Natural Resources and Applied Life Sciences, Vienna, Austria.

Kaba, O., Bal, B.C., 2024. Investigation of the effect of CNC machine cutting parameters on the surface roughness of walnut wood. *Kahramanmaras Sutcu Imam University Journal of Engineering Sciences*, 27(1): 69-77. https://doi.org/10.17780/ksujes.1352802

Kaçal, A., Sofuoğlu, S.D., 2013. Experimentally and Statistically Evaluating of Drilling of Massive Wooden Table which is Made of Scotch Pine (*Pinus sylvestris* L.), 21st International Wood Machining Seminar, Tsukuba International Congress Center, Tsukuba, Japan. August 4-7, 2013, 421-428.

Karagöz, Ü., 2010. Investigation of Machining Parameters on the Surface Quality in CNC Routing Wood And Wood-Based Materials, Süleyman Demirel University, Graduate School of Sciences, Master thesis, Isparta.

Karagöz, Ü., 2011. The effecting factors on surface quality of wood and wood-based materials machined by CNC. Kastamonu University Journal of Forestry Faculty, 11(1): 18-26.

Kilic, M., Hiziroglu, S., Burdurlu, E., 2006, Effect of machining on surface roughness of wood, Building and Environment, 41(8): 1074-1078. https://doi.org/10.1016/j.buildenv.2005.05.008.

Khorasani, A.M., Yazdi, M.R.S., Safizadeh, M.S., 2012, Analysis of machining parameters effects on surface roughness: a review, *Int. J. Computational Materials Science and Surface Engineering*, 5(1): 68-84

Koc, K.H., Erdinler, E.S., Hazır, E., Öztürk, E., 2017. Effect of CNC application parameters on wooden surface quality, *Measurement*, 107: 12-18. https://doi.org/10.1016/j.measurement.2017.05.001

Koç, K.H, Koç, R., 2005. Bilgisayar destekli üretim ve Türkiye mobilya endüstrisinin geleceği, *Mobilya Dekorasyon*, 67: 22-38. http://nek.istanbul.edu.tr:4444/ekos/MAKALE/M4628.pdf

Malkoçoglu, A., Ozdemir, T., 2006. The machining properties of some hardwoods and softwoods naturally grown in Eastern Black Sea Region of Turkey. *Journal of Materials Processing Technology*, 173(3): 315–320. https://doi.org/10.1016/j.jmatprotec.2005.09.031

Sofuoğlu, S.D., 2008. Effect of Wood Machining Properties of Some Native Wood Species on Surface Quality, İstanbul University, Institute of Sciences, PhD thesis, Istanbul.

Sofuoglu, S.D., 2015a. Determination of optimal machining parameters of massive wooden edge-glued panels made of European larch (*Larix decidua* Mill.) using Taguchi design method. *BioResources*, 10(4): 6797-6808. https://doi.org/10.15376/*biores.*10.4.7772-7781

Sofuoglu, S.D., 2015b. Using artificial neural networks to model the surface roughness of massive wooden edge-glued panels made of scotch pine (*Pinus sylvestris* L.) in a machining process with computer numerical control. *BioResources,* 10(4): 6797-6808. https://doi.org/10.15376/*biores.*10.4.6797-6808

Sofuoglu, S.D., 2016. Determination of Optimal Machining Parameters of Massive Wooden Edge- Glued Panels Which is Made of Scots Pine (*Pinus sylvestris* L.), Using Taguchi Design Methods. *European Journal of Wood and Wood Products*, 75(1):33-42. https://doi.org/10.1007/s00107-016-1028-z

Sofuoglu, S.D., Kaçal, A., 2013. Investigating of machining performance in terms of tool wear and hole accuracy in drilling of particleboard surfaced with synthetic resin sheet, 21st International Wood Machining Seminar, Tsukuba International Congress Center, Tsukuba, Japan, August 4-7, 2013, s. 233-240.

Sofuoglu, S.D., Kurtoğlu, A., 2014. Some machining properties of 4 wood species grown in Turkey. *Turkish Journal of Agriculture and Forestry*, *38*(3): 420-427. https://doi.org/10.3906/tar-1304-124

Sofuoglu, S. D., Tosun, M., Atılgan, A., 2023. Determination of the machining characteristics of Uludağ fir (Abies nordmanniana Mattf.) densified by compressing. *Wood Material Science & Engineering,* 18(3): 841–851. https://doi.org/10.1080/17480272.2022.2080586

Sutçu, A., Karagoz, U., 2012. Effect of machining parameters on surface quality after face milling of MDF, *Wood Research*, 57(2): 231-240.

Tiryaki, S., 2014. Effecting factors on surface roughness in wood machining. 15(2): 176-182. https://doi.org/10.18182/tjf.93755

Tosun, M., 2021. The Effect of Thermo-Mechanical Densification on Machining Properties of Massive Wooden Material, Kutahya Dumlupinar University, Institute of Graduate Education, Master thesis, Kutahya, Turkiye.

Tosun, M., Sofuoglu, S. D., 2023. The use of an artificial neural network for predicting the machining characterising of wood materials densified by compressing. *Bilge International Journal of Science and Technology Research*, 7(1): 55-62.

Tosun, M., Sofuoglu, S. D. (2023). Determination of processing characteristics of wood materials densified by compressing. *Maderas. Ciencia y tecnología*, 25:1-16. http://dx.doi.org/10.4067/s0718-221x2023000100427

ISO 21920-2, 2021. Geometrical product specifications (GPS) - Surface texture: Profile - Part 2: Terms, definitions and surface texture parameters

Usta, I., Demirci, S., Kılıç, Y., 2007. Comparison of surface roughness of Locust Acacia (*Robinia pseudoacacia* L.) and European Oak (*Quercus petraea* (Mattu.) Lieble.) in terms of the preparative process by planning. *Building and Environment*, 42: 2988-2992.

Vitosytė, J., Ukvalbergienė, K., and Keturakis G., 2015. Roughness of sanded wood surface: an impact of wood species, grain direction and grit size of abrasive material. *Materials Science (Medžiagotyra*), 21(2): 255-259 (5), https://doi.org/10.5755/j01.mm.21.2.5882