



### The effects of step over, feed rate and finish depth on the surface roughness of fiberboard processed with CNC machine

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#### Abstract

Fiberboard is used extensively in furniture production in all over the world. One of the most important reasons for the preference of fiberboard is the easy shaping of its surfaces. In the past, the surfaces of the fiberboard were processed using conventional machines. Nowadays, Computer Numerical Control (CNC) machines are used in the processing of the fiberboard. CNC machines is operated using some computer control commands which provide the action of the machine. The code file consisting of these commands contains some adjustments such as step over, spindle speed, feed rate, finish depth, machining strategy, step down, plunge rate etc. These adjustments change the surface roughness of the processed section of fiberboard. In this study, the influence of finish depth (2 and 6 mm), step over (40%, 60% and 80%) and feed rate (3, 5 and 7 m/min) settings on the surface roughness of fiberboard were investigated. *Ra* roughness value of processed section of fiberboard test samples was determined using contact stylus method. According to the obtained data, it was concluded that the surface roughness increased as finish depth, feed rate and step over are increased.

**Keywords:** CNC machines, surface roughness, step over, feed rate, finish depth

### CNC makineleri ile işlenen lif levhaların yüzey pürüzlülüğü üzerine bıçak adımı, besleme hızı ve kesme derinliğinin etkileri

#### Öz

Lif levha tüm dünyada mobilya üretiminde büyük miktarlarda kullanılmaktadır. Lif levhanın tercih edilmesinin en önemli nedenlerinden biri yüzeyinin kolay şekillendirilmesidir. Geçmişte, Lif levhaların yüzeyleri konvansiyonel makinelerle işlenmiştir. Günümüzde, Bilgisayar Sayısal Kontrol (CNC) makineleri lif levhaların işlenmesinde kullanılmaktadır. CNC makineleri, makinenin hareketini sağlayan bilgisayar kontrol komutları kullanılarak çalıştırılmaktadır. Bu komutlardan oluşan kod dosyaları, bıçak adımı, bıçak motoru hızı, besleme hızı, kesme derinliği, işleme taktığı, bıçak dalma derinliği, dalma hızı gibi birçok ayarlamaları içermektedir. Bu ayarlamalar, lif levhanın işlenen kısmının yüzey pürüzlülüğünü değiştirmektedir. Bu çalışmada, kesme derinliği, (2 mm ve 6 mm) bıçak adımı (%40, %60 ve %80) ve besleme hızı (3, 5 ve 7 m/min) ayarlarının lif levhanın yüzey pürüzlülüğü üzerine etkileri araştırılmıştır. Lif levha test örneklerinin işlenen kısımlarının *Ra* pürüzlülük değeri iğne taramaları temas yöntemi kullanılarak belirlenmiştir. Elde edilen verilere göre; kesme derinliği, besleme hızı ve bıçak adımı arttıkça yüzey pürüzlülüğünün arttığı belirlenmiştir.

**Anahtar kelimeler:** CNC makineleri, yüzey pürüzlülüğü, bıçak adımı, besleme hızı

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## **1 Introduction**

CNC machines have emerged primarily to meet the needs of aircraft and helicopter factories. It has been developed and widespread during the application in the automotive industry. With the introduction of CNC machines, the design and use of new machines have been completely changed, and new possibilities for engineers, workshops and factory owners have begun to emerge (Erer, 2000).

CNC machines are used in many different areas to process materials in all over the world. Today, there are many different types and special CNC machines developed for different types of production and for different purposes.

Many different parameters have to be adjusted on the CNC machines for the processing of material using code file. These are spindle speed, feed rate, cutter step over, cutter plunge speed, tool strategy etc. According to these adjustments, the surface of the material has different surface roughness. These adjustments effect the quality of processed surface.

CNC machines are used to cut, drill, shape, and other process of the wooden materials such as particleboard, fiberboard and solid wood. Particularly, the surfaces of the fiberboards are processed in workshops and factories to manufacture furniture parts and decoration objects.

Many researchers have been studied the effect of the settings made in the code files of the CNC machines on the material surface quality in the past. For example, review studies conducted by Benardos and Vosniakos (2003) and Karagöz (2011) revealed general criteria on this issue. In these studies, parameters effecting roughness are the parameters related to the cutting tool, to cutting, to machining, and to the material being machined.

In another study conducted by Sütçü and Karagöz (2012), the effects of parameters such as feed rate, spindle speed, finish depth and step over on the surface roughness of the fiberboards were investigated. According to the results of this study; as the spindle speed increased and as the feed rate, step over and cutting depth decreased, the surface roughness decreased. Similar results were obtained by Deus at al., (2015) and Lou et al., (1998). In the study conducted by Sofuoğlu (2015), it was determined that the surface roughness increased as the feed speed increased, and the offset strategy gave better results than the raster strategy.

The processing time is extremely important for work pieces machined on CNC machines. Increasing or decreasing the total number of work pieces per day depends on the CNC machine adjustments. Very slow feed rate or step over reduces the number of work pieces. On the other hand, very high feeding speed and blade step increase the number of work pieces per day, but the surface roughness is badly affected. In a study on this subject, it has been investigated how CNC machine adjustment change the process time and surface roughness of the work pieces. Bal (2018) studied the effects of step over and feed rate on the surface roughness and processing time of the fiberboard. According to obtained data; it was reported that surface roughness decreases as the step over and feed rate increases, but processing time decreases.

In previous studies, the effects of some CNC machines adjustments using different spindle speed on the surface roughness of the fiberboards were investigated. The aim of this study is to determine the effects of step over, feed rate and finish depth on the surface roughness of fiberboard using the same spindle speed.

## **2 Material and Method**

### **2.1 Material**

Fiberboards were supplied by means of purchase from the market. The obtained fiberboards are single-sided lamination fiberboards. These type fiberboards are used to produce kitchen cabinet doors. The dimensions of the supplied fiberboards are 18x2100x2800 mm (thickness x width x length).

The codes necessary for the test samples to be processed in the CNC machine were created in the ArtCAM program. The code file was transferred to the CNC control program (Mach3), and the machine was controlled by Mach3 program. The cutting speed of the CNC machine's spindle motor is set to 4000 rpm, the feed rate is 3, 5 and 7 m/min, and the step over is set to 40%, 60% and 80% processing raster strategy. Finish depth was set to 2 and 6 mm.

In the processing of the test specimens, two flute cutters produced from high speed steel (HSS) were used. A total of 6 cutters were used. The cutter showed in Fig. 1.



Fig. 1. Cutter used in the tests

CNC machine used to perform the tests is a 3-axis CNC machine (CNC router). The CNC machine is a specially manufactured machine by US Mekatronik Company (Fig. 2).

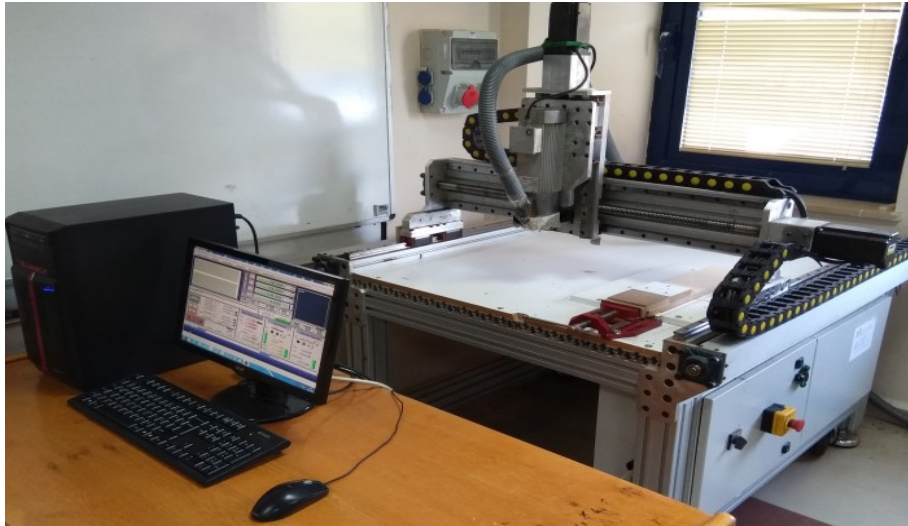


Fig. 2. CNC machine

### **2.2 Method**

In the experiments, fiberboard test specimens were prepared as 18x120x120 mm (thickness x width x length) and 10 test specimens were prepared for each group. In the middle of the test specimens, 100x100 mm squares were processed using the CNC machine. Roughness measurements were made in this section.

The surface roughness of the test specimens was measured using Mitutoyo surfstest SJ-210 (Fig 3). Surface roughness meter settings and features; cutting length  $\lambda_c$ : 2.5 mm, stylus angle:  $60^\circ$ , drive unit speed: 0.75 mm/sn, x-axis measurement range: 12.5 mm, z-axis: 360  $\mu\text{m}$ . The roughness value ( $R_a$ ) was determined using TS 971 standard.



Fig. 3. Surface roughness tester

### 3 Results and Discussion

The results of surface roughness obtained from tests were given in Fig. 3 and Fig. 4. When the data given in Fig 3 and 4, it can be seen easily that the  $R_a$  values of test samples processed 6 mm depth is higher than that of test samples processed 2 mm depth. In addition, the highest  $R_a$  value (14.9  $\mu\text{m}$ ) was measured from group processed using 7 m/min feed rate and 80% step over. The lowest  $R_a$  value (9.9  $\mu\text{m}$ ) was measured from group processed using 3 m/min feed rate and 40% step over in 2 mm finish depth.

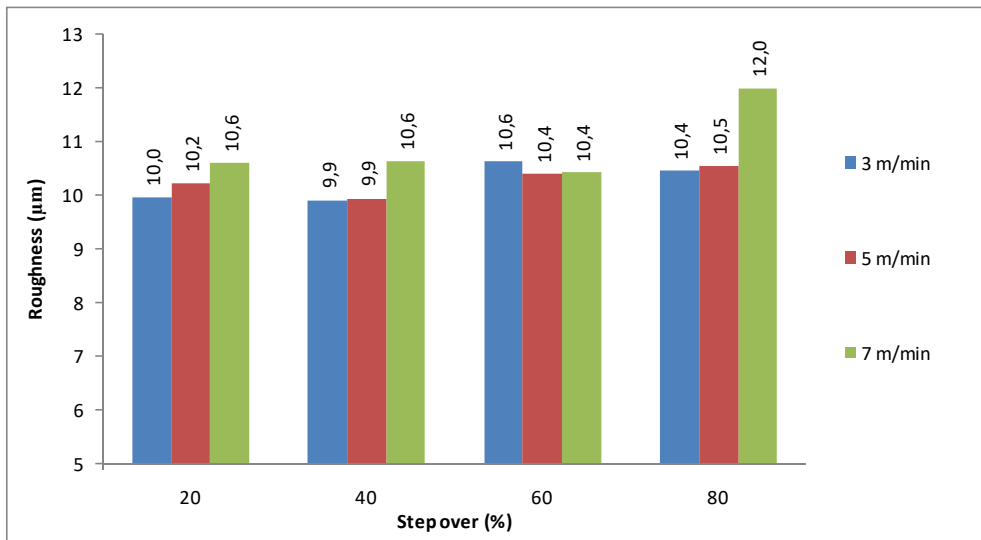


Fig. 3. Surface roughness (finish depth: 2 mm)

When the data given in Fig. 4 analyzed, it can be said that the differences of  $Ra$  values among groups is very evident. But, the  $Ra$  values given in Fig. 3 aren't very evident. It is thought that the reason of this difference is that the density of the fiberboard is variable on outer layers than that of on inner layers. As the density of the fibres board increases, the surface roughness values of fiberboard processed with CNC machines decreases. Similar results were reported by Lou et al., (1998), Sütçü and Karagöz (2012) and Deus et al., (2015).

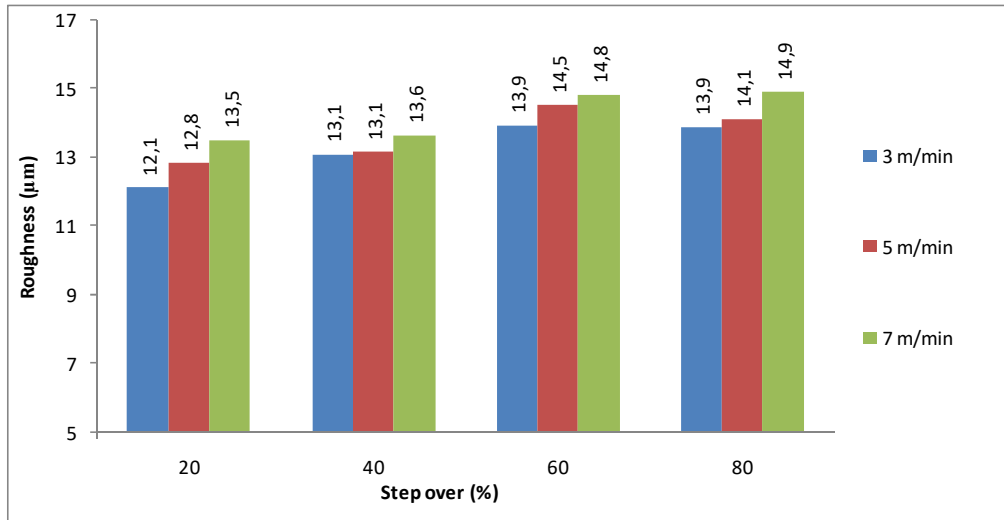


Fig 4. Surface roughness (finish depth: 6 mm)

Three-Way ANOVA test results were given in Table 1. The table shows the effects of finish depth, step over, feed rate and their interactions. The effects of main factors were statistically significant. In other words, finish depth, step over and feed rate affect the surface roughness of fiberboard. Three-Way ANOVA test results are statistically significant.

Table 1. Three-Way ANOVA test results

Source	Sum of Squares	df	Mean Square	F	Sig.
Finish depth (FD)	656.373	1	656.373	1148.484	0.000
Step over (SO)	59.063	3	19.688	34.448	0.000
Feed rate (FR)	37.517	2	18.758	32.822	0.000
FD * SO	22.313	3	7.438	13.014	0.000
FD * FR	2.741	2	1.371	2.398	0.093
SO * FR	3.525	6	.587	1.028	0.408
FD * SO * FR	10.310	6	1.718	3.007	0.008

Table 2 shows Duncan test results about the effects of step over on the  $Ra$  values. When the Table 2 analyzed, it can be seen that step over of 20% and 40% was differ from step over percentages of 60% and 80%. According to mean values of groups; the lowest  $Ra$  values was  $11.53 \mu\text{m}$ , and the highest value was  $12.62 \mu\text{m}$ . Similar results were reported about the effects of step over on the surface roughness by other researchers (Lou et al. 1998; Sütçü and Karagöz 2012; Bal 2018).

Table 2. Duncan test results of step over

Step over (%)	Replicate (number)	<i>Ra</i> (μm)
20%	60	11.53 <b>A</b>
40%	60	11.72 <b>A</b>
60%	60	12.59 <b>B</b>
80%	60	12.62 <b>B</b>

Table 3 shows Duncan test results about the effects of feed rate on the *Ra* values. According to given results, it can be said that feed rate of 7 m/min was higher *Ra* value than that of other feed rate. It can be seen easily that surface roughness increases as the feed rate increase. In addition, considering the step over, feed rate and finish depth, the lowest effect on the surface roughness is the feed rate according to Table 1. There is no difference between feed rate groups of 3 and 5 m/min. Similar results were reported about the effects of feed rate on the surface roughness by some researchers (Davis 1962; Lou et al. 1998; Deus et al. 2015; Sedlecký 2017; Sedlecký et al. 2018; Bal 2018).

Table 3. Duncan test results of feed rate

Feed rate (m/min)	Replicate (number)	<i>Ra</i> (μm)
3	80	11.73 <b>A</b>
5	80	11.95 <b>A</b>
7	80	12.66 <b>B</b>

Table 4 shows Duncan test results about the effects of finish depth on the *Ra* values. It can be seen that *Ra* value of 2 mm finish depth was lower than that of 6 mm finish depth. The difference between two results was statistically significant. Similar results were obtained by Sütçü and Karagöz (2012) and Lin et al. (2006). They determined that surface roughness increase with increasing finish depth due to the difference density between the layers in fiberboard panels. Density of the material is the most important wood properties related to the physical (Kollmann and Cote 1968; Bozkurt and Göker 1996; Bal and Bektaş 2018) mechanical (Kollmann and Cote 1968; Bozkurt and Göker 1996; Bektaş 1997) and machinability (Davis 1962; Sütçü and Karagöz 2013) properties.

Table 4. Duncan test results of finish depth

Finish depth (mm)	Replicate number	<i>Ra</i> (μm)
2	120	10.46 <b>A</b>
6	120	13.77 <b>B</b>

#### 4. Conclusion

In this study, the effects of the step over, feed rate and finish depth on the surface roughness of fiberboards were investigated. According to data obtained, following results can be said;

- Surface roughness value increases, as the feed rate increases. Especially, roughness of the test samples processed using 7 m/min feed rate are higher than that of other feed rate. The difference is statistically significant.
- Surface roughness value increases, as the step over increases. Roughness of the test samples processed using 20%, 40% step over are lower than that of step over of 60% and 80%. The differences between these two groups are significant.
- Roughness value increases, as the finish dept increases. It can be said that the reason of difference is the density of fiberboard. The outer layers of the fiberboard have higher density than that of inner layers.

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