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# Effect of the Number of Knives, Feed Rate, and Cutting Depth on Surface Roughness of Some Wood Species Processed with Planer

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**Abstract**
In this study, effect of the number of knives, feed rate and cutting depth on surface roughness of some solid woods were investigated. The specimens were prepared of scots pine (*Pinus sylvestris* L.), Turkish beech (*Fagus orientalis* L.), walnut (*Juglans regia* L.), and chestnut (*Castanea sativa* M.) and African mahogany (*Khaya sp.*) which are commonly used in furniture industry. Mitutoyo SJ-301 stylus scanner device was utilized to measure the surface roughness. The surface roughness was measured according to TS 930. At the end of the results of the tests, the smoothest surfaces were obtained with scots pine (3.56 $\mu m$) while the roughest surfaces were obtained with African mahogany (7.36 $\mu m$) among the wood species. Smoother surface could be obtained with 4 knives planing (5.41 $\mu m$), 5 *m/min* feed rate (5.38 $\mu m$), and 1 *mm* cutting depth (5.15 $\mu m$). In this study, the average surface roughness values of wood species could be estimated by means of the developed equations.
**Key Words:** Surface smoothness; surface roughness; wood planning; feed rate; cutting.

## Introduction

The effect of the surface treatment operations is very important on the quality of the furniture. The operations such as painting, lacquering, and varnishing made to protect and to increase the value of the furniture, are called surface treatment. In addition to this, the preparation process such as planing and sanding is also within this definition. The success on the surface treatment is not only related to the knowledge and the ability of the people who are painting and varnishing, but also related to the errors occurring in stages such as drying, storing, and machinery process. For this reason, to make the product more uniform these errors are eliminated by planing and sanding operations. According to Burdurlu and Baykan the primary cutting method is planing which is done by planing machines in which knives with different numbers can be attached to the cutter heads (Burdurlu and Baykan, 1998).

Many studies have shown that the achieved surface quality of wood products may be obtained by employing suitable conditions of improvement in a considerable number of well-defined preparative processes. Extensive investigations by Richter et al. have shown that wood species and their structure, cutting direction and cutting depth, the number of cutters and feed rate, and also the sanding process for the preparation of the obtained material are tend to be more effective factors on the surface roughness of wood products (Richter et.al., 1995). This phenomenon was initially described in detail by Stumbo, who also briefly alluded to the cutting process in surface preparations. Stumbo found out that the surface roughness of the planed and sanded Weeping birch (*Betula verrucosa Ehrh.*) was dependent on the presence of the number of the cutters and the cutting speed. In this case, he also observed that the surface roughness can be decreased at the slow feed rate when the number of the cutters and the cutting speed is increased. It was also noticed by Stumbo that the surface roughness of the attempted wood material is subjected to be increased if the material was not completely dry (Stumbo, 1960).

Stewart, Richter et al., and Murmanis et al. have reported in their studies that the depth of cut and the feed rate are effective on the surface roughness. According to the resullts of their research, surface roughness decreases when the feed rate and the cutting depth decreases, whereas it increases when the feed rate and the cutting depth increases (Richter et. al., 1995; Stewart, 1976; Murmanis et. al., 1986).

Örs and Baykan, Örs and Gürleyen, and Usta et al. have determined that the surface quality can be increased in sanding and planing processes by increasing the number of cutters and the number of grains (Örs and Baykan, 1999; Örs and Gürleyen, 2002; Usta, et.al., 2007). In addition to this, non-homogeneous wood material has a different resistance property according to the cutting direction and the amount of moisture it holds. This situation directly affects the planing and sanding performance of the materials. These issues are examined in Baykan, Yalçınkaya, and Gürleyen's studies and they have found out that those smoother surfaces are obtained in tangential direction in the process of sanding and planing (Baykan, 1995; Yalçınkaya, 1997; Gürleyen, 1998).

Pahlitzsch and Dziobek have informed that the roughness increases when the amount of moisture increases (Pahlitzsch and Dziobek, 1962).

In this study, surface roughness of some wood species that are commonly utilized in furniture industry were investigated as they are planed by the cutters with 2 and 4 knives, with different cutting depth (1, 2, 4 *mm*), and 5 - 9 *m/min* feed rate.

## Materials and Method

### Test Materials and Cutters

In this study, Scots pine (*Pinus sylvestris* L.), Turkish beech (*Fagus orientalis* L.), walnut (*Juglans regia* L.), chestnut (*Castanea sativa* M.) and African mahogany (*Khaya sp.*) were used. The timbers were randomly selected for this study from the timber industries in Turkey. The knives used in the tests were High Speed Steel (HSS) with 40° angle and with 400 x 35 x 3 *mm* size which were of furniture industry standart. Every precaution available was taken to keep the sharpness of the knives uniformly good in all tests, by changing to a new set of knives, when necessary.

### Preparation of the Specimens

Before the planing process, strips were kept at 20 ± 2℃ and at 65 ± 3 percent relative humidity until their weight became stable by holding them in a chamber. The moisture contents (MC) and densities of the wooden materials were determined according to the procedure of TS 2470, and TS 2471, respectively (TS 2470 and TS 2471, 1976). The wooden materials with approximately 12 percent average MC were planed at radial section. Work process at planer machine is shown in Fig. 1.

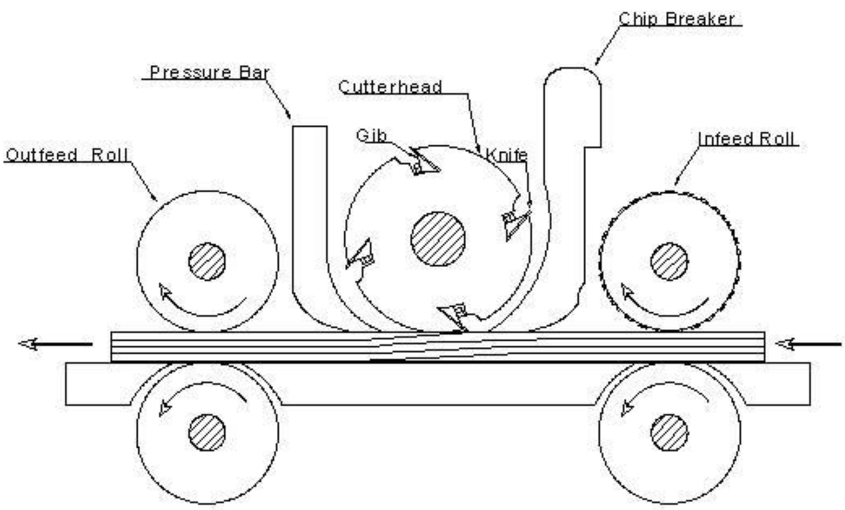


Figure 1. Work proccess at planer machine.

### Plan of the Study

60 sets of specimens consisting of 3 replications each, 5 wood species (scots pine, Turkish beech, walnut, chestnut and mahogany), 2 number of knives (2 and 4 knives), 2 feed rate (*5 m/min* and 9 *m/min*),

and 3 cutting depth (1 *mm*, 2 *mm* and 4 *mm*) or a total of 180 specimens were prepared and tested. 8 surface roughness measurements were taken for each specimen in perpendicular to grain direction. Therefore, a total of 1440 surface roughness values were obtained.

### Surface Roughness Tests

The surface roughness values were measured by Mituyota Sj-301 device. The specimens were measured according to the suggestions of the production company by these rates; measuring range: 12.5mm, measuring speed: 0.25 m*m/s*, stylus tip diameter: 90° / 5 *μmR*, skid force: less than 400 *mN*. To prevent the specimen surface from having been scratched, measurements were performed under the conditions of 20 ± 2°C and at 65 ± 3 percent relative humidity, without vibration and away from the noise.

Measurements were repeated when the tip of the scanning stylus was attached to the lumen. The roughness evaluations were determined as ± 0. 01 by choosing the rates; scanning length (lt): 12 *mm*, sampling length: 2.5 *mm* (Anonym). The measurements were also done according to the procedures of TS 6956, and TS 930 (TS 6956 and TS 930, 1989).

### Results and Discussion

Oven dry and air dry densities of wood species used given in Table 1. The values of surface roughness are separately given in Table 2 to Table 6 for each wood species.

Table 1. Oven dry and air dry densities of the specimens used in the study

| Wood species | Oven dry density (gr/cm3) | Air dry density (gr/cm3) |
|---|---|---|
| Scots Pine | 0.49 | 0.52 |
| Beech | 0.63 | 0.66 |
| Walnut | 0.64 | 0.68 |
| Chesnut | 0.59 | 0.63 |
| Mahogany | 0.52 | 0.55 |

The smoothnest roughness is obtained with 4 knives planning, 5 *m/min* feed rate, and 1 *mm* cutting depth on Scots pine according to the **Table 2.**

Table 2. Mean value of surface roughness of scots pine (*: Coefficients of variation)

| Wood species | Number of knives | Feed rate (m/min) | Cutting depth (mm) | Mean Ra (μm) ($\overline{X}$) | COV* (%) |
|---|---|---|---|---|---|
| Scots pine | 2 | 5 | 1 | 3.55 | 0.21 |
| | | | 2 | 3.63 | 0.21 |
| | | | 4 | 3.76 | 0.21 |
| | | 9 | 1 | 3.75 | 0.21 |
| | | | 2 | 3.98 | 0.18 |
| | | | 4 | 3.99 | 0.23 |
| | 4 | 5 | 1 | 2.87 | 0.16 |
| | | | 2 | 3.19 | 0.17 |
| | | | 4 | 3.64 | 0.24 |
| | | 9 | 1 | 3.04 | 0.17 |
| | | | 2 | 3.53 | 0.19 |
| | | | 4 | 3.74 | 0.21 |

The smoothnest roughness is obtained with 4 knives planning, 5 *m/min* feed rate, and 1 *mm* cutting depth on Turkish beech according to the Table 3.

Table 3. Mean value of surface roughness of Turkish beech

| Wood species | Number of knives | Feed rate (m/min) | Cutting depth (mm) | Mean Ra (μm) ($\overline{X}$) | COV (%) |
|---|---|---|---|---|---|
| Turkish beech | 2 | 5 | 1 | 3.87 | 0.30 |
| | | | 2 | 4.19 | 0.16 |
| | | | 4 | 5.08 | 0.17 |
| | | 9 | 1 | 4.67 | 0.12 |
| | | | 2 | 5.61 | 0.12 |
| | | | 4 | 6.31 | 0.13 |
| | 4 | 5 | 1 | 3.55 | 0.14 |
| | | | 2 | 3.96 | 0.20 |
| | | | 4 | 4.02 | 0.13 |
| | | 9 | 1 | 4.07 | 0.10 |
| | | | 2 | 4.30 | 0.18 |
| | | | 4 | 4.98 | 0.14 |

The smoothnest roughness is obtained with 4 knives planning, 5 *m/min* feed rate, and 1 *mm* cutting depth on Walnut according to the Table 4.

Table 4. Mean value of surface roughness of walnut

| Wood species | Number of knives | Feed rate (m/min) | Cutting depth (mm) | Mean Ra (μm) ($\overline{X}$) | COV (%) |
|---|---|---|---|---|---|
| Walnut | 2 | 5 | 1 | 5.35 | 0.16 |
| | | | 2 | 5.56 | 0.17 |
| | | | 4 | 6.56 | 0.16 |
| | | 9 | 1 | 6.72 | 0.20 |
| | | | 2 | 7.13 | 0.25 |
| | | | 4 | 6.80 | 0.16 |
| | 4 | 5 | 1 | 3.72 | 0.23 |
| | | | 2 | 5.82 | 0.27 |
| | | | 4 | 6.08 | 0.30 |
| | | 9 | 1 | 4.15 | 0.27 |
| | | | 2 | 6.71 | 0.12 |
| | | | 4 | 6.71 | 0.12 |

The smoothnest roughness is obtained with 4 knives planning, 5 *m/min* feed rate, and 4 *mm* cutting depth on Chesnut according to the Table 5.

Table 5. Mean value of surface roughness of chesnut

| Wood species | Number of knives | Feed rate (m/min) | Cutting depth (mm) | Mean Ra (μm) ($\overline{X}$) | COV (%) |
|---|---|---|---|---|---|
| Chesnut | 2 | 5 | 1 | 7.49 | 0.26 |
| | | | 2 | 6.16 | 0.30 |
| | | | 4 | 6.62 | 0.21 |
| | | 9 | 1 | 7.57 | 0.25 |
| | | | 2 | 6.32 | 0.27 |
| | | | 4 | 6.57 | 0.28 |
| | 4 | 5 | 1 | 6.48 | 0.29 |
| | | | 2 | 9.77 | 0.27 |
| | | | 4 | 5.21 | 0.29 |
| | | 9 | 1 | 6.55 | 0.27 |
| | | | 2 | 8.81 | 0.15 |
| | | | 4 | 6.09 | 0.25 |

Table 6. Mean value of surface roughness of mahogany.

| Wood species | Number of knives | Feed rate (m/min) | Cutting depth (mm) | Mean Ra (μm) ( $\overline{X}$ ) | COV (%) |
|---|---|---|---|---|---|
| African Mahogany | 2 | 5 | 1 | 5.83 | 0.21 |
| | | | 2 | 7.19 | 0.26 |
| | | | 4 | 8.32 | 0.11 |
| | | 9 | 1 | 7.97 | 0.16 |
| | | | 2 | 10.01 | 0.19 |
| | | | 4 | 7.99 | 0.21 |
| | 4 | 5 | 1 | 5.56 | 0.21 |
| | | | 2 | 6.86 | 0.23 |
| | | | 4 | 7.18 | 0.22 |
| | | 9 | 1 | 6.35 | 0.22 |
| | | | 2 | 7.22 | 0.20 |
| | | | 4 | 7.81 | 0.19 |

The smoothnest roughness is obtained with 4 knives planning, 5 m/min feed rate, and 1 mm cutting depth on African Mahogany according to the Table 6.

Multiple variance analysis was performed on the data obtained from a total of 180 specimens (1440 measurements) for determining the effects of cutter depth, feed rate, number of knives, and wood species on the surface roughness. The results of the variance analysis are shown in Table 7.

The success list of wood species which were planed with different planing conditions is shown in Table 8, scots pine (3.56 $\mu m$), Turkish beech (4.55 $\mu m$), walnut (5.94 $\mu m$), chesnut (6.99 $\mu m$) and mahogany (7.36 $\mu m$). This situation could be explained by the thinner cell wall and bigger cell- lumen and thinner texture of scots pine when compared with the other wood species.

Table 7. The results of ANOVA

| Source | Degrees of Freedom | Sum of Squares | Mean Square | *F* Value | Probabilitiy (p=0.05) |
|---|---|---|---|---|---|
| A | 4 | 2995.771 | 748.943 | 491.2688 | 0.0000 |
| B | 1 | 105.176 | 105.176 | 68.9901 | 0.0000 |
| AB | 4 | 96.610 | 24.153 | 15.8429 | 0.0000 |
| C | 1 | 130.267 | 130.267 | 85.4485 | 0.0000 |
| AC | 4 | 63.665 | 15.916 | 10.4403 | 0.0000 |
| BC | 1 | 16.258 | 16.258 | 10.6647 | 0.0011 |
| ABC | 4 | 8.542 | 2.135 | 1.4007 | 0.2315 |
| D | 2 | 203.548 | 101.774 | 66.7588 | 0.0000 |
| AD | 8 | 263.897 | 32.987 | 21.6379 | 0.0000 |
| BD | 2 | 77.081 | 38.541 | 25.2807 | 0.0000 |
| ABD | 8 | 282.668 | 35.334 | 23.1770 | 0.0000 |
| CD | 2 | 4.053 | 2.027 | 1.3294 | 0.2650 |
| ACD | 8 | 48.792 | 6.099 | 4.0007 | 0.0001 |
| BCD | 2 | 34.437 | 17.218 | 11.2944 | 0.0000 |
| ABCD | 8 | 27.530 | 3.441 | 2.2573 | 0.0214 |
| Error | 1380 | 2103.819 | 1.525 | - | - |
| Total | 1439 | 6462.115 | - | - | - |

A: Wood species, B: Number of knive, C: Feed rate, D: Cutting depth

Table 8. Mean value of surface roughness according to wood species

| Wood species | Mean ( $\overline{X}$ ) Ra (μm) | HG |
|---|---|---|
| Scots pine | 3.56 | A |
| Turkish beech | 4.55 | B |
| Walnut | 5.94 | C |
| Chesnut | 6.99 | D |
| African Mahogany | 7.36 | E |

LSD± 0, 2019 Ra (μm)

The surface roughness of all wood species decreases when the feet rate decreases whereas it increases when the number of knives on the cutter heads decreases. This situation can be explained by the increase of the feed rate, the decrease of the number of knives participating during planing in unit time and the increased thickness of the chip which was broken off the wood. In contrast to feed rate a decrease was determined on the surface roughness when the number of knives increased on the planning process. The best result was obtained on the planning process with 4 knive cutters. This is because of the increase of the number of knives touching the surface in unit time when the number of knives increases in the same planing conditions.

Mean surface roughness values (Ra *μm*) according to the number of planing knives, feed rates and cutting depths in wood species are shown in Table 9.

Table 9. Mean value of surface roughness according to wood species and number of the cutter and feed rate, and the cutting depth

| No | Wood species | Number of knive | Feed rate (*m/min*) | Cutting depth | Values of Surface Roughness Ra (μm) Mean ($\overline{X}$) | HG | No | Wood species | Number of knive | Feed Rate (m/min) | Cutting depth | Values of Surface Roughness Ra (μm) Mean ($\overline{X}$) | HG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S | 4 | 5 | 1 mm | 2.868 | A | 31 | M | 2 | 5 | 1 mm | 5.826 | JKL |
| 2 | S | 4 | 9 | 1 mm | 3.036 | AB | 32 | W | 4 | 5 | 4 mm | 6.079 | KLM |
| 3 | S | 4 | 5 | 2 mm | 3.194 | ABC | 33 | C | 4 | 9 | 4 mm | 6.093 | KLM |
| 4 | S | 4 | 9 | 2 mm | 3.528 | ABCD | 34 | C | 2 | 5 | 2 mm | 6.162 | KLMN |
| 5 | S | 2 | 5 | 1 mm | 3.547 | ABCD | 35 | B | 2 | 9 | 4 mm | 6.312 | LMN |
| 6 | B | 4 | 5 | 1 mm | 3.548 | ABCD | 36 | C | 2 | 9 | 2 mm | 6.320 | LMN |
| 7 | S | 2 | 5 | 2 mm | 3.632 | BCDE | 37 | M | 4 | 9 | 1 mm | 6.349 | LMN |
| 8 | S | 4 | 5 | 4 mm | 3.641 | BCDE | 38 | C | 4 | 5 | 1 mm | 6.480 | LMNO |
| 9 | W | 4 | 5 | 1 mm | 3.717 | BCDE | 39 | C | 4 | 9 | 1 mm | 6.554 | MNOP |
| 10 | S | 4 | 9 | 4 mm | 3.739 | CDE | 40 | W | 2 | 9 | 1 mm | 6.561 | MNOP |
| 11 | S | 2 | 9 | 1 mm | 3.750 | CDE | 41 | C | 2 | 9 | 4 mm | 6.567 | MNOP |
| 12 | S | 2 | 5 | 4 mm | 3.755 | CDE | 42 | C | 2 | 5 | 4 mm | 6.619 | MNOP |
| 13 | B | 2 | 5 | 1 mm | 3.867 | CDE | 43 | W | 4 | 9 | 2 mm | 6.710 | MNOP |
| 14 | B | 4 | 5 | 2 mm | 3.955 | DE | 44 | W | 4 | 9 | 4 mm | 6.710 | MNOP |
| 15 | S | 2 | 9 | 2 mm | 3.980 | DEF | 45 | W | 2 | 9 | 1 mm | 6.561 | MNOP |
| 16 | S | 2 | 9 | 4 mm | 3.994 | DEF | 46 | W | 2 | 9 | 4 mm | 6.798 | NOPQ |
| 17 | B | 4 | 9 | 1 mm | 4.018 | DEF | 47 | M | 4 | 5 | 2 mm | 6.857 | NOPQ |
| 18 | B | 4 | 5 | 4 mm | 4.069 | DEF | 48 | W | 2 | 9 | 2 mm | 7.125 | OPQR |
| 19 | W | 4 | 9 | 1 mm | 4.148 | DEF | 49 | M | 4 | 5 | 4 mm | 7.183 | PQR |
| 20 | B | 2 | 5 | 2 mm | 4.186 | DEF | 50 | M | 2 | 5 | 2 mm | 7.188 | PQR |
| 21 | B | 4 | 9 | 2 mm | 4.297 | EFG | 51 | M | 4 | 9 | 2 mm | 7.223 | PQR |
| 22 | B | 2 | 9 | 1 mm | 4.673 | FGH | 52 | C | 2 | 5 | 1 mm | 7.488 | QRS |
| 23 | B | 4 | 9 | 4 mm | 4.984 | GHI | 53 | C | 2 | 9 | 1 mm | 7.570 | RS |
| 24 | B | 2 | 5 | 4 mm | 5.075 | HI | 54 | M | 4 | 9 | 4 mm | 7.810 | RST |
| 25 | C | 4 | 5 | 4 mm | 5.210 | HIJ | 55 | M | 2 | 9 | 1 mm | 7.967 | ST |
| 26 | W | 2 | 5 | 1 mm | 5.353 | HIJ | 56 | M | 2 | 9 | 4 mm | 7.985 | ST |
| 27 | M | 4 | 5 | 1 mm | 5.556 | IJK | 57 | M | 2 | 5 | 4 mm | 8.322 | TU |
| 28 | W | 2 | 5 | 2 mm | 5.563 | IJK | 58 | C | 4 | S9 | 2 mm | 8.809 | U |
| 29 | B | 2 | 9 | 2 mm | 5.608 | IJK | 59 | M | 2 | 9 | 2 mm | 9.990 | V |
| 30 | W | 4 | 5 | 2 mm | 5.823 | JKL | 60 | C | 4 | 5 | 2 mm | 10.095 | V |

LSD±0.6993 Ra (μm) S:Scots pine B:Turkish Beech W:Walnut C:Chesnut M:Mahogany HG : Homogeneity group

When it's observed according to the cutting depth it was seen that when the cutting depth is decreased the smoother surface was obtained. The reason of such result can be; when the cutting depth increases the chip thickness broken off the wood also increases and as a result of this breaking off the chips increases because of the increase of the cutting strength on the wood. The smoothest surface in scots pine wood was obtained when planed with a plane with 4 knives with 5 *m/min*. feed rate and 1 mm cutting depth according to the wood species x number of knives x feed rate x cutting depth (*AxBxCxD*). It's known that traheid cell diameter of scots pine wood is smaller and the density of it is lower when compared with other wood species. As a result of this it's possible that scots pine show a lower cutting strength when compared with other wood species. Therefore, it's possible to obtain smoother surfaces in scots pine wood.

**Predictive Equations**

To provide a means of comparing the results of the surface roughness tests as well as to obtain functional relationships between surface roughness and the various parameters for each wood species, curves were fitted to the individual test data points by means of regression techniques. Thus, the curves had the following forms:

$$SR_{pine} = 3.46 - 0.22\,X + 0.06\,Y + 0.15\,Z \quad [1]$$

$$SR_{beech} = 3.26 - 0.39\,X + 0.23\,Y + 0.36\,Z \quad [2]$$

$$SR_{walnut} = 4.62 - 0.41\,X + 0.21\,Y + 0.46\,Z \quad [3]$$

$$SR_{chestnut} = 7.25 + 0.18\,X + 0.009\,Y - 0.37\,Z \quad [4]$$

$$SR_{mahogany} = 6.13 - 0.53\,X + 0.27\,Y + 0.4\,Z \quad [5]$$

where, $SR_{pine}$, $SR_{beech}$, $SR_{walnut}$, $SR_{chestnut}$, $SR_{mahogany}$ = surface roughness of wood species, respectively ($\mu m$); $X$ = number of knives; $Y$ = feed rate (*m/min*); $Z$ = cutting depth (*mm*).

The coefficients of determination ($R^2$) values were 0.59, 0.88, 0.74, 0.36 and 0.70 for the expressions [1], [2], [3], [4] and [5], respectively. To provide a practical evaluation of how well the values predicted by these aquations agreed with the observed surface roughness results, the differences between the predicted and observed values were determined and the differences were expressed as a percentage of predicted values (Table 10).

Table 10. Comparison of observed test results obtained in this study with values obtained with predictive expressions

| Wood species | Number of knive | Feed rate (*m/min*) | Cutting depth (*mm*) | Mean Surface roughness Ra ($\mu m$) Predicted | Observed | Difference (%) | Wood species | Number of knive | Feed rate (*m/min*) | Cutting depth (*mm*) | Mean Surface roughness Ra ($\mu m$) Predicted | Observed | Difference (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scotch Pine | 2 | 5 | 1 | 3.46 | 3.55 | -2.54 | Chesnut | 2 | 5 | 1 | 7.27 | 7.49 | -2.94 |
| | | | 2 | 3.61 | 3.63 | -0.55 | | | | 2 | 6.89 | 6.17 | 11.73 |
| | | | 4 | 3.91 | 3.76 | 3.99 | | | | 4 | 6.15 | 6.62 | -7.10 |
| | | 9 | 1 | 3.69 | 3.75 | -1.60 | | | 9 | 1 | 7.31 | 7.58 | -3.52 |
| | | | 2 | 3.84 | 3.98 | -3.52 | | | | 2 | 6.93 | 6.33 | 9.54 |
| | | | 4 | 4.14 | 3.99 | 3.76 | | | | 4 | 6.18 | 6.57 | -5.94 |
| | 4 | 5 | 1 | 3.01 | 2.87 | 4.88 | | 4 | 5 | 1 | 7.63 | 6.48 | 17.69 |
| | | | 2 | 3.16 | 3.19 | -0.94 | | | | 2 | 7.26 | 9.77 | -25.72 |
| | | | 4 | 3.47 | 3.64 | -4.67 | | | | 4 | 6.51 | 5.21 | 24.87 |
| | | 9 | 1 | 3.24 | 3.04 | 6.58 | | | 9 | 1 | 7.66 | 6.55 | 16.89 |
| | | | 2 | 3.98 | 3.53 | 12.75 | | | | 2 | 7.29 | 8.81 | -17.28 |
| | | | 4 | 3.7 | 3.74 | -1.07 | | | | 4 | 6.54 | 6.09 | 7.33 |
| Turkish Beech | 2 | 5 | 1 | 3.98 | 3.67 | 8.45 | African Mahogany | 2 | 5 | 1 | 6.81 | 5.83 | 16.88 |
| | | | 2 | 4.34 | 4.19 | 3.66 | | | | 2 | 7.21 | 7.19 | 0.23 |
| | | | 4 | 5.06 | 5.08 | -0.33 | | | | 4 | 8.02 | 8.32 | -3.64 |
| | | 9 | 1 | 4.89 | 4.67 | 4.71 | | | 9 | 1 | 7.88 | 7.97 | -1.09 |
| | | | 2 | 5.25 | 5.61 | -6.36 | | | | 2 | 8.28 | 10.01 | -17.28 |
| | | | 4 | 5.97 | 6.31 | -5.39 | | | | 4 | 9.09 | 7.99 | 13.77 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 1 | 3.21 | 3.55 | -9.58 | | 4 | 5 | 1 | 5.75 | 5.56 | 3.48 |
| | | | 2 | 3.57 | 3.96 | -9.77 | | | | 2 | 6.16 | 6.84 | -9.94 |
| | | | 4 | 4.28 | 4.02 | 6.56 | | | | 4 | 6.96 | 7.18 | -3.11 |
| | | 9 | 1 | 4.12 | 4.07 | 1.31 | | | 9 | 1 | 6.82 | 6.35 | 7.40 |
| | | | 2 | 4.48 | 4.30 | 4.27 | | | | 2 | 7.22 | 7.22 | -0.05 |
| | | | 4 | 5.2 | 4.99 | 4.28 | | | | 4 | 8.03 | 7.81 | 2.77 |
| Walnut | 2 | 5 | 1 | 5.31 | 5.35 | -0.81 | Walnut | 4 | 5 | 1 | 4.49 | 3.72 | 20.81 |
| | | | 2 | 5.77 | 5.56 | 3.71 | | | | 2 | 4.95 | 5.82 | -15.00 |
| | | | 4 | 6.69 | 6.56 | 1.93 | | | | 4 | 5.87 | 6.08 | -3.45 |
| | | 9 | 1 | 6.16 | 6.72 | -8.29 | | | 9 | 1 | 5.34 | 4.15 | 28.67 |
| | | | 2 | 6.62 | 7.13 | -7.11 | | | | 2 | 5.8 | 6.70 | -13.39 |
| | | | 4 | 7.54 | 6.80 | 10.88 | | | | 4 | 6.72 | 6.71 | 0.15 |

**Conclusion**

This study was carried out for investigation of the surface roughness of some wood species that are commonly utilized in furniture industry when they are planed by the cutters with 2 and 4 knives, with different cutting depth (1, 2, 4 *mm*), and 5 - 9 *m/min* feed rate. The surface roughness values of planed scots pine, Turkish beech, walnut, chestnut and mahogany woods were compared by using the planes with two and four knives, 5–9 *m/min*. feed rate and with 1 *mm*, 2 *mm* and 4 *mm* cutting depth. According to the results the smoothnest surface was obtained in scots pine when planed with a plane with 4 knives, 5 *m/min*. feed rate and with 1 *mm* cutting depth**.**

The results of the tests are congenial with the studies in literature. In those studies it is informed that the surface roughness decreases when the feed rate decreases and the number of knives increases. It’s necessary to increase the number of knives and to decrease cutting depth and feed rate in order to obtain smoother surfaces in planing furniture industry. It’s better to prefer scots pine wood to obtain smoother surfaces in planing, as well.

According to the result, it’s possible to obtain smoother surfaces with higher feed rate and with more planes in the same planning conditions. This situation provides the employer to save time and also helps the employer in wages by reducing the expenses of the work time. If the cutters used are sharp and if their fly points are on the same line, performance of the cutter and surface quality increases.

The most important conclusion obtained is that the comparisons of the predicted and observed results have indicated that the surface roughness of wood species evaluated in this study could be estimated by developed predictive expressions.

This study provides wood technology researchers some information concerning the effects of surface roughness factors such as number of cutter, feed rate, cutting depth on surface roughness of wood species. The information could maintain supportive insight to researchers in engineering of wood science.

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