REASEARCH TO PROPOSE SOME TECHNOLOGICAL PARAMETERS WHEN SLICING *Betula alnoides* WOOD

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SUMMARY

The article introduces research results in order to propose some reasonable technological parameters when slicing *Betula anoides* wood by VS-10 slicing machine manufactured by Taiwan, with two criteria are high quality and low cost. The research variables selected are the cutting speed of the slicing machine and the sloping angle of the slicing knife. The selected research parameters are surface roughness, frequency of crack and power cost of the machine. The research process is carried out by experimental methods, the achieved results are as follows: The number of repetitions needed during the experimental study of *Betula anoides* wood sliced by VS-10 machine was 6 times. Correlation equation between cutting speed and power cost, surface roughness: N = 0.09 V + 0.081; Hmax = -71 V + 258.99. Correlation equation between sloping angle of the slicing knife with surface roughness and power cost of the machine: Hmax = 0.058 ε^2 – 3.857ε + 141.771; N = 0.001 ε + 0.277. Correlation equation between sloping angle of the slicing knife and cutting speed of the slicing machine with surface roughness and power cost of the machine: Hmax = 3.864 ε - 1.618 εV + 89.001; N = -0.005 ε + 0.003 ε V + 0.244. By solving the multi-objective optimization problem, two technological parameters were identified and proposed: The slicing speed is 3m/s, the sloping angle of the slicing knife is 20 degrees.

Keywords: *Betula anoides* wood, technological parameters, veneer production, veneer technology, wood cutting parameters, wood cutting technology.

1. INTRODUCTION

Veneer is one of the most valuable products in the wood processing industry, *Betula anoides* wood is currently one of the materials used to produce veneer. In the veneer production, technological parameters has the direct effect on product quality and economic efficiency (Hoang Tien Duong, 2016; Hoang Nguyen and Hoang Xuan Nien, 2005). Currently, how are technological parameters to ensure quality requirements with low energy costs is always concerned by enterprises. In general at enterprises of Vietnam, the use of the slicing machine is mainly based on experience, workmanship, there are no scientific bases and data for the use of machines yet, therefore, it has not promoted all the capabilities of the machine, especially when using the machine with the conditions of raw materials, quality requirements as well as different costs. With purposes are creating scientific bases and technical solutions to help the enterprises improving economic efficiency and offering scientific bases for training and applied research, we proceed research to determine reasonable technological parameters when using the machine in veneer production. From the above situations, we conduct research to offer reasonable technical parameters for *Betula anoides* wood in use of slicing machines. These research results will be useful documents in application for training and production practices.

As we know, in 1870, I.A. Time published the research "The strength of metal and wood when cutting", this is the first time in the world, the theory of wood cutting process is presented. In 1886, professor K.A. Zvorukin has determined the formula for calculating the wood cutting force with factors that influence the cutting force. In the documents "Wood cutting" (1956 and 1975), "Calculation of wood cutting regime", Prof. A.I. Besatski used empirical methods to formulate the theory of wood cutting and his research results are widely applied in manufacturing practices in Russia. In fact, veneer production technology was published from 1960s of the 20th century.

In the 70s, the Federal Republic of Germany transferred technology and installed veneer production equipment to China. By the early years of the 21st century, veneer technology has been put into production and wide application in the world. In Vietnam, the first veneer production line was built in the 70s of the 20th century. Technology was transferred from abroad. In 1980, Nguyen Hoang compiled the document "Woodworking machinery and equipment", this is the first time in our country there is scientific work in which the theory of wood cutting is mentioned relatively fully. In the following years, some documents on wood cutting including wood slicing were also published such as: Nguyen Hoang, Nien Hoang Xuan (2005), Wood processing machinery; Duong Hoang Tien (2016), Principle of wood materials cutting. In these documents the theory of wood slicing is presented quite fully.

As we mentioned above, the quality and efficiency of veneer production process are assessed by many criteria, among which the important parameters are surface roughness of boards, frequency of cracking, cost of electrical energy. These parameters depend on many factors with different degrees, in which the speed of the cutter and the sloping angle of the slicing knife are important factors (Hoang Tien Duong, 2016; Hoang Nguyen and Hoang Xuan Nien, 2005), so in this study, the surface of board, the power consumption, the crack frequency, the cutting speed and the sloping angle of knife were chosen as the study parameters.

2. RESEARCH METHODOLOGY

2.1. Materials

Researched material is *Betula anoides* wood, originating in Southeast Asia. In Vietnam, mainly in the northern mountainous provinces with the height of 400 - 500 m such as Quang Ninh, Ha Giang, Lang Son, Son La, Lai Chau... and some other areas such as Kom Tum, Lam Dong, Gia Lai, concentrated in the Southeastern part of the Southeast such as Binh Thuan and Dong Nai. *Betula anoides* is a large tree with dark pink wood. *Betula anoides* wood belongs to the sixth class, has good mechanical properties, durability and high stability, good resistance to termites. Besides the use of *Betula anoides* to produce carpentry, construction works, making door frames, flooring, ceiling, beds, wardrobes, kitchen cabinets, dining tables and chairs, television shelves, etc. Currently, *Betula anoides* wood is also widely used for veneer production. In this study, cuting samples are *Betula anoides* wood, aged from 10 to 12 years in Gia Lai province. Parameters of samples include: cuting samples moisture from 25 - 30%; size of cuting samples is LxBxh = 800 x 200 x 100mm. The research equipment is slicing machine VS-10 manufactured by Taiwan. This equipment is from the College of Technology, Economics and Forest Product Processing - Phuly city - Ha Nam province.

2.2. Methods

To collect the data, we use empirical methods. The slicing method is tangental slicing, with veneer thickness is 1mm. Two research variables were selected: (1) V speed (m/s): Cutting speed V (m/s) is the relative movement speed of the cutter relative to the workpiece. (2) Sloping angle of the slicing knife ε (degrees): Sloping angle ε is the angle created by the cutter's movement direction with the line perpendicular to the cutting edge. When experimenting, we change slicing speed by different levels in the speed limit of VS – 10 machine, the velocity value V is taken from the average velocity value in slicing cycle. Controlling slicing speed by controlling the number of slicing cycle of VS -10 machine. For sloping angle of the slicing knife ε, it is changed with various levels within the possible range of the VS - 10 machine. The values of angle ε is taken from values of sloping angle in the empirical planning table. Control the angle value ε by changing the position of workpiece holder on VS-10 machine. The research parameters are: Power consumption N and veneer quality (Hmax roughness and frequency of crack). Measuring surface roughness of boards by TR-200 machine made in China. Measure electricity consumption with multimeter FLUKE. In the experiment, we measured electricity consumption when the machine is cuting, calculated for a fixed-size veneer product. Checking the frequency of crack by penetrates with ink, cutting and magnifying glass. Experimental research steps include: exploration research to determine the number of repetitions needed; single factor research; multi- factor study according to the selected experimental plan (Nguyen Van Bi, 2006; Nguyen Ngoc Kieng, 1996; Giang Thi Kim Lien, 2009). Experimental data was calculate, analyze by SPSS software (Nguyen Hai Tuat and Nguyen Trong Binh, 2005). Reasonable technology parameters are determined by solving a multi-objective optimization problem with the general function method.

3. RESULTS AND DISCUSSION

3.1. Results of exploration research

Conducting exploration test with cutting speed v = 2.5 m/s and sloping angle of ε = 30°, number of experiments n = 15. Results of measuring roughness of sample boards and power consumption are shown in table 1.

Table 1. Results of probe experimention

N°	H_{max}(μm)	N (kW)
1	76.14	0.301
2	77.30	0.335
3	78.10	0.330
4	77.60	0.122
5	77.78	0.112
6	78.68	0.313
7	76.70	0.323
8	77.58	0.314
9	77.60	0.281
10	76.22	0.392
11	79.24	0.323
12	77.56	0.523
13	76.42	0.622
14	77.38	0.301
15	78.06	0.324
TB	77.49	0.328

The minimum number of replicate experiments n is determined according to the statistical probability theory, the results obtained are as follows: For the roughness H_{max} probe sample, the calculated result is n_1 = 5.913; For the probe sample of power consumption N, the calculated result is n_2 = 5.527. From the above results, we choose the Number of repetitive experiments is n = 6.

3.2. Single-factor study results

Study the effect of cutting speed to power consumption and roughness of veneer surface from Betula Anoides Wood: In this study, we select the sloping angle ε = 30°, cutting speed V var from 2 m/s to 3 m/s. Levels of speed are: 2; 2.2; 2.4; 2.6; 2.8 and 3.0 m/s. Sampling results with 6 iterations are shown in table 2.

Table 2. Research results of effect of cutting speed on electricity consumption

No	V(m/s)	1	2	3	4	5	6	N (kW)
1	2.0	0.280	0.275	0.278	0.280	0.270	0.275	0.276
2	2.2	0.275	0.278	0.280	0.287	0.280	0.275	0.279
3	2.4	0.305	0.318	0.305	0.300	0.285	0.290	0.301
4	2.6	0.320	0.321	0.326	0.318	0.315	0.325	0.321
5	2.8	0.345	0.335	0.338	0.345	0.337	0.340	0.340
6	3.0	0.352	0.348	0.357	0.351	0.350	0.345	0.351

The correlation equation was determined:

$N = 0.09\ V + 0.081$

The graph shown in figure 1.

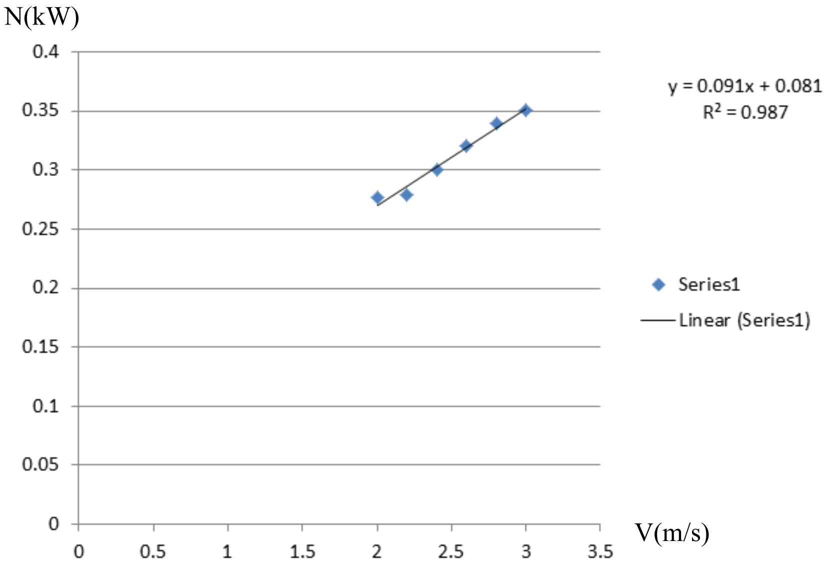

Figure 1. Graph of correlation between power consumption and slicing velocity

When studying the effect of slicing speed on surface roughness, the results are shown in table 3.

Table 3. Experimental results affect the speed of surface roughness

No	V(m/s)	1	2	3	4	5	6	H_{max}(µm)
1	2.0	123.05	122.85	121.63	123.68	122.58	120.25	122.34
2	2.2	106.45	107.20	106.20	105.87	101.35	107.15	105.70
3	2.4	85.85	86.12	85.45	85.27	86.34	86.12	85.86
4	2.6	71.55	72.12	71.58	70.85	71.57	71.59	71.54
5	2.8	58.32	57.95	58.23	59.12	58.45	58.10	58.36
6	3.0	48.15	47.87	47.58	48.55	48.34	49.20	48.28

The correlation equation is:

$H_{max} = -71\ V + 258.99$

The graph is shown in figure 2.

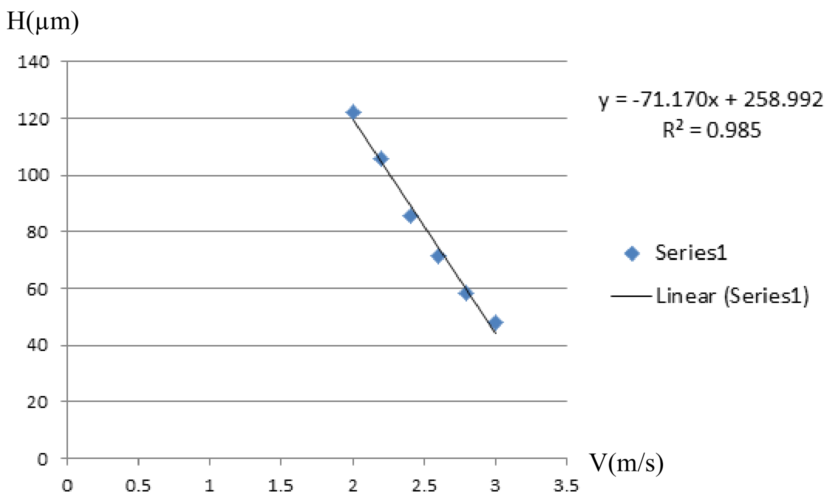

Figure 2. Graph of correlation between the slicing velocity and roughness of the surface

* Study the effect sloping angle of slicing knife to power consumption and roughness of veneer surface. For this study, we choose the cutting speed v = 2.5 m/s. The sloping angle of slicing knife var from 20º to 40º. The sloping angle levels include: 20; 25; 30; 35; 40º. Sampling results with 6 iterations are shown in table 4.

Table 4. Experimental results on affecting of sloping angle of slicing knife to roughness of the board surface

No	ε(degrees)	1	2	3	4	5	6	H_{max}(μm)
1	20	87.85	88.57	86.85	87.58	86.35	87.46	87.443
2	25	83.80	83.20	82.85	82.68	82.65	83.15	83.055
3	30	76.05	75.55	74.85	74.65	75.50	75.25	75.308
4	35	76.35	76.10	77.25	77.15	75.85	75.30	76.333
5	40	79.65	78.37	79.50	80.86	78.35	79.54	79.378

The correlation equation is:

$$Hmax = 0.058\,\varepsilon^2 - 3.857\varepsilon + 141.771$$

The correlation graph is shown in figure 3.

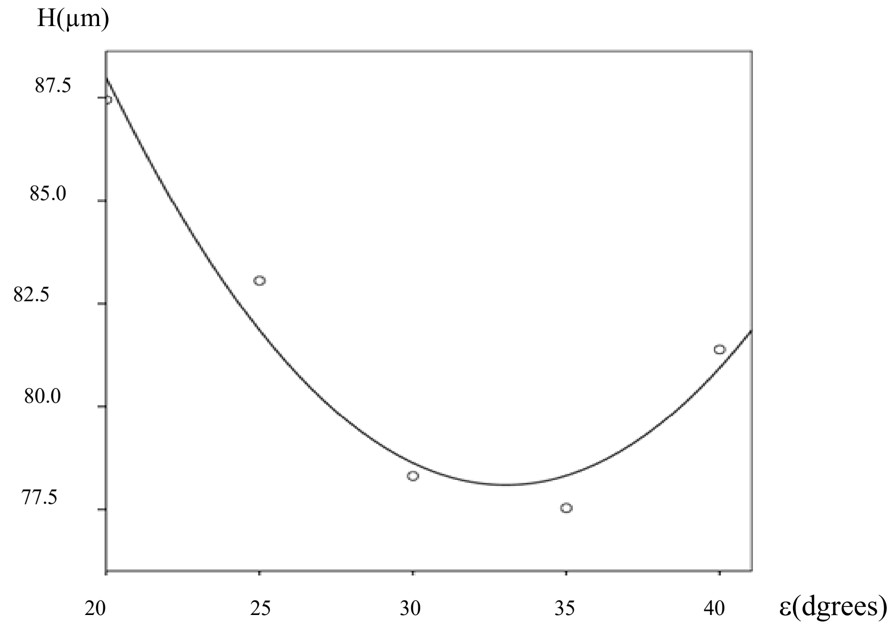

Figure 3. Graph of correlation between knife angle and roughness of veneer surface

When studying the effect of sloping angle to power consumption, the results are shown in table 5.

Table 5. The results of the influence of sloping angle to electricity consumption

No	ε (degrees)	1	2	3	4	5	6	N (kW)
1	20	0.30	0.32	0.31	0.29	0.30	0.32	0.305
2	25	0.31	0.31	0.32	0.32	0.32	0.31	0.314
3	30	0.32	0.32	0.32	0.31	0.32	0.33	0.320
4	35	0.33	0.33	0.32	0.33	0.32	0.33	0.325
5	40	0.33	0.34	0.36	0.33	0.33	0.33	0.335

The correlation equation is:

$$N = 0.001\,\varepsilon + 0.277$$

The correlation graph is shown in figure 4.

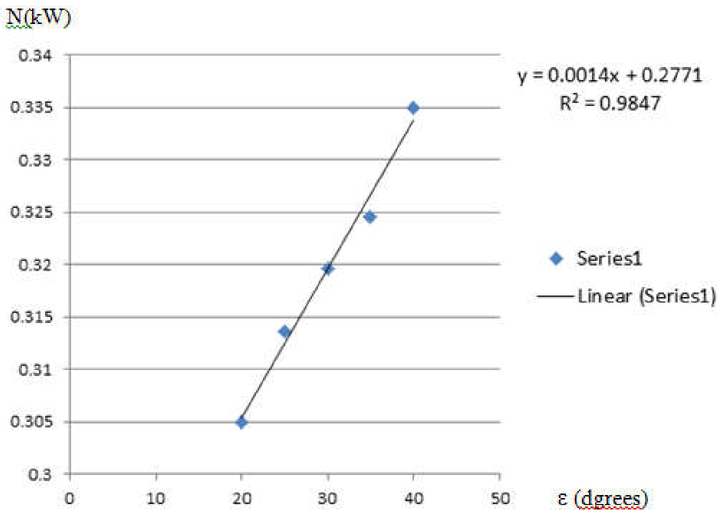

Figure 4. The correlation graph between sloping angle of knife and power consumption

3.3. Multi-factor research results

With two variables, cutting speed and sloping angle of knife, experimental planning matrix is constructed as table 6.

Table 6. Experimental planning matrix

No	X_1	X_2	V(m/s)	ε (degrees)
1	+	+	3.0	40
2	-	+	2.0	40
3	+	-	3.0	20
4	-	-	2.0	20
5	+	0	3.0	30
6	-	0	2.0	30
7	0	+	2.5	40
8	0	-	2.5	20
9	0	0	2.5	30

a. Effect of sloping angle of slicing knife, slicing speed on roughness of board surface

When studying about the influence of sloping angle of slicing knife, slicing speed on roughness of board surface, the results are shown in table 7.

Table 7. The result of the influence of the cutting speed, the sloping angle of the slicing knife on roughness of board surface

No	V (m/s)	ε(degrees)	H_{max}(μm)						Average H_{max}(μm)
			1	2	3	4	5	6	
1	3.0	40	58.05	57.2	58.48	58.45	57.14	57.12	57.740
2	2.0	40	94.75	95.74	94.56	93.74	93.55	94.65	94.498
3	3.0	20	75.45	76.15	75.43	75.65	76.25	75.14	75.678
4	2.0	20	95.24	96.10	95.25	95.15	95.24	96.25	95.538
5	3.0	30	48.15	48.30	49.26	48.54	48.57	48.25	48.512
6	2.0	30	121.65	120.54	120.58	120.72	120.85	123.66	121.333
7	2.5	40	80.25	80.15	80.25	80.34	78.85	78.35	79.698
8	2.5	20	87.65	88.37	87.12	86.35	88.45	87.68	87.603
9	2.5	30	76.32	75.28	74.65	75.85	75.65	74.85	75.433

The correlation equation is:

H_{max} = 3.864 ε - 1.618 εV + 89.001

The correlation graph is shown in figure 5.

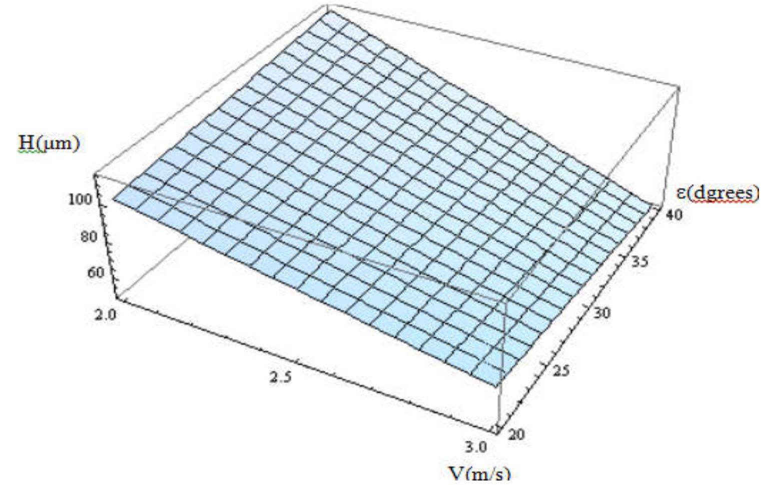

Figure 5. The correlation graph between slicing speed, sloping angle of slicing knife and surface roughness

b. Effect of sloping angle of slicing knife, slicing speed on electricity consumption

When studying about the influence of sloping angle of slicing knife, slicing speed on electricity consumption, the results are shown in table 8.

Table 8. The result of the influence of the cutting speed, the sloping angle of the slicing knife on electricity consumption

No	V (m/s)	ε (degrees)	N (kW)						Average N (kW)
			1	2	3	4	5	6	
1	3.0	40	0.346	0.345	0.344	0.346	0.346	0.345	0.346
2	2.0	40	0.298	0.287	0.289	0.300	0.295	0.298	0.295
3	3.0	20	0.312	0.318	0.306	0.318	0.320	0.295	0.312
4	2.0	20	0.293	0.289	0.298	0.305	0.291	0.294	0.295
5	3.0	30	0.356	0.348	0.358	0.351	0.347	0.345	0.351
6	2.0	30	0.282	0.278	0.280	0.285	0.275	0.280	0.280
7	2.5	40	0.348	0.338	0.335	0.325	0.338	0.340	0.337
8	2.5	20	0.305	0.307	0.305	0.312	0.300	0.304	0.306
9	2.5	30	0.324	0.318	0.322	0.323	0.324	0.321	0.322

The correlation equation is:

$$N = - 0.005\ \varepsilon + 0.003\ \varepsilon\ V + 0.244$$

The correlation graph is shown in figure 6.

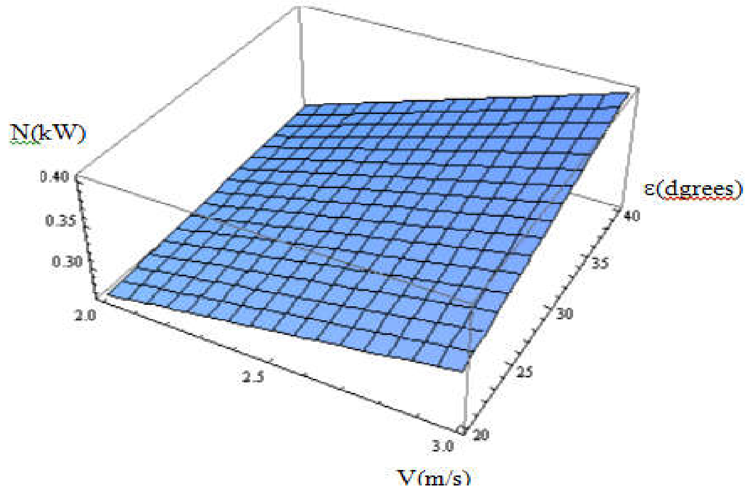

Figure 6. The correlation graph between slicing speed, sloping angle of slicing knife and electricity consumption

c. Effect of sloping angle of slicing knife, slicing speed on cracked degree of veneer

When studying about the influence of sloping angle of slicing knife, slicing speed on cracked degree, the results are shown in table 9.

Table 9. The result of the influence of the cutting speed, the sloping angle of the slicing knife on number of open cracks on the edge of veneer

No	V (m/s)	ε (degrees)	Number of measurements 1	2	3	4	5	6	Average number of open cracks on the edge of veneer
1	3.0	40	1	2	3	1	2	3	2.0
2	2.0	40	2	3	4	3	2	3	2.8
3	3.0	20	1	1	0	2	1	1	1.0
4	2.0	20	1	1	1	2	0	1	1.0
5	3.0	30	2	3	4	3	1	1	2.3
6	2.0	30	1	2	1	1	1	1	1.2
7	2.5	40	2	2	3	2	2	3	2.3
8	2.5	20	0	2	1	2	1	1	1.2
9	2.5	30	1	1	2	0	1	2	1.2

Table 10. The result of the influence of the cutting speed, the sloping angle of the slicing knife on number of cracks on the surface of veneer

No	V (m/s)	ε (degrees)	Number of measurements 1	2	3	4	5	6	Average number of cracks on the surface of veneer
1	3.0	40	5	6	5	7	6	5	5.6
2	2.0	40	6	5	4	5	6	6	5.3
3	3.0	20	5	6	7	7	5	6	6.0
4	2.0	20	6	6	7	5	6	5	5.8
5	3.0	30	5	6	6	5	6	5	5.5
6	2.0	30	5	6	5	5	5	6	5.3
7	2.5	40	5	6	5	5	5	6	5.3
8	2.5	20	6	6	5	5	5	5	5.3
9	2.5	30	5	6	5	6	6	6	5.6

With the values in table 9 to 10, most of the criteria of cracks are satisfactory, that shows the influence of sloping angle of knife and slicing speed are not bad.

3.4. Determine a reasonable technology parameters when slicing Betula Anoides wood

From the above research results, the parameters of cracking are mostly satisfactory, for simplicity, we choose two functions, roughness (H_{max}) and power consumption (N) to set and solve the optimal problem. We have two objective functions as follows:

$H_{max} = 3.864\ \varepsilon - 1.618\ V + 89.001$;

$N = -\ 0.005\ \varepsilon + 0.003\ \varepsilon\ V + 0.244$

See as $V = x_1$; $\varepsilon = x_2$; $H_{max} = y_1$; $N = y_2$; The above objective functions are rewritten as follows: $y_1 = 3.864x_2 - 1.618x_1x_2 + 89.001$; $y_2 = -0.005x_2 + 0.003x_1x_2 + 0.244$.

Considered in about $2 \le x_1 \le 3$ and $20 \le x_2 \le 40$, we get: $y_{1min} = 49.640$ at point (3.40); $y_{2min} = 0.264$ at point (2.20). The optimal goal problem set out are:

$$\begin{cases} y_1 = 3.864x_2 - 1.618x_1x_2 + 89.001 \rightarrow \min \\ y_2 = -0.005x_2 + 0.003x_1x_2 + 0.244 \rightarrow \min \\ 2 \le x_1 \le 3; 20 \le x_2 \le 40 \end{cases}$$

Using the general function method to solve the above problem, we have:

- The proportional functions are:

$$\phi_1 = \frac{y_1}{y_{1\min}} = 0.077x_2 - 0.032x_1x_2 + 1.792$$

$$\phi_1 = \frac{y_2}{y_{2\min}} = 0.018x_2 - 0.011x_1x_2 + 0.924$$

- The general proportional function are:

$\phi = \phi_1 + \phi_2 = 0.095x_2 - 0.021x_1x_2 + 2.716$

The optimal solution for above function considered in $2 \leq x_1 \leq 3$ and $20 \leq x_2 \leq 40$ are: $\emptyset_{min} = 3.356$ gained at point (3; 20)

Determined slicing speed and sloping angle of knife compared to wood cutting theory in published documents are appropriate and acceptable (Hoang Tien Duong, 2016; Hoang Nguyen and Hoang Xuan Nien, 2005), so to achieve the optimum effect, we choose the speed of 3 m/s and sloping angle of 20 degrees.

4. CONCLUSIONS

From the synthesis, analysis of documents and empirical research, we confirm that the cutting speed V, the sloping angle of knife ε during the slicing process affects the power consumption and the quality of the veneer especially roughness of veneer surface.

The minimum number of iterations is 6 when study of slicing Betula Anoides wood by VS-10 machine.

The results of the single-factor study showed a correlation function between the cutting speed, the tool angle and the power cost and surface roughness as follows:

$N = 0.09\ V + 0.081$; $H_{max} = -71\ V + 258.99$

$N = 0.001\ \varepsilon + 0.277$;

$H_{max} = 0.058\ \varepsilon^2 - 3.857\varepsilon + 141.771$

The results of multi-factor studies show the correlation function of parameters with electric cost and roughness of veneer surface as follows:

$N = -\ 0.005\ \varepsilon + 0.003\ \varepsilon\ V + 0.244$;

$H_{max} = 3.864\ \varepsilon - 1.618\ \varepsilon V + 89.001$

The result of solving the multi-objective optimization problem shows reasonable technology parameters when slicing Betula Anoides wood with VS-10 slicing machine as follows: Cutting speed is 3 m/s and sloping angle of knife is 20 degrees.

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NGHIÊN CỨU ĐỀ XUẤT MỘT SỐ THÔNG SỐ CÔNG NGHỆ KHI LẠNG GỖ XOAN ĐÀO

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TÓM TẮT

Bài báo giới thiệu kết quả nghiên cứu nhằm đề xuất một số thông số công nghệ hợp lý khi lạng gỗ Xoan đào trên máy lạng *VS-10* do Đài Loan sản xuất, với hai tiêu chí là chất lượng cao và chi phí thấp. Các biến số nghiên cứu được lựa chọn là tốc độ cắt của máy lạng và góc nghiêng của dao lạng. Các hàm chỉ tiêu được chọn là độ nhẵn, số vết nứt và chi phí điện năng của máy. Quá trình nghiên cứu thực hiện bằng phương pháp thực nghiệm, kết quả đạt được như sau: Số lần lặp cần thiết trong quá trình nghiên cứu thực nghiệm lạng gỗ Xoan đào bằng máy VS-10 là 6 lần. Phương trình tương quan giữa tốc độ cắt và chi phí điện năng, độ nhám bề mặt: N = 0,09 V + 0,081; Hmax = -71 V + 258,99. Phương trình tương quan giữa góc nghiêng với chi phí điện năng và độ nhám bề mặt: Hmax = 0,058 ε^2 – 3,857 ε + 141,771; N = 0,001 ε + 0,277. Phương trình tương quan giữa tốc độ cắt và góc nghiêng dao với chi phí điện năng và độ nhám bề mặt ván lạng: Hmax = 3,864 ε - 1,618 εV + 89,001; N = - 0,005 ε + 0,003 ε V + 0,244. Bằng cách giải bài toán tối ưu đa mục tiêu, đã xác định được và đề xuất hai thông số công nghệ: Tốc độ lạng là 3 m/s, góc nghiêng dao là 20 độ.

Từ khóa: Các thông số công nghệ, công nghệ cắt gỗ, công nghệ lạng gỗ, gỗ Xoan đào, sản xuất ván lạng, thông số cắt gỗ.

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