# RESEARCH ON THE EFFECT OF DEPTH OF CUT ON SURFACE ROUGHNESS AND POWER WHEN MILLING PLANE SURFACES ON MAKINO KJ MILLING MACHINE

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**GENERAL INFORMATION**

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**ABSTRACT**

Milling machines are often used in companies, vocational training centers and universities in Vietnam, especially Makino KJ milling machines. Through experimental research, the regression model of roughness has been built as a trigonometric function of cutting parameters, which is also the reason why this article needs to be studied. Therefore, the core point of this article will be to study and choose the most reasonable cutting depth to reduce power consumption during the machining of the end face and meet the requirements for roughness when machining flat milling products on Makino KJ milling machines.

## 1. INTRODUCTION

The article uses the object, scope and research equipment of Makino KJ milling machine, the milling cutter is a face milling cutter, the turning material is the steel used to manufacture the machine after the C45 casting process, using the plane milling method, the main parameters to study are the cutting depth (t) affecting the roughness and power consumption. The research method is based on the theory of cutting machining on machine tools. The experimental research method in machine manufacturing to determine the objective function, on that basis, the correlation between the objective function and the influencing parameters is established. Using the optimization problem solving method to find the reasonable usage mode of Makino KJ milling machine.and conduct studies on the changes of parameters during the cutting process when machining flat surfaces in many different experiments, from which we use the single-factor evaluation method to be able to give the optimal mode when choosing the parameters of the cutting depth affecting the power and quality of the product surface roughness when machining flat surfaces on the Makino KJ milling machine. (Lan et al., 2021).

## 2. METHODOLOGY

### 2.1. Selection of parameters affecting the objective function

Factors related to the workpiece: Use C45 steel.

Factors related to the machining mode: Selection of cutting depth (t).

### 2.2. Method of determining specific electricity

To determine the specific cost of electricity during the experiment, we determine the consumption level during the cutting process. Therefore, it is necessary to measure the current intensity. Because it is necessary to determine the change in power before and during the cutting process of the blade, from which we can know the power difference to convert to non-electrical quantities.(Giang et al., 2023).

- Power before cutting

$N_0 = \sqrt{3}.I_0.U_0.\text{Cos}\,\varphi_0$ (1)

$N_0$ – No load wattage (W).

$I_0$. - No load current (A)

$U_0$.- Low voltage network voltage (V).

$\text{Cos}\,\varphi_0$ . Power factor no load.

- Power while cutting.

$N_1 = \sqrt{3}.I_1.U_1.\ \text{Cos}\,\varphi_1$ .(2)

$N_1$ - Total power consumption

$I_1$ - The current when cut has the maximum value.

$U_1$ - Low voltage network voltaeg (V).

$\text{Cos}\,\varphi_1$. Power factor has load.

In the experiment, we only conduct the experiment when the voltage is stable. From (1), (2) we see:

The power consumed during cutting is

$N = N_1 - N_0 = U.\sqrt{3}.(I_1 - I_0).\text{Cos}\,\varphi$ (3)

### 2.3. Determination method of machining surface roughness

Using the TR200 roughness meter to directly measure the roughness of the product surface, the roughness value is displayed on the LCD screen, from which we can determine the roughness of the product after processing. (Tuan et al., 2021; Loi et al., 2021).

## 3. EXPERIMENTS AND RESULTS

### 3.1. Experimental equipment

Makino KJ universal milling machine

Milling cutter and steel billet C45

Main shaft rotation levels, 7 levels from 60 - 2500 rpm

14 levels of cross-feed from 0.036 – 0.938 mm / revolution


**Figure 1.** Machine milling Makino KJ

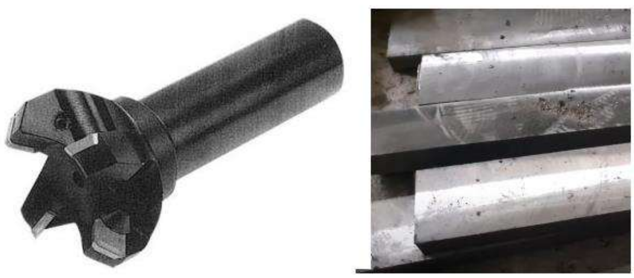

**Figure 2.** Milling cutter and steel billet C45

### 3.2. Measure current connected by computer

Current measuring devices are shown in Figure 3.

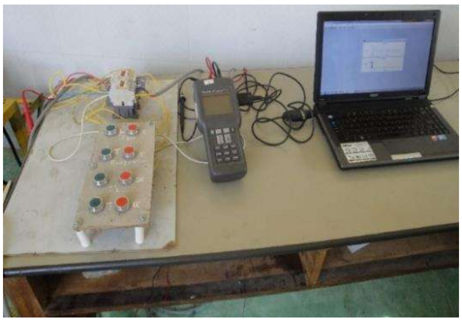

**Figure 3**. Fluke connected to computer

The apparatus used to determine roughness is shown in figure 4.


**Figure 4**: Surface roughness tester TR 200

### 3.3. Measurement results

**Table 1**. Effect of cutting depth on power and product surface roughness, Spindle speed n = 960 rpm, $\varphi = 6^{O}$, S= 0.4 mm / round

| Numerial order | Cutting depth | Measured times | $U_1$ | $I_0$ | $I_1$ | $\cos\varphi_t$ | $N_t$ | T(s) | F($m^2$) | N ($Wh/m^2$) | Ra |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.2 | 1 | 230.15 | 5.66 | 8.24 | 0.43 | 442.24 | 11 | 0.001965 | 687.68 | 1.33 |
| | | 2 | 230.27 | 5.66 | 8.45 | 0.42 | 467.36 | 11 | 0.001965 | 726.74 | 1.36 |
| | | 3 | 231.29 | 5.66 | 8.57 | 0.41 | 477.96 | 11 | 0.001965 | 743.23 | 1.37 |
| **2** | 0.4 | 1 | 231.30 | 5.63 | 8.05 | 0.42 | 407.19 | 11 | 0.001965 | 633.18 | 1.22 |
| | | 2 | 232.37 | 5.63 | 8.11 | 0.43 | 429.20 | 11 | 0.001965 | 667.40 | 1.25 |
| | | 3 | 232.20 | 5.63 | 8.08 | 0.44 | 433.55 | 11 | 0.001965 | 674.17 | 1.28 |
| **3** | 0.6 | 1 | 231.50 | 5.88 | 8.46 | 0.44 | 454.66 | 11 | 0.001965 | 707.00 | 1.47 |
| | | 2 | 230.26 | 5.88 | 8.47 | 0.44 | 454.50 | 11 | 0.001965 | 706.74 | 1.48 |
| | | 3 | 232.62 | 5.88 | 8.59 | 0.43 | 469.51 | 11 | 0.001965 | 730.08 | 1.50 |
| **4** | 0.8 | 1 | 229.80 | 6.01 | 8.71 | 0.44 | 472.85 | 11 | 0.001965 | 735.25 | 1.61 |
| | | 2 | 230.15 | 6.01 | 8.73 | 0.43 | 466.24 | 11 | 0.001965 | 725.00 | 1.67 |
| | | 3 | 230.02 | 6.01 | 8.76 | 0.45 | 493.03 | 11 | 0.001965 | 766.65 | 1.92 |
| **5** | 1 | 1 | 232.50 | 6.07 | 8.99 | 0.45 | 529.15 | 11 | 0.001965 | 822.82 | 1.92 |
| | | 2 | 231.70 | 6.07 | 8.97 | 0.47 | 546.99 | 11 | 0.001965 | 850.57 | 1.94 |
| | | 3 | 232.10 | 6.07 | 8.98 | 0.46 | 538.13 | 11 | 0.001965 | 836.79 | 1.98 |

### 3.4. Processing of experimental data

#### *3.4.1. Experimental data and minimum number of repetitions*

To get the standard data, I use the Person indicator ($\chi 2$). We divide the output quantity (Y1) into L groups so that each group has 5 output quantities (Y1) and is calculated according to the formula below (Loc et al., 2021).

$$L = 1+3,2.\text{Lg } n \quad (4)$$

n- experimental probe ( n= 15 )

The mean value of the group with each other: $Y_1^{\bullet} = (y_{1-L} + Y_i)/L$, $(i = 1\ldots k)$

Experimental error standard:

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n} n_i (y^{\bullet} - \overline{y})^2 \quad (5)$$

The standard value $\chi^2_{tt}$ is calculated as the formula below.

$$\chi^2_{tt} = \frac{\sum_{i=1}^{n}\left(n_i - p_i.n\right)^2}{p_i.n} \quad (6)$$

$$P_i = e^{-\lambda.y_n} - e^{-\lambda.y_l}$$

$p_i$ - Theoretical random quantity probability

$y_n$- Minimum value ; $y_l$- Maximum value; $\lambda = -1/\bar{y}$

The minimum number of times performed for each experiment is determined by the formula

$$m = \frac{\tau^2.s^2}{\Delta^2} \quad (7)$$

S - The level of variance when doing experiments; m - Results repeat when experimenting; $\tau$ - Student standards look up table $\Delta$ - Absolute error value.

### *3.4.2. Use methods to process results when doing experiments*

We use experimental planning software to determine the results, from which we process and conclude the homogeneity of variance when doing experiments, regression models and determine the compatibility of regression models (Loc et al., 2021).

### 3.5. Results of single factor experiments

Conduct an exploratory experiment and then substitute the parameters into (6), from which we determine the standard $\chi^2_{tt}$ = 5,35 is smaller than the standard in the table ($\chi^2_b$ = 9,47), the experimental data follow the normal distribution law, substitute the data into (7), determine the number of repetitions for each experiment m = 2.65 and get the result m = 3 (Loc et al., 2021).

### *3.5.1. Depth of cut (t) affects power*

We change the cutting depth value of the knife according to the parameters of each cut as follows: $t_1$= 0.2mm; $t_2$= 0.4mm; $t_3$= 0.6mm; $t_4$= 0.8mm; $t_5$= 1mm, with n = 950 rpm unchanged during the machining process, the main tilt angle of the alloy piece is fixed $6^0$, the feed rate S = 0.3mm/rev is fixed. The result parameters and data processing are as in Table 2. I use the software and experimental planning program to process and get the following results (Loc et al., 2021, Duc et al., 2020)

Regression model:

**$N_r$ =779,4 - 445,28.t + 503,57.$t^2$** (8)

Apply according to Kokhren

$$G_{tt} = S^2_m / \sum_{u=1}^{N} S^2_u, \quad G_{tt} = 0,293$$

Calculation by Fisher criterion

$$F_{tt} = \frac{S^2}{S_e^2}, \quad F_{tt} = 3,64.$$

Homogeneity of variance when we test

Gtt = 0.293 < Gb = 0.615.

We check that the model $F_{tt}$ < $F_b$ and determine that the model is considered homogeneous (Duc et al., 2020).Observe the results obtained when drawing a graph to determine the relationship between electricity and cutting depth of the product as shown in Figure 5.

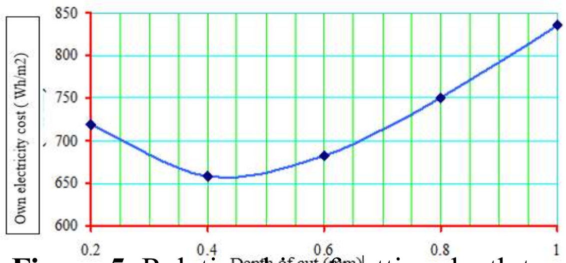


**Figure 5**. Relationship of cutting depth to power

### *3.5.2. Correlation of cutting depth with surface roughness of the product*

The experimental method is the same as above, the experimental parameters and data processing method are based on the experimental planning software, we see the roughness as the equation below:

$$\mathbf{Ra = 1,43 - 0,769.t + 1,305.t^2} \qquad (9)$$

Kokhren processing parameters according to $G_{tt} = S^2_m / \sum_{u=1}^{N} S^2_u$, $G_{tt} = 0,218$,

Fisher processing parameters according to $F_{tt} = \dfrac{S^2}{S_e^2}$ thì $F_{tt} = 3,85$.

When we check the homogeneity of variance, we get the following results: $G_{tt} = 0,218 < G_b = 0,616$. We can conclude that the variance during the experiment is homogenous. Check the regression model $F_{tt} < F_b$ and we can conclude that the model is compatible (Duc et al., 2020).

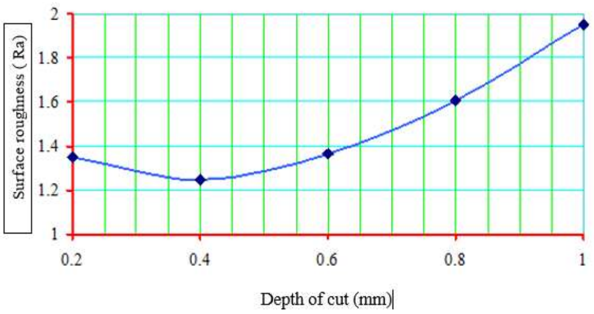


**Figure 6**. Relationship between cutting depth and product surface roughness

With the above results, we can show on the graph the relationship between cutting depth and roughness of the machined product in figure 6.

Considering the cutting depth of the product. Observing the graphs in Figure 6 and Figure 5 combined with the regression equation represented in Equation (9), (8), we see that for the cutting depth t = 0.4 mm, the power and roughness give the smallest parameters.

### *3.5.3. Experiment on Makino KJ milling machine in optimal mode*

When I found the optimal usage mode of Makino KJ milling machine, I re-performed the experiment on the mode on Makino KJ milling machine and optimized the calculated results as above, and the experimental results were processed and statistically calculated as in table 2.

**Table 2** Experimental results of optimal cutting depth when flat on Makino KJ milling machine

| **Numerical order** | **1** | **2** |
|---|---|---|
| **The goal function** | Electrictiy $Nr_{min}$ (Wh/m$^2$) | Surface roughness $Ra_{min}$ (µm) |
| **The optimal value is calculated according to the theory** | 682.85 | 1.225 |
| **Experimental value according to the optimal mode** | 711.78 | 1.245 |
| **Error** | 4.42% | 2.28% |

According to the parameter results in table 2, I have some conclusions and comments.

The error value of the experimental power function on the Makino KJ milling machine when in optimal mode compared to the theoretical parameters has been calculated to be 4.42%, so the optimal value is reliable.

The experimental error value of the roughness of the machined part surface compared to the theoretical value is 2.28%, we can say that the calculated optimal value above is reliable.

## 4. CONCLUSION

After experiments, calculating parameters, analyzing on the graph, I have drawn the following conclusions:

The article has chosen the power function and the roughness of the machined surface, which are two factors affecting the objective function of the cutting depth.

Through the article, we know and choose the appropriate parameters of the cutting depth (t) with other parameters fixed in the process of milling the plane on the Makino KJ milling machine to achieve the goal of the lowest power cost and the highest roughness

Using the optimization problem solving method, the article has given the reasonable cutting parameters of the Makino KJ milling machine when milling the plane with C45 steel billet, which is the cutting depth parameter t = 0.4 mm with the Makino KJ milling machine modes, the power and roughness of the machined surface of the product are determined to be optimal with the minimum level $Nr_{min}$= 682,85 Wh/m$^2$ and $Ra_{min}$ = 1,225 μm

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# NGHIÊN CỨU ẢNH HƯỞNG CỦA CHIỀU SÂU CẮT ĐẾN ĐỘ NHÁM BỀ MẶT VÀ ĐIỆN NĂNG KHI PHAY MẶT PHẲNG TRÊN MÁY PHAY MAKINO KJ

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**THÔNG TIN CHUNG**

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**TỪ KHOÁ**

*Chiều sâu cắt;*

*Độ nhám;*

*Công suất;*

*Máy phay Makino KJ.*

**TÓM TẮT**

Máy phay thường được sử dụng trong các công ty, trung tâm đào tạo nghề và các trường đại học tại Việt Nam, đặc biệt là máy phay Makino KJ. Thông qua nghiên cứu thực nghiệm, mô hình hồi quy của độ nhám đã được xây dựng dưới dạng hàm lượng giác của các thông số cắt, đây cũng là lý do khiến bài viết này cần được nghiên cứu. Do đó, trọng tâm của bài viết này sẽ là nghiên cứu và lựa chọn chiều sâu cắt hợp lý nhất để giảm tiêu thụ công suất trong quá trình gia công mặt cuối và đáp ứng yêu cầu về độ nhám khi gia công các sản phẩm phay phẳng trên máy phay Makino KJ.