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Influence Of The Cutting Parameters On The Surface Roughness When Milling 060A4 Steel

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Abstract - This article presents empirical study to determine the influence of cutting parameters on the surface roughness when milling 060A4 steel. Three cutting parameters have been covered in this study including the cutting speed, the feed rate and the cutting depth. Surface roughness has been selected as the criteria to evaluate the milling process in this study. Experimental process was carried out on a vertical milling machine. Box-Behnken design matrixes were used to design experiments with a total of 18 experiments. Analysis of experimental results has determined the influence of the input parameters as well as the interaction between them on the surface roughness. The cutting parameters optimization problem was also carried out in this study. Solving the problem has found the optimal value of the input parameters to ensure that the surface roughness reaches the smallest value. Optimization results have been verified again by experimental process. Finally, the further development direction for the next study is mentioned in this article.

Key words - milling, 060A4 steel, surface roughness, cutting parameters, optimization

I. INTRODUCTION

Milling is a popular machining method, resulting in high productivity and is widely used in mechanical machining. Milling method can be performed to process many different types of surfaces, with a variety of materials. Surface roughness has a great influence on the life of the products and is often chosen as one of the criteria to evaluate the efficiency of milling process in particular and cutting processes in general [1-4]. The study of milling process to find any solutions to reduce the surface roughness when milling has been done by many authors. Among them, the authors often focus on the study of the influence of cutting parameters on the surface roughness when milling. This is also easily explained because control of the cutting parameters is more easily performed by the machine operator than by adjusting other parameters. The results of those studies are the basis for the selection of parameters of the cutting mode in each specific condition.

Empirical AISI 304 steel milling process has been done in [5], and the results of this study have given the following conclusion: both the parameters of cutting speed and the feed rate have a great influence on the surface roughness. In which, the influence of cutting speed on the surface roughness is greater than the one of feed rate.

In [13], the author has studied the milling process of two types of alloys including Al-1Fe-1V-1Si and Al-2Fe-1V-1Si, and then made a comment such as: all three parameters of cutting parameters are almost have negligible influence on the surface roughness when milling 1Fe-1V-1Si alloy; When milling Al-2Fe-1V-1Si alloy, the cutting parameters have a great influence on *Rz* test criteria. But for *Ra* criteria, the parameters of cutting have negligible influence.

In. [6], when milling AISI 316L SS steel with a cutting tool with a milling cutter with a cutting piece coated with WC layer, it is shown that: Both the two parameters including the feed rate and the cutting speed all have a significantly influence on the surface roughness. In which, the influence of the feed rate on the surface roughness is greater than the influence of the cutting speed; The law of the influence of the feed rate and the cutting depth on the surface roughness is quite complicated. When increasing the value of these two parameters, sometimes it increases, sometimes decreases the value of surface roughness.

The content of the study was presented in [2], which gave a conclusion such as: The feed rate has the greatest influence on the surface roughness, followed by the influence of the cutting speed and the cutting depth that have a smaller influence on the surface roughness than the one of the feed rate and the cutting speed; The interaction between the feed rate and the cutting depth has the strongest influence on the surface roughness, followed by the influence of the interaction between the cutting speed and the feed rate, the interaction between the cutting speed and the cutting depth has a negligible effect on the surface roughness.

In. [7], when studying milling Ti-6242S alloy, the author gave a conclusion such as: All three parameters of cutting parameters have a significant influence on the surface roughness; Increasing the value of the feed rate and the cutting depth results in an increase in the surface roughness. Conversely, having a decrease in the surface roughness occurs when an increase in the value of the cutting speed occurs.

In [8], the author has experimented milling 6061 aluminum alloy under the minimum quantity lubrication (MQL) with a high speed steel cutting tool and made a comment: The interaction between the cutting speed and the feed rate has a great influence on the surface roughness; The influence of the cutting speed on the surface roughness is greater than the one of the feed rate.

The results of the study that are presented in [9] has shown that: When milling SKD61 steel, all three parameters of the cutting parameters including the cutting speed, the feed rate, the cutting depth and hardness of the machining materials have all a significant influence on the surface roughness.

In [3], the author has carried out an experiment in 42CrMo4 steel milling with the cutting tools coated with TiN, then the conclusions of this study were shown as follows: The cutting speed has little influence on the surface roughness; For the feed rate, when machining with a fixed cutting depth, the influence of the feed rate on the surface roughness is greater when machining with a variable cutting depth.

In [10], the author has shown that: When experimenting with milling AA2014 alloy (T4), the feed rate has a significant influence on the surface roughness, while the cutting speed has a negligible influence on the surface roughness; An increase in the value of the feed rate results in an increase in surface roughness. Meanwhile, the law of influence of cutting speed on the surface roughness is quite complicated, when increasing the value of the cutting speed, sometimes the value of surface roughness increases, sometimes the one decreases.

From a number of general studies as above, the author has shown, although there have been many studies investigating the influence of the cutting parameters on the surface roughness when milling was published, in each specific machining condition, the degree as well as the law of influence of the cutting mode parameters on the surface roughness is different. From there it shows that, in order to apply the results of the study into the production process, it is required to carry out an empirical study with each specific processing condition on machining materials and cutting tools. In this article, the author will conduct the study to determine the influence of the cutting mode parameters on the surface roughness when milling 060A4 steel.

II. THE MILLING PROCESS EXPERIMENTED

2.1. Experimental system

The experimental sample used is 060A4 steel (BS - China standard). In Table 1, the author shows the equivalent symbols of this steel according to several standards. In Table 2, the chemical composition of steel is presented. The sizes including length, width and height of the experimental sample are 80mm, 40mm and 30mm, respectively.

Table 1. Designation of 060A4steel in several standards

Country	**China**	**USA**	**Germamy**	**Italy**	**Japan**
Standard	BS	AISI	DIN	UNI	JIS
Symbols	060A4	1045	CK45	C45	S45C

Table 2. Chemical component and mechanical properties of 060A4 steels

Composition (%)									
C	Si	Mn	Cr	Ni	Mo	V	Ti	B	Cu
0.44	0.23	0.67	0.20	0.15	0.03	0.02	0,002	0.0008	0.22

The experimental machine used in this study was a vertical milling machine with the serial number JL-VH320B. This is a product of Jen Lian Company - Taiwan (Figure 1). The machine has some specifications as shown in Table 3.

Surface roughness tester SJ201 (Mitutoyo - Japan) was used during the experiment. At least three times of measurement will be carried out in each experimental sample. The surface roughness value at each experiment is the average value of the consecutive times of measurement. During the measurement process, the standard length of the machine is set to 0.8mm, the measuring head diameter is 0.005mm.

2.2. Experimental design

The Box-Behnken experimental design matrix was used to design the experiments in this study. The input parameters of each experiment are the cutting parameters, including the cutting speed, the feed rate and the cutting depth. Each parameter will have three value levels. The value of the parameters at the levels are chosen according to the practical experience as shown in Table 4. The experimental design matrix of 18 experiments is presented in Table 5.

III. RESULTS AND DISCUSSION

Experimental process was carried out in the order as shown in Table 5, the value of surface roughness at each experiment was also included in this table. The statistical software Minitab 16 was used to graph the influence of the input parameters on the surface roughness as shown in Figure 2. The interaction influence among the input parameters on the surface roughness is shown in Figure 3.

Fig 1. Experimental machine

After the process of observation, the author gave Figure 2 as follows:

- Out of the three parameters investigated, the feed rate is the one that has the greatest influence on the surface roughness. Meanwhile, the cutting speed and the cutting depth have their negligible influence on the surface roughness. However, if considered in details, it can be seen that the part cutting speed affecting surface roughness is greater than the influence of the cutting depth.

- When the feed rate increases, the surface roughness increases rapidly, this is also consistent with the studies published on the milling process [12].

Table 3. Some specifications of the experimental machine [11]

Table	Working surface of table	300 x 1500 mm
	Longitudinal travel	1000 mm
	Cross travel	380 mm
	Vertical travel	460 mm
	T-slots (size x number x distance)	16 x 3 x 70 mm
	Longitudinal feeds	12 ÷ 270 mm/min (12 steps)
	Rapid longitudinal traverse	1800 mm/min
	Rapid vertical traverse	680 mm/min
Vertical Main Spindle	Spindle speeds	70 ÷ 3800 rpm (Mechanical Variable speed)
	Quill travel / Quill Dia	150 / ∅105
	Taper of spindle nose	NT 40
	Swivelling angle of spindle head (R & L) each side	900
	Swivelling angle of overarm	3600
	Overarm travel	450 mm
	Distance of spindle end to table top	90 ÷ 500 mm

Table 4. Input parameters with different levels

Parameter	Unit	code	Values at different levels		
			-1	0	1
Cutting speed	m/min	v	168	240	312
Feed rate	mm/tooth	f	0.12	0.24	0.36
Depth of cut	mm	a_p	0.336	0.48	0.624

After the process of observation, the author gave Figure 3 as follows:

- When the cutting speed is 168 m/min: if there is an increase in the feed rate, the surface roughness increases slowly.

- When the cutting speed is 240 m/min: when the feed rate increases from 0.12 to 0.24 mm/tooth, the surface roughness increases slowly, but if the feed rate continues to increase, the surface roughness increases rapidly.

- When the cutting speed is 312 m/min: when the feed rate increases from 0.12 to 0.24 mm/tooth, the surface roughness decreases, but if the feed rate increases from 0.24 to 0.23 mm/tooth, the surface roughness increases rapidly.

- When machining with the cutting speed of 168 m/min: if the cutting depth increases, the surface roughness increases slowly.

- If the cutting speed is 240 m/min: the surface roughness will decrease quickly if the cutting depth increases from 0.336 to 0.480 mm, but if the cutting depth continues to increase, the surface roughness will increase rapidly.

- In the case of machining with the cutting speed of 312 m/min: when the cutting depth increases from 0.336 to 0.480 mm, the surface roughness increases rapidly, but if the cutting depth continues to increase, the surface roughness will decrease rapidly.

- When the feed rate is 0.12 mm/tooth and 0.24 mm/tooth, the cutting depth has almost no influence on the surface roughness.

- When machining with a feed rate of 0.36 mm/tooth: if the cutting depth increases from 0.336 mm to 0.48 mm, the surface roughness decreases rapidly, but if the cutting depth continues to increase, the surface roughness increases rapidly.

Table 5. Plan matrix of testing and results

No.	Code value			Actual values			Surface roughness
	v	f	a_p	v (m/min)	f (mm/tooth)	a_p (mm)	Ra (µm)
1	0	0	0	240	0.24	0.48	0.775
2	0	1	1	240	0.36	0.624	1.683
3	1	0	-1	312	0.24	0.336	0.558
4	0	0	0	240	0.24	0.48	0.717
5	1	1	0	312	0.36	0.48	1.017
6	0	-1	-1	240	0.12	0.336	0.575
7	0	0	0	240	0.24	0.48	0.683
8	1	-1	0	312	0.12	0.48	0.600
9	0	0	0	240	0.24	0.48	0.725
10	0	-1	1	240	0.12	0.624	0.600
11	1	0	1	312	0.24	0.624	0.517
12	-1	1	0	168	0.36	0.48	0.992
13	0	0	0	240	0.24	0.48	0.683
14	-1	-1	0	168	0.12	0.48	0.692
15	-1	0	-1	168	0.24	0.336	0.683
16	0	1	-1	240	0.36	0.336	1.567
17	-1	0	1	168	0.24	0.624	0.850
18	0	0	0	240	0.24	0.48	0.733

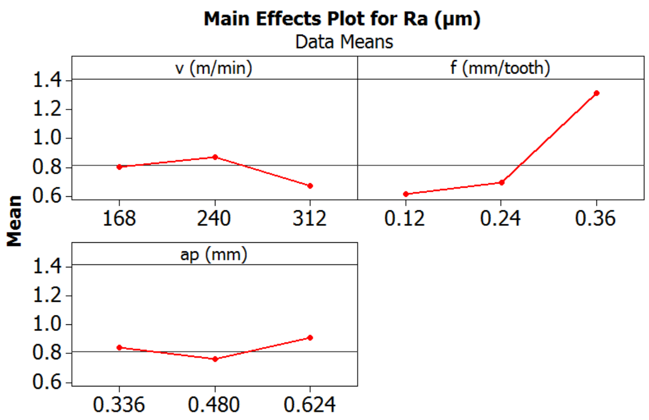

Fig 2. Influence of cutting parameters on *Ra*

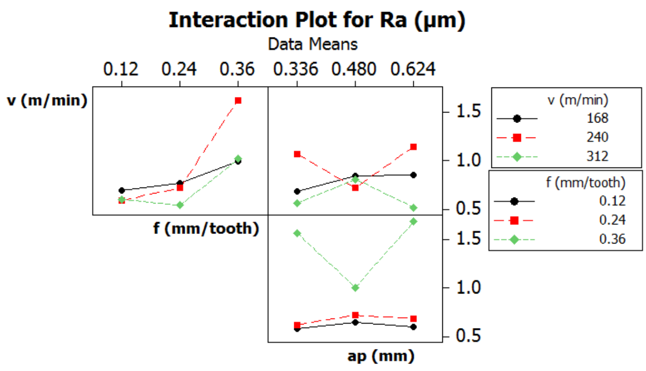

Fig 3. Interaction effects of cutting parameters on *Ra*

IV. OPTIMIZATION OF THE MILLING PROCESS

The statistical software Minitab 16 was once again used to solve the optimization problem of the milling process. The optimization graph is shown in Figure 4.

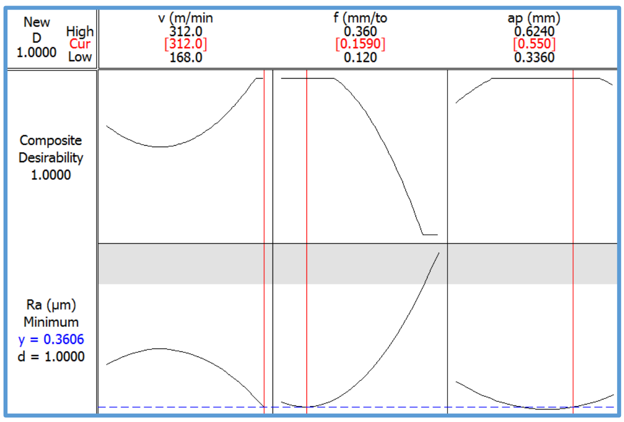

Fig. 4. Graph optimization

The results in Figure 4 show the optimum values of the parameters of the cutting speed, the feed rate and the cutting depth are 312 m/min, 0.159 mm/tooth and 0.55 mm, respectively. The expected function is equal to 1, which means that the probability of reaching the minimum surface roughness when machined with the optimum value set of the cutting mode parameters is 100%. The optimum value set of the parameters was also used to carry out the milling process with 5 steel samples. The average value of surface roughness in 5 experiments was 0.368 µm. So the difference between the experimental results and the predicted results is only about 2.01%.

V. CONCLUSION

The 060A4 steel milling experiment was carried out in this study. The determination of the optimum value of the cutting parameters has also been performed. Some conclusions are drawn as follows:

- Of the three cutting mode parameters including the cutting speed, the feed rate and the cutting depth, only the feed rate is a parameter that has a significant influence on the surface roughness. In case the feed rate increases, the surface roughness increases rapidly. The cutting speed and the cutting depth have a negligible influence on the surface roughness.

- The optimal value of the cutting speed, the feed rate and the cutting depth are 312 m/min, 0.159 mm/tooth and 0.55 mm, respectively. When machining with these values of the cutting mode parameters, the surface roughness has the smallest value, about 0.368 μm.

- The determination of the value of the cutting parameters to ensure simultaneously the targets such as the minimum surface roughness, the minimum shear force, and the maximum material removal rates, etc. are the further directions for the next study.

REFERENCES

[1]. Eyup Bagci, Ercüment U. Yüncüoğlu (2017), *The Effects of Milling Strategies on Forces, Material Removal Rate, Tool Deflection, and Surface Errors for the Rough Machining of Complex Surfaces*, Strojniški vestnik - Journal of Mechanical Engineering Vol. 63, No. 11, pp. 643-656.

[2]. Mohammed T. Hayajneh, Montasser S. Tahat, Joachim Bluhm (2007), *A Study of the Effects of Machining Parameters on the Surface Roughness in the End-Milling Process*, Jordan Journal of Mechanical and Industrial Engineering, Vol. 1, No. 1, pp. 1-5.

[3]. Dražen Bajić, Luka Celent, Sonja Jozić (2012), *Modeling of the Influence of Cutting Parameters on the Surface Roughness, Tool Wear and Cutting Force in Face Milling in Off-Line Process Control*, Strojniški vestnik - Journal of Mechanical Engineering 58, Vol. 11, pp. 673-682.

[4]. Phan Bui Khoi, Do Duc Trung, Ngo Cuong, Nguyen Dinh Man (2015), *Research on Optimization of Plunge Centerless Grinding Process using Genetic Algorithm and Response Surface Method*, International Journal of Scientific Engineering and Technology, Vol. 4, No. 3, pp. 207-211

[5]. Luis Wilfredo Hernández-González, Roberto Pérez-Rodríguez, Ana María Quesada-Estrada, Luminita Dumitrescu (2018), *Effects of cutting parameters on surface roughness and hardness in milling of AISI 304 steel*, DYNA, 85(205), pp. 57-63.

[6]. Muhammmad Yasir, Turnad Lenggo Ginta, Bambang Ariwahjoedi, Adam Umar Alkali, Mohd Danish (2016*), Effect of cutting spedd and feed rate on surface roughness of AISI 316LSS using end-milling*, ARPN Journal of Engineering and Applied Sciences, Vol. 11, No. 4, pp. 2496-2500.

[7]. Erol Kilickap, Ahmet Yardimeden, Yahya Hı¸sman Çelik (2017), *Mathematical Modelling and Optimization of Cutting Force, Tool Wear and Surface Roughness by Using Artificial Neural Network and Response Surface Methodology in Milling of Ti-6242S*, Applied Sciences, Vol. 7, No. 1064, doi:10.3390/app7101064

[8]. Okokpujie Imhade P., Okonkwo Ugochukwu C. (2013), *Effects of Cutting Parameters on Surface Roughness during End Milling of Aluminium under Minimum Quantity Lubrication (MQL)*, International Journal of Science and Research, Vol. 4, No. 5, pp. 2937-2943.

[9]. Huu-That Nguyen, Quang-Cherng Hsu (2016), *Surface Roughness Analysis in the Hard Milling of JIS SKD61 Alloy Steel*, Applied Sciences, Vol. 6, No. 172, doi:10.3390/app6060172

[10]. Hasan Gökkaya (2010), *The Effects of Machining Parameters on Cutting Forces, Surface Roughness, Built-Up Edge (BUE) and Built-Up Layer (BUL) During Machining AA2014 (T4) Alloy*, Strojniški vestnik - Journal of Mechanical Engineering, Vol. 56, pp. 584-593.

[11]. https://www.jenlian.com.tw/vertical%20horizontal%20milling%20machine.htm

[12]. Do Duc Trung (2020*), Influence of Cutting Parameters on Surface Roughness during Milling AISI 1045 Stee*l, Tribology in Industry, Vol. 42, No. 4, pp. 658-665, doi: 10.24874/ti.969.09.20.11

[13]. B. N. Pathak, K. L. Sahoo, and Madhawanand Mishra (2013), *Effect of Machining Parameters on Cutting Forces and Surface Roughness in Al-(1-2) Fe-1V-1Si Alloys*, Materials and Manufacturing Processes, No. 28, pp. 463–469.