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Influence of Cutting Parameters on the Tool Wear When Milling Steel S55C

Le Hong Ky
Vinh Long University of Technology Education, 73 Nguyen Hue Street, Vinh Long City, Vinh Long Province, Vietnam
(lehongkydhspktvl@gmail.com, kylh@vlute.edu.vn)

Abstract-In this paper, a study to determine the influence of cutting parameters on the wear when milling is presented. The material used in this study is S55C steel. The cutting parameters mentioned in this study include the cutting velocity, the feed rate and the depth of cut. Conducting experiments according to Box-Behnken plan and analyzing the results show that all three parameters of cutting velocity, feed rate and cutting depth have a significant influence on the tool wear. The influence of these parameters on the tool wear is quite complex, increasing the value of these parameters sometimes increases, sometimes reduces the amount of tool wear.

Keywords- *Surface Milling, S55C Steel, Tool Wear, Cutting Parameter*

I. INTRODUCTION

Machining, cutting in general and machining by milling in particular, the wear of the cutting tool is always a very important issue because it directly affects the durability, tool life and greatly affects machining accuracy [1]. The study of the influence of technology parameters on the wear amount of a milling tool has been conducted by many studies [2-9]. Fritz Klocke et al. [1], Christian Brecher et al. [10-12] studied simulations to predict tool durability; however, in their study, the properties of processed materials have not been considered, making the simulation results not close to the experimental results. Fritz Klocke et al. [13] studied the effect of tool structural parameters on tool wear speed during machining. Waldemar TUSZYNSKI et al. [14] studied the effect of the coating material on tool wear. Zhaoju Zhu et al. [15] studied the effect of tool wear on the cutting ability of Ti6Al4V titanium alloy. In this paper, conducting an experimental study to investigate the effect of cutting parameters on the tool wear of the tool when milling a S55C material.

II. EXPERIMENTAL DESIGN

A. Experimental system

- In this study, a semi-automatic milling machine with symbol 535 was used.

- Selecting the test sample of used S55C steel, this type of material is being commonly used to manufacture gears, shafts and parts that require high accuracy, high abrasion resistance.

- Choose a type of milling cutter made from steel P18 with 4 cutting pieces.

- Using cool fluid is VBC CUT PINE-150MR industrial oil of Buhmwoo (Korea), with the method of overflow irrigation, flow of 22 liters / minute.

- Use the scanning electron microscope VHX-6000 to measure the tool wear. At each experiment, three steel samples were performed. The amount of tool wear (U) is measured on each sample at least 3 times, the value of U in each experiment is the average of consecutive measurements. The amount of tool wear considered in this study is the amount of wear calculated from the beginning of the machining process to the end of machining. Therefore, it is easy to calculate the amount of tool wear in each test.

B. Experimental plan

The order and number of experiments were carried out in accordance with Box-Behnken experimental planning. Experimental matrix of Box-Behnken format with three input parameters (V, F, DOC) in encrypted form of parameters is presented in Table 1.

Regarding the value of the variables during the experiment selected under fine milling conditions of S55C material, under fine milling conditions when processing high alloy steels in the research [16] and in accordance with the technological capabilities of testing machines. The value of the input parameters corresponding to each encoding value is shown in Table 2.

TABLE I. EXPERIMENT MATRIX

No.	V	F	DOC
1	-1	-1	0
2	1	-1	0
3	-1	1	0
4	1	1	0
5	-1	0	-1
6	1	0	-1
7	-1	0	1
8	1	0	1
9	0	-1	-1
10	0	1	-1
11	0	-1	1
12	0	1	1
13	0	0	0
14	0	0	0
15	0	0	0

TABLE II. VALUE AT LEVELS OF INPUT PARAMETERS

Input parameters	Symbol	Levels		
		-1	0	+ 1
Cutting velocity (m/min)	V	80	120	160
Feed rate (s/tooth)	F	60	80	100
Depth of cut (mm)	DOC	0.25	0.50	0.75

III. EXPERIMENTAL RESULTS AND ANALYSIS

Conducting experiments in the order of the experimental points as shown in Table 1, the value of the experimental variables at each coding point is shown in Table 2. The value of U in each experimental point is presented in Table 3.

TABLE III. EXPERIMENTAL RESULTS

No.	Cutting parameters						Tool wear
	Code			Value			
	V	F	DOC	V (m/min)	F (s/tooth)	DOC (mm)	U (mm)
1	-1	-1	0	80	60	0.50	0.895
2	1	-1	0	160	60	0.50	0.585
3	-1	1	0	80	100	0.50	0.515
4	1	1	0	160	100	0.50	1.297
5	-1	0	-1	80	80	0.25	0.746
6	1	0	-1	160	80	0.25	1.085
7	-1	0	1	80	80	0.75	0.464
8	1	0	1	160	80	0.75	1.047
9	0	-1	-1	120	60	0.25	0.585
10	0	1	-1	120	60	0.25	0.801
11	0	-1	1	120	100	0.75	0.420
12	0	1	1	120	100	0.75	0.937
13	0	0	0	120	80	0.50	0.471
14	0	0	0	120	80	0.50	0.678
15	0	0	0	120	80	0.50	0.473

Using Minitab 16 statistical software to analyze the results in Table 3, we get the results of regression model information and the analysis of variance for U parameters as shown in figures 1 to 6.

Observing Figure 1 to Figure 6 shows:

- The probability value (P) on the influence level of parameters V, F, DOC as well as the interaction between the factors V*V, V*F are all smaller than the significance level. This means that the parameters V, F, DOC, V*V, V*F all have a significant effect on tool wear.

- Through the influence column shows that V*F has the largest impact on tool wear, followed by the level of influence of V*V, V, F... The parameter V*DOC has the least effect on tool wear.

- The effect of the parameters V, F, DOC and their interaction to tool wear are also quite complex, increasing the value of these parameters sometimes increases, sometimes reduces the wear of tool wear. For example, F affects tool wear more than DOC, but F*F affects tool wear less than DOC*DOC.

Response Surface Regression: U versus V, F, DOC

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Estimated Regression Coefficients for U
Term          Coef   SE Coef       T      P
Constant   0.54067   0.07496   7.213  0.001
V          0.17425   0.04590   3.796  0.013
F          0.13313   0.04590   2.900  0.034
DOC       -0.04362   0.04590  -0.950  0.386
V*V        0.21604   0.06757   3.197  0.024
F*F        0.06629   0.06757   0.981  0.372
DOC*DOC    0.07879   0.06757   1.166  0.296
V*F        0.27300   0.06492   4.205  0.008
V*DOC      0.06100   0.06492   0.940  0.391
F*DOC      0.07525   0.06492   1.159  0.299
S = 0.129839    PRESS = 0.959622
R-Sq = 91.69%  R-Sq(pred) = 5.38%  R-Sq(adj) = 76.73%
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Figure 1. REGESION OF TOOL WEAR

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Analysis of Variance for U

Source          DF   Seq SS   Adj SS   Adj MS      F      P
Regression       9  0.92989  0.92989  0.10332   6.13  0.030
  Linear         3  0.39991  0.39991  0.13330   7.91  0.024
    V            1  0.24290  0.24290  0.24290  14.41  0.013
    F            1  0.14178  0.14178  0.14178   8.41  0.034
    DOC          1  0.01523  0.01523  0.01523   0.90  0.386
  Square         3  0.19433  0.19433  0.06478   3.84  0.091
    V*V          1  0.15793  0.17233  0.17233  10.22  0.024
    F*F          1  0.01347  0.01623  0.01623   0.96  0.372
    DOC*DOC      1  0.02292  0.02292  0.02292   1.36  0.296
  Interaction    3  0.33565  0.33565  0.11188   6.64  0.034
    V*F          1  0.29812  0.29812  0.29812  17.68  0.008
    V*DOC        1  0.01488  0.01488  0.01488   0.88  0.391
    F*DOC        1  0.02265  0.02265  0.02265   1.34  0.299
Residual Error   5  0.08429  0.08429  0.01686
  Lack-of-Fit    3  0.05600  0.05600  0.01867   1.32  0.459
  Pure Error     2  0.02829  0.02829  0.01415
Total           14  1.01418
```

Figure 2. ANOVA ANALYSIS FOR TOOL WEAR

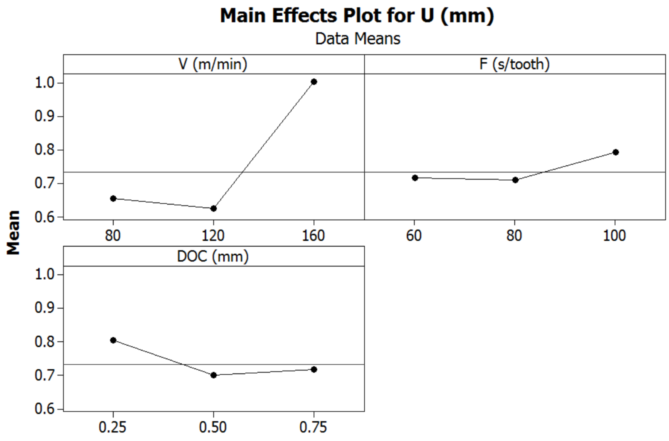

Figure 3. Effect of cutting parameters on tool wear

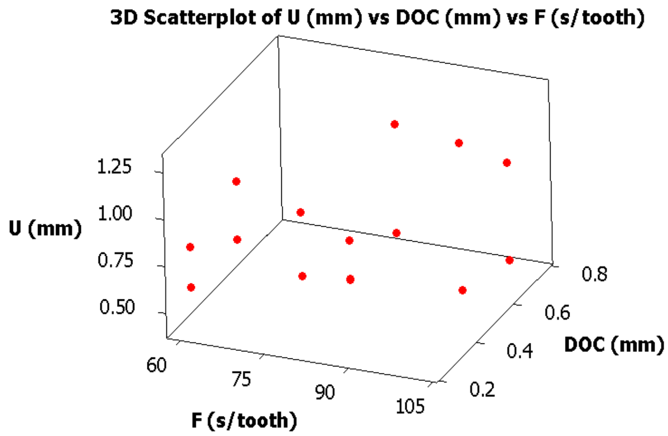

Figure 5. Interaction plot for V vs DOC on tool wear

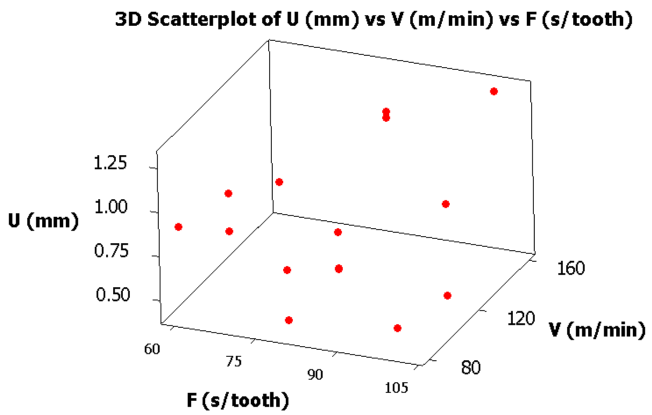

Figure 4. Interaction plot for V vs. F on tool wear

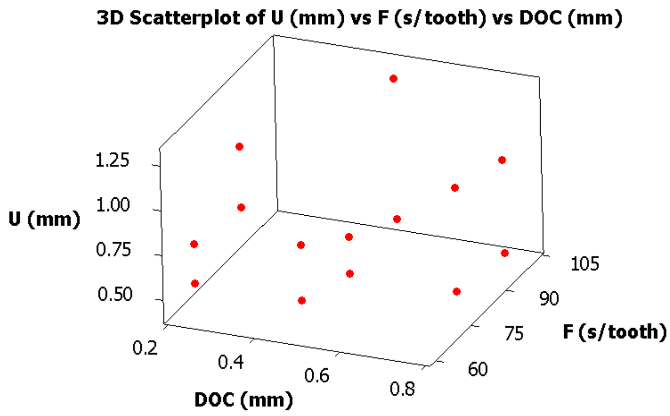

Figure 6. Interaction plot for F vs DOC on tool wear

- Although the probability values of DOC, F*F, DOC*DOC, V*DOC, F*DOC have corresponding values of 0.386, 0.372, 0.295, 0.391 and 0.299 (greater than the significance level α, often choose α = 0.05) but we should not exclude these two components from the regression model. Because if we exclude these two components from the regression model, we will weaken the model's compatibility even if we recalculate other regression coefficients [17]. In addition, the probability value at Lack-of-Fit has a value of 0.459, much greater than the significance level α. Therefore, the components DOC, F*F, DOC*DOC, V*DOC, F*DOC are retained in the regression model. From this, we build a complete quadratic regression model for tool wear as follows:

The regression equation (1) with determination coefficient R^2 = 0.9169 is also very close to 1, which confirms that this equation is highly compatible with the experimental data. This equation reflects the influence of the cutting mode parameters to tool wear, and is also the basis for selecting the value of the cutting parameters to reduce tool wear under specific conditions when processing S55C steel.

IV. CONCLUSION

Some conclusions drawn from this study when milling S55C steel are as follows:

1. The cutting parameters and most interactions between these parameters have a significant effect on tool wear of which, the cutting velocity has the greatest influence, followed by the influence of the feed rate and the depth of cutting.
2. The effect of cutting parameters on the tool wear is quite complex, increasing the value of these parameters increases, sometimes reduces the value of tool wear. This level of influence is built into formula (1). This equation is the basis for determining the value of the cutting velocity, the feed rate and the depth of cutting in each specific case to ensure the smallest amount of tool wear.

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PhD. Le Hong Ky was born in Vietnam in 1963. He obtained a Engineer in Mechanical Engineering in 1987 from Ho Chi Minh University of Technology and Education, Vietnam. In 1996, he received Master of Mechanical Engineering from Ho Chi Minh University of Technology and Education, Vietnam. In 2016 he got Doctor in Mechanical Engineering at National Research Institute of Mechanical Engineering (NARIME), Vietnam.

Now He is a Lecturer and works as an Vice Rector at Vinh Long University of Technology Education, Vietnam. His current research focuses on optimization in machining processes such as grinding, EDM machining etc. and optimum design of gearboxes. Reviewer for the ICERA 2019, ICMSET 2019 and MEAE 2019.

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