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Effect of Machining Parameters on Surface Roughness of Workpiece in Drilling A6061 Aluminum Alloy

Nguyen Hong Son
Center for Mechanical Engineering, Hanoi University of Industry, Hanoi, Vietnam -100000
Email: nguyenhongson[AT]haui[DOT]edu[DOT]vn

***Abstract*— This paper presents the empirical research process to determine the effect of drill bit diameter, spindle speed and feed rate on surface roughness of workpiece in drilling A6061 aluminum alloy. Fifteen experiments were conducted according to the Box-Behnken method in this study. As a result, spindle speed has the greatest effect on surface roughness, followed by drill bit diameter, and the feed rate has the least effect on surface roughness. The interaction between drill bit diameter and feed rate has the strongest effect on surface roughness, followed by the interaction between drill bit diameter and spindle speed, the interaction between spindle speed and feed rate has the least effect on surface roughness. The range of values of each parameter to ensure small surface roughness in specific cases was also shown in this study.*

***Keywords*— A6061 aluminum alloy drilling, machining parameters, surface roughness.*

I. INTRODUCTION

Drilling is the most common machining method for making holes in solid materials, and is often used as a preparation step for subsequent steps such as broaching, boring. Hole's surface roughness is always an important determinant of product life. Determining the effect of machining parameters on surface roughness in drilling will facilitate the selection of the values of these parameters in a reasonable manner to reduce surface roughness, and eliminate machining steps such as broaching, boring, thereby improving the efficiency of the drilling process. Therefore, there have been several studies investigating the effect of drill bit diameter, spindle speed and feed rate on surface roughness in drilling a number of different materials. Balaji et al. [1] experimented with AISI 304 stainless steel. Sanjay et al. [2] studied mild steel drilling. Deepan Bharathi Kannan et al. [3] conducted an experiment on stainless steel. Prakash et al. [4] conducted an experiment to drill medium density fiberboard panels. Evren Kabakli et al. [5] studied low-alloy hot-rolled steel plate drilling. Ahmed Basil Abdulwahhab et al. [6] conducted an experiment on AISI 1015 steel material. Praksh et al. [7] conducted experiments in drilling Medium Density Fiber board panles. Abhinaw Roy et al. [8] studied the processing of AISI1020 steel. Soepangkat et al. [9] studied experiments with materials made of stainless steel GFRP ... In this study, experiments will be conducted to determine the effect of drill bit diameter, speed spindle and feed rate on surface roughness when drilling A6061 aluminum alloy.

II. EMPIRICAL RESEARCH

A. Machine, Machining Materials and Cutting Tool

The experiments were implemented on DMN400 CNC milling machine of DOOSAN - Korea (Fig. 1).

Fig. 1. Experimental machine-tool

The component is A6061 aluminum alloy, whose chemical composition is shown in Table I. This is an easy-to-process material with high corrosion resistance and plasticity. This material is widely used in the automotive and aviation industry. Fig. 2 shows the component after drilling and cutting out to measure surface roughness.

TABLE I. Chemical Composition Of A6061

Components	Si	Mg	Mn	Cu	Fe	Cr	Zn	Ti	Al	Others
%	0.6	1.0	0.15	0.3	0.7	0.35	0.25	0.15	96.45	0.05

Fig. 2. Experimental component

Fig. 3. Cutting tools

The cutting tool used in the experiment is WIDIN (Korea) hard alloy drill bits with sizes of diameter of 8, 10 and 12 mm (Fig. 3). This type of drill bit is commonly used for aluminum drilling.

B. Design of Experiments

The experiments were designed according to the Box-Behnken matrix. With three input parameters including drill bit diameter (d - mm), spindle speed (n - rev/min) and feed rate (f - mm/rev), the experimental plan consists of 15 experiments, established by Minitab 16 statistical software as shown in Table II.

TABLE III. Experimental Matrix and Results

No.	d (mm)	n (rev/min)	f (mm/rev)	R_a
1	8	2500	0.1	1.82
2	12	2500	0.1	0.92
3	8	5000	0.1	2.51
4	12	5000	0.1	1.96
5	8	3750	0.08	1.54
6	12	3750	0.08	1.30
7	8	3750	0.12	2.40
8	12	3750	0.12	1.21
9	10	2500	0.08	1.12
10	10	5000	0.08	1.90
11	10	2500	0.12	1.38
12	10	5000	0.12	2.37
13	10	3750	0.1	1.28
14	10	3750	0.1	1.30
15	10	3750	0.1	1.66

C. Surface Roughness Tester

The roughness meter used in this study is a surface roughness tester (Mitutoyo - Japan). At each hole, measure roughness at least 3 times. The roughness value at each experiment is the average value of successive measurements, included in Table II.

D. Result Analysis

The Minitab 16 statistical software was used to analyze the experimental results in Table II. The results are shown in Fig. 4 to 8.

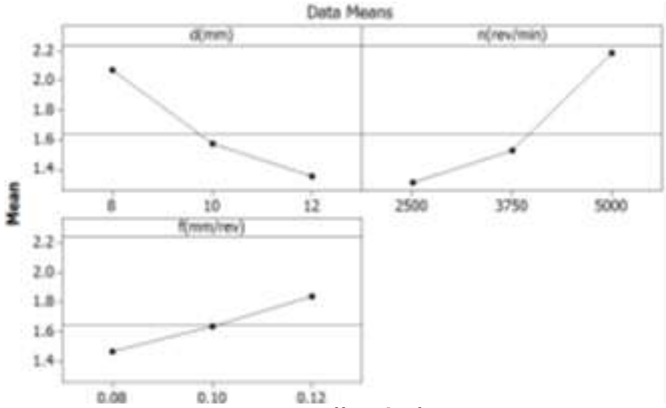

Fig. 4. Main effect plot for R_a

From the graph in Fig. 4 shows:

- Spindle speed has the greatest effect on surface roughness, followed by drill bit diameter, feed rate has the least effect on surface roughness.
- When the drill bit diameter increases, the surface roughness decreases. Meanwhile, if the spindle speed and the feed rate increase, the surface roughness will increase.

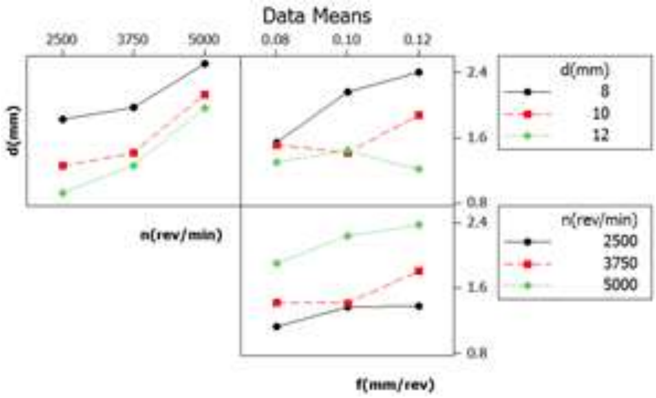

Fig. 5. Interaction plot for R_a

From the graph in Fig. 5 shows: The interaction between drill bit diameter and feed rate has the greatest effect on surface roughness, followed by the interaction between drill bit diameter and spindle speed, the interaction between spindle speed andfeed rate has the least effect on surface roughness.

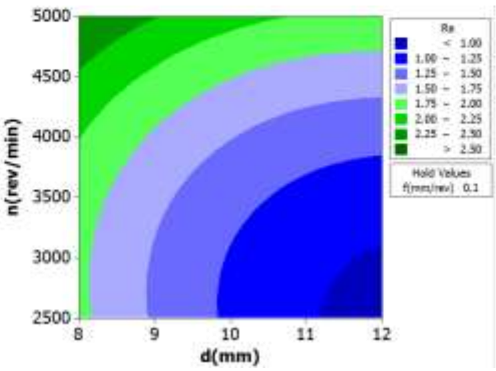

Fig. 6. Contour plot of R_a vs n(rev/min), d(mm)

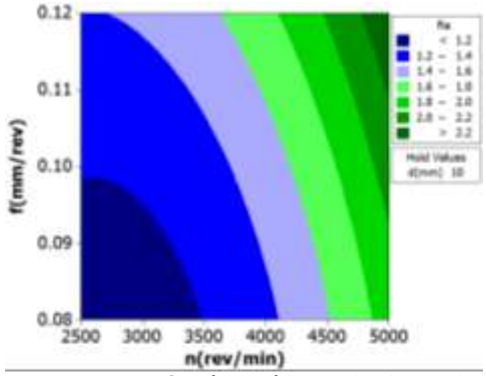

Fig. 7. Contour plot of R_a vs f (mm/rev), n(rev/min)

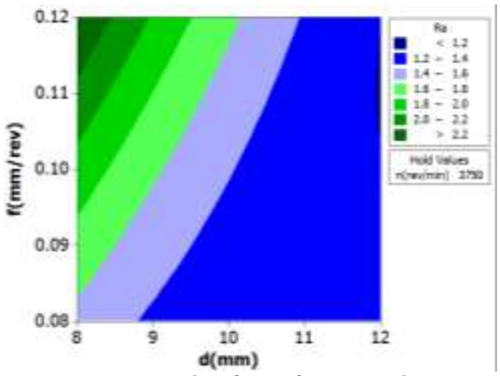

Fig. 8. Contour plot of R_a vs f (mm/rev), d(mm)

From Fig. 6, 7 and 8 shows:

- When the feed rate is 0.1 (mm/rev), the roughness of the machining surface will reach the minimum value if the spindle speed is less than about 3000 (rev/min), the drill bit diameter is larger than 11 (mm).
- In the case of using a drill bit diameter of 10 (mm), if the feed rate is less than about 0.1 (mm/rev), the spindle speed is less than 3500 (rev/min) then the roughness of the machining surface will be less than 1.2 (µm).
- When the spindle speed is 3750 (mm/min), the surface roughness of the machining hole will be less than 1.2 (µm) if a drill bit with a diameter of about 8 (mm) is used and the feed rate is greater than about 0.11 (mm/rev).

III. Conclusions

This study has determined the effect of drill bit diameter, spindle speed, feed rate as well as the interaction between these parameters to the surface roughness of hole in drilling A6061 aluminum alloy. This study also showed the value range of the above parameters to ensure the hole's surface with small roughness in some specific cases.

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