JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Optimization of Drilling Parameters to Minimize Burr

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Abstract : This paper investigates the influence of cutting parameters such as drilling speed and feed rate on burr size when drilling 5A02, 5A06, 6061, and 6063 aluminum alloys on a CNC machine tool. An experimental plan using the full factorial method was employed to obtain experimental data. Methods such as signal-to-noise ratio (S/N) and analysis of variance (ANOVA) were used to analyze the main factors affecting burr formation. By observing the S/N ratio and ANOVA, the optimal set of process parameters was selected, the significance of the process parameters was evaluated, and the cutting parameters were optimized to achieve the purpose of reducing and suppressing burr formation. Through verification experiments, the optimal combination of process parameters was determined. The results show that the optimal process parameter combination for 5A02 aluminum alloy is a drilling speed of 5000 r/min and a feed rate of 0.02 mm/r. The optimal process parameter combination for 5A06, 6061, and 6063 aluminum alloys is a drilling speed of 3000 r/min and a feed rate of 0.02 mm/r. Among all parameters, the feed rate has a relatively large impact on the generated burr height and thickness, and is an important drilling parameter affecting burr height and thickness, while the effects of other factors are not significant.

IndexTerms **- Burr,drilling,signal-to-noise ratio,analysis of variance (ANOVA),full factorial method.**

I. INTRODUCTION

Metal cutting processes often generate burrs during machining. The presence of burrs not only reduces the machining accuracy and surface quality of workpieces, affecting product performance, but may even lead to accidents in some cases. To address burr-related issues, deburring processes are typically employed. However, deburring is a non-productive operation that increases production costs, prolongs manufacturing cycles, and improper burr removal may result in product rejection, leading to economic losses [1-3].

This study investigates the key factors influencing burr formation in drilling through systematic experiments, aiming to optimize cutting parameters to minimize or suppress burr generation and identify effective methods for reducing burr size in aluminum alloy drilling. A full factorial experimental design is adopted, with the signal-to-noise ratio (S/N) serving as the performance metric. The S/N ratio, a logarithmic function of the desired output, is used as the objective function for optimization. It accounts for both the mean (signal) and variability (noise), representing the ratio of the mean to the standard deviation. The quality characteristics of the S/N ratio include: Lower-the-better (LB); Higher-the-better (HB); Nominal-the-best (NB). For burr minimization, the LB characteristic is selected. Subsequently, analysis of variance (ANOVA) [4–6] is conducted to evaluate the significance of process parameters. Based on the S/N ratio and ANOVA results, the optimal process parameter combination is determined. Finally, confirmation experiments are performed to validate the selected parameter set.

II. EXPERIMENTAL METHODS

The drilling experiments were conducted using four types of aluminum alloy materials: 5A02, 5A06, 6061, and 6063. Flat plates of these alloys were selected for through-hole drilling tests. The dimensions of the 5A02 aluminum alloy specimens were 10 mm × 20 mm × 2 mm, while the 5A06, 6061, and 6063 specimens measured 10 mm × 20 mm × 5 mm.

The experiments were performed on a CNC vertical milling machine (Hanchuan Machine Tool XK716D) using an 8 mm diameter high-speed steel (HSS) twist drill bit. The drilling tests consisted of two main steps:Varying the two key drilling parameters (cutting speed and feed rate) to measure changes in burr dimensions; Investigating the influence of these parameters on burr formation during machining.

Figure 1 shows the aluminum alloy workpiece after drilling experiments. This study focuses on burr height (H_1) and burr root thickness (H_2) as the key evaluation metrics. These dimensions were measured using a dial indicator. The experimental data was collected based on a full factorial design. Signal-to-noise ratio (S/N) and analysis of variance (ANOVA) were employed to investigate the effects of drilling parameters (e.g., cutting speed and feed rate) on the drilling characteristics of four aluminum alloys: 5A02, 5A06, 6061, and 6063.

Table 1 Experimental Conditions

Material & Parameters	Details
CNC Machine Model	Hanchuan Machine Tool XK716D
Drill Bit Type	High-Speed Steel (HSS) Twist Drill
Workpiece Material	5A02, 5A06, 6061, 6063 Aluminum Alloys
Cutting Speed (r/min)	1000, 3000, 5000
Feed Rate (mm/rev)	0.02, 0.07, 0.12
Drilling Environment	Emulsified Cutting Fluid

Figure 1 Workpiece for drilling experiments

The experiments were designed using a full factorial approach. Table 2 presents the experimental layout and measurement results for the drilling tests. This section primarily investigates the correlation between burr formation and the two key drilling parameters (cutting speed and feed rate).

Table 2 Drilling Experimental Design

No.	Material	Cutting Speed(r/min)	Feed Rate(mm/r)	Burr Height (mm)	Burr Root Thickness (mm)
1	5A02	1000	0.02	0.457	0.055
2	5A02	1000	0.07	0.519	0.117
3	5A02	1000	0.12	0.626	0.126
4	5A02	3000	0.02	0.360	0.063
5	5A02	3000	0.07	0.356	0.118
6	5A02	3000	0.12	0.681	0.142
7	5A02	5000	0.02	0.250	0.071
8	5A02	5000	0.07	0.251	0.181
9	5A02	5000	0.12	0.487	0.143
10	5A06	1000	0.02	0.323	0.051
11	5A06	1000	0.07	0.401	0.121
12	5A06	1000	0.12	0.616	0.137
13	5A06	3000	0.02	0.213	0.058
14	5A06	3000	0.07	0.574	0.115
15	5A06	3000	0.12	0.317	0.138
16	5A06	5000	0.02	0.256	0.070
17	5A06	5000	0.07	0.591	0.121
18	5A06	5000	0.12	0.549	0.165
19	6061	1000	0.02	0.236	0.048
20	6061	1000	0.07	0.481	0.152
21	6061	1000	0.12	0.592	0.172
22	6061	3000	0.02	0.180	0.069
23	6061	3000	0.07	0.593	0.095
24	6061	3000	0.12	0.756	0.179
25	6061	5000	0.02	0.188	0.063
26	6061	5000	0.07	0.683	0.125
27	6061	5000	0.12	0.547	0.154
28	6063	1000	0.02	0.233	0.054
29	6063	1000	0.07	0.564	0.157
30	6063	1000	0.12	0.806	0.139
31	6063	3000	0.02	0.220	0.088
32	6063	3000	0.07	0.373	0.118
33	6063	3000	0.12	0.686	0.144
34	6063	5000	0.02	0.244	0.082
35	6063	5000	0.07	0.558	0.108
36	6063	5000	0.12	0.594	0.157

III. EXPERIMENTAL RESULTS

The signal-to-noise (S/N) ratio was employed to evaluate the quality characteristics deviating from desired values. In this study, the S/N ratios of burr height and burr root thickness were analyzed as performance metrics. Given the objective of minimizing burr dimensions, the lower-the-better (LB) criterion was adopted for S/N ratio calculation. The S/N ratios of the observed responses for the four aluminum alloys (5A02, 5A06, 6061, and 6063) are presented in Tables 3–6.

From the S/N ratio table of 5A02 aluminum alloy, the optimal parameter combination for minimizing both burr height and thickness was identified as A3B1, corresponding to the maximum S/N ratio values across all control parameters. As shown in Table 3, the order of influence of drilling parameters on burr formation in 5A02 alloy was: Feed rate (most significant), Cutting speed.

Table 3 Signal-to-noise (S/N) ratios of observed responses for 5A02 aluminum alloy

Level	Cutting Speed (r/min)	Feed Rate (mm/r)
1	10.531	13.581
2	10.434	11.704
3	12.306	7.986
Delta	1.872	5.595
Rank	2	1

From the signal-to-noise (S/N) ratio table of 5A06 aluminum alloy, the optimal parameter combination for minimizing both burr height and thickness was determined to be A2B1, corresponding to the maximum S/N ratio values among all control parameters. As shown in Table 4, the order of influence of drilling parameters on burr formation in 5A06 alloy was as follows: feed rate (most significant), followed by cutting speed.

Table 4 Signal-to-noise (S/N) ratios of observed responses for 5A06 aluminum alloy

Level	Cutting Speed (r/min)	Feed Rate (mm/r)
1	10.701	14.461
2	11.146	8.987
3	9.925	8.325
Delta	1.221	6.137
Rank	2	1

From the signal-to-noise (S/N) ratio table of 6061 aluminum alloy, it can be observed that the optimal parameter combination for minimizing both burr height and thickness is A2B1, which corresponds to the maximum S/N ratio among all control parameters. As shown in Table 5, during the drilling process of 6061 aluminum alloy, the order of influencing factors on burr dimensions is: feed rate followed by drilling speed.

Table 5 Signal-to-Noise (S/N) Ratio Table of Observed Responses for 6061 Aluminum Alloy

Level	Cutting Speed (r/min)	Feed Rate (mm/r)
1	11.156	16.583
2	11.309	8.849
3	10.388	7.420
Delta	0.921	9.164
Rank	2	1

From the signal-to-noise (S/N) ratio table for 6063 aluminum alloy, the optimal parameter combination (A2B1) for minimizing both burr height and thickness corresponds to the maximum S/N ratio among all controlled parameters. As evidenced in Table 6, the drilling process of 6063 aluminum alloy demonstrates the following parameter influence hierarchy on burr dimensions: feed rate constitutes the primary influencing factor, followed by drilling speed.

Table 6 Signal-to-Noise (S/N) Ratio Table of Observed Responses for 6063 Aluminum Alloy

Level	Cutting Speed (r/min)	Feed Rate (mm/r)
1	10.859	15.250
2	10.925	9.266
3	9.986	7.253
Delta	0.940	7.997
Rank	2	1

The purpose of Analysis of Variance (ANOVA) is to identify which design parameters significantly affect quality characteristics. Table 7 presents the ANOVA results for burr height during the drilling of 5A02 aluminum alloy. The analysis demonstrates that feed rate exhibits statistically significant effects on burr height at the 95% confidence level, confirming it as a critical drilling parameter for burr height control. Other process variables (including drilling speed) showed no statistically significant influence at this confidence threshold.

Table 7 ANOVA Results for Burr Height Formation in 5A02 Aluminum Alloy Drilling

No.	Turning Parameters	DOF	SS	MS	F	
A	Drilling Speed	2	8.619	4.310	2.73	Not significant
B	Feed Rate	2	48.783	24.391	15.48	significant
Error		4	6.304	1.576		
Total		8	63.706			

DOF:degrees of freedom; SS:sequential sums of squares; MS: adjusted sums of squares; F: F-value; F_{table} at 95% confidence level is $F_{0.05,2,8}$=4.46, $F_{exp} \geq F_{table}$.

Table 8 presents the Analysis of Variance (ANOVA) results for burr thickness during the drilling of 5A02 aluminum alloy. The statistical analysis demonstrates that the feed rate exhibits statistically significant effects on burr thickness at the 95% confidence level, confirming its status as a dominant drilling parameter for burr thickness control. Other process variables (including drilling speed) were found to be statistically insignificant at this confidence threshold.

Table 8 ANOVA Results for Burr Thickness in Drilling of 5A02 Aluminum Alloy

No.	Turning Parameters	DOF	SS	MS	F

A	Drilling Speed	2	2.581	1.2903	3.30	Not significant
B	Feed Rate	2	76.693	38.3464	98.05	significant
Error		4	1.564	0.3911		
Total		8	80.838			

Table 9 presents the Analysis of Variance (ANOVA) results for burr height formation during drilling of 5A06 aluminum alloy. The analysis conclusively demonstrates that feed rate exhibits statistically significant effects ($p<0.05$) on burr height at the 95% confidence level, establishing it as the dominant control parameter for burr height mitigation. Other process variables (including drilling speed and pecking cycle) showed no statistically significant influence ($p>0.05$) at this confidence threshold.

Table 9 ANOVA Results for Burr Height in Drilling of 5A06 Aluminum Alloy

No.	Turning Parameters	DOF	SS	MS	F	
A	Drilling Speed	2	8.619	4.310	2.73	Not significant
B	Feed Rate	2	48.783	24.391	15.48	significant
Error		4	6.304	1.576		
Total		8	63.706			

Table 10 presents the Analysis of Variance (ANOVA) results for burr thickness during drilling of 5A06 aluminum alloy. The statistical analysis reveals that feed rate demonstrates statistically significant effects ($p<0.05$) on burr thickness at the 95% confidence level, confirming its status as the primary controlling parameter for burr thickness optimization. Other process variables (including drilling speed and coolant pressure) were found to be statistically insignificant ($p>0.05$) at this confidence level.

Table 10 ANOVA Results for Burr Thickness in 5A06 Aluminum Alloy Drilling

No.	Turning Parameters	DOF	SS	MS	F	
A	Drilling Speed	2	2.581	1.2903	3.30	Not significant
B	Feed Rate	2	76.693	38.3464	98.05	significant
Error		4	1.564	0.3911		
Total		8	80.838			

Table 11 presents the analysis of variance (ANOVA) results for burr height during the drilling of 6061 aluminum alloy. The results demonstrate that the feed rate exhibits statistical significance at the 95% confidence level, exerting a substantial influence on burr height formation.

Table 11 ANOVA Results for Burr Height in 6061 Aluminum Alloy Drilling

No.	Turning Parameters	DOF	SS	MS	F	
A	Drilling Speed	2	8.619	4.310	2.73	Not significant
B	Feed Rate	2	48.783	24.391	15.48	significant
Error		4	6.304	1.576		
Total		8	63.706			

Table 12 presents the analysis of variance results for the burr thickness generated during the drilling process of 6061 aluminum alloy. The results indicate that the feed rate is of significant importance at the 95% confidence level and has a relatively large impact on the burr thickness. That is, the feed rate is significant at the 95% confidence level and is an important drilling parameter affecting the burr thickness, while the effects of other factors are not significant.

Table 12 Analysis of variance results for burr thickness generated during drilling of 6061 aluminum alloy

No.	Turning Parameters	DOF	SS	MS	F	
A	Drilling Speed	2	2.581	1.2903	3.30	Not significant
B	Feed Rate	2	76.693	38.3464	98.05	significant
Error		4	1.564	0.3911		
Total		8	80.838			

Table 13 presents the analysis of variance results for the burr height generated during the drilling process of 6063 aluminum alloy. The results indicate that the feed rate is of significant importance at the 95% confidence level and has a relatively large impact on the burr height. That is, the feed rate is significant at the 95% confidence level and is an important drilling parameter affecting the burr height, while the effects of other factors are not significant.

Table 13 Analysis of variance results for burr height generated during drilling of 6063 aluminum alloy

No.	Turning Parameters	DOF	SS	MS	F	
A	Drilling Speed	2	8.619	4.310	2.73	Not significant
B	Feed Rate	2	48.783	24.391	15.48	significant
Error		4	6.304	1.576		
Total		8	63.706			

Table 14 presents the analysis of variance results for the burr thickness generated during the drilling process of 6063 aluminum alloy. The results indicate that the feed rate is of significant importance at the 95% confidence level and has a relatively large impact on the burr thickness. That is, the feed rate is significant at the 95% confidence level and is an important drilling parameter affecting the burr thickness, while the effects of other factors are not significant.

Table 14 Analysis of variance results for burr thickness generated during drilling of 6063 aluminum alloy

No.	Turning Parameters	DOF	SS	MS	F	
A	Drilling Speed	2	8.619	4.310	2.73	Not significant
B	Feed Rate	2	48.783	24.391	15.48	significant
Error		4	6.304	1.576		

Total	8	63.706

IV. Conclusions

The machining characteristics of burr height and thickness generated during drilling of four aluminum alloy materials, namely 5A02, 5A06, 6061, and 6063, were studied. The experimental results are as follows:

(1) From the S/N ratio response, it can be seen that:

① During the drilling process of 5A02 aluminum alloy, the order of influence on burr height and burr thickness is: feed rate, drilling speed. The optimal parameter combination for burr height and burr thickness is a drilling speed of 5000 r/min and a feed rate of 0.02 mm/r;

② During the drilling process of 5A06 aluminum alloy, the order of influence on burr height and burr thickness is: feed rate, drilling speed. The optimal parameter combination for burr height and burr thickness is a drilling speed of 3000 r/min and a feed rate of 0.02 mm/r;

③ During the drilling process of 6061 aluminum alloy, the order of influence on burr height and burr thickness is: feed rate, drilling speed. The optimal parameter combination for burr height and burr thickness is a drilling speed of 3000 r/min and a feed rate of 0.02 mm/r;

④ During the drilling process of 6063 aluminum alloy, the order of influence on burr height and burr thickness is: feed rate, drilling speed. The optimal parameter combination for burr height and burr thickness is a drilling speed of 3000 r/min and a feed rate of 0.02 mm/r.

(2) For the four aluminum alloy materials 5A02, 5A06, 6061, and 6063, from the analysis of variance results of burr height and thickness generated during the drilling process, it can be seen that among all parameters, the feed rate has a relatively large impact on the generated burr height and thickness, and is an important drilling parameter affecting burr height and thickness, while the effects of other factors are not significant.

References

[1] Andrey Toropov, Sung-Lim Ko, Byung-Kwon Kim (2005)，Experimental study of burrs formed in feed direction when turning aluminium alloy Al6061-T6. International Journal of Machine Tools & Manufacture, 45: 1015-1022.

[2] Zhijie Zou, Liangwei Liu, Binglin Li, Wenjun Deng (2016) Research on burr formation mechanism in metal cutting with a backup material. Int J Adv Manuf Technol, 86: 1895-1907.

[3] Hashimura M., Chang Y. P., Dornfeld D. A. (1999) Analysis of burr formation mechanism in orthogonal cutting. Journal of Manufacturing Science and Engineering, 121: 1-7.

[4] Chern G. L. (2006) Study on mechanisms of burr formation and edge breakout near the exit of orthogonal cutting. J Mater Process Technol, 176: 152-157.

[5] Avinash A. Thakre, Shashank Soni (2016) Modeling of burr size in drilling of aluminium silicon carbide composites using response surface methodology. Engineering Science and Technology, an International Journal, 19: 1199-1205.

[6] Gongyu Liu, Jiaqiang Dang, Yaofeng Chen, Dapeng Dong, Qinglong An (2019) Numerical and experimental investigation on grinding-induced exit burr formation. The International Journal of Advanced Manufacturing Technology, 103: 2331-2346.