Process Parameters Optimization in Drilling Using Taguchi Method

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1 Introduction

To create or enlarge a hole into or through a workpiece material drilling process is used. One of the most important processes in manufacturing industry is drilling. Drilling covers around 28% of all machining processes. Burr is unwanted materials remain after machining process. Burr is produced by all traditional machining processes. During machining operation, plastic deformation is the main cause of formation of burr. The presence of burr on drilling workpiece creates a problem in both assembly line and handling. Dey et el. [1] studied an experiment using artificial neural network (ANN). Obtained result from this experiment stated that minimum burr height and burr thickness are produced at maximum drill diameter, higher point angle and minimum spindle speed. ANN model gives a very close matching to the experiment results but a small deviation. Kundu et al. [2] investigated that unwanted burr is present in the workpiece during drilling. To optimize burr height with backup assist is developed by controlling different process parameters. The obtained result shows that for better drilling processes backup support is more important. Hashimura et al. [3] investigate that to minimize burr in drilling process, process parameters play a vital role. In this paper a fundamental structure is presented depends on various work materials to minimize burr. Formation of burr is analyzed by finite element analysis. The result showed that by controlling process parameters like feed rate and cutting angle, burr formation is minimized. Sathiyamurthy and Ramamoorthy [4] developed a 3D model to optimize burr by finite element method. Burr is occurs in most of the drilling process. Additional cost is needed to remove the burr, which is cost-effective in manufacturing industry. Patil et el. [5] studied on deburring process

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to remove the burr completely. The result showed that burr size decreases with the increase of feed rate. At 39º burr point, angle burr height is minimum. Takazawa [6] and Glilliespie [7] investigated a deburring process for burr formation. Liu et al. [8] investigated on burr formation for composite material in drilling process. Chang and Bone [9] studied on burr formation optimization using ultrasonic drilling operation. Banerjee et al. [10] designed a new horn and analysis using ANSYS for ultrasonic machining. Banerjee et al. [11] investigated parametric optimization of AL/SiC metal matrix composites during ultrasonic machining process.

The aim of this work is to measure the burr height and burr thickness under different machining parameters. Different parameters are point angle, spindle speed and drill bit diameter. Also to find out the minimal burr height and thickness produced in this drilling process.

2 Experimental Details

Total experiment is carried out under cooling conditions in a drill machine. Three different twist drill diameters were selected. The diameters are 8.62 mm, 9.42 mm and 11.35 mm. High-speed steel (HSS) cutting tool is used to drill aluminium bar workpiece of dimensions 152 mm * 40 mm * 15 mm. Burr height and burr thickness is found out, which is most important to characterize burr seize.

3 Experimental Procedure

The aluminium block was fixed in the vice. With the help of tachometer spindle speed was measured. To obtain correct spindle speed this process was used. Initially, bar was marked for making hole at a separate distance. A trial process was done before the final drilling process. First of all twist drill angles of three different diameters, 8.62 mm, 9.42 mm and 11.35 mm had same point angle 115° was measured. Then total of nine experiments was done for each of twist angle (3) and corresponding three spindle speeds. Secondly, at drill bit angle 102° next set of experiment was done. For the final experiment drill point angle was set to 84°. Total 27 numbers of experiments were conducted. In every machining process cutting fluid was used. To measure the burr height digital vernier caliper was used. Four side burr height was measured and then average burr height was taken. Same steps were done for measuring burr thickness. Different parameters for conducting experiment are shown in Table 1.

Table 1 Different parameters for conduction experiment

Parameters	Level 1	Level 2	Level 3
Drill diameter in mm	8.62	9.42	11.35
Point angle in degree	84	102	115
Spindle speed in rpm	628	1265	2217

4 Result Investigation and ANOVA Analysis

Experiments result in drilling process by using Taguchi's L27 orthogonal array has shown in Table 2. To determinate the output parameters like burr height and burr thickness, the input parameters like spindle speed, point angle and drill bit diameter were given in drilling process.

ANOVA has been used to determine the importance of machining parameters on burr formation. Some parameter of machining is more important than others' process parameters. Percentage contribution has been done to establish the importance of machining parameters with the help of ANOVA. Minitab 18 software has been used to determine 3-away ANOVA. ANOVA results for burr height are shown in Table 3.

If F-test values are greater than F-table values, then process parameters would be significant. Table 1 in this paper shows drill point angle is most significant and gives 94% confidence level. Burr height contribution is 33.42%. Drill bit dia. and spindle speed have 20.97% contribution level whereas point angle and spindle speed has 18% contribution level. From this, it is stated that point angle plays a significant role during drilling process and gives maximum burr height.

Table 4 shows the ANOVA result of burr thickness. It is clear that point angle acts a vital role during drilling process and which gives 94% confidence level. F-Test vale is 9.20 is greater than F-table value (2.8) = 4.56. Point angle gives burr thickness about 44.90%, where RPM and drill bit dia. gives 12.71% contribution level and point angle and drill bit dia. give 10.21% contribution level to burr thickness.

From Figs. 1 and 2 it is observed that by controlling process parameters like spindle speed, drill bit dia. and point angle, average burr height is shown. It is observed that average burr height shows when drill bit diameter is 9.42 mm.

Also, drill bit dia. at 8.65 mm and 11.45 mm average burr height shown. Average burr height is shown when point angle is 102°. If point angle is increased then burr height also increased. At 628 rpm in case of spindle speed, average burr height is shown. Spindle speed also varies from 626 to 1262 rpm to obtain average burr height (Table 5).

Figures 3 and 4 shows the mean effect plot and interaction plot for burr thickness, respectively. It was observed that value of burr thickness low at low-level drill bit diameter, i.e. 8.62 mm. Burr thickness will be increased up to intermediate value of drill bit dia. then it is decreased. Burr thickness is decreased with the increased of point angle. In case of spindle speed, bur thickness is increased with the increased of spindle speed (Table 6).

Table 2 Obtained results of Burr height and Burr thickness

S. No	Drill bit diameter (mm)	Spindle speed (r.p.m)	Point angle (°)	Height of Burr (mm)	Thickness of burr (mm)
1	8.62	628	84	5.66	0.782
2	8.62	1265	84	3.41	0.486
3	8.62	2217	84	6.62	0.653
4	8.62	628	102	4.79	0.370
5	8.62	1265	102	3.92	0.670
6	8.62	2217	102	4.42	0.540
7	8.62	628	115	2.89	0.420
8	8.62	1265	115	4.56	0.380
9	8.62	2217	115	4.29	0.510
10	9.42	628	84	6.64	0.760
11	9.42	1265	84	6.83	0.940
12	9.42	2217	84	4.62	0.844
13	9.42	628	102	4.61	0.402
14	9.42	1265	102	3.35	0.443
15	9.42	2217	102	3.66	0.750
16	9.42	628	115	3.51	0.355
17	9.42	1265	115	6.12	0.444
18	9.42	2217	115	5.21	0.594
19	11.35	628	84	5.76	0.834
20	11.35	1265	84	6.99	0.680
21	11.35	2217	84	4.70	0.784
22	11.35	628	102	2.66	0.560
23	11.35	1265	102	4.44	0.484
24	11.35	2217	102	3.60	0.410
25	11.35	628	115	2.45	0.408
26	11.35	1265	115	6.35	0.702
27	11.35	2217	115	3.25	0.289

5 Conclusion

Burr is unwanted materials remain in the workpiece after machining. This experimental work has been done to established burr optimization strategy. From this work, it has been concluded that,

- Point angle is most important parameter which gives 94% contribution level and burr height is 33.42%.
- Drill bit dia. and spindle speed has 20.97% contribution level whereas point angle and spindle speed have 18% contribution level.

Table 3 ANOVA results of burr height

Source	DOF	Adj. SS	Adj. MS	*F*-Value	*P*-Value	Percentage
Drill bit dia. (D)	2	1.30	0.643	0.91	0.436	2.78
Point angle (P)	2	15.762	7.880	11.07*	0.002	33.40
RPM (R)	2	3.005	1.5030	2.10	0.181	6.42
D * P	4	2.561	0.640	0.91	0.503	5.52
D*R	4	9.890	2.4749	3.45	0.061	20.97
P * R	4	8.965	2.2411	3.13	0.075	18.89
Error	8	5.688	0.7101			12.02
Total	26	47.171				

*Significant. *F*-value (2.8) = 4.56, *F*-value (4.8) = 3.81 at 95 at 94% confidence level

Table 4 ANOVA results for burr thickness

Source	DOF	Adj. SS	Adj. MS	*F*- value	*P*-value	Percentage
Drill bit dia. (D)	2	0.0120	0.006106	0.26	0.700	1.31
Point angle (P)	2	0.4150	0.207441	9.20	0.007	44.90
RPM (R)	2	0.0310	0.015594	0.68	0.526	3.40
D * P	4	0.0945	0.023602	1.07	0.400	10.20
D * R	4	0.1180	0.029541	1.32	0.342	12.77
P * R	4	0.0730	0.018300	8.80	0.551	7.90
Error	8	0.1798	0.022480			19.50
Total	26	0.9235				100

*Significant. *F*-value (2.8) = 4.56, *F*-value (4.8) = 3.81 at 95 at 94% confidence level

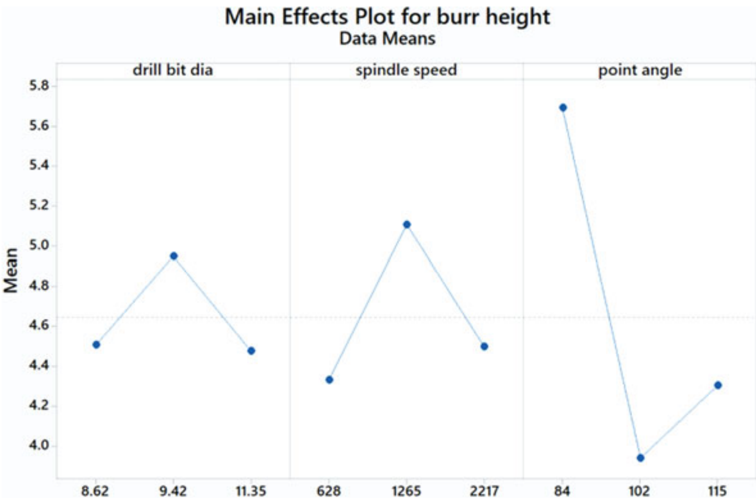

Fig. 1 Mean effect plot for burr height

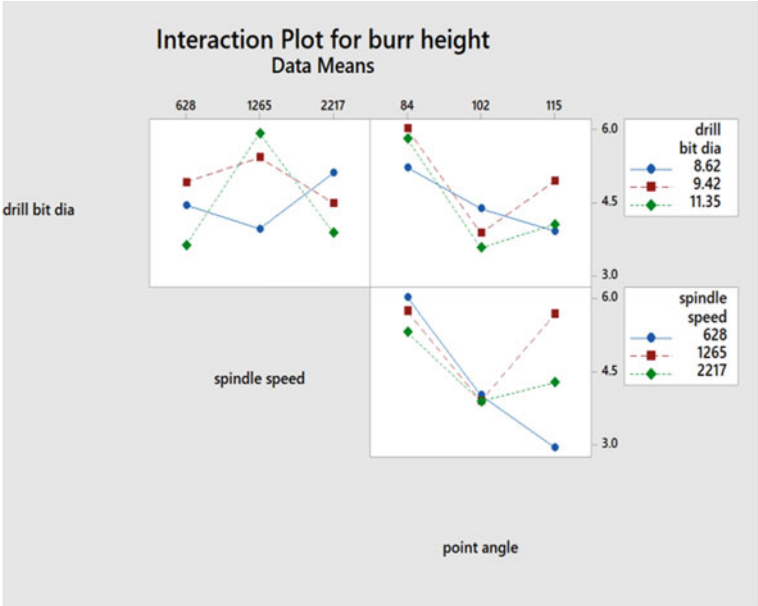

Fig. 2 Interaction plot for burr height

Table 5 Optimum level process parameters for burr height

Process parameters	Drill bit diameter	Point angle	Spindle speed
Optimum levels	11.35 mm	102°	628 rpm

- Feed also plays a vital role during machining. It is clear that alternation of spindle speed and point angle gives positive effect on burr formation.
- The best machining value of different process parameters for burr height are spindle speed of 628 rpm, drill bit diameter of 11.35 mm and point angle of 102°.
- The best machining value of different process parameters for burr thickness are spindle speed of 628 rpm, drill bit diameter of 11.35 mm and point angle of 115°.

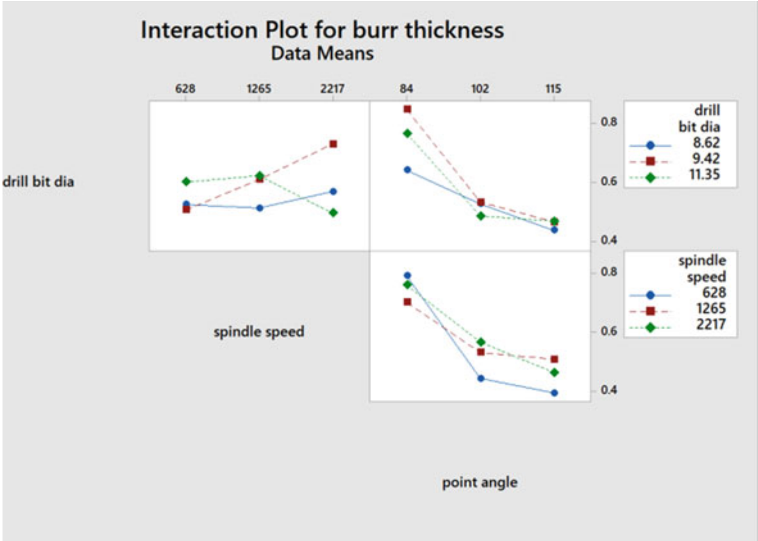

Fig. 3 Mean effect plot for burr thickness

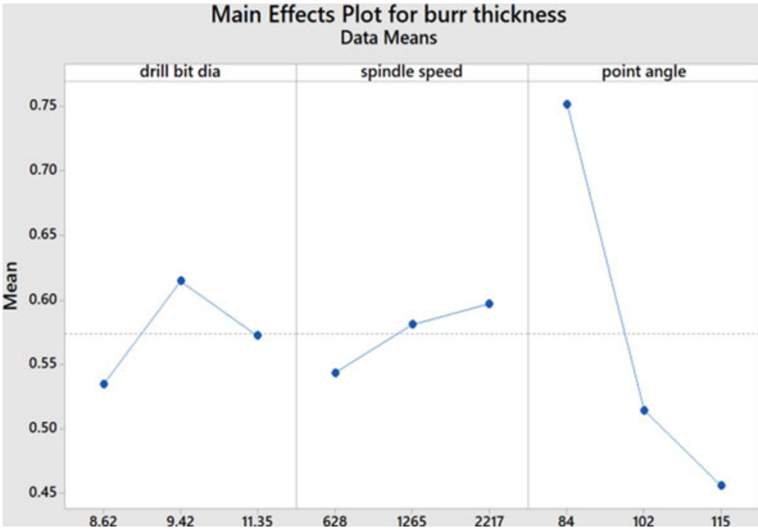

Fig. 4 Interaction plot for burr thickness

Table 6 Optimum level process parameters for burr thickness

Process parameters	Drill bit diameter	Point angle	Spindle speed
Optimum levels	8.62 mm	115°	628 rpm

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