Vol-07 Issue 08, August-2023 ISSN: 2456-9348
Impact Factor: 6.736

International Journal of Engineering Technology Research & Management
www.ijetrm.com

EXPERIMENTAL ANALYSIS ON OPTIMIZATION OF MACHINING PARAMETERS TO MINIMIZE THE FORMATION OF BURR IN AL-SIC COMPOSITES

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ABSTRACT
Burr formation is very common phenomenon during various machining process such as drilling results into deterioration of quality of produced material and reduces the strength of the component. Therefore it is very important to reduce it to optimum level with the help of geometry and various other process parameters. The concentrated parameters in this project are its cutting speed, point angle of drill bit, the concentration of silicon carbide reinforcement and its feed rate. Various methods are available out of which the combination of "Response Surface Method" and "Taguchi Technique" is used to obtain the optimum limit to take burr formation to optimum level. However the most influencing parameters to responses are the point angle of drill bit, the feed rate and the percentage mixture of silicon carbide reinforcement material in the matrix say 30%. It can be concluded that higher the concentration of silicon carbide, enhancing the point angle and lowering down the feed rate resulted into optimum burr formation.

Keywords:
Al-SiC metal matrix composite; Burr formation; the point angle of drill bit, the feed rate; taguchi technique; response surface method.

INTRODUCTION

The usage of aluminum and silicon carbide is increasing now-a-days. Due to its vast use of application in application industry, put its focus as many machining operations are performed during assembly of components through drilling process [1]. In aerospace industry assembling of parts is very common phenomenon for which drill is made [2]. When drill is made through composite it very common to get burrs at entry, intermediate and at exit point due to plastic deformation [5]. It is needed to completely eliminate it as sharp, uneven edges of burr is non-desirable [8]. Non removal of such burrs may led to the problem of misalignment of parts, cracks in the assembly and lowering the strength of the assembly ultimately led to fatigue failure when subjected to cyclic loading [13] . Hence these burrs need to be removed which is a time consuming and expensive process because of the involvement of soft abrasives against hard material.
Drilling is the process of producing and enlarging holes with the help of drill bits[15]. Various cutting tool is present out of which twist drill is most common. Standard material used are high speed steel with some modification in the percentage of carbon and coating material. In this solid carbide tool is used to make drill[17].
Burrs are mainly the minute undesirable extended part that flow along-with the hole and appear as fine wire of edges or simply can be referred to as extra unwanted material keeps on the surface after machining operation[21]. The main cause behind it is the plastic deformation happens during the machining process.
By manipulating the drilling parameters, it is possible to minimize it. Here we have used Al-SiC composite plate to perform drilling operation. Parameters such as the cutting speed, point angle of drill bit and concentration of reinforcement material in the matrix is observed. With the help of taguchi technique and response surface method we will try to obtain the most appropriate or ideal burr height and burr thickness.

1. Experimentation and method

This project is focused on obtaining most appropriate the height and thickness of burr by varying the drill parameters as mentioned above. This work is to be carried out on Al-SiC metal matrix composites in CNC vertical milling machine. "Response Surface Methodology (RSM)" is used to plan experimental analysis in MINITAB 19 software with 27 experiments.

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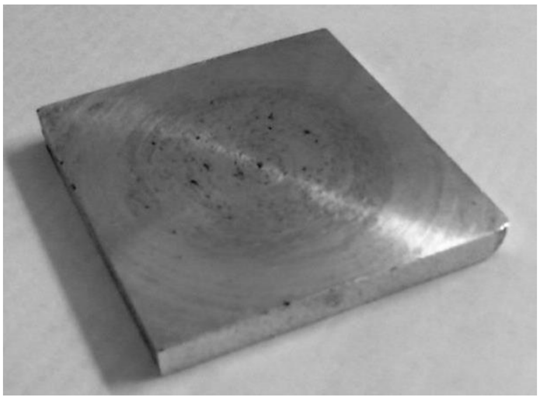

Figure 2.1: AL-SiC workpiece

a. Material composition

Table 2.1: Chemical composition of Al6061 alloy

Magnesium	**Silicon**	**Copper**	**Iron**	**Titanium**	**Vanadium**
0.766	**0.354**	**0.214**	**0.132**	**0.019**	**0.013**
Manganese	**Zinc**	**Chromium**	**Zirconium**	**Nickel**	**Aluminium**
0.029	**0.085**	**0.166**	**0.024**	**0.012**	**98.186**

Table 2.2: Mechanical properties of work pieces

Material	Density (gm/cm^3)	Hardness value (HRB)	Ultimate Tensile Strength (MPa)	Thermal Conductivity (W/mK)	Elastic Modulus (GPa)
Al6061	2.71	47.1	322	167	68.1
Al6061+15%SiC	2.86	73	375	173	193
Al6061+30%SiC	2.95	80	395	184	211

Total 4 factor and 3 levels of each are selected, hence a combination of 27 experiments by Box-Behenken design was selected.

Table 2.3: Various Machining Parameters and Their Levels

Factors		Levels		
		+1	0	-1
Cutting speed(m/min)	A	80	60	40
Feed rate(mm/rev)	B	0.2	0.15	0.1
% of SiC	C	30	15	0
Point angle(degrees)	D	140	118	96

Table 2.4 shows the combination of 27 experiments by Box Behnken design was selected.
Table 2.4 also shows L27 orthogonal array, having factors as A, B,C, and D.
Also -1,0 and 1 to be indicating the levels. In L27 orthogonal array, 27 experiments have to be conducted.

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Table 2.4: Experimental Runs in coded terms and actual terms

Run No.	A	B	C	D	Run No.	Cutting Speed	Feed Rate	% of SiC	Point Angle
1	-1	-1	0	0	**1**	40	0.1	15	118
2	1	-1	0	0	**2**	80	0.1	15	118
3	-1	1	0	0	**3**	40	0.2	15	118
4	1	1	0	0	**4**	80	0.2	15	118
5	0	0	-1	-1	**5**	60	0.15	0	96
6	0	0	1	-1	**6**	60	0.15	30	96
7	0	0	-1	1	**7**	60	0.15	0	140
8	0	0	1	1	**8**	60	0.15	30	140
9	-1	0	0	-1	**9**	40	0.15	15	96
10	1	0	0	-1	**10**	80	0.15	15	96
11	-1	0	0	1	**11**	40	0.15	15	140
12	1	0	0	1	**12**	80	0.15	15	140
13	0	-1	-1	0	**13**	60	0.1	0	118
14	0	1	-1	0	**14**	60	0.2	0	118
15	0	-1	1	0	**15**	60	0.1	30	118
16	0	1	1	0	**16**	60	0.2	30	118
17	-1	0	-1	0	**17**	40	0.15	0	118
18	1	0	-1	0	**18**	80	0.15	0	118
19	-1	0	1	0	**19**	40	0.15	30	118
20	1	0	1	0	**20**	80	0.15	30	118
21	0	-1	0	-1	**21**	60	0.1	15	96
22	0	1	0	-1	**22**	60	0.2	15	96
23	0	-1	0	1	**23**	60	0.1	15	140
24	0	1	0	1	**24**	60	0.2	15	140
25	0	0	0	0	**25**	60	0.15	15	118
26	0	0	0	0	**26**	60	0.15	15	118
27	0	0	0	0	**27**	60	0.15	15	118

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3. RESULTS AND DISCUSSION

3.1 Modelling Of Height And Thickness Of Burrs

Table below shows analytical result which contains 27 combination of the above mentioned four parameter i.e. its feed rate, cutting speed, the point angle of drill bit and concentration of silicon carbide. It gives the complete idea of the experiments to be conducted.

Table 3.1 Burr height and burr thickness

Run No.	Burr Height at four positions (mm)				Average Burr Height (mm)	Run No.	Burr Thickness at four position(mm)				Average Burr Thickness(mm)
	1	2	3	4			1	2	3	4	
1	0.841	0.588	1.133	0.998	0.891	**1**	0.2811	0.306	0.3354	0.1618	0.2709
2	0.92	1.231	0.332	1.664	1.036	**2**	0.2712	0.2945	0.1911	0.3423	0.2747
3	1.074	1.328	1.156	0.862	1.105	**3**	0.3224	0.26	0.2891	0.2364	0.2868
4	1.584	2.702	0.946	0.89	1.53	**4**	0.422	0.3268	0.2871	0.2256	0.3153
5	2.48	2.121	1.316	2.024	1.985	**5**	0.5267	0.4312	0.571	0.1603	0.4223
6	1.481	0.772	0.805	1.304	1.09	**6**	0.2811	0.2248	0.3104	0.1369	0.2383
7	0.812	1.072	1.082	0.421	0.846	**7**	0.3318	0.217	0.1572	0.2376	0.2368
8	1.242	0.768	1.138	0.338	0.871	**8**	0.2928	0.1727	0.2092	0.2481	0.2307
9	1.06	1.268	0.741	1.132	1.092	**9**	0.2892	0.353	0.3098	0.2665	0.3055
10	2.56	1.462	1.736	1.479	1.81	**10**	0.4346	0.2826	0.2767	0.3149	0.3272
11	1.273	0.805	1.92	1.598	1.4	**11**	0.3205	0.2612	0.2953	0.347	0.306
12	1.75	1.304	0.512	1.04	1.151	**12**	0.2235	0.2715	0.3624	0.3335	0.2977
13	0.531	1.282	0.671	0.985	0.868	**13**	0.2707	0.3285	0.285	0.2814	0.2923
14	1.38	1.115	0.67	1.163	1.082	**14**	0.2376	0.2767	0.2201	0.2812	0.2539
15	0.367	0.933	0.49	0.576	0.592	**15**	0.2232	0.2693	0.1298	0.1937	0.204
16	1.136	1.052	1.472	0.472	1.033	**16**	0.3049	0.2855	0.2955	0.2506	0.2841
17	0.521	1.189	1.508	0.727	0.987	**17**	0.3246	0.3323	0.1553	0.219	0.2578
18	2.121	1.847	1.42	2.521	1.978	**18**	0.3542	0.3338	0.4597	0.3971	0.3862
19	0.664	0.367	1.18	1.34	0.887	**19**	0.2533	0.3289	0.2871	0.1803	0.2624
20	0.532	1.045	0.833	0.992	0.85	**20**	0.258	0.2	0.2207	0.1965	0.2195
21	0.723	0.89	0.992	1.191	0.949	**21**	0.428	0.217	0.361	0.2273	0.3073
22	1.623	1.753	0.846	2.743	1.741	**22**	0.36	0.303	0.2582	0.3401	0.3176
23	0.074	0.351	0.782	0.114	0.375	**23**	0.1894	0.1575	0.1485	0.1688	0.1661
24	1.642	1.116	1.48	0.708	1.237	**24**	0.3066	0.2784	0.2394	0.324	0.2871
25	0.655	0.225	0.87	1.112	0.715	**25**	0.2477	0.2043	0.181	0.1751	0.202
26	0.638	1.024	0.571	0.423	0.664	**26**	0.169	0.2211	0.1747	0.1917	0.1891
27	0.624	0.812	0.714	0.975	0.782	**27**	0.247	0.2696	0.2035	0.18439	0.226

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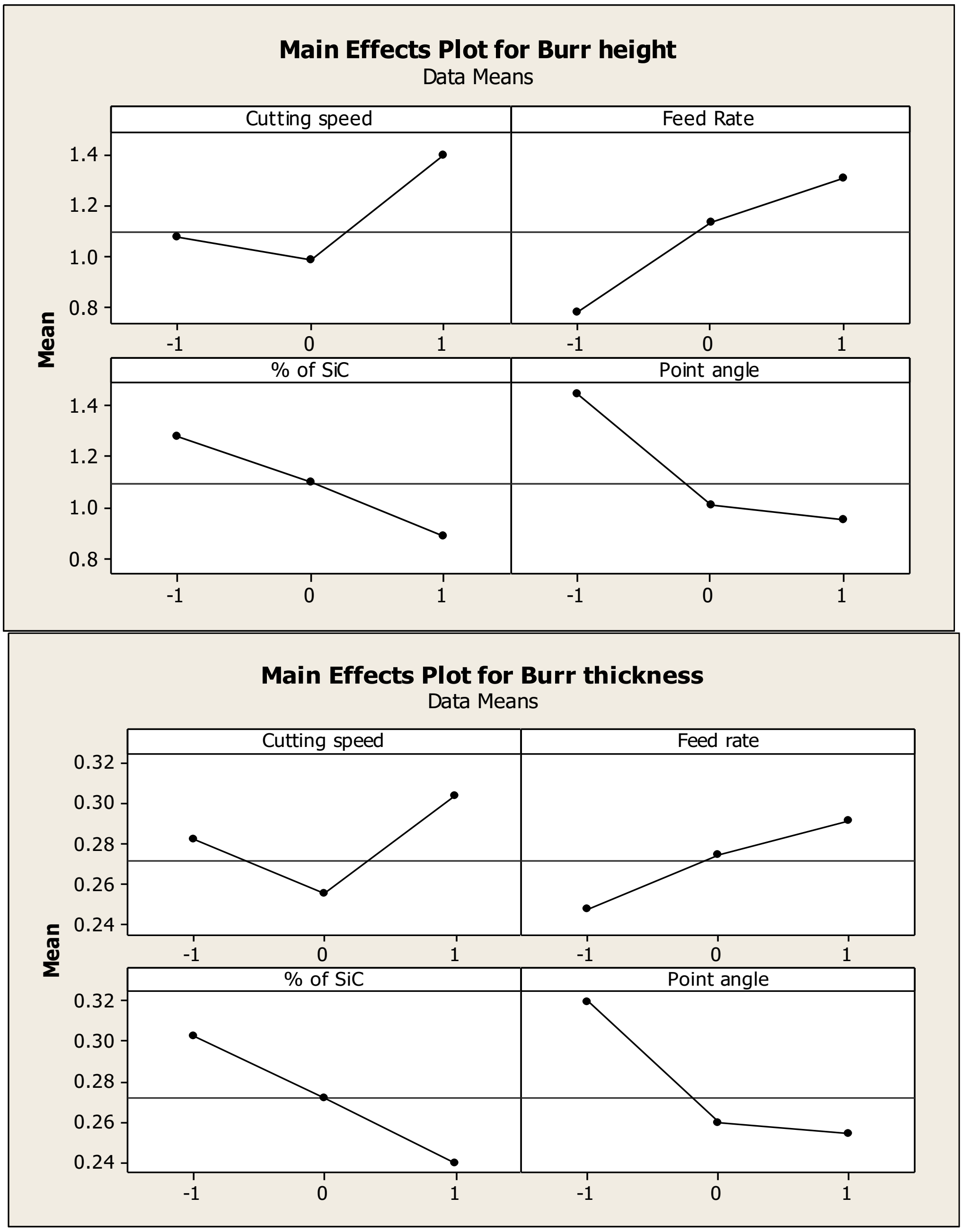

Figure 3.1: Main effects graph for Mean Height and Thickness of Burr

3.2 Response surface modelling of burr height

The non-linear equation of second order is developed to analyse the effect of various parameters on burr height. Response surface equation for four factors are being considered in this project [16]

$$y = \beta_0 + \sum_{j=1}^{4} \beta_j x_j + \sum_{j=1}^{4} \beta_j x_j^2 + \sum_i^3 \sum_j^4 \beta_{ij} x_i x_j + \varepsilon \quad .....(5)$$

Where, y: response and x_j: coded values for j = *f*, *v*, *w* and θ

Coefficients of regression for the equations to be determined as β_0, β_j, β_{ij}.

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Table 3.3: Analysis of Variance Results for Burr Height and Burr Thickness

Source	Sum of Square	DOF	Mean Square	F-value	P-value ProbF	Source	Sum of Square	DOF	Mean Square	F-value	P-value ProbF
Model	3.99341	14	0.28524	7.84	0 (significant)	Model	0.07441	14	0.0054	6.92	0.001 (significant)
A - cutting speed	0.31285	1	0.31286	8.6	0.013	A - cutting speed	0.00143	1	0.00143	1.83	0.2
B - Feed rate	0.82306	1	0.82307	22.62	0	B - Feed rate	0.00439	1	0.00439	5.62	0.035
C - % of SiC	0.47044	1	0.47044	12.93	0.004	C - % of SiC	0.01403	1	0.01403	18.1	0.001
D - Point angle	0.72835	1	0.72834	20.02	0.001	D - Point angle	0.01292	1	0.01292	16.57	0.002
A^2	0.42388	1	0.65457	18.01	0.001	A^2	0.00833	1	0.01592	20.41	0.001
B^2	0.01236	1	0.02119	0.59	0.47	B^2	0.00017	1	0.00292	3.73	0.076
C^2	0.00393	1	0.08485	2.32	0.152	C^2	0.0008	1	0.00386	4.95	0.045
D^2	0.48557	1	0.48558	13.34	0.004	D^2	0.01139	1	0.01139	14.62	0.003
AB	0.01973	1	0.01974	0.53	0.474	AB	0.00016	1	0.00016	0.21	0.665
AC	0.2514	1	0.2515	6.91	0.023	AC	0.00734	1	0.00734	9.42	0.011
AD	0.24582	1	0.24583	6.75	0.022	AD	0.00022	1	0.00022	0.28	0.602
BC	0.01255	1	0.01254	0.35	0.567	BC	0.00351	1	0.00351	4.51	0.056
BD	0.00489	1	0.00488	0.14	0.721	BD	0.00307	1	0.00306	3.92	0.072
CD	0.19848	1	0.19847	5.47	0.039	CD	0.00791	1	0.00791	10.16	0.008
Residual	0.43642	12	0.03634			Residual	0.00936	12	0.00078		
Total	4.4298	26				Total	0.085	26			

3.3 Response surface modeling of burr thickness

Expression for Burr thickness (in coded terms of process parameters):

$$T = 0.205701 + 0.010932A + 0.019124B - 0.034193C - 0.032816D + 0.054620A^2 + 0.023391B^2 + 0.026918C^2 + 0.032817D^2 + 0.006174AB - 0.042823AC - 0.00751AD + 0.029624BC + 0.027674BD + 0.044474CD$$

Expression for burr height:

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$H = 0.721 + 0.1654A + 0.2519B - 0.1880C - 0.23636D + 0.3403A^2 + 0.3117D^2 - 0.2517AC - 0.2469AD + 0.21275CD$

Expression for burr thickness:

$T = 0.2157 + 0.019125B - 0.0331C - 0.03381D + 0.054619A^2 + 0.02591C^2 + 0.031817D^2 - 0.042725AC + 0.02862BC + 0.02757BD + 0.0454CD$

4. Conclusions

CNC machine is used to conduct the experiment using solid carbide drills. Height and thickness of burr under various drilling conditions and for different combination of feed rate, cutting speed, percentage of silicon carbide reinforcement and point angle were collected. Different results are obtained from the experiments through responses. The "Response Surface Method" model based in terms of feed rate, point angle, the cutting speed, percentage of silicon carbide reinforcement were developed as per the design of experiments. Mains contribution of the study is to the minimize burr size produced during drilling and finding out most appropriate drill parameters with the help of combination of "Taguchi technique" and "Response Surface Methodology(RSM)"

4.1 Scope for future work

The scope to work in this direction is immense where study related to the relation between height and thickness of burr with drill geometry, speed, feed and concentration of reinforcement can be further increased and some other future work is proposed hereby:-

1. Analysis of the relation between point angle and burr size on heat treated material along with heat treated reinforcement material.
2. In present work Al-SiC micro-composite was used. Instead study can be done on nano-composite as a specimen material.

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