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Effect of Drilling Process Parameters on Surface Roughness of LM6/B_4C Composites

C. Sarala Rubi, J. Udaya Prakash

Abstract: ***Metal matrix composites are a new course of materials with superior properties to those of the components. Such materials ' machining is distinct from that of traditional materials. So the optimization of machining process parameters becomes inevitable. By applying Taguchi's Signal-to-Noise ratio method, this paper examines the effects of drilling process parameter such as feed, spindle speed, drill material and percentage reinforcement on the drilled hole's surface roughness. Variance analysis was used to evaluate each system parameter's contribution to surface roughness. The composites were manufactured by stir casting technique using aluminium alloy (LM6) as matrix material and boron carbide particulates at 3%, 6% and 9% by weight as material for the reinforcement. There are four factors investigated each at three levels, so 3^4 which implies 81 experiments has to be conducted, but by using Design of Experiments approach 27 experiments were conducted using L_{27} orthogonal array The minimum surface roughness measured for the hole was 1.08 µm at combination of 3000 rpm spindle speed, 50 mm/min feed rate, 3% reinforcement and Carbide drill.***

Keywords: ***ANOVA, Composites, Drilling, Surface Roughness, Taguchi Technique.***

I. INTRODUCTION

Metal matrix composites (MMCs) are a new range of non-metallic materials in a metal matrix with properties that are superior to those of the components [1]. Such materials are used in automotive brake rotors and in IC engines for various parts. These materials have generally less weight and more wear resistance. Drilling of these materials is distinct from traditional materials [2].

A need for thorough and systematic analysis of their machining behaviour was expected due to increased engineering applications of these composites. The accurate and low cost drilling is needed for the desired surface finish [3]. The surface of the machining component is greatly influenced by parameters such as recrystallization, cracking, cavities, plastic deformation, micro hardness and residual stress [4]. Features such as roughness of the surface and surface damage of the machined component also affect properties such as corrosion, creep, fatigue life and dimensional accuracy of a machined component [5]. The main alarm when machining MMCs is the variation of micro structure just under the drilled surface [6]. Machining causes different geometric and metallurgical defects in the surface area and it is not possible to make conclusive decisions about the machinability of any material by looking wear rates of the tool. [7]. Nevertheless, due to the poor drilling properties of MMCs, it becomes a challenging task for manufacturing engineers. Unlike conventional materials machining, there are many problems with MMC drilling, such as high thrust forces burr formation and tool wear [8].

Taguchi is a powerful tool for the development of high-quality systems. To optimize the model for efficiency, quality and cost, it provides a simple, effective and systematic approach. If development parameters are qualitative and distinct, the technique is valuable [9]. The development of Taguchi parameters will optimize performance characteristics by setting design parameters and increasing system performance sensitivity to the origin of variation [10].

II. MATERIALS AND METHODS

A. Materials

Aluminum alloy LM6 is used as matrix material in this analysis and boron carbide is used as reinforcement. Materials selected for this investigation is purely on the basis of properties, cost and application. Aluminium alloy is hard to machine due to its dragging tendency and high silicon content. Aluminium composite (LM6) have the best protection under standard and marine conditions. Table I shows the composition of the mixture of LM6 Aluminum using Optical Emission Spectrometry (ASTM E 1251-07).

Table- I Composition of aluminum alloy (LM6)

Constituent	Si	Cu	Fe	Mg	Mn	Ti	Ni	Zn	Al
Weight %	11.48	0.013	0.52	0.02	0.01	0.02	0.01	0.01	Remainder

B. Fabrication of Aluminium Matrix Composites

Aluminum alloy ingots LM6 are set in a crucible of graphite and melted in an electric furnace. At 800 ° C, the melt was degassed. To create a vortex, the molten metal was stirred and the boron carbide particles preheated (250° C) were added. The slurry has been stirred for 10 minutes at 600 rpm in order to ensure better wettability of particles with molten metal. Ti has been added for good wettability of composites enhanced by B_4C.

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* Correspondence Author
C.Sarala Rubi, Department of Physics, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India, Email:csaralarubi@veltech.edu.in
Dr.J.UdayaPrakash* Department of Mechanical Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India, Email: udayaprakashj@veltech.edu.in

The weight-added percentage of B_4C was 3, 6 and 9% by wt. The molten stirred metal was poured into cast iron mould (preheated at 650°C) and then solidified. The stir casting set up is shown in figure 1.

Fig. 1. Stir Casting Setup

C. Drilling of AMCs

Drilling of composites of the metal matrix is an effective machining technique. The tests were performed with prefixed cutting conditions at the Vertical Machining Center (VMC 100). To capture and record experiment data, the computer-controlled data acquisition system is used. The thrust force is measured by the Kistler dynamometer. The photograph of VMC and drills used in this research work is shown in figures 2 and 3 respectively.

Fig. 2. Vertical Machining Centre

Fig. 3. Photograph of Drills

Surface roughness of the machined component was measured using surface roughness tester (Surfcorder SE 3500) and shown in figure 4.

Fig. 4 Surface Roughness Tester

D. Design of Experiments

The experimental program was designed to determine the factors that influence the drilling process in order to achieve minimum surface roughness. The experiments were established on the basis of an orthogonal array of L_{27} in order to relate the effect of reinforcing percentage, drill material, speed and feed. Table II displays the system parameters and their levels.

Table- II Process Parameters and their Levels

Level	Feed	Speed	Drill	Reinforcement
1	50	1000	HSS	3 %
2	100	2000	Carbide	6 %
3	150	3000	Coated Carbide	9 %

III. RESULTS AND DISCUSSION

The selected set was the L_{27} with 27 rows. The columns were given the factors and the interactions. The experimental plan consisting of 27 runs in which the first column is allocated to feed, the second column to speed, the fifth column to drill material, the eighth column to reinforcement percentage and the interactions to the remaining columns were used. Table III demonstrates the experimental results.

Table III Experimental Results

Expt. No.	Feed (mm/min)	Speed (rpm)	Drill	R %	SR (µm)	S/N Ratio
1	50	1000	HSS	3	3.24	-10.20
2	50	1000	Carbide	6	2.26	-7.09
3	50	1000	Coated	9	2.30	-7.25
4	50	2000	HSS	6	1.71	-4.64
5	50	2000	Carbide	9	2.64	-8.42
6	50	2000	Coated	3	2.84	-9.06
7	50	3000	HSS	9	3.04	-9.66
8	50	3000	Carbide	3	1.08	-0.67

9	50	3000	Coated	6	1.86	-5.38
10	100	1000	HSS	3	3.26	-10.27
11	100	1000	Carbide	6	3.14	-9.93
12	100	1000	Coated	9	2.20	-6.85
13	100	2000	HSS	6	1.52	-3.64
14	100	2000	Carbide	9	2.04	-6.18
15	100	2000	Coated	3	2.62	-8.35
16	100	3000	HSS	9	3.80	-11.59
17	100	3000	Carbide	3	1.65	-4.37
18	100	3000	Coated	6	2.97	-9.46
19	150	1000	HSS	3	3.11	-9.84
20	150	1000	Carbide	6	2.71	-8.65
21	150	1000	Coated	9	3.52	-10.93
22	150	2000	HSS	6	2.20	-6.86
23	150	2000	Carbide	9	2.60	-8.30
24	150	2000	Coated	3	3.59	-11.11
25	150	3000	HSS	9	2.86	-9.14
26	150	3000	Carbide	3	3.44	-10.72
27	150	3000	Coated	6	2.55	-8.14

All models, plots and analysis are performed using Minitab statistical software in this study. Figure 5 shows that the surface roughness is directly proportional to feed rate, drill material and the percentage of the material strengthening and decreases with the speed of the spindle.

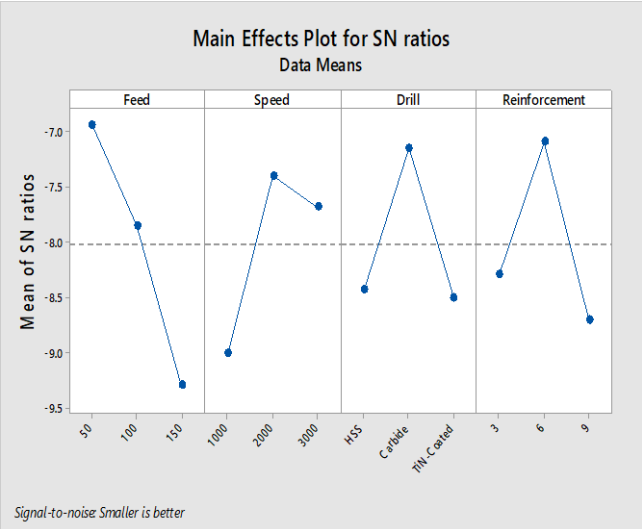

Fig. 5. Response Graphs

For each variable level, Table IV shows the average feature of each response. The table contains delta-based ranks comparing the magnitude of the relative impact. The delta value for each element is the least average of the largest minus. Ranks are allocated based on values of delta; rank 1 for the highest value of delta, rank 2 for the second highest, and so on. The ranks indicate that feed has the highest impact on the roughness of the surface, followed by the percentage of reinforcement, rate and drill content. Figure 5 shows that the level 1 of the feed, the level 2 of the spindle speed, level 2 of the drill material and the level 3 of the strengthening percentage provide the optimum S / N ratio.

Table IV Response Table

Level	Feed	Speed	Drill	Reinforcement
1	**-6.932**	-9.002	-8.428	-8.289
2	-7.85	**-7.397**	**-7.149**	**-7.089**
3	-9.3	-7.682	-8.504	-8.703
Delta	2.368	1.605	1.355	1.614
Rank	1	3	4	2

Table VI ANOVA Table

Source	DF	SS	MS	F	Contribution
Feed	2	25.654	12.827	1.01	14.656
Speed	2	13.202	6.601	0.52	7.542
Drill	2	10.433	5.216	0.41	5.960
Reinf %	2	12.656	6.328	0.5	7.230
Feed*Drill	4	17.188	4.297	0.34	9.820
Feed*Drill	4	9.47	2.368	0.19	5.410
Feed*Reinf	4	10.372	2.593	0.2	5.926
Pooled Error	6	76.063	12.677		43.455
Total	26	175.039			100.000

Variance analysis (ANOVA) was performed to assess the contribution of device variables to the roughness of the surface.Table 5 describes the surface roughness S / N data. The feed is important from the ANOVA table. The interacti ons have been pooled into the term of error.

Confirmation Experiment:

In order in determine the optimal conditions, experimental results were examined. From Figure 5, optimum parameters for achieving minimum surface roughness are the variables at level F1, S2, D2, R2 which is feed rate 50 mm / min, spindle speed 2000 rpm, Carbide drill and 6% reinforcement. Using Taguchi Technique, the optimal parameters are used to perform the confirmation test and also to estimate the surface roughness. The predicted surface roughness is 1.67 µm and the experimental value is 1.70 µm. So for this research work, optimization holds good.

IV. CONCLUSIONS

The following conclusions were drawn by analyzing the impact of drilling process parameters of aluminum matrix composites.

i) Aluminium matrix composites (LM6/B_4C) 3%, 6% and 9% were successfully manufactured through stir casting technique.

ii) Feed has the highest statistical influence on surface roughness followed by interaction between drill material and feed.

iii) The confirmation experiments show that there is a marginal error associated with the surface roughness.

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AUTHORS PROFILE

C.Sarala Rubi received her B.Sc Physics from Manonmaniam Sundaranar University, Tirunelveli in 2006, and M.Sc Physics from the University of Bharathidhasan, Trichy in 2008. She was awarded M.Tech in 2010 by Anna University in Nano-Science and Technology. Her research interests include composites of the metal matrix, thermoelectric materials, and nano-materials. Six academic papers have been published in authoritative foreign journals.

Dr. J. Udaya Prakash obtained his B.E. (Mechanical Engineering) from University of Madras in the year 1996, M.E. (Production Engineering) from Anna University, Chennai in the year 2000 and Ph.D. (Mechanical Engineering) from Anna University, Chennai in the year 2016. His research interests include Metal Matrix Composites, Wire EDM, Tribology and Drilling of MMCs. Published 36 research articles in reputed International journals.