International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Optimization of Machining Parameters in Drilling of Aluminum Matrix Composites (LM6/Fly Ash) utilizing Taguchi Technique

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Abstract: The present study revolves around the possibility of setting machining parameters in the drilling of composites of aluminum matrix (LM6/Fly ash) using the signal to noise ratio analysis. The aim of this work is to consider, the impact of input parameters, feed, speed, drill and percentage of composite material reinforcement on thrust force during AMCs drilling. AMCs were manufactured by the stir casting process with LM6 aluminium alloy as matrix material and fly ash as reinforcement material. Investigations were directed on a CNC vertical machining center for estimating thrust force. The Taguchi strategy for trial configuration is a generally admitted system employed for delivering great items requiring less effort. In the same way, L_{27} orthogonal array is employed for the analyses. The response table, graphs and variance analyzes are used to demonstrate the potential environment and the effects of machining parameters. It is evident that there is a tremendous improvement in the drilling procedure by using this methodology.

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

I. INTRODUCTION

Metal matrix Composites (MMCs) due to their rough properties are difficult to machine. It is necessary to build up an apt method of upheaval for their powerful machining. AMCs plays a prominent role in day-to-day mechanical world [1]. MMCs have got a considerable concern due to their designing properties [2]. Composite materials are manufactured by the process of stir casting, in which ceramic particles are blended together with a liquid metal. This process is carried out by methods of mechanical mixing and hardening of the liquefy [3]. Fly ash has become a matter of concern among the scientists due to its low density [4]. In the final stage of processing, drilling is put through, and these drilled holes are considered as stress concentration locations. Hence utmost care is taken to the service failures [5, 6]. While drilling, the thrust force must be kept under control. The structures are joined by drilling and this drilling is necessary for other applications [7].

Revised Manuscript Received on December 30, 2019.
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There is a huge variation between the drilling customary metals and their composites to that of MMC [8]. Design of Experiment (DoE) is an astounding technique for illustrating and analyzing the impact of different control factors. DoE along with Taguchi technique is designed to automate processes and to assess the optimum combination of factors [9]. Taguchi gives an astonishing and effective working policy under various conditions. Taguchi has been designed, in such a way, so that it can consider the effect of several factors and defines the plan of experiment [10]. Experiments are carried out to find out the limitations that affect the response. To test the current variance, this approach uses a non-exclusive S / N ratio. Such S / N ratios are used as measures of the effect on the performance characteristics of noise factors [11]. ANOVA is a statistical tool used in response to design parameters or their interactions. ANOVA calculates and expresses in percentage the relative contribution of the control variable to the overall measured response. [12].

II. MATERIALS AND METHODS

A. Materials

Aluminum alloy LM6 is used as matrix material in this analysis and fly ash 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) acts as the best protection under both standard and marine conditions. It can be rendered comparatively thinner and more complicated than any other casting alloy type. Table I showed 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

Fly ash particles of 12 microns were used as the reinforcement for this work. The use of fly ash particles increases hardness, wear resistance, damping properties and strength, and decreases the weight of aluminum alloy. Fly ash particles can be used in composite metal matrix because discontinuous dispersions as they are available in large quantities as a low cost and low density waste from thermal power plants.

Low density, low thermal conductivity and high electrical resistivity can be useful in making composites that are light weight.

Table II described the composition of fly ash using chemical analysis. Figure 1 revealed the morphology of fly ash particles.

Table- II Chemical composition of Fly Ash

Constituent	Al	Si	O	Fe	Ti	K	Ca	LOI
Weight %	16.73	26.43	38.88	3.82	1.42	0.99	0.5	Remainder

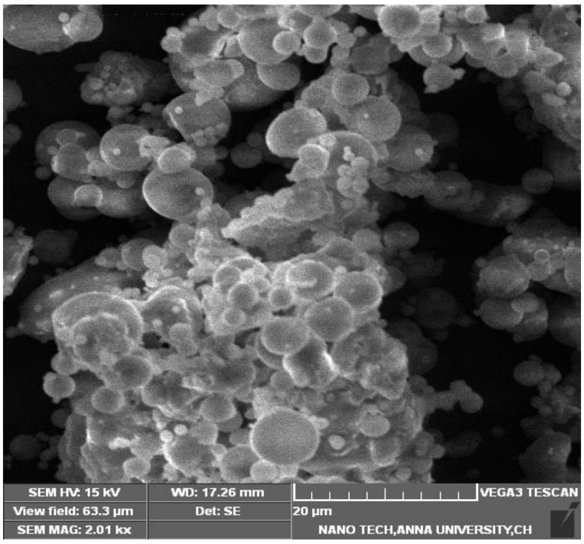

Fig. 1. Morphology of fly ash particles

B. Fabrication of Aluminium Matrix Composites

Aluminum Alloy LM6 ingots are placed in a crucible of graphite and melted in an electric furnace. The temperature rose gradually to 850^o C. The melt was degassed with degasser at 800^o C. To create a vortex, the molten metal was stirred and the fly ash particles preheated (250^o C) were applied. The slurry has been stirred for 10 minutes at 600 rpm in order to ensure better wettability of particles with molten metal, magnesium (1% wt) was added to the molten metal. The percentage of fly ash added by weight was 3, 6, and 9%. The stirred molten metal was poured into cast iron mould which is preheated (650^o C) and then cooled to room temperature.

Fig. 2. 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.

Fig. 3. Vertical Machining Centre

D. Design of Experiments

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

Table- III 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 corresponding to the number of three-level experiments with 13 columns. 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, the eighth column to reinforcement and the interaction and other results of the remaining columns were used. Table IV demonstrates the experimental results.

Table IV Experimental Results

Expt. No.	Feed (mm/min)	Speed (rpm)	Drill	R %	Thrust Force(N)	S/N Ratio
1	50	1000	HSS	3	153	-43.7
2	50	1000	Carbide	6	127	-42.1
3	50	1000	Coated	9	123	-41.8
4	50	2000	HSS	6	111	-40.9
5	50	2000	Carbide	9	119	-41.5
6	50	2000	Coated	3	84	-38.5
7	50	3000	HSS	9	96	-39.7
8	50	3000	Carbide	3	132	-42.4
9	50	3000	Coated	6	88	-38.9
10	100	1000	HSS	3	238	-47.5
11	100	1000	Carbide	6	188	-45.5
12	100	1000	Coated	9	225	-47.0
13	100	2000	HSS	6	188	-45.5
14	100	2000	Carbide	9	143	-43.1
15	100	2000	Coated	3	131	-42.4
16	100	3000	HSS	9	164	-44.3
17	100	3000	Carbide	3	157	-43.9
18	100	3000	Coated	6	141	-43.0
19	150	1000	HSS	3	286	-49.1
20	150	1000	Carbide	6	210	-46.4
21	150	1000	Coated	9	210	-46.5
22	150	2000	HSS	6	230	-47.2
23	150	2000	Carbide	9	155	-43.8
24	150	2000	Coated	3	192	-45.7
25	150	3000	HSS	9	183	-45.3
26	150	3000	Carbide	3	175	-44.9
27	150	3000	Coated	6	185	-45.4

All models, plots and analysis are performed using Minitab statistical software in this study. Figure 4 shows that the thrust force increases with an increase in feed and decreases with an increase in the spindle speed, the type of drill and the percentage of the material strengthening.

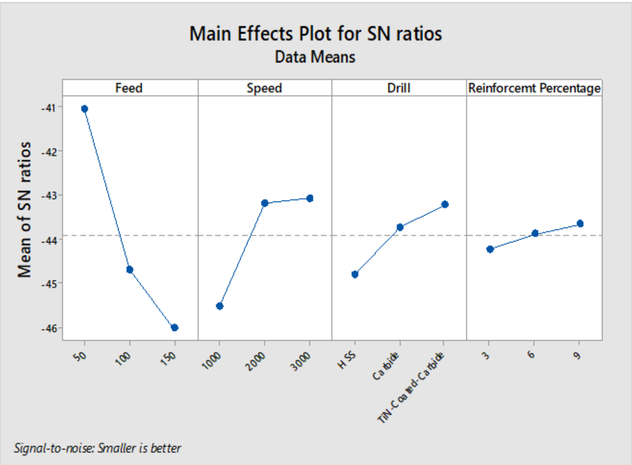

Fig. 4. Response Graphs

The Table V shows the average feature of each response for each variable level. The table contains delta-based ranks comparing the relative magnitude of impact. The delta value for each element is the largest minus the least average. Ranks are allocated based on values of delta; rank 1 at the highest value of delta, rank 2 at the second highest, etc. The ranks indicate the overall significance of the answer to each variable. The ranks and delta values indicate that feed has the greatest impact on the strength of the thrust, followed by the speed of the spindle and the size of the drill. Figure 4 shows that the level 1 of the feed, the level 3 of the spindle frequency, the level 3 of the drill form and the level 3 of the strengthening percentage provide the total S / N thrust ratio.

Table V Response Table

Level	Feed	Speed	Drill	Reinforcement
1	-41.05	-45.52	-44.8	-44.23
2	-44.69	-43.18	-43.74	-43.88
3	-46.02	-43.07	-43.23	-43.66
Delta	4.97	2.45	1.57	0.57
Rank	1	2	3	4

Table VI ANOVA Table

Source	DF	SS	MS	F	Contribution
Feed	2	119.2	59.6	67.67	63.26 %
Speed	2	34.5	17.2	19.56	18.28 %
Drill	2	11.6	5.8	6.58	6.15 %
Reinf %	2	1.5	0.8	0.85	0.80 %
Feed*Drill	4	9.4	2.3	2.66	4.97 %
Pooled Error	14	12.3	0.9		6.54 %
Total	26	188.5			100 %

Analysis of variance (ANOVA) was conducted to test the importance of the system variables towards the Thrust Force. Table 6 describes the S / N data ANOVA for the Thrust Power. At 5 percent sense point, the F-value from the table is $F_{0.05,\ 2,\ 14}$ = 3.74 and $F_{0.05,\ 4,\ 14}$ = 3.11. So we see from the ANOVA table that the type of feed, spindle Speed and drill is significant. The interactions were pooled up into the error term.

Confirmation Experiment:

In order in determine the optimal conditions, experimental results were examined. From Figure 4, optimum parameters for achieving minimum thrust force are the variables at level F1, S3, D3, R3 which is feed rate 50 mm / min, spindle speed of 3000 rpm, TiN Coated carbide drill and 9 percent reinforcement. Using Taguchi Technique, the optimal parameters are used to perform the confirmation test and also to estimate the thrust strength. The thrust force value predicted is 74 N and the thrust force experimental value is 76 N. So the methodology of optimization is perfect for this research work.

IV. CONCLUSIONS

Through optimizing the drilling process parameters of AMCs, the following conclusions was drawn.

i) Feed (63.26%) has the highest statistical effect on composite thrust strength values followed by spindle speed (18.28%) and drill size (6.15%).

ii) The cumulative error associated with the ANOVA is 6.54% because the parameters indicate a confidence level of 90 percent.

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

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