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OPTIMIZATION OF MACHINING PARAMETERS FOR ALUMINUM AND SILICON CARBIDE COMPOSITE USING GENETIC ALGORITHM

C.Dhavamani [a] **T.Alwarsamy** [b]
[a] *Assistant Professor, Mechanical Engineering Department, Mahendra Engineering College, Tiruchengode – 637 503, India*
E-mail: dhava_cs@ yahoo.co.in
Tel: +910 94430 99759; Fax: +91 04288 238777

[b] *Professor of Mechanical Engg, Liaison Officer, DOTE , Chennai – 600 025*

Abstract

Aluminium matrix particulate composites are one of the materials finding wide ranging applications in automobile, aerospace and military industries because of their attractive properties such as high strength to weight ratio, high wear resistance, high temperature stability, etc Though most engineering components aluminium matrix particulate composites are primarily manufactured in near net shape, machining of Metal matrix composites (MMCs) have joined the group of difficult-to-cut materials because of the inherent abrasiveness of ceramic reinforcements. The main objective of this paper is to study of drilling of Aluminium Silicon Carbide (AlSiC) is investigated. Optimum machining condition for maximizing metal removal rate and minimizing the surface roughness is determined using desirability function approach. The influences of different parameters in machining Al/SiC particulate composite have been analyzed in detail. Aluminium hybrid composites reinforced with Silicon carbide particulates were fabricate by stir casting methods. Different volume fractions of SiC (10, 15 & 20% vol) were used for synthesis. This paper attempts to establish a comprehensive mathematical model for correlating the interactive and higher-order influences of various machining parameters using Taguchi method with an L 27 fractional factorial design were selected for the present experiment to obtain the optimal settings of factors and study their effects on multiple performance characteristics . Analysis of variance (ANOVA) has been performed to verify the fit and adequacy of the developed mathematical models. In the present work, a multiple regression model is used to represent relationship between input and output variables and a multi-objective optimization method based on a Genetic Algorithm (GA) is used to optimize the process.
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1. Introduction

Currently, the use of composite materials has increased in various areas of science and technology due to their special physical and mechanical properties. Automotive, aircraft and train companies need to replace steel and cast iron in mechanical components with lighter high strength alloys like Al and Metal Matrix Composites (MMC). Despite the superior mechanical and thermal properties of particulate Metal Matrix Composites, their poor machinability is the main deterrent to their substitution of metal parts. Machining is a material removal process and therefore is important for the final fabrication stage prior to application. Consequently the development of effective machining methods, leading to a reduction in the overall cost of components, is one of the major challenges yet to be solved. In this paper, a multi-objective optimization method, based on a Taguchi technique and using genetic algorithms, is proposed to obtain the optimal parameters in drilling of composite materials. The models of used properties are obtained from experimental data.

Several authors [1-10], when reporting on drilling of composite materials by conventional tools, have shown that the quality of the holes is strongly dependent on the cutting parameters, tool geometry and tool materials. An inappropriate choice of these parameters can lead to an unacceptable surface quality of the hole.
[1], Drilling of Al/SiCp Metal Matrix Composites in which Surface roughness, flank wear reduction by taguchi technique by Gul Tosum & Mehtap Muatoglu. [2], Improvement of the Mechanical Properties of 2124 Al/SiCp MMC plate by optimization of the solution treatment by M.P Thomas & J.E king. [3], Failure analysis of Woven fabric composites with moulded in holes to achieve Fatigue crack growth resistance and Improve tensile properties by H.J.Lin, C.C.Tsai & J.S.Shu [4], Buckling optimization of symmetrically laminated plates with various geometries and end conditions to improve Uniaxial compression (i.e.) Maximum Buckling resistance by Sequential linear Programming technique by Hsuan-Ten, Bor-Hornglin [5], Delamination analysis of carbon fiber reinforced laminates :Evaluation of a special step drill in which Maximize thrust force during drilling and Delamination, Minimize Delamination by Antonio.T.Marques , Luis M.Durao, Antonia.G.Magalhanes, [6], Optimization of process parameters during drilling of Glass-fiber Polyester reinforced composites using DOE and ANOVA by N.S.Mohan,S.M.Kulkarni, [7], Application to Taguchi method in the optimization of cutting parameters for turning operation by Guey-Jiuh Tzou, Ding-yeng chen, , [8], Some Studies on drilling of hybrid metal matrix composites based on Taguchi Techniques the tool used is Solid Carbide,Multiface drill, 5mm diameter by Taguchi Technique , ANOVA by S.Basavarajapa

Nomenclature	
μm	- Micrometer
Al/SiC composites.	- Silicon Carbide Aluminium metal Matrix
Al	- Aluminium
Dia	- Diameter
F	- Feed
S	- Cutting Speed
Min	- Minute
T	- Time of machine
V	- Percentage of reinforcement

MRR	- Metal Removal Rate
Mm/rev	- Millimeter per revolution
Rpm	- Revolution per minute
Sec	- Second
$W/mm^3/min$	- Watt per millimeter cube per minute.
GAs	- Genetic Algorithms.

2. Experimental study

2.1 Primary machining characteristics

The work material used was 2124 Aluminium alloy (7 Si 0.33mg 0.3Mn 0.5 Fe 0.1 Cu 0.1 Ni 0.2 Ti) reinforced with green bonded silicon carbide particles of size 25 µm with different volume fractions manufactured through stir casting route. In this research, Al - SiC composites were produced varying percentage of SiC (ie 10,15, 20, wt %) by two step stir casting method. Stir casting setup

The tool wear measurement was made by an optical microscope with the following specifications. VERSAMET 3, working distance 1 to 5.5mm, magnification 50 to 1000X, illumination - 12V, 100W

The specific energy is measured as the ratio of net power consumed to the metal removal rate. The power was measured using a single element Electro dynamometer types, MECO G SP 1 single –phase wattmeter with the following specifications voltage 250/500V, current 5/10 amp, and accuracy +1%.

The centre line average value of the surface roughness was measured with the help of a MITUTOYA SURF III surface tester. The specifications of the tester is as follows : Speed of traverse 2-5 mm/sec., range of traverse – 2.5mm/sec., driving system reciprocating motion, line voltage-ac 100-220V, 50/60 HZ, accuracy +2.5% , power-2VA, measuring range – 0.3-100 microns.

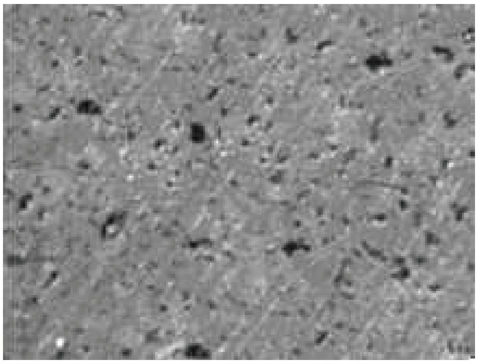
Tools used are SANVICK solid tungsten carbide drill with the specifications as below R410.5 0400 30 01, R410.5 0700 30 01 & R410.5 1000 30 01 and the work piece dimensions are 10mm X 40mm X 250mm. The drill tests are conducted and the results are listed in table 1.

3. Microstructure Analysis

Optic microscope and Scanning Electronic Microscope (SEM) were employed to analyze the microstructure and also the wear surface profile to decide the wear mechanism of the material. Samples were mechanically polished using standard metallographic practices and etched with Keller’s regent prior to micro structural examination.

Figure 1 *(Al – 10wt % SiC Composites (stirring at semi solid state)*

Figure 2 *(Al -10wt % SiC Composites (stirring at liquid state)*



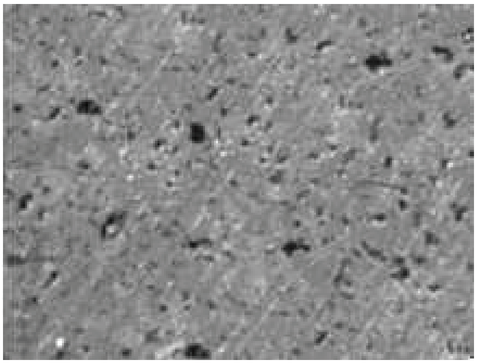


Table 1: Experimental data obtained

Sl. No	% vol.of SiC	Cutting Speed m/min	Feed Rate mm/rev	Dia of drill mm	Machining time min	Flank wear mm	Specific energy X10-3 W/mm3/min	Surface roughness micrometer
1	10	400	0.12	4	2	0.141	38.157	9.02
2	10	400	0.22	7	4	0.232	528.393	12.09
3	10	400	0.40	10	6	0.435	75.100	14.31
4	10	1000	0.12	7	4	0.343	34.283	7.56
5	10	1000	0.22	10	6	0.581	52.245	9.57
6	10	1000	0.40	4	2	0.352	41.568	8.60
7	10	1500	0.12	10	6	0.718	36.881	6.79
8	10	1500	0.22	4	2	0.579	31.973	6.53
9	10	1500	0.40	7	4	0.734	44.907	8.19
10	15	400	0.12	7	6	0.413	68.531	9.21
11	15	400	0.22	10	2	0.261	66.895	7.56
12	15	400	0.40	4	4	0.542	81.881	11.38
13	15	1000	0.12	10	2	0.368	42.710	4.23
14	15	1000	0.22	4	4	0.683	56.961	7.61
15	15	1000	0.40	7	6	0.996	74.658	8.78
16	15	1500	0.12	4	4	0.815	40.211	5.40

17	15	1500	0.22	7	6	1.166	57.424	6.67
18	15	1500	0.40	10	2	0.678	51.444	5.12
19 20	25	400	0.12	10	4	0.560	90.228	5.90
20	25	400	0.22	4	6	1.118	112.290	8.75
21	25	400	0.40	7	2	0.651	102.520	6.54
22	25	1000	0.12	4	6	1.212	71.697	5.47
23	25	1000	0.22	7	2	0.778	71.321	4.38
24	25	1000	0.40	10	4	1.133	98.295	5.62
25	25	1500	0.12	7	2	0.910	50.347	3.11
26	25	1500	0.22	10	4	1.293	75.604	4.27
27	25	1500	0.40	4	6	1.969	87.256	5.12

4. Optimization

In this part of study, the second order polynomial models developed for primary machining characteristics are further utilized to optimize the cutting conditions using non-linear goal programming. The goal programming problem formulation involves the following steps.

1. Determination of decision variables.
2. Formulation of objectives
3. Assigning objectives to priority levels
4. Forming the achievements function.

The input parameters used in the experiments are taken as the decision variable. The goals or targets are fixed for each objective. i.e. Metal Removal Rate, Tool wear, Specific energy and surface roughness using statistical means of the experimental results. The boundary conditions of each variable are also considered as objectives. The priority levels for the goals are fixed according to their importance. The objective of the achievement functions is to minimize the deviations from the target values. The problems are solved using pattern search technique. When the achievement function is 0.0 the goal is achieved from the particular objective. The under achievement and over achievement are the deviations from the goals fixed for the maximization and minimization objectives respectively. For minimization of an objective, the over achievement should be minimized and for the maximization of an objective, the under achievement should be minimized.

5. Formulation of the optimization problem

5.1 Decision variables

The cutting parameters are used as decision variables, in the examined optimization problem. These variables are Cutting Speed, S, Feed, F, and Diameter of drill, D,

In Composition parameters, % volume of SiC also used as a decision variable.

5.2 Objective functions

In this multi-objective optimization, four different and mutually conflicting objectives are selected to be optimized. The first objective is the Metal Removal Rate, MRR, which can be computed by the expression: $MRR = \Pi/4 * D^2 * F * S$

The second optimization objective is Flank wear. Flank wear should be minimized

The third optimization objective is Specific energy. Specific energy should be minimized.

The fourth optimization objective is surface roughness. Surface roughness should be minimized.

5.3Description of the GAs process

To solve the multi-objective optimization problem, Gen.and Liu have proposed alternative approach: a genetic algorithm for solving nonlinear goal programming problem because genetic algorithms belong to the class of problem-independent and probabilistic algorithms and can handle any kind of objective functions and any kind of constraints. Due to its evolutionary nature, a genetic algorithm performs multiple directional and robust searches in complex spaces by maintaining a population of potential solutions. Thus it provides us much ability to deal with much complex real-world nonlinear goal programming.

To handle the constraints, a mechanism was added. It is based on the following principles, which are proposed by kurpati et al. (13):

- In a given population, feasible solutions are preferred over unfeasible solutions.
- The amount of unfeasibility is an important piece of information and should not be ignored while handling constraints.
- The number of violated constraints is also important piece of information.

5.4Brief introduction to flow chart of GA process

Parameter setting - Gives the required input data.

Initialization process - Initialization pop size times of input values.

Evaluation - find out the deviation

5.5 Selection process

Arrange the deviation in ascending order along with all input values generate the random number and compare with cumulative probability of first deviation and find out new set of selection input values.

5.6Crossover operation

With the crossover probability, the first 2 sets of input values are interchanged and find out the new set of crossover input values.

5.7 Mutation process

Find out the input values which is not in range again go for the step of initialization to initialize a new set which is fall with in the range.

5.8 Termination set

Find out the optimum input values and deviations by comparing each and every steps of process until the ith generation process.

7. Outcomes and discussion

By using genetic algorithm using non-linear goal programming the optimal cutting conditions (i.e.) optimal cutting speed, feed, diameter of cut, machine time can be found out for different volume

Fixed Goals	Achievement functions	Decision variables

fractions of the AL/SiC along with the minimized optimum deviation values and optimum output values i.e. goal values.

Table 2: Results and Outcomes

MRR mm^3/min	Wear mm	Specific energy X10-^{3} W/mm^3 /min	Surface roughness µm	MRR mm3 /min	Wear mm	Specific energy X10 -3 W/ mm 3/min	Surface sroughness µm	% vol of SiC	Cutting speed rpm	Feed rate mm/rev	Dia of drill mm	Time in min
2765	0.48	77.11	10.0	0.0	0.0	0.0	0.0	10	897.22	0.24	4.00	2.0
8468	0.48	77.11	10.0	0.0	0.0	0.0	0.0	10	826.12	0.28	7.00	2.0
17281	0.48	77.11	10.0	0.0	0.0	0.0	0.17 OA	10	802.41	0.28	10.00	2.0
2765	0.71	60.75	6.92	0.0	0.0	0.0	0.19 OA	15	902.2	0.24	4.00	2.0
8468	0.71	60.75	6.92	0.0	0.0	10.2 OA	0.24 OA	15	902.0	0.24	7.00	2.0
17281	0.71	60.75	6.92	0.0	0.02 OA	10.4 OA	0.34 OA	15	902.2	0.24	10.00	2.0
2765	0.98	52.79	5.78	0.0	0.02 OA	0.0	0.0	25	927	0.22	4.00	2.0
8468	0.98	52.79	5.78	0.0	0.0	0.0	0.0	25	933.2	0.22	7.00	2.0
17281	0.98	52.79	5.78	0.0	0.0	0.0	0.0	25	928	0.23	10.00	2.0

OA – Over Achievements

By analyzing some decision could be taken, depending upon specific conditions of the desired drilling process. Increase in volume fraction increase average drill flank wear linearly in all direction. The increase in volume fraction of SiC increases the specific energy but decreases the surface roughness.

The increase in drill speed increases the flank wear. The increase in drill speed decreases the specific energy, but increases the surface roughness.

The increase in feed rate increases the specific energy and wear.

The increase in drill diameter has less effect on specific energy and has no effect on surface roughness.

The input parameters are Speed, Feed and Depth of cut. The output parameters are Flank wear and surface roughness. During the drilling process, when the speed value gets increased and the feed value gets decreased its corresponding thrust force and torque value gets decreased. This can be proved by using Minitab Software. The result of Minitab Software is shown in the graph given below.

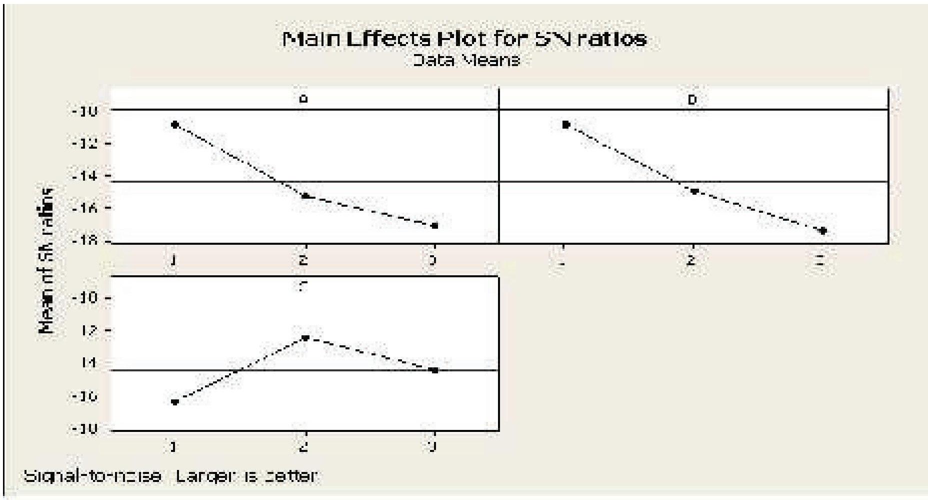


Fig 7.1 S/N ratios for drilling process

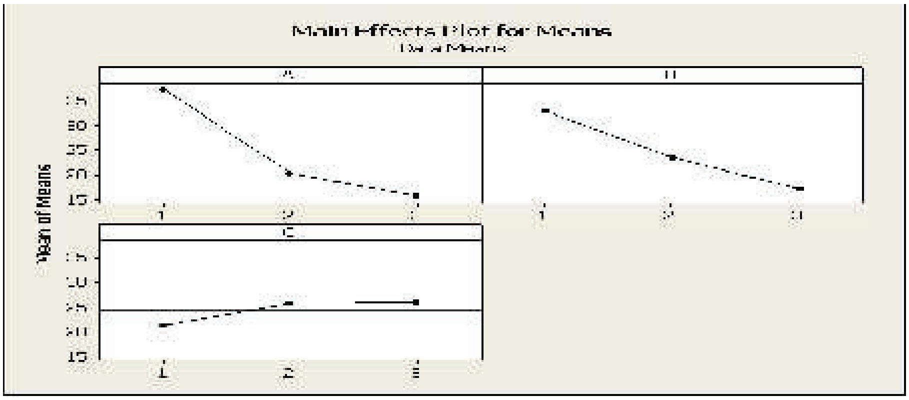


Fig 7.2 S/N ratios for mean value

8. Conclusion

In this work, effect of various factors (drilling speed, feed dia of cut) and few selected interaction process are studied for maximizing MRR, Surface finish and minimization of Specific energy and flank wear using Taguchi's parameter design, The analysis shows that factors like speed, feed, dia of cut play significant role in finish drilling operation.

In order to optimize both the objectives simultaneously, mathematical models are developed using non-linear regression method. The optimum search of machining parameters values for the objective of maximizing both MRR and SF are formulated as a multi-objective , multi variable, non-linear optimization problem.

The rationale behind the use of Genetic Algorithm has the capability to find the global optimal parameters whereas the traditional optimization techniques normally tend to be trapped at local optima.

The application of multi-objective optimization, which is based on an a Taguchi Method, increases the flexibility on selecting the optimal cutting parameters for drilling processes of composite materials. Simultaneously considering productivity and surface quality, as optimization objectives, one can choose the most adequate solution for each particular operation.

A genetic algorithms and non-linear goal programming procedure has been proposed for solving the problem of optimization of cutting conditions with the objective of minimizing the deviations. After a computational experimentation the proposed genetic algorithm is found to yield much better quality solutions.

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