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Optimal machining conditions for turning of Al/SiC MMC using PSO and Regression analysis

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ABSTRACT

Machining of composite materials is an important and current topic in modern researches on manufacturing processes. In this research study of turning of Aluminium Silicon Carbide (Al/SiC) is investigated. The objective of this research manufactures the AMC through a liquid metallurgical route by varying the percentages of SiC particles (5% and 10%). The study employs CNC turning operation and establishes a mathematical relationship between three process parameters, e.g., cutting speed, feed, and depth of cut and surface roughness (R_a). The matrix composite used in the study is Aluminium alloy with Silicon Carbide (SiC) particles as the reinforcement. Analysis of variance 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 Particle Swarm Optimization (PSO) is used to optimize the process

Keywords – Aluminium Metal matrix composites, machining, Surface roughness, Regression Analysis, PSO

1. Introduction

Aluminium Metal matrix composites (AMC) materials possess light weight and high strength compare to common structural materials and are extensively used in automobiles and aerospace applications (Allision, J.E., Gole, G.S., 1993)[3] Kadirgama et al. (2010). An attempt has been made to manufactures the AMC and employs CNC turning operation and establishes a mathematical relationship, based on a Regression analysis and using PSO, is proposed to obtain the optimal parameters in turning of composite materials. Muthukrishnan et al (2008 b)[9] studied the application of ANOVA and ANN analysis for optimization of machining parameters in turning Al/SiC composites. They concluded that ANOVA and ANN modeling techniques provide a systematic and effective methodology for the optimization. Raviraj Shetty et al (2009) [10] studied the taguchi optimization methodologies to optimize the cutting parameter in turning of age hardened Al/SiC – MMC with CBN cutting tool. Authors analysed the data using ANOVA with the help of commercial software package Minitab -15.

2. Experimental details

2.1 Work material

The material selected were Aluminium 6061 alloy and Metal matrix composites of Aluminium. The test specimens are cast into ø30x80mm sizes, to accommodate 8samples machining in each piece. Specimens are rough machined to get shaft. The diameter is maintained 25mm to ensure rigidity of mounted piece in the chuck. The specimen is machined with four different input parameters for 60mm length on each piece.

TABLE 2.1: Chemical Composition of Work Materials

Wt %	6061 Alloy	Al/SiC (5%)	Al/SiC (10%)
Al	97.6	92.94	87.64
Si	0.68	0.64	0.62
Fe	0.61	0.57	0.54
Cu	0.021	0.019	0.018
Ti	0.053	0.05	0.046
Mg	0.92	0.881	0.81
Mn	0.044	0.0418	0.038
Zn	0.072	0.0676	0.062
Cr	0.005	0.0047	0.0044

Fig 2.1: Al/SiC (5%&10%) work pieces

2.2 Experimental plan and cutting conditions

The experiments were carried out on a CNC turning centre machine (Siemens 802D) Core carbide engineering works Hyderabad India. Specimens of Ø25 mm x 75mm size were used for the experimentation.

Fig 2.2: SIEMENS - 802D CNC

Fig 2.3: Experimental setup

The test specimen was mounted in a chuck. The experimental setup is shown in Fig.2.3. The required cutting speed, feed rate and depth of cut were incorporated in CNC part programming to perform the operations. Each sample was marked with corresponding trial number to identify the conditions used. The steps were repeated until the whole experiment was complete. The levels of the individual process parameters/factors are given in Table 2.2

TABLE 2.2: Process Parameters and their Levels

Sl. No	Parameter	Level 1	Level2	Level 3
1	Cutting speed mm/min	228	450	740
2	Feed rate mm/rev	0.05	0.08	0.1
3	Depth of cut mm	0.4	0.6	1

The instrument used for measuring surface finish was surface tester. Mitutoyo Talysurf was used to measure surface roughness of each trial sample. This device consists of a tracer head and an amplifier. The head housed a diamond stylus, having a point radius of 0.003mm, which been against the surface of the work and may be moved by hand or it may be another driven. Any movement of the stylus covered by surface irregularities is converted into electric fluctuations by the tracer head. These signals are magnified by the amplifier and registered on the digital display. The readings shown on the digital display indicates the average height of the surface roughness. The roughness readings were taken in random order to average out effects of uncontrolled variables which could be present in the experiment. Ra value was repeated at least 3 times and then average of these values was recorded.

2.3 Statistical Analysis

The mathematical relationship between responses and machining parameters was established for Al/SiC (5%) (1) and Al/SiC(10%) (2) using the multiple regression analysis. In the present study, the correlation between the process parameters cutting speed, feed rate, depth of cut and surface roughness are established. The multiple linear regression models were obtained using statistical software MINITAB. Mathematical relationship between responses and machining parameters.

$$Ra = -18.7 - 0.00122\,A + 443\,B + 10.4\,C + 0.000001\,AA - 2541\,BB - 4.71\,CC - 0.0015\,AB - 0.00229\,AC + 40.7\,BC \quad \text{------- (1)}$$

$$Ra = -3.61 + 0.00252\,A - 14.2\,B + 13.2\,C - 0.000002\,AA + 640\,BB - 9.67\,CC - 0.0407\,AB + 0.00212\,AC + 21.1\,FD \quad \text{------- (2)}$$

Where A is speed in mm/min; B is feed in mm/rev; C is Depth of Cut in mm.

The use of ANOVA is to analyze the influence of process parameters like cutting speed, feed rate, depth of cut, number of cutting edges, and step over distance on surface roughness.

3. Particle Swarm Optimization

The initial ideas on particle swarm are essentially aimed at producing computational intelligence by exploiting simple analogues of social interaction, rather than purely individual abilities. Each individual in the particle swarm is Composed of three D-dimensional vectors; where D is the dimensionality of the search space. The current position is x_i, the previous best position is p_i, and the velocity is v_i. The current position x_i can be considered as a set of coordinates describing a point in space. On each iteration of the algorithm, the current position is evaluated as a problem solution. If that position is better than any other that has-been found far, then the coordinates are stored in the second vector, p_i. The value of the best function result so far is stored in variable that can be called $pbest_i$ (“previous best”), for comparison on later iterations. The objective is to keep finding better positions and updating p_i and $pbest_i$. New points are chosen by adding v_i coordinates to x_i, and the algorithm operates by adjusting v_i, which can effectively be seen as a step size. If the search space is D-dimensional, the i[th] individual (particle) of the population (swarm) can be represented by a D-dimensional vector Xi = $(x_{i1}, x_{i2}\ldots x_{iD})^T$. The velocity (position change) of this particle can be represented by another D-dimensional vector, $V_i = (v_{i1}, v_{i2}, \ldots v_{iD})^T$. The best previously visited position of the ith particle is denoted as Pi = $(p_{i1}, p_{i2}, \ldots p_{iD})^T$. Defining g as the index of the global guide of the particle in the swarm, and superscripts denoting the iteration number, the swarm is manipulated according to the following two equations :

$v_{id}^{n+1} = \chi[w\ v_{id}^{n} + c_1 r_1^n (p_{id}^n - x_{id}^n)/\Delta t + c_2 r_2^n (p_{gd}^n - x_{id}^n)/\Delta t]$--(3)

$x_{id}^{n+1} = v_{id}^{n} + \Delta t\ v_{id}^{n+1}$--- (4)

where d =1, 2, . . . , D; i =1, 2, . . . , N; N is the size of the swarm population; χ is a constriction factor which controls and constricts the velocity's magnitude; w is the inertial weight, which is often used as a parameter to control exploration and exploitation in the search space; c_1 and c_2 are positive constant parameters called acceleration coefficients; r_1 and r_2 are random numbers, uniformly distributed in [0,1]; Δt is the time step usually set as 1 and n is iteration number.

4. Results and Analysis

Based on the mathematical model given by equations (1) and (2), the study on the effects of various machining parameters on Ra has been made so as to analyze the suitable parametric combinations that can be made for achieving controlled surface roughness. The plots were drawn for various combinations of Cs versus Ra, F versus Ra, D versus Ra and are shown in Figures - 4.1 and 4.2.

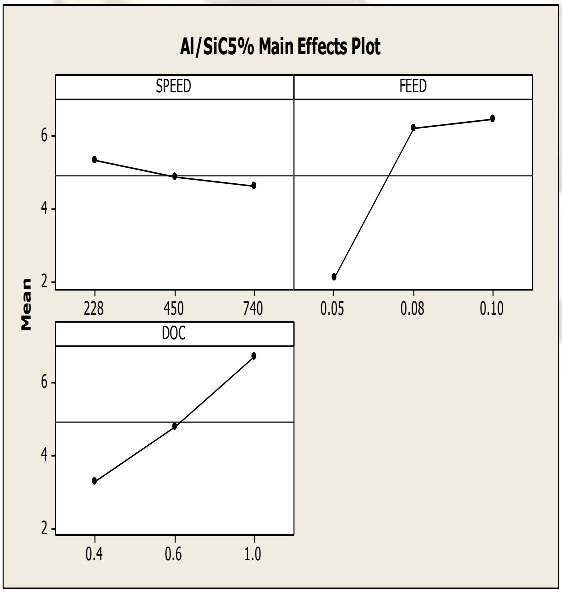

Fig4.1: Main Effects Plot of Al/SiC(5%)

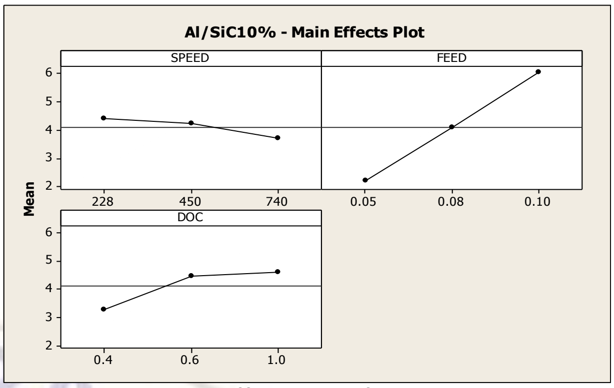

Fig 4.2: Main Effects Plot of Al/SiC (10%)

TABLE 4.1: Analysis of variance for SiC-5%

Source	DF	Seq SS	Adj SS	Adj MS	F	%P
A	1	2.59	0.02	0.02	0.03	1.42
B	1	97.9	17.1	17.1	25.1	53.7
C	1	54.2	1.64	1.64	2.3	29.7
AA	1	0.04	0.04	0.04	0.07	0.02
BB	1	13.7	13.7	13.7	20.21	7.52
CC	1	0.82	0.82	0.82	1.2	0.45
AB	1	0	0	0	0	0
AC	1	0.38	0.38	0.38	0.56	0.21
BC	1	1.17	1.17	1.17	1.72	0.64
Error	17	11.5	11.5	0.68		
Total	26	182				

TABLE 4.2: Analysis of variance for SiC-10%

Source	DF	Seq SS	Adj SS	Adj MS	F	%P
A	1	2.36	0.05	0.04	0.13	2.78
B	1	63.9	0.04	0.04	0.11	75.5
C	1	6.4	2.29	2.29	6.21	7.55
AA	1	0.09	0.09	0.09	0.24	0.12
BB	1	0.93	0.93	0.93	2.53	1.2
CC	1	3.26	3.26	3.26	8.84	3.84
AB	1	0.67	0.67	0.67	1.83	0.79
AC	1	9.41	9.41	9.41	1.13	0.48
BC	1	0.41	0.41	0.41	1.11	0.48
Error	17	6.27	6.2	0.36		
Total	26	84.8				

By using Brinell hardness tester, the hardness values are obtained. The hardness value for 5% SiC composite is 71 BHN and 104 BHN for 10% SiC composite.

By using particle swarm optimization the optimal cutting conditions (i.e.) optimal cutting speed, feed, depth of cut can be found out for different volume fractions of the AL/SiC along with the minimized optimum output values.

The optimal machining parametric combination obtained by PSO, viz., for Al/SiC-SiC5% cutting speed: 233 mm/min, feed rate: 0.05 mm/rev, depth of cut: 0.4 mm can be used to achieve minimum Surface roughness (Ra) of 1.2883μm and for Al/SiC-SiC10 cutting speed: 228 mm/min, feed rate: 0.05 mm/rev, depth of cut: 0.4 mm can be used to achieve minimum Surface roughness (Ra) of 1.558μm.

Conclusion

In this study, the PSO and Regression analysis was applied for analyzing surface roughness for two different compositions of Al/SiC composite. Based on experimental work, following conclusions were drawn.

1. From Fig 4.1, it is it is observed that Feed rate is found to be having minimum surface roughness at 0.05mm/rev at their by increasing up to 0.08mm/rev and then it is constant.
2. From Fig 4.2, it is observed that feed rate is the most influential factor and directly proportional for increase in surface roughness i.e., as feed increases the surface roughness also increases hence reduced feed is desirable for minimum surface roughness.
3. The hardness value for 5% SiC composite is 71 BHN and for 10% SiC composite is 104 BHN. Increase in percentage volume of SiC will increases the surface roughness due to the reason that, increase in percentage of SiC will increase the hardness of the specimen.
4. From the main effects plot, the surface roughness for both materials, improves with increase in cutting speed.

References

[1] N. Muthukrishnan, J. Paulo Davim, Optimization of machining parameters of Al/SiC-MMC with ANOVA and ANN analysis, *Journal of materials processing technology, 209 (2009) 225–232.*

[2] Pai Dayanand, Rao Shrikantha & Shetty Raviraj, Application of Taguchi and Response Surface Methodologies for Metal Removal Rate and Surface Roughness in Grinding Of Drac's, *International Journal of Engineering and Management sciences. Vol-3 2012.*

[3] Allision, J.E., Gole, G.S, Metal Matrix Composites in automotive Industry: opportunity and challenges, *Springer-Verlag Vol-45 1993.*

[4] H.Ganesan, G.Mohankumar, K.Ganesan, and K.RameshKumar, Optimization of Machining Parameters in Turning Process using Genetic Algorithm and Particle Swarm Optimization with Experimental Verification, *International Journal of Engineering Science and Technology Vol. 3 No. 2 Feb 2011.*

[5] Cui Yana, Wang Lifengb and Ren Jianyue, Multi-functional SiC/Al Composites for Aerospace Applications, *Chinese Journal of Aeronautics 21(2008) 578-584.*

[6] A. Chennakesava Reddy and Essa Zitoun, Matrix Al-alloys for silicon carbide particle reinforced metal matrix composites, *Indian Journal of Science and Technology vol. 3 No. 12 (Dec 2010).*

[7] Rabindra Behera and G. Sutradhar, Machinability of Lm6/Sicp Metal Matrix Composites with Tungsten Carbide Cutting Tool Inserts, *ARPN Journal of Engineering and Applied Sciences Vol. 7, No. 2, February 2012.*

[8] R. Ramanujam, R. Raju and N. Muthukrishnan, Taguchi Multi-machining Characteristics Optimization in Turning of Al-15%SiCp Composites using Desirability Function Analysis, *Journal of Studies on Manufacturing (Vol.1-2010/Iss.2-3).*

[9] Muthukrishnan; (2008,b) Machinability issues in turning of AlSiC(10p) metal matrix composites, *Int.Journal of Adv.Mfg.Tech, Vol.39, pp.211-218.*

[10] Raviraj shetty; (2009), Taguchi's techniques in machining of metal matrix composites, *J. of the Braz .society ofMech.Sci. & Eng. Vol.16, No.1, pp.12-20.*