ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Special Issue , August 2019

International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

Multi Objective Optimization of Machining Parameters of AA7075 Hybridmmc by desirability Function Analysis

V.Venkata Reddy , K.Srinivasulu Reddy

Mechanical Engineering Department, Acharya Nagarjuna University, Guntur, India

Department of Mechanical Engineering, Sreenidhi Institute of Science and Technology, Hyderabad, India
2

ABSTRACT: This paper presents optimization of machining parameters for turning of AA7075/SiC/FA(10 wt.%) hybrid metal matrix composite using desirability function analysis (DFA). The experiments were conducted using Taguchi's L16 orthogonal array on conventional lathe machine with tungsten carbide tool. The machining parameters such as depth of cut, cutting speed and feed rate are optimized by multi-response considerations namely material removal rate and surface roughness .The optimal machining parameters have been determined by the composite desirability value obtained from desirability function analysis, and significant contribution of parameters can be determined by analysis of variance (ANOVA). The analysis results shows that optimal combination for high MRR and low surface roughness are high spindle speed, low feed rate and high depth of cut. Confirmation test is also conducted to validate the test results. Experimental results have shown that machining performance can be improved effectively through this approach.

KEYWORDS: Turning, Material removal rate (MRR), Desirability function analysis (DFA).

I. INTRODUCTION

Aluminium alloys reinforced with ceramic materials are the new breed of engineering materials with improved properties like specific strength, superior resistance to corrosion and wear, higher hardness, lower coefficient of thermal expansion, higher resistance to thermal shock when compared to the unreinforced alloys [1,3-4]. Aerospace and automotive industries demand for materials with lightweight and improved mechanical properties. Hence researchers focused on fabrication and characterization of Aluminium metal matrix composites (AMMCs) with ceramic particulates reinforcement [1-2, 5-6]. Presence of hard ceramic reinforcements in the AMMCs, which makes them difficult to machine and make the surface rough leading to higher tool wear rate [7-9,11]. Automobile parts like engine blocks, cylinders, and pistons justify the importance of optimal machining process parameters.It was reported that feed rate is the most influencing parameter followed by the depth of cut and cutting speed for quality characteristics like surface roughness (Ra) and material removal rate (MRR) on turning of A356/5 wt.% SiCp, [8]. Pradhan and Sahoo [10] reported that the most significant parameter for the surface finish is feed, followed by cutting speed and depth of cut, during turning of SiC reinforced AMMCs with uncoated carbide inserts. Ciftci et al. [11] observed uncoated carbide tools produced better surface roughness values when compared to the coated carbide tools, during turning of Al 2014/SiC MMCs in dry machining condition. The present investigation is focused on turning performance of Al 7075/Fly ash/SiC AMMC in terms of Ra and MRR under dry machining condition with uncoated carbide tipped tool inserts.

II. EXPERIMENTATION DESCRIPTION

AMMCs having 10 % by weight SiC and Flyash particles of size 53µm were fabricated by stir casting route are taken as reference for machining as at this percentage, better mechanical properties were observed by Venkata Reddy et al [3]. The composites were prepared by stir casting route.Melting of A7075 ingots was performed in an electric furnace with graphite crucible. At 770°C, molten metal pool is stirred in the middle of the crucibleusing a mechanical stirrer at 500 rpm. SiC and flyash particulates are preheated and dropped uniformly into the melt. To avoid the agglomeration, smooth and continuous flow of the particles is ensured during stirring.As the casting is exposed to the atmosphere during the stirring,Argon inert gas shielding is maintained throughout for 2 to 3 minutes to avoid oxidation.Then, molten metal is poured into cast iron moulds which is preheated to 200 ^{0}C. The fabricated ingots were kept in a muffle furnace at 110 ^{0}C for 24hours to remove any residual stresses induced in the castings and to reduce the chemical inhomogenities.

Uncoated tungsten carbide inserts are used as cutting tool. Rough turning on fabricated ingots is first performed on Lathe machine to make specimens of uniform diameter as shown in figure 1. Initially, based on the available feeds, and speeds on the Lathe, pilot experiments were conducted to find the range of feeds and speeds for good surface finish and material removal rate. After identifying the levels for cutting speed, feed and depth of cut, Taguchi'sL16orthogonal array is selected for the design of experiments. Factors and their levels selected are given in Table1.

Table 1. Factors and levels selected

S.No	Factor	Notation	Unit	Levels of Factors			
				Level 1	Level 2	Level 3	Level 4
1	Cutting Speed	N	rpm	400	800	1200	1600
2	Feed	f	mm/rev	0.05	0.10	0.16	0.20
3	Depth of cut	d	mm	0.2	0.4	0.6	0.8

Figure 1. Specimens of A7075 reinforced with flyash and SiC.

Average surface roughness (Ra) of 16 specimens was measured with Surface Roughness measuring instrument Mitutoyo's Surftest SJ-210. Surface roughness is measured at three different locations and average value is taken.
For the productivity evaluation material removal rate was evaluated using empirical relation given by the Eq.1.
MRR=1000vfd mm^3/min (1)
(or) MRR = πDNfd, (2)
where N is spindle speed (rpm), v is cutting speed (m/min), D is diameter of the work piece (mm), f is feed (mm/rev) and d is depth of cut (mm).

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Special Issue , August 2019

International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

III. METHODS

A. Desirability Function Analysis (DFA)

Derringer and Suich [15] developed the technique of ''desirability function analysis" that can be widely applied in industries for simultaneous optimization of multiple basing on the principle that quality of a product or process possessing many features is completely unacceptable if it lies outside the desirable limit. Then, Candioti et al [16] optimized multiple responses by considering the solutions of Derringer and such to find the suitable operating conditions that satisfied the criteria of all the responses to provide a best value. In DFA, the optimization of multiple response characteristics is converted into compound desirability function analysis grade. The procedure involves is shown in fig.2. In this work it is decided to optimize simultaneously Ra and MRR. Experimental data sets based on L16 orthogonal array was used.

B. Analysis of variance.

A statistical technique applied to evaluate the difference among the available set of sources is Analysis of variance (ANOVA).ANOVA is applied to quantify the contribution of chosen input parameters over the output response. Inferences from ANOVA table can be used to identify the parameters responsible for the performance of the selected process and can control the parameters for better performance.

IV. RESULTS & DISCUSSIONS

A Calculating the compound desirability functional grade

The individual desirability response values and the compound desirability grade for each of the combination of parameters is given in Table 2. For surface roughness, 'lower-the-better' criterion is preferred and for MRR 'higher-the-better' criterion is preferred. On the other hand, in order to obtain an improved quality in the performances and to decrease the vagueness in the data, desirability function analysis method is additionally used for computing the compound desirability functional grade values.

B Desirability Functional Analysis

The 16 turned work pieces are tested for two output characteristics namely material removal rate and surface roughness. The material removal rate is measured as the multiplication of cutting speed, feed rate and depth of cut in mm^3/min and the surface roughness is with SJ -210 surf test in µm. For the experimental results, the individual desirability values are obtained using equations 1 and 2 and the values are given in the table 2. Finally, the individual desirabilites are combined interms of composite desirability (D_G) using the equation 3.For finding the composite desirability equal weightage is assumed i.e. 0.5 for both the performance characteristics.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

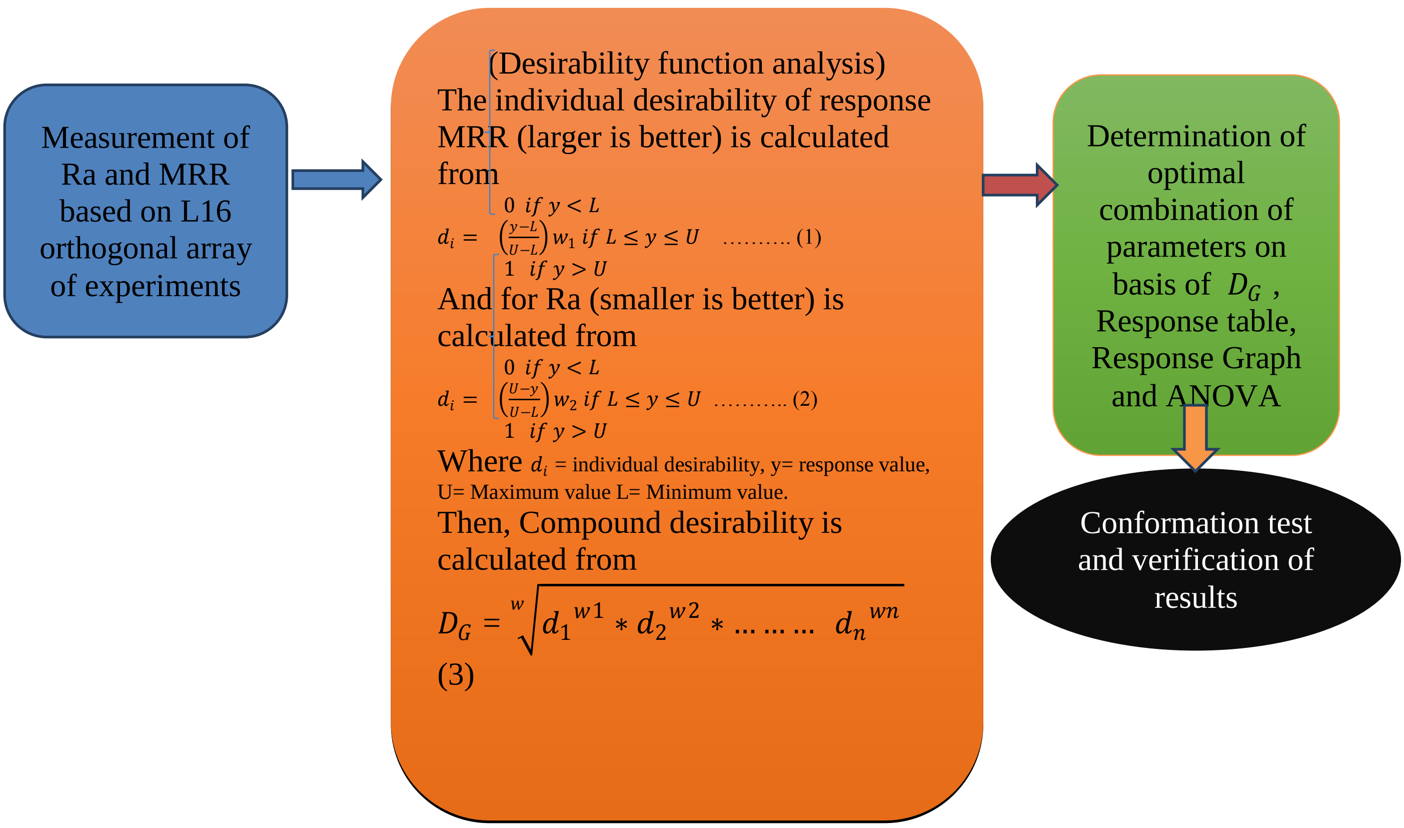

Fig.3 Steps for the desirability function analysis.

Table 2. L16 Orthogonal array, individual desirability values and compound desirability grade.

	L16 Design of experiments			Individual Desirability		
Exp. No.	Speed	Feed	DOC	d (Ra)	d (MRR)	CDFG
1	400	0.05	0.20	0.0000	0.8703	0.0000
2	400	0.10	0.40	0.3320	0.7769	0.5079
3	400	0.16	0.60	0.5517	0.4351	0.4900
4	400	0.20	0.80	0.7821	0.0000	0.0000

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

5	800	0.05	0.40	0.3498	0.8356	0.5406
6	800	0.10	0.20	0.3555	0.9102	0.5688
7	800	0.16	0.80	0.9870	0.6057	0.7732
8	800	0.20	0.60	0.9545	0.5858	0.7478
9	1200	0.05	0.60	0.5571	0.9546	0.7293
10	1200	0.10	0.80	0.9155	0.9166	0.9161
11	1200	0.16	0.20	0.5940	0.6706	0.6312
12	1200	0.20	0.40	0.9417	0.6249	0.7671
13	1600	0.05	0.80	0.7505	1.0000	0.8663
14	1600	0.10	0.60	0.9671	0.9760	0.9716
15	1600	0.16	0.40	1.0000	0.8737	0.9347
16	1600	0.20	0.20	0.7821	0.7692	0.7757

The effect of different machining parameters on composite desirability functional grade can be studied by using response graph and response Table 3. The mean response values for each level of parameter on composite desirability is calculated and presented in Table 3, and graphically shown in Figure 3. Basically, the larger the composite desirability, the better is the multiple performance characteristics. From the response graph and response table the best values of various parameters for the combined objective of minimum surface roughness and maximum metal removal rate are identified as high cutting speed, medium feed rate and high depth of cut shown in Figure 3.Based on Table 3 and Fig. 3, the optimum setting of the machining process parameters is found to be cutting speed at level four (1600 rpm) (A4), feed rate at level two (0.10 mm/min) (B2) and depth of cut at level four (0.60 mm) (C3). The use of these conditions will at the same time minimize the Ra and maximizing the MRR throughout machining within the range of factors studied.

Table 3. Response table for compound desirability functional grade (CDFG)

Machining Parameters	Level 1	Level 2	Level 3	Level 4	Delta	Rank
Cutting Speed (A)	0.2495	0.6576	0.7609	0.8871	0.6376	1
Feed Rate (B)	0.5341	0.7411	0.7073	0.5727	0.2070	3
Depth of Cut (C)	0.4939	0.6876	0.7346	0.6389	0.2407	2

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Special Issue , August 2019

International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

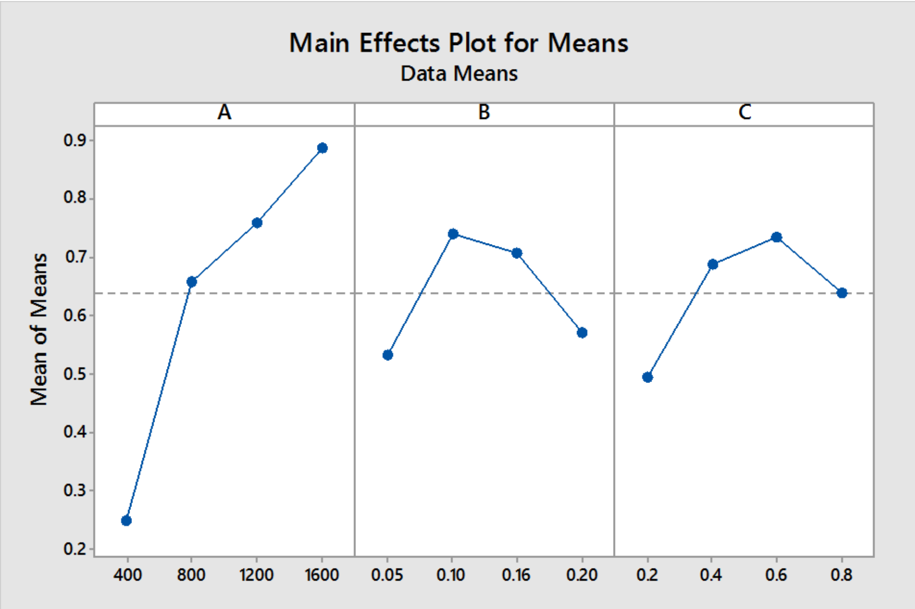

Fig. 3. Response graph for every level of machining parameters

Based on Table 3 and Fig. 3, the optimum setting of the machining process parameters is found to be cutting speed at level four (1200 rpm) (A4), feed rate at level two (0.10 mm/min) (B2) and depth of cut at level four (0.80 mm) (C4). The use of these conditions will at the same time minimize the Ra and maximizing the MRR throughout machining within the range of factors studied. The response equation of the GFRG is shown in **Eq.(7).** The main influencing factor for multi-performance is the maximum of this value (i.e. rank 1), which is cutting speed (A). Also the same information can be obtained from Fig. 8.

$$GFRG = 0.6313 - 0.000068\,A - 0.957\,B - 0.316\,C + 0.000000\,A*A - 3.49\,B*B - 0.292\,C*C + 0.000346\,A*B + 0.000328\,A*C + 3.414\,B*C \quad (7)$$

ANOVA is performed for analyzing the role of each factor on the multiple performance characteristics. The analysis is done at a confidence level of 95%. Fisher's F-test is employed to find out the change in which the process parameters have a significant effect on multiple performance characteristics. Larger F-value shows that the change of process parameters has a stronger influence on the performance characteristic. The results of the ANOVA are shown in Table 4. As in the ANOVA table of CDFG, the percentage contribution of the cutting speed is 43.43. This indicates that the cutting speed played a main role to determine the CDFG.

Table 4. ANOVA for CDFG

Source	DF	Seq SS	Adj MS	F-Value	P-Value
A	1	0.81283	0.021340	2.14	0.019
B	1	0.00228	0.093190	9.34	0.022
C	1	0.04646	0.081470	8.17	0.029
A*A	1	0.0795	0.079500	7.97	0.030
B*B	1	0.11837	0.110940	11.12	0.016
C*C	1	0.08373	0.083730	8.39	0.027

A*B	1	0.01358	0.019800	1.98	0.209
A*C	1	0.0153	0.015300	1.53	0.262
B*C	1	0.03811	0.038112	3.82	0.098
Error	6	0.05985	0.009975		
Total	15	1.27002			

V. CONCLUSION

In this present paper, machining of Al–10%FA/SiC metal matrix composite is carried out with input parameters considered as cutting speed, feed and depth of cut, and the response parameters as surface roughness, and MRR in lathe machine. Taguchi's L16 orthogonal array design is used for performing turning operation on the composite.

- It was found that a cutting speed of 1600 rpm, feed of 0.1 mm/min and a depth of cut of 0.80 mm is the optimal combination of input parameters.
- ANOVA statistics exposed that cutting speed is the most influencing factor in effecting the response parameters
- Therefore, it is concluded that the optimization procedure proposed in this present paper significantly improved the production of turning of Al–10%FA/SiC metal matrix composite.

REFERENCES:

1. Das, Diptikanta, et al. "Turning performance of Al 7075/SiCp MMC and multi-response optimization using WPCA and Taguchi approach." Materials Today: Proceedings 5.2 (2018): 6030-6037.
2. Venkata Reddy et al. "Studies on microstructure and mechanical behavior of A7075 -Flyash/SiC hybrid metal matrix composite" IOP Conf. Series: Materials Science and Engineering, 310 (2018) 012047.
3. Koli, Dinesh Kumar, Geeta Agnihotri, and Rajesh Purohit. "Advanced aluminium matrix composites: The critical need of automotive and aerospace engineering fields." Materials Today: Proceedings 2.4-5 (2015): 3032-3041.
4. Sarada, B. N., PL Srinivasa Murthy, and G. Ugrasen. "Hardness and wear characteristics of hybrid aluminium metal matrix composites produced by stir casting technique." Materials Today: Proceedings 2.4-5 (2015): 2878-2885.
5. Mishra, P., et al. "Multi-response optimization of process parameters using Taguchi method and grey relational analysis during turning AA 7075/SiC composite in dry and spray cooling environments." International Journal of Industrial Engineering Computations 6.4 (2015): 445-456.
6. M.Chandrasekaran, and Santosh Tamang. "Desirability analysis and genetic algorithm approaches to optimize single and multi-response characteristics in machining Al-SiC MMC." 5th international & 26th all India manufacturing technology, Design and Research conference (2014) 653.1-653.6.
7. Das, D., et al. "Fabrication process optimization for improved mechanical properties of Al 7075/SiCp metal matrix composites." Management Science Letters 6.4 (2016): 297-308.
8. Gururaja, Suhasini, Mamidala Ramulu, and William Pedersen. "Machining of MMCs: a review." Machining Science and Technology 17.1 (2013): 41-73.
9. Andrewes, Caroline JE, Hsi-Yung Feng, and W. M. Lau. "Machining of an aluminum/SiC composite using diamond inserts." Journal of materials processing technology 102.1-3 (2000): 25-29.
10. -Sahoo, Ashok Kumar, and Swastik Pradhan. "Modeling and optimization of Al/SiCp MMC machining using Taguchi approach." Measurement 46.9 (2013): 3064-3072.
11. Ciftci, Ibrahim, Mehmet Turker, and Ulvi Seker. "Evaluation of tool wear when machining SiCp-reinforced Al-2014 alloy matrix composites." Materials & design 25.3 (2004): 251-255.