Australian Journal of Basic and Applied Sciences, 7(9): 341-353, 2013
ISSN 1991-8178

Modelling and Analysis of Process Parameters on Turning of Aluminium Hybrid Composites

[1]P. Suresh, [2]K. Marimuthu, [3]S. Ranganathan

[1]Department of Mechanical Engineering, Nehru Institute of Engineering and Technology, Coimbatore 641 105, Tamilnadu, India.
[2]Department of Mechanical Engineering, Coimbatore Institute of Technology, Coimbatore 641 014, Tamilnadu, India.
[3] Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha University, Chennai-602 105, Tamilnadu, India.

Abstract: The present study investigates the influence of process parameters in turning of Al-SiC-Gr hybrid composites which is produced through compo casting technique. The central composite design has been utilized to plan the experiments and response surface methodology (RSM) is employed for developing experimental models. Analysis on machining characteristics of Al-SiC-Gr hybrid composites is made based on the developed models. In this study, cutting speed, feed rate, depth of cut and combined equal weight fraction of SiC-Gr particulates are considered as input process parameters. The process performances such as surface roughness (SR) and material removal rate (MRR) are evaluated. Analysis of variance test has been carried out to check the adequacy of the developed regression models. The multi-objective performance characteristics are also studied based on the composite desirability approach.

Key words: *Turning, ANOVA, RSM, Desirability approach*.

INTRODUCTION

Composites are normally composed of distinct constituents dispersed in a continuous matrix phase. The reinforcement provides a unique feature to the composites and mainly depends on the properties, geometry, architecture and interface of constituents. Based on the physical and chemical characteristics of matrix phase, composites are categorized into polymer matrix, metal matrix and ceramic matrix composites (Krishan K. Chawla, 2006). In aluminium metal matrix composites (AMCs), the matrix phase is aluminium / aluminium alloy and other constituent is reinforcement generally non-metallic or ceramic like SiC, Al_2O_3 etc. The foremost benefits of AMCs as compared with conventional alloys are as follows: low density, high strength, better stiffness, superior high temperature properties, good damping characteristics and improved performances in electrical, abrasion and wear resistance (Surappa, 2003). The incorporation of ceramic particles like silicon carbide, alumina or boron carbide in Al alloy increases both mechanical strength and wear resistances. In Al-SiC composites, the presence of hard abrasive SiC particles complicates the machining process. The machinability of particulate metal matrix composites (PMMCs) is improved by reinforcing the soft particles like graphite along with hard ceramic particles (Jinfeng Leng *et al*., 2008). The addition of graphite content in AMCs reduces the cutting forces and this has been attributed by the solid lubrication of Gr particulates. During the machining of Al-Gr composites, graphite particles act as a chip breaker which results in discontinuous chips, less tool wear and low power consumption (Hocheng *et al*., 1997). Al-Gr composites are used for bearings, pistons etc due to the existence of peculiar properties such as self-lubrication, low wear rate and less friction. It also avoids seizing during inadequate liquid lubrication condition which in turn significantly increases the life, reduces the cost and weight of the component (Songmene and Balazinski, 1999). The percentage reinforcement of Gr in Al-Gr composite and SiC in Al-SiC composite is limited to certain level beyond which it is not beneficial to add either Gr or SiC as reinforcement. The use of multiple reinforcements yields hybrid composites to possess better tribological properties over the composites with single reinforcement (Suresha and Sridhara, 2010). Paulo Davim (2003) established a correlation between cutting speed, feed and cutting time with tool wear, power required and surface roughness in radial turning of Al-SiC composite with PCD tools using ANOVA analysis. He concluded that the feed rate and cutting velocity has the major influence on tool wear and surface finish. Kannan and Kishawy (2008) deliberated the tool wear, surface integrity and chip formation under both dry and wet turning of Al-SiC particulate composites with tungsten carbide tool. The wet turning has less favorable effect over surface roughness when compared to dry conditions due to flushing away of particulates over the machined surface, thereby producing voids and pit holes. The subsurface deformation extends up to a maximum of 150 μm below the machined surface in Al-2219/15SiC composites, whereas in case of Al-2219/15SiC/3Gr hybrid composites it is only about 120μm, due to low friction

Corresponding Author: P. Suresh, Assistant Professor, Department of Mechanical Engineering, Nehru Institute of Engineering and Technology, Coimbatore, Tamil Nadu, India.
E-mail: psuresh2730@gmail.com

introduced by smear of graphite particles (Basavarajappa *et al*., 2007). In this proposed work, the effect of process parameters and their significance on the individual performance characteristics of surface roughness (SR) and material removal rate (MMR) are statistically evaluated and modelled by ANOVA and RSM. Further by using desirability approach, the optimum parameters setting condition for multi response is determined.

Experimental Procedures:

Al–SiC–Gr hybrid composites required for the investigation were fabricated through compo casting technology. The aluminium alloy LM25 was used as the matrix and its composition details are 7%Si, 0.35%Mg, 0.45%Fe, 0.13%Cu, 0.08%Zn, 0.01%Ni, 0.16%Mn, 0.01Pb, 0.05%Ti, Al-balance. Al–SiC–Gr hybrid composites with combined weight % reinforcement of 5%, 7.5% and 10% were produced. The casting produced was machined to dimensions, 30mm diameter and 250mm length. The machining experiments were performed on all gear lathe machine with a maximum speed of 1200 rpm and a 6 KW drive motor. The tool holder ISO 6 L 12 12 K20 and tungsten carbide tool insert DCMT 31 52 MF were used to turn the hybrid composite rods. The experimental parameters and their levels chosen are given in Table 1.

Table 1: Experimental parameters and its levels

Process parameters	Levels		
	-1	0	1
Cutting speed, A (m/min)	33	73	113
Feed rate, B (mm/rev)	0.25	0.32	0.39
Depth of cut, C (mm)	0.2	0.5	0.8
Combined equal weight fraction of SiC-Gr, D (%)	5	7.5	10

Table 2: Experimental design and output response

Ex no.	Input process parameters								Observed response	
	Coded Value				Actual Value				SR	MRR
	A	B	C	D	A	B	C	D	(µm)	gm/min
1	0	0	-1	0	73	0.32	0.2	7.5	6.09	19.45
2	0	0	0	-1	73	0.32	0.5	5	7.93	16.37
3	0	0	0	0	73	0.32	0.5	7.5	6.27	20.41
4	0	0	0	0	73	0.32	0.5	7.5	6.43	20.52
5	0	0	0	0	73	0.32	0.5	7.5	6.47	19.97
6	0	0	0	0	73	0.32	0.5	7.5	6.28	19.52
7	-1	-1	-1	1	33	0.25	0.2	10	7.02	4.25
8	1	-1	1	1	113	0.25	0.8	10	4.83	21.57
9	-1	1	1	1	33	0.39	0.8	10	6.14	17.99
10	-1	-1	1	1	33	0.25	0.8	10	6.78	11.99
11	1	-1	-1	1	113	0.25	0.2	10	3.24	13.52
12	1	1	-1	-1	113	0.39	0.2	5	5.58	23.17
13	-1	-1	1	-1	33	0.25	0.8	5	8.52	6.82
14	0	1	0	0	73	0.39	0.5	7.5	6.34	25.61
15	-1	1	1	-1	33	0.39	0.8	5	9.47	12.23
16	0	0	0	0	73	0.32	0.5	7.5	6.58	20.57
17	0	0	1	0	73	0.32	0.8	7.5	7.24	28.01
18	1	1	1	1	113	0.39	0.8	10	5.42	35.16
19	0	0	0	0	73	0.32	0.5	7.5	6.23	20.45
20	1	1	-1	1	113	0.39	0.2	10	3.12	25.2
21	-1	-1	-1	-1	33	0.25	0.2	5	9.85	1.21
22	0	0	0	0	73	0.32	0.5	7.5	5.96	20.12
23	1	-1	-1	-1	113	0.25	0.2	5	6.43	9.52
24	-1	1	-1	1	33	0.39	0.2	10	4.78	11.85
25	1	0	0	0	113	0.32	0.5	7.5	4.91	22.68
26	-1	1	-1	-1	33	0.39	0.2	5	9.41	9.51
27	0	-1	0	0	73	0.25	0.5	7.5	5.24	16.43
28	-1	0	0	0	33	0.32	0.5	7.5	7.64	8.14
29	0	0	0	1	73	0.32	0.5	10	5.32	19.58
30	1	1	1	-1	113	0.39	0.8	5	6.91	30.52
31	1	-1	1	-1	113	0.25	0.8	5	5.21	21.73

The surface roughness (SR) was found out by using Mitutoyo Surf test SJ-201 with cutoff length of 0.8 mm and traverse length of 5 mm. The material removal rate (MRR) is determined from the amount of material machined in the given period of time in minutes. The experiments are planned based on Central Composites Design (CCD) scheme of Design of Experiments (DOE). The experimental design having K factors with each factor at two levels is called two level factorial designs, provides a linear relationship exists between the factors and the response. Three or higher level experiments results with nonlinear relationship, which ends up with increased cost and time of testing. CCD is most efficient experimental technique in studies involving 3k or more number of factors. CCD can be used to study factors at three levels in reduced number of tests (Suresha and Sridhara, 2010). Table 2 presents the experimental design and the experimental results obtained.

Mathematical Modelling and Checking the Competence based on RSM:

The analysis of variance (ANOVA) of the experimental data was computed to statistically analyze the relative significance of the parameters cutting speed (A), feed rate (B), depth of cut (C) and combined % reinforcement (D) on the response variables, SR and MRR. The ANOVA tables for SR and MRR are shown in Tables 3 and 4, respectively. In SR model, F value of 36.70 in Table 3 indicates that the model is significant. The values of probability less than 0.05 imply that model terms are significant. In the SR model, A, B, C, D, B×B, A×B, A×C, A×D, B×C, B×D, C×D are significant model terms. The model terms having values greater than 0.1 indicate that not significant. The "lack of fit F value" of 4.92 implies that the lack of fit is not significant relative to the pure error. There is only a 3.2 % chance that a "lack of fit F value" this large could occur due to noise. Non-significant lack of fit is good.

Table 3: Analysis of variance for surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	72.0666	72.0666	5.1476	36.70	0.000
Linear	4	61.8089	61.8089	15.4522	110.17	0.000
A	1	31.8934	31.8934	31.8934	203.38	0.000
B	1	28.5264	28.5264	28.5264	227.38	0.000
C	1	1.3889	1.3889	1.3889	9.90	0.006
D	1	15.4315	15.4315	15.4315	160.61	0.000
Square	4	1.0525	1.0525	0.2631	1.88	0.164
A*A	1	0.0333	0.0037	0.0037	0.03	0.873
B*B	1	0.2020	0.7092	0.7092	5.06	0.039
C*C	1	0.5642	0.3220	0.3220	2.30	0.149
D*D	1	0.2530	0.2530	0.2530	1.80	0.198
Interaction	6	9.2052	9.2052	1.5342	10.94	0.000
A*B	1	0.8510	0.8510	0.8510	6.07	0.025
A*C	1	1.0764	1.0764	1.0764	7.67	0.014
A*D	1	1.5688	1.5688	1.5688	11.18	0.004
B*C	1	2.4414	2.4414	2.4414	17.41	0.001
B*D	1	0.8883	0.8883	0.8883	6.33	0.023
C*D	1	2.3793	2.3793	2.3793	16.96	0.001
Residual Error	16	2.2442	2.2442	0.1403		
Lack-of-Fit	10	2.0003	2.0003	0.2000	4.92	0.032
Pure Error	6	0.2439	0.2439	0.0407		
Total	30	74.3108				

S = 0.374516 PRESS = 13.6437
R-Sq = 96.98% R-Sq(pred) = 81.64% R-Sq(adj) = 94.34%

Table 4: Analysis of variance for material removal rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	1732.82	1732.82	123.773	154.90	0.000
Linear	4	1491.21	1491.21	372.803	466.55	0.000
A	1	393.87	393.87	393.869	492.91	0.000
B	1	259.46	259.46	259.464	324.71	0.000
C	1	787.78	787.78	787.780	985.88	0.000
D	1	50.10	50.10	50.100	62.70	0.000
Square	4	193.83	193.83	48.457	60.64	0.000
A*A	1	159.13	70.59	70.589	88.34	0.000
B*B	1	1.20	0.40	0.404	0.51	0.487
C*C	1	15.27	25.01	25.014	31.30	0.000
D*D	1	18.23	18.23	18.230	22.81	0.000
Interaction	6	47.78	47.78	7.963	9.97	0.000
A*B	1	26.01	26.01	26.010	32.55	0.000
A*C	1	14.75	14.75	14.746	18.45	0.001
A*D	1	2.10	2.10	2.103	2.63	0.124
B*C	1	3.46	3.46	3.460	4.33	0.054
B*D	1	0.46	0.46	0.462	0.58	0.458
D*D	1	1.00	1.00	1.000	1.25	0.280
Residual Error	16	12.78	12.78	0.799		
Lack-of-Fit	10	11.92	11.92	1.192	8.28	0.009
Pure Error	6	0.86	0.86	0.144		
Total	30	1745.61				

S = 0.893902 PRESS = 93.1238
R-Sq = 99.27% R-Sq(pred) = 94.67% R-Sq(adj) = 98.63%

In addition, it can be noticed that the MRR model from Table 4, an F value of 154.90 implies that the model is significant. In the MRR model, A, B, C, D, A×A, C×C, D×D, A×B, A×C are most influential model terms. The "lack of fit F value" of 8.28 indicates that the lack of fit is not significant relative to the pure error. The parametric analysis has been carried out to study the influences of the input process parameters such as cutting speed, feed rate, depth of cut and combined weight SiC-Gr % reinforcement on the process responses, i.e., SR and MRR during turning of hybrid composites. Three-dimensional response surface plots were developed based on the RSM quadratic models to assess the variation of response surface. These plots can also indicate the relationship between the input process parameters and responses. The adequacy of the models has been verified by using residual analysis which is shown in figures 1 and 2. The normal probability plots of residuals reveals that the residuals fall on a straight line and this entailed that the errors are distributed normally with respect to the predicted values. The residuals are distributed in both positive and a negative direction and do not show any obvious pattern which implies that the model is adequate.

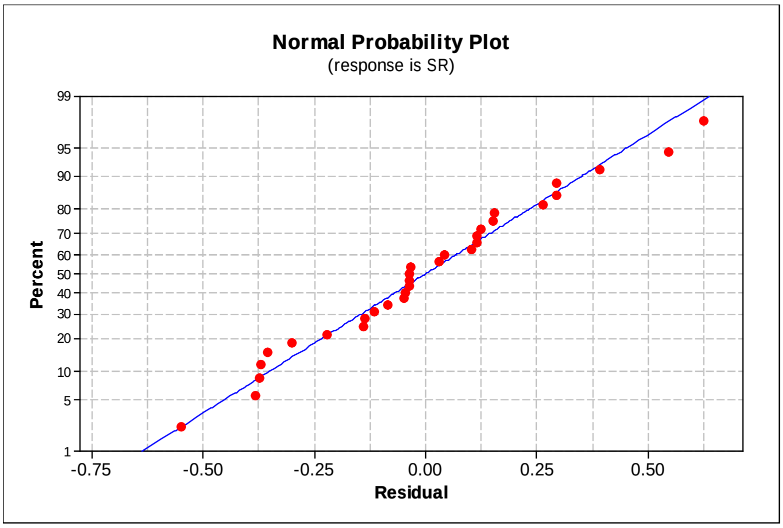


Fig. 1: Normal probability plot of residual for surface roughness

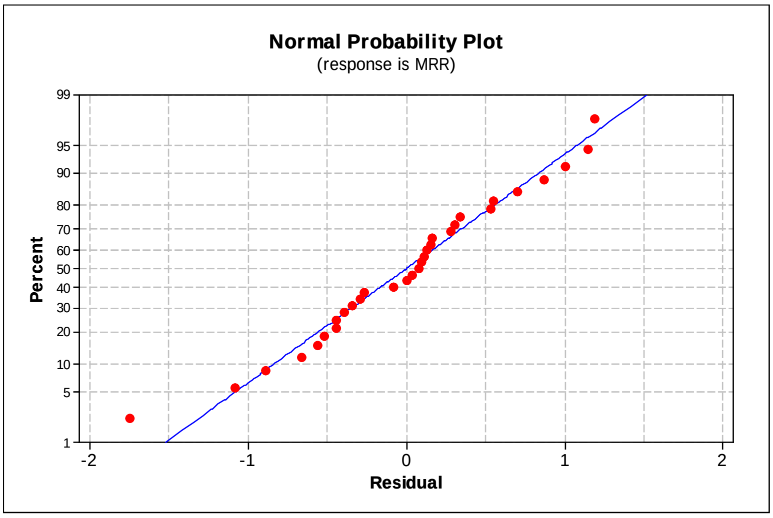
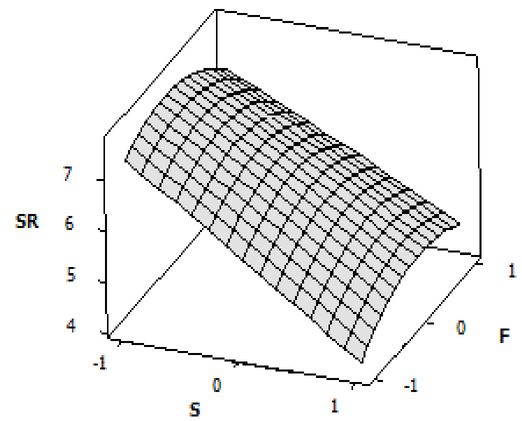


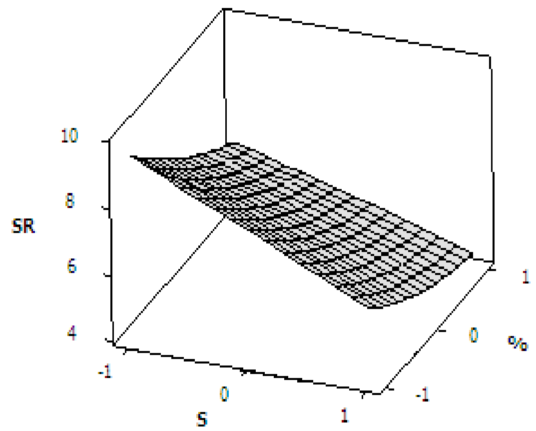
Fig. 2: Normal probability plot of residual for material removal rate

Effect of process parameters on SR:

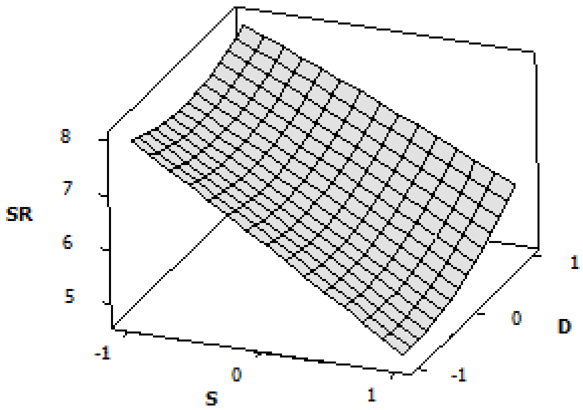
The surface roughness affects the dimensional accuracy of the machined components. The effects of cutting speed and feed rate on SR, while keeping the other parameter at centre level, are shown in surface plot Fig. 3a, based on the RSM model.



(a)

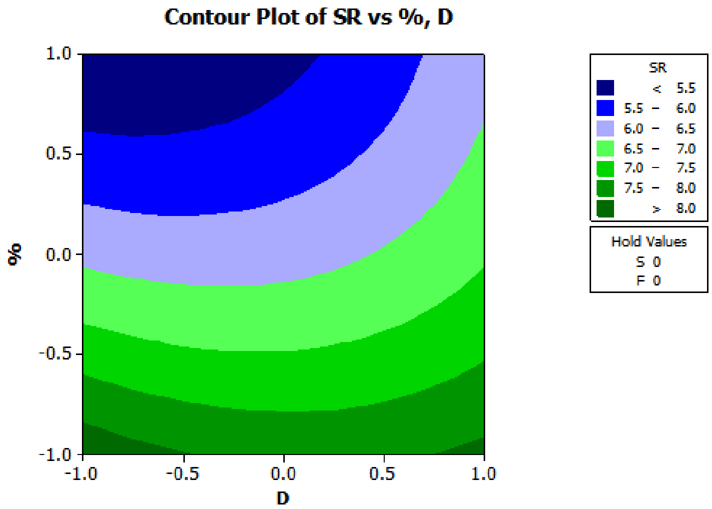


(b)

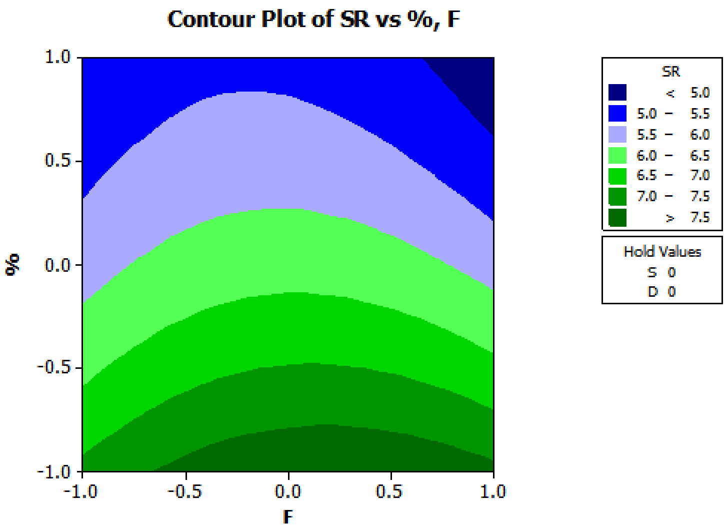


(c)

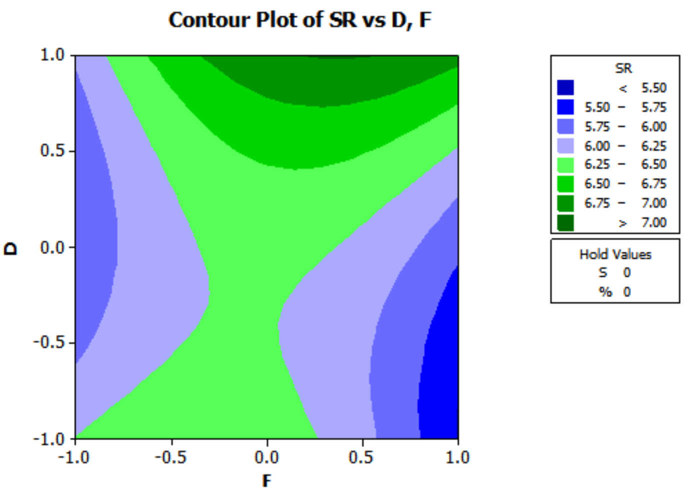
Fig. 3: (a), (b) and (c). Estimated surface plots for surface roughness


Contour Plot of SR vs %, D
SR
< 5.5
5.5 – 6.0
6.0 – 6.5
6.5 – 7.0
7.0 – 7.5
7.5 – 8.0
> 8.0
Hold Values
S 0
F 0
%
D

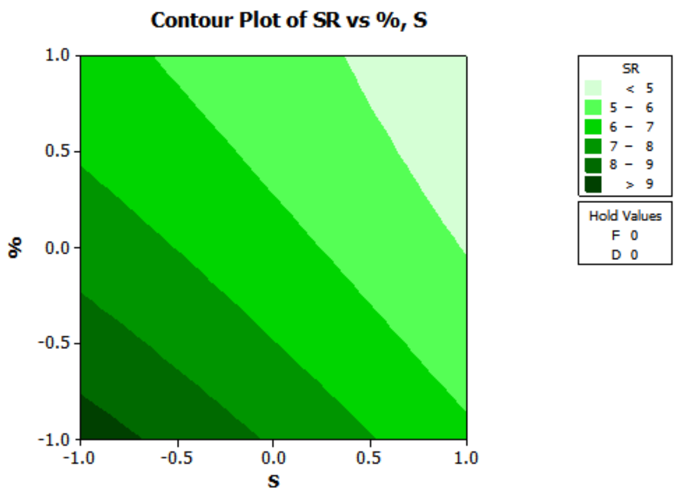
(a)


Contour Plot of SR vs %, F
SR
< 5.0
5.0 – 5.5
5.5 – 6.0
6.0 – 6.5
6.5 – 7.0
7.0 – 7.5
> 7.5
Hold Values
S 0
D 0
%
F

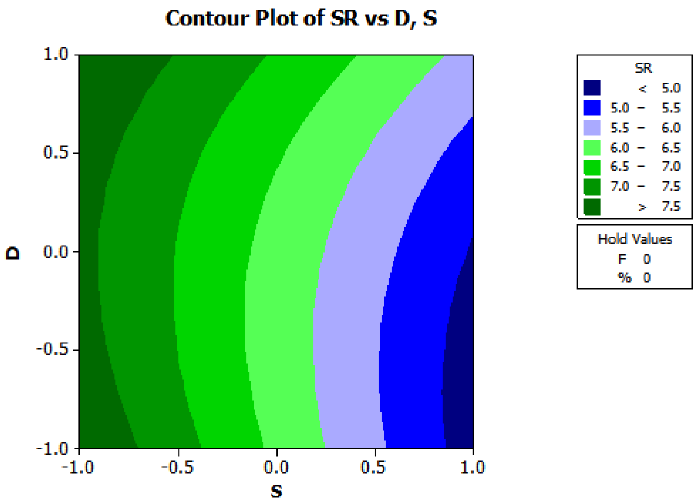
(b)


Contour Plot of SR vs D, F
SR
< 5.50
5.50 – 5.75
5.75 – 6.00
6.00 – 6.25
6.25 – 6.50
6.50 – 6.75
6.75 – 7.00
> 7.00
Hold Values
S 0
% 0
D
F

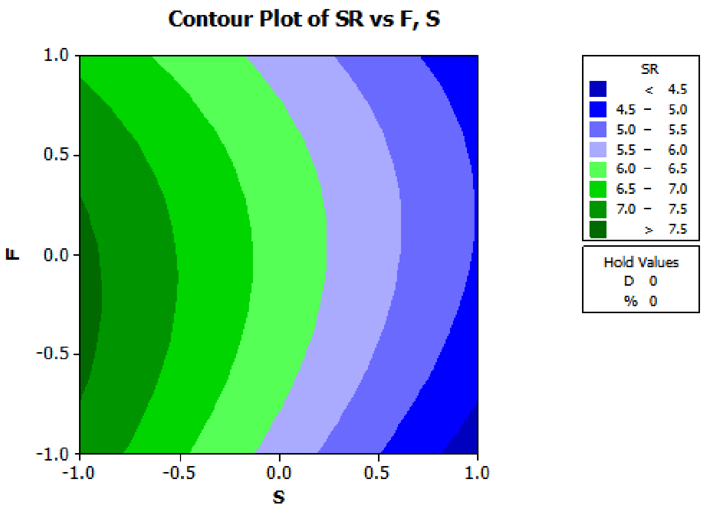
(c)



(d)



(e)



(f)

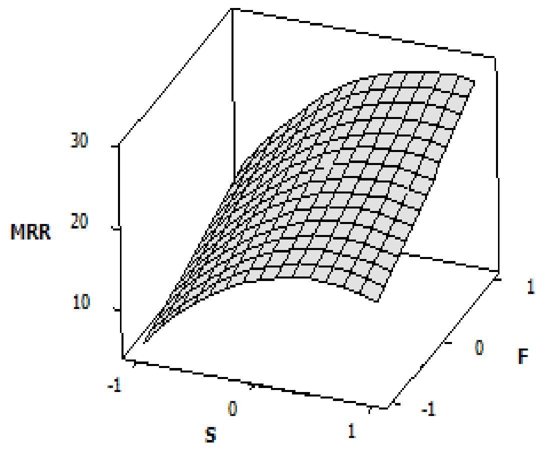
Fig. 4: (a) - (f). Estimated contor plots for surface roughness

The linear variation of the SR with the feed rate has been observed. The surface plots show that the SR is minimum at higher cutting speed and lower feed rate. The effects of speed and % reinforcement, while keeping the other parameters at centre level, are shown in Fig. 3b. The linear nature of variation of the SR with the cutting speed and % reinforcement has been observed. Surface plots reflect that the % reinforcement has moderate effect on SR. It is evident from the plot that the SR of Al–SiC–Gr hybrid composites decrease with increase in % reinforcement. This is due to increase in brittleness of the material and avoids build up edge formation in the tool tip. From the surface plot, it is clear that the change in cutting speed plays an important role in achieving less SR. Additionally; the responses depend more on the cutting speed rather than on % reinforcement. The combination of low % reinforcement and low cutting speed leads to larger SR.

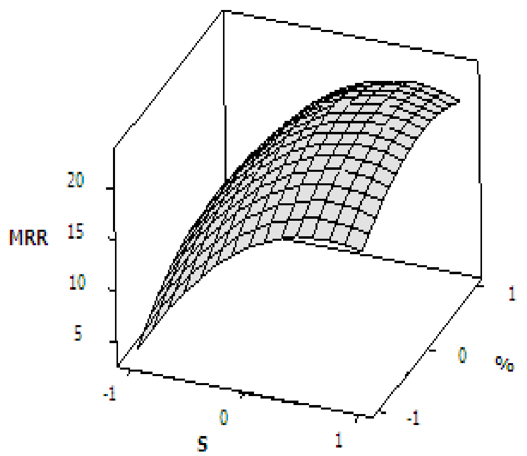
From the surface plot Fig. 3c, it is found that increase in depth of cut leads to an increase in penetration on tool on the work piece, which is subjected to increase in surface roughness of the machined surface. As a result, the observed SR becomes larger. Fig. 4(a-f) represents estimated contour plots for surface roughness. From the ANOVA of SR shown in Table 3, it can be observed that the influence of feed rate on SR is more compared to the other parameters. Hence, feed rate is the most significant input parameter affecting SR, followed by cutting speed, % reinforcement and then by depth of cut. It is worth noting that SR of Al–SiC–Gr composites are found to be more sensitive to feed rate and cutting speed.

Effect of process parameters on MRR:

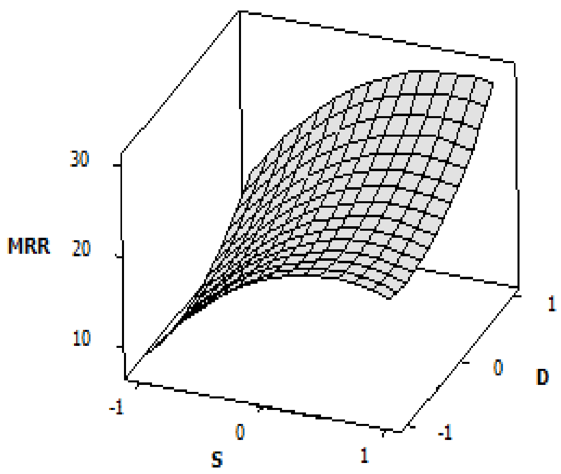
MRR in is an important factor because of its vital effect on machining characteristics of the material in the industrial economy. The surface plot Fig. 5a revels that the combination of higher feed rate and moderate cutting speed leads to larger MRR.



(a)

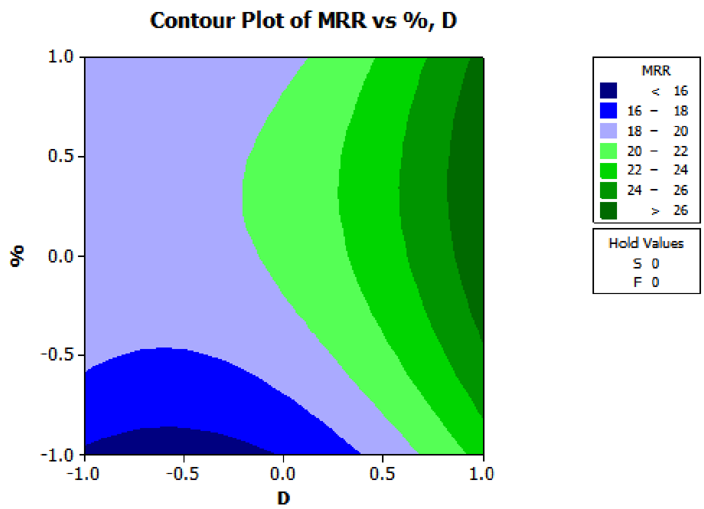


(b)

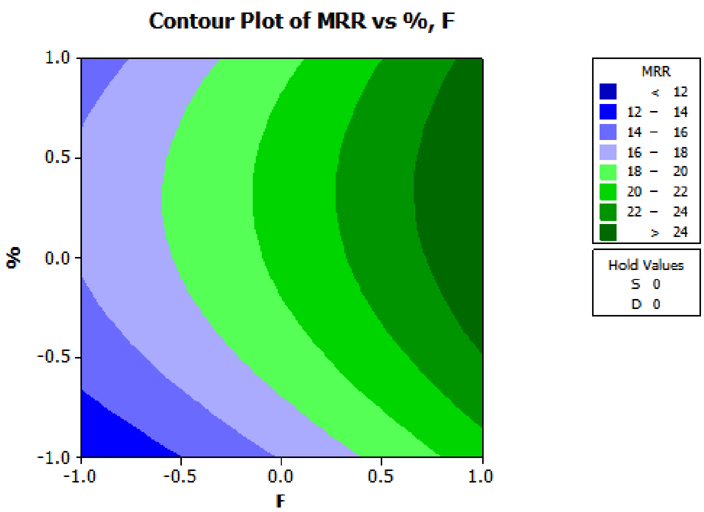


(c)

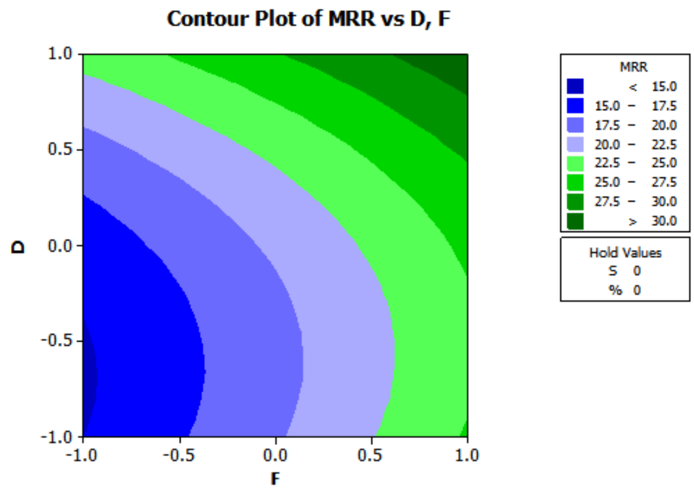
Fig. 5: (a), (b) and (c). Estimated surface plots for material removal rate



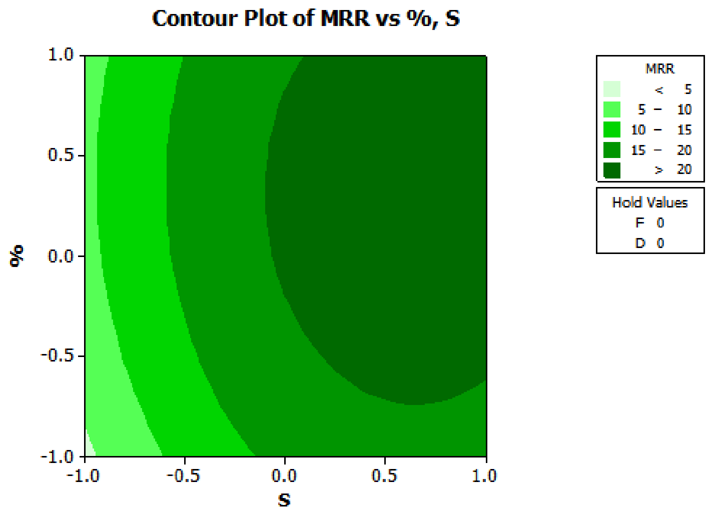
(a)



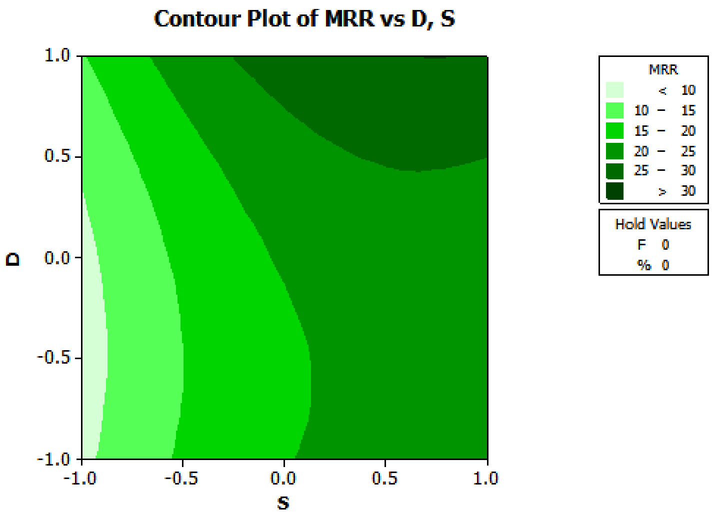
(b)


Contour Plot of MRR vs D, F
D
F
MRR
< 15.0
15.0 – 17.5
17.5 – 20.0
20.0 – 22.5
22.5 – 25.0
25.0 – 27.5
27.5 – 30.0
> 30.0
Hold Values
S 0
% 0

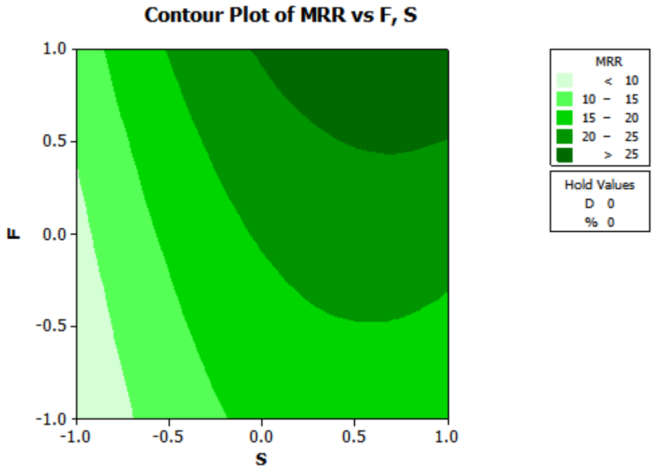
(c)


Contour Plot of MRR vs %, S
%
S
MRR
< 5
5 – 10
10 – 15
15 – 20
> 20
Hold Values
F 0
D 0

(d)


Contour Plot of MRR vs D, S
D
S
MRR
< 10
10 – 15
15 – 20
20 – 25
25 – 30
> 30
Hold Values
F 0
% 0

(e)



(f)

Fig. 6: (a) – (f). Estimated contour plots for material removal rate

Table 5: Values of individual and composite desirability of the response

Ex no.	Input process parameters				Individual response desirability		Composite desirability
	A	B	C	D	D1	D2	
1	0	0	-1	0	0.5587	0.5373	0.5479
2	0	0	0	-1	0.2853	0.4465	0.3569
3	0	0	0	0	0.5319	0.5655	0.5485
4	0	0	0	0	0.5082	0.5688	0.5376
5	0	0	0	0	0.5022	0.5526	0.5268
6	0	0	0	0	0.5305	0.5393	0.5349
7	-1	-1	-1	1	0.4205	0.0895	0.1940
8	1	-1	1	1	1.0000	0.9366	0.9643
9	-1	1	1	1	0.5513	0.4943	0.5220
10	-1	-1	1	1	0.4562	0.3175	0.3806
11	1	-1	-1	1	0.9822	0.3626	0.5968
12	1	1	-1	-1	0.6345	0.6468	0.6406
13	-1	-1	1	-1	0.1976	0.1652	0.1807
14	0	1	0	0	0.5215	0.7187	0.6122
15	-1	1	1	-1	0.0565	0.3246	0.1354
16	0	0	0	0	0.4859	0.5703	0.5264
17	0	0	1	0	0.3878	0.7894	0.5533
18	1	1	1	1	0.6582	1.0000	0.8113
19	0	0	0	0	0.5379	0.5667	0.5521
20	1	1	-1	1	0.7459	0.5997	0.6688
21	-1	-1	-1	-1	0.0000	0.0000	0.0000
22	0	0	0	0	0.5780	0.5570	0.5674
23	1	-1	-1	-1	0.5082	0.2448	0.3527
24	-1	1	-1	1	0.7533	0.3134	0.4859
25	1	0	0	0	0.7340	0.6324	0.6813
26	-1	1	-1	-1	0.0654	0.2445	0.1264
27	0	-1	0	0	0.6850	0.4483	0.5542
28	-1	0	0	0	0.3284	0.2041	0.2589
29	0	0	0	1	0.6731	0.5411	0.6035
30	1	1	1	-1	0.4368	0.8633	0.6141
31	1	-1	1	-1	0.6895	0.6044	0.6455

The linear nature of variation of the MRR with the feed rate has been observed. The effects of cutting speed and % reinforcement on MRR, while keeping the other parameter at centre level, are shown in surface plot (Fig. 5b). The MRR increases with the increase of cutting speed up to a certain level and after that it has less effect. From the surface plot, it is found that the % reinforcement has an effect on MRR. The MRR increases with the increase of % reinforcement. The MRR of the graphite particulate composite is better among the other ceramic particles reinforcement. The increase in combined % reinforcement of SiC and Gr particulates results in decrease in hardness and fracture toughness of Al-SiC-Gr hybrid composites (Songmene and Balazinski, 1999). Therefore the machining of Al-SiC-Gr hybrid composites with higher weight fraction of graphite is easy with maximum MRR and less tool wear. The effects of cutting speed and depth of cut on MRR, while keeping the other parameter at centre level, are shown in Fig. 5c. The estimated contour plots for MRR is shown in Fig. 6(a-f). Moreover, it can be clearly seen that an increase in depth of cut leads to a sharp increase in MRR. From the ANOVA of MRR (Table 3), it can be observed that the influence of depth of cut on MRR is more compared to the other parameters. Hence, depth of cut is the most significant input parameter affecting MRR, followed by cutting speed, feed rate and then by combined % reinforcement. Consequently, it can be concluded that MRR of Al–SiC–Gr are found to be more sensitive to depth of cut and cutting speed.

Multi-Response Optimization Using Composite Desirability:

In the present work, multi-response problems with two responses SR and MRR have been considered. It is observed that with the increase of MRR, SR also increases. For the production purpose, the best combination of parameter level should produce the minimum SR and maximum MRR. Two responses, i.e., SR and MRR, have been optimized simultaneously based on composite desirability optimization technique. In response optimization, a measure of how the solution has satisfied the combined goals for all responses must be assured. The commonly used multiple response method is a desirability technique. It is an attractive method for industry for the optimization of multiple quality characteristic problems. The method makes use of an objective function, D(X), called the desirability function and transforms an estimated response into a scale-free value (di) called desirability. The desirable ranges are from 0 to 1. One represents the ideal case; zero indicates that one or more responses are outside their acceptable limits. Composite desirability is the weighted geometric mean of the individual desirability's for the responses. The factor settings with maximum total desirability are considered to be the optimal parameter conditions (El-Taweel, 2009).

If the desirable is to maximize a response, the individual desirability is calculated as:

$$d_i = 0 \qquad i < L_i$$
$$d_i = [\ (i - L_i) / (T_i - L_i)\ ]^{ri} \qquad L_i \leq i \leq T_i \qquad (1)$$
$$d_i = 1 \qquad i > T_i$$

If the desirable is to minimize a response, the individual desirability is calculated as:

$$d_i = 0 \qquad i > H_i$$
$$d_i = [\ (H_i - i) / (H_i - T_i)\ ]^{ri} \qquad T_i \leq i \leq H_i \qquad (2)$$
$$d_i = 1 \qquad i < T_i$$

If the desirable is to target a response, the individual desirability is calculated as:

$$d_i = [(i - L_i) / (T_i - L_i)]^{ri} \qquad L_i \leq i \leq T_i \qquad (3)$$

$$d_i = [\ (H_i - i) / (H_i - T_i)\ ]^{ri} \qquad T_i \leq i \leq H_i \qquad (4)$$
$$d_i = 0 \qquad i < L_i$$
$$d_i = 0 \qquad i > H_i$$

where, i predicted value of i_{th} response, y_i target value for i_{th} response, L_i lowest acceptable value for i_{th} response, H_i highest acceptable value for i_{th} response, d_i desirability for i_{th} response, D composite desirability, r_i weight of desirability function of i_{th} response, n number of responses, w_i importance of i_{th} response.

If the importance is the same for each response, the composite desirability is:

$$D = (d_i \times d_2 \times \ldots. \times d_n)^{1/n} \qquad (5)$$

The values of composite desirability for 31 performed experimental runs are also shown in Table 5. The experiment no. 8 represents the maximum desirability values of the two responses (SR and MRR) and also the optimization results. The value of composite desirability (D) was taken as 0.9643. The current optimal process parameter settings based on the considered range of parameters are cutting speed of 113 m/min, feed rate of 0.25 mm/rev, depth of cut of 0.8 mm and combined weight fraction of SiC-Gr 10%. Also, the results showed that optimal turning of composite rod is obtained at high levels of % SiC-Gr reinforcement, depth of cut and cutting speed under relatively lower feed rate if the two responses (SR and MRR) are given equal weight age.

Conclusions:

In this study, the influence of process parameters on SR and MRR in turning of Al-SiC-Gr hybrid composites is modelled and analyzed. Summarizing the main features, the following conclusions could be drawn:

The surface roughness of turning Al-SiC-Gr composite is minimum at higher cutting speed and lower feed rate. It is evident that the SR of Al–SiC–Gr hybrid composites decrease with increase in combined SiC-Gr % reinforcement.

The MRR increases with the increase in combined SiC-Gr % reinforcement. The increase in combined % reinforcement of SiC and Gr particulates results in decrease in hardness and fracture toughness of Al-SiC-Gr hybrid composites. With high feed rate and moderate speeds & depth of cut, the MRR is improved.

From the desirability approach, based on the considered range of parameters, it is found that the largest value of composite desirability is obtained at the experiment setting of $A_3B_1C_3D_3$.

The optimum condition for turning Al-SiC-Gr are cutting speed of 113 m/min, feed rate of 0.25 mm/rev, depth of cut of 0.8 mm and combined weight fraction of SiC-Gr 10%, which are the recommended levels of controllable process parameters for lower surface roughness and better MRR.

It is evident from the above study that individual and multiple-performance characteristics can be greatly simplified through RSM and desirability approach. It is shown that the performance characteristics of surface roughness and material removal rate while turning of Al-SiC-Gr composite are improved together by using the proposed methods.

REFERENCES

Basavarajappa, S., G. Chandramohan., M. Prabu., K. Mukund and M. Ashwin., 2007. Drilling of hybrid metal matrix composites—Workpiece surface integrity. International Journal of Machine Tools & Manufacture, 47: 92-96.

El-Taweel, T.A., 2009. Multi-response optimization of EDM with Al–Cu–Si–TiC P/M composite electrode. Int J Adv Manuf Technol, 44: 100-113.

Hocheng, H., S.B. Yen, T. Ishihara and B.K. Yen, 1997. Fundamental turning characteristics of a tribology-favoured graphite/aluminium alloy composite material. Composites Part A, 28(A): 883-890.

Jinfeng Leng., Gaohui Wu., Qingbo Zhou., Zuoyong Dou and XiaoLi Huang, 2008. Mechanical properties of SiC/Gr/Al composites fabricated by squeeze casting technology. Scripta Materialia, 59: 619-622.

Kannan, S and H.A. Kishawy, 2008. Tribological aspects of machining aluminium metal matrix composites. J Mater Process Technol., 198: 399-406.

Krishan K. Chawla., 2006. Composite Materials Science and Engineering. Springer International Edition.

Paulo Davim, J., 2003. Design of optimization of cutting parameters for turning metal matrix composites based on the orthogonal arrays. J Mater Process Technol., 132: 340-344.

Songmene, V and Balazinski, 1999. Machinability of Graphitic Metal Matrix composites as a function of Reinforcing Particles. Annals of the CIRP, 48: 1.

Surappa, M.K., 2003. Aluminium matrix composites: Challenges and opportunities. Sadhana, 28: 319-334.

Suresha, S and B.K. Sridhara, 2010. Effect of addition of graphite particulates on the wear behavior in aluminium–silicon carbide–graphite composites. Materials and Design, 31: 1804-1812.