Lakshmi Narasimha Murthy Journal of Engineering Research and Application www.ijera.com
ISSN : 2248-9622, Vol. 8, Issue 6 (Part -IV) June 2018, pp 01-10

RESEARCH ARTICLE OPEN ACCESS

Mechanical Characterization and Optimization of Machinability Characteristics of Aluminium Copper Graphite Silicon Carbide Hybrid Composites

Lakshmi Narasimha Murthy H.R*, Suresha S**, Ramalingaiah***
** Research scholar, Department of Mechanical Engineering, P.E.S College of Engineering , Mandya, Karnataka, India,*
*** Former Faculty, Department of Mechanical Engineering, Vidyavardhaka College of Engineering, Gokulam 3rd Stage,Mysuru, Karnataka, India,*
**** Retired Professor, Department of Mechanical Engineering, P.E.S College of Engineering , Mandya, Karnataka, India*
Corresponding Auther: Lakshmi Narasimha Murthy

ABSTRACT
Hybrid composites of aluminium alloyed with copper have strengths on par with regular metals. Addition of graphite and silicon carbide results in improved mechanical properties over the alloy. Machining is vital in producing different components of these hybrid composites. Inclusion of graphite reduces the difficulty of machining because of its solid lubricant characteristic. Influence of cutting speed, depth of cut and feed on turning of aluminium copper alloy with reinforcement of graphite is investigated when amount of silicon carbide is varied according to design of experiments. Tool wear increases with increase of cutting speed, depth of cut and feed. Increase of feed results in increase of both cutting force and roughness of turned surface.

Keywords - Design of experiments, Hybrid composites, Machinability

Date of Submission: 08-06-2018 Date of acceptance:23-06-2018

I. INTRODUCTION

Characteristics of aluminium are better when it is alloyed and copper is preferred as its addition modifies thermal resistance and strength. Increased linearity of hardness, reduction in corrosion rate, impact energy and grain size is due to 6 wt. % inclusion of copper in the range 3, 6 and 9 wt. % [1]. Additions of 6% Zn and 8% Cu individually have shown higher tensile strengths compared to equal inclusion of 10% in Al-Sic-Zn-Cu composites [2]. Graphite addition of 2, 4, 6 and 8% to Al 8011 alloy has improved tensile strength and hardness [3]. Identical behaviour is noticed due to1, 3 and 5% graphite reinforcement in Al 7075 alloy [4]. Aluminium exhibits increased corrosion rate and reduced polarization resistance for up to 3% addition of Gr [5]. Nickel coating of graphite results in improved hardness, tensile strength and negligible formation of voids of Al6061 alloy [6].

Reinforcement of 3-15% SiC to Al-Si alloy improves tensile strength and hardness but yields low ductility caused due to hardness [7]. Reduction in impact strength and higher strength to weight ratio are observed in Al 6063 alloy with 5 to 20 % SiC [8]. Similar characteristics in aluminium are noticed with individual addition of tungsten carbide, molybdenum carbide, titanium carbide and iron carbide [9]. Conventional and non-conventional machining of aluminium alloys are influenced by SiC reinforcement. Life of WC tool is inferior to that of MCD and PCD tools in turning AA2124 alloy with 25 % SiC [10]. But, different trend is observed while turning A356 alloy reinforced by 20% SiC for PCD tools [11]. Feed affecting surface roughness and cutting force being influenced by both depth of cut and feed are noticed during turning Al/SiC/10p/ composites [12].

Reinforcement effects of SiC are enhanced in aluminium alloy when graphite is also added. Inclusion of 5-15 % SiC and Gr results in higher tensile strength of Al-SiC-Gr composites than that of Al-SiC composites [13]. Solid lubricant characteristic of graphite eases machining of aluminium composites. Graphite reinforcement of 2, 4, 6 and 8% has reduced roughness of turned surface in Al8011 alloy [3]. Continuous chips are noticed due to the presence of Gr when aluminium hybrid composites are turned [14].Cutting speed and feed are responsible for surface quality in turning Al-SiC-Gr hybrid composite with PCD tool [15]. Aluminium with 2,4,6 and 8% SiC and rice husk ash has shown increase of cutting force due to feed and depth of cut and its decrease with cutting speed [16]. Surface quality of turned Al 7075 alloy is influenced not only by reinforcement of 10 % flyash together with 2, 4 and 6% Gr but also by cutting speed [17]. Hence, machining of hybrid aluminium composites is an important issue to be addressed. Turning characteristics of aluminium-copper-graphite-silicon carbide hybrid composites are considered.

II. MATERIALS

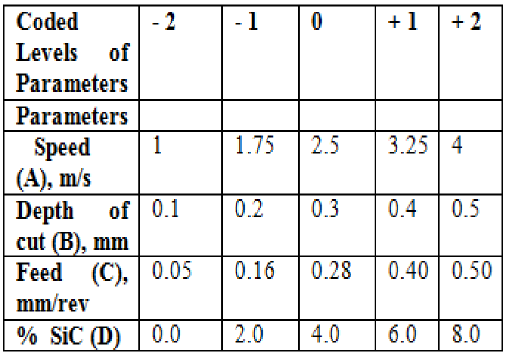
Aluminium copper alloy, Al2419, is the base material and Table-1 gives details of its spectrum analysis. Graphite of 1% and 0-8% silicon carbide in particulate form are reinforced to aluminium. Cutting speed, depth of cut and feed are considered as machinability parameters during turning Al-Cu-Gr-SiC hybrid composites. Levels of SiC and turning parameters are determined using Central Composite Design (CCD), which is an experimental technique of Response Surface Methodology (RSM). Table-2 provides five levels of all factors of turning and % SiC for Al-Cu-Gr-SiC hybrid composites. Considerable information in minimum number of experimental trials is the result because CCD is a comprehensive experimental technique. Regular experiments require $L^K = 5^4 = 625$ trials when each of the four factors of Table-2 is varied at 5 levels (L). On the other hand, experimental plan as per CCD requires 25 trials only without compromising required information compared to conventional experiments. Specimen required for tensile, hardness and turning characteristics of Al-Cu-Gr-SiC hybrid composites are fabricated with SiC reinforcement as per Table-2.

Table-1: Metallurgical details of Al2149

Cu	Mn	Zr	V	Fe	Ti
5.92	0.539	0.197	0.148	0.130	0.109

Zn	Si	Ni	Mg	Cr	Balance
0.105	0.049	0.033	0.008	<0.001	92.42

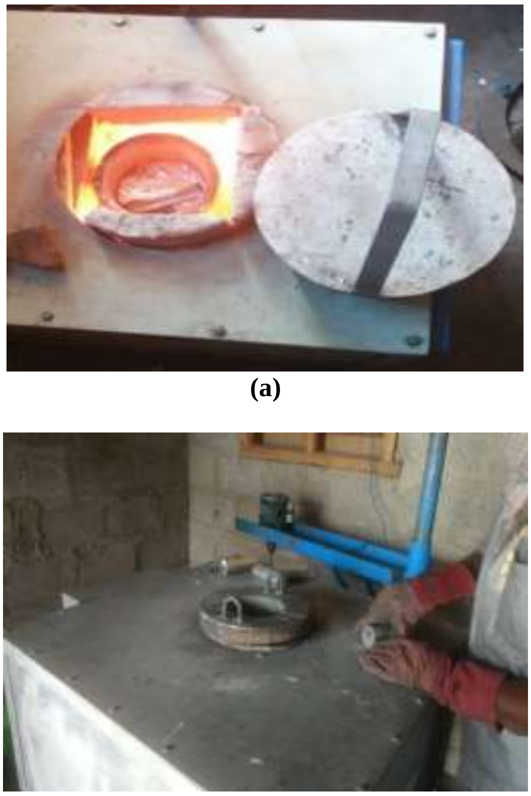
Table-2: Turning parameters of Al-Gr-SiC hybrid composites



Coded Levels of Parameters	- 2	- 1	0	+ 1	+ 2
Parameters					
Speed (A), m/s	1	1.75	2.5	3.25	4
Depth of cut (B), mm	0.1	0.2	0.3	0.4	0.5
Feed (C), mm/rev	0.05	0.16	0.28	0.40	0.50
% SiC (D)	0.0	2.0	4.0	6.0	8.0

Composites are fabricated by stir casting [2, 6, 8, 14, 18, 19]. Melting of ingots of Al2419 alloy in crucible is shown in Fig-1. Magnesium ribbons are added for improving wettability of SiC and Gr particulates, which are added and stirred prior to pouring of melt in to metal moulds. Tension specimen is 15 mm diameter and 110 mm length and machinability specimen is 240 mm length with 50 mm diameter after casting. Tension specimen is turned for a gauge length of 36 mm with 9 mm diameter and for gripping length of 25 mm with 12 mm diameter on either end as per ASTM E8-09. Ends are knurled to ensure proper gripping. Specimen with thickness 10 mm and diameter 12 mm are machined and polished for hardness testing. Specimen of tension and hardness test are respectively shown in Fig-2 and Fig-3. A sample SEM image is taken to know the presence and distribution of particulates of Gr and SiC in composite with reinforcement of 1%Gr and 8%SiC. A fairly uniform distribution of reinforcement can be noticed in the SEM image as shown in Fig-4.

.

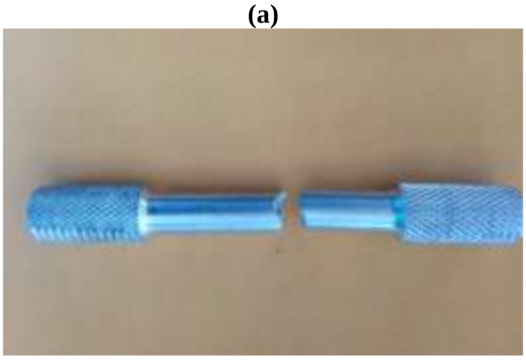


(a)

(b)

Fig-1: (a) Melting of Aluminium Alloy Ingots (b) Crucible with Stirrer

(a)



(b)

Fig-2: (a) Tension Test Specimen
(b) Specimen after Tension Test

Fig-3: Hardness Test Specimen

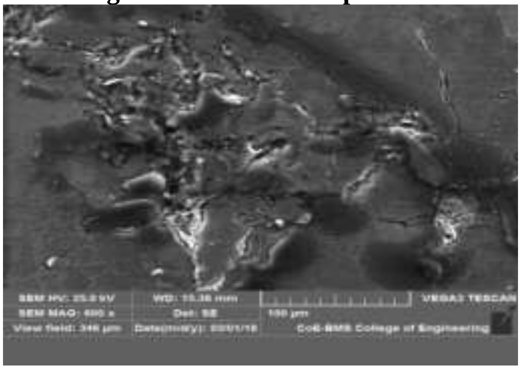


Fig-4: SEM image of Composite with 1% Gr and 8% SiC

III. EXPERIMENTS AND RESULTS

A 60 ton UTM is used to know tensile characteristics of composites. Three samples are considered for each of the SiC reinforcement as detailed in Table-2 and the values are averaged. Table-3 provides these values for tensile yield strength, ultimate tensile strength and % elongation. Hardness tests are carried out with three indentations for each sample of reinforcement as in Table-2 and average values are given in Table-3.

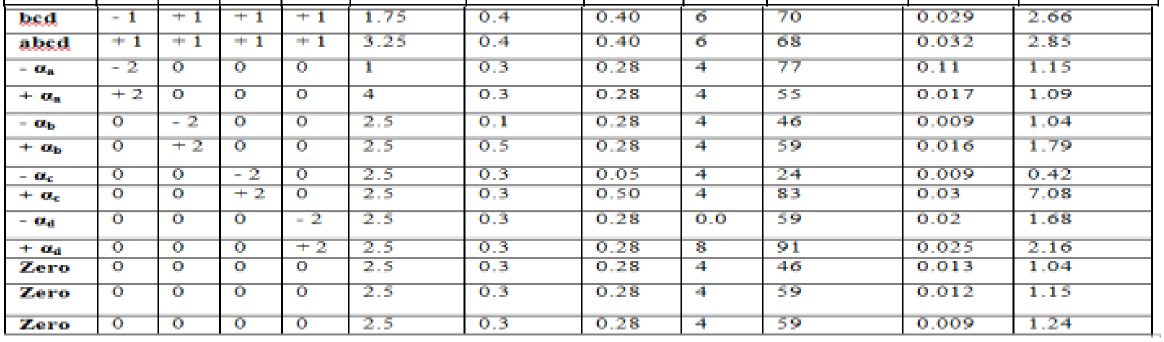
Table-3: Tensile Characteristics of Al-Cu-Gr-SiC Composites

%SiC	**Tensile Yield Strength ,MPa**	**Ultimate Tensile Strength ,MPa**	**% Elongation**	**BHN**
0	166.46	214.10	13.45	62.80
2	173.83	226.56	12.74	70.93
4	188.43	247.00	11.43	78.70
6	212.96	269.30	9.84	92.06
8	221.30	288.03	8.51	100.20

Turning of Al-Cu-SiC-Gr Hybrid Composites is carried out considering the parameters of Table-2 keeping 100 mm as length for turning. These parameters are varied as per the experimental plan. The coded and actual values of parameters for different test combinations (tc) of experimental plan are given in Table-4. Three mutually normal components of cutting force are measured during turning and their resultant (F) is considered. Tool wear (W) and surface roughness (Ra) are measured after each experiment. These are the responses and their values are given in Table-4.

Table–4: Coded and Actual Values of Parameters and Test Results for Al-Cu-Gr-SiC Hybrid Composites.

tc	Parameters										
	Coded Value				Actual Value				Test Results		
	A	B	C	D	A Speed m/s	B Depth of Cut mm	C Feed Mm/rev	D % SiC	Cutting Force (F) N	Tool Wear (W) mm	Surface Roughness (Ra)
1	- 1	- 1	- 1	- 1	1.75	0.2	0.16	2	55	0.009	0.72
a	+ 1	- 1	- 1	- 1	3.25	0.2	0.16	2	46	0.012	1.2
b	- 1	+ 1	- 1	- 1	1.75	0.4	0.16	2	59	0.015	0.59
ab	+ 1	+ 1	- 1	- 1	3.25	0.4	0.16	2	46	0.02	0.99
c	- 1	- 1	+ 1	- 1	1.75	0.2	0.40	2	68	0.024	0.95
ac	+ 1	- 1	+ 1	- 1	3.25	0.2	0.40	2	59	0.028	0.98
bc	- 1	+ 1	+ 1	- 1	1.75	0.4	0.40	2	81	0.022	0.77
abc	+ 1	+ 1	+ 1	- 1	3.25	0.4	0.40	2	81	0.024	1.12
d	- 1	- 1	- 1	+ 1	1.75	0.2	0.16	6	57	0.01	0.94
ad	+ 1	- 1	- 1	+ 1	3.25	0.2	0.16	6	57	0.014	0.96
bd	- 1	+ 1	- 1	+ 1	1.75	0.4	0.16	6	55	0.017	1.26
abd	+ 1	+ 1	- 1	+ 1	3.25	0.4	0.16	6	30	0.019	0.99
cd	- 1	- 1	+ 1	+ 1	1.75	0.2	0.40	6	46	0.024	0.86
acd	+ 1	- 1	+ 1	+ 1	3.25	0.2	0.40	6	59	0.027	1.07
bcd	- 1	+ 1	+ 1	+ 1	1.75	0.4	0.40	6	70	0.029	2.66
bcd	- 1	+ 1	+ 1	+ 1	1.75	0.4	0.40	6	70	0.029	2.66
abcd	+ 1	+ 1	+ 1	+ 1	3.25	0.4	0.40	6	68	0.032	2.85
$-\alpha_a$	- 2	0	0	0	1	0.3	0.28	4	77	0.11	1.15
$+\alpha_a$	+ 2	0	0	0	4	0.3	0.28	4	55	0.017	1.09
$-\alpha_b$	0	- 2	0	0	2.5	0.1	0.28	4	46	0.009	1.04
$+\alpha_b$	0	+ 2	0	0	2.5	0.5	0.28	4	59	0.016	1.79
$-\alpha_c$	0	0	- 2	0	2.5	0.3	0.05	4	24	0.009	0.42
$+\alpha_c$	0	0	+ 2	0	2.5	0.3	0.50	4	83	0.03	7.08
$-\alpha_d$	0	0	0	- 2	2.5	0.3	0.28	0.0	59	0.02	1.68
$+\alpha_d$	0	0	0	+ 2	2.5	0.3	0.28	8	91	0.025	2.16
Zero	0	0	0	0	2.5	0.3	0.28	4	46	0.013	1.04
Zero	0	0	0	0	2.5	0.3	0.28	4	59	0.012	1.15
Zero	0	0	0	0	2.5	0.3	0.28	4	59	0.009	1.24



IV. DISCUSSION OF RESULTS

Tensile Strength and Hardness

Fig-5 is the plot of tensile yield strength and ultimate tensile strength as provided in Table-3. There is continuous improvement of strengths with % SiC addition and this can be attributed to formation of aluminium carbide, to which transfer of load takes place, and also to uniform distribution of SiC and Gr

particulates as observed in SEM image of Fig-4. Similar trend is noticed when SiC is added by 5, 10 and 15% along with Gr to Al6061 alloy wherein the highest tensile strength is 192.45 MPa for 15% reinforcement [13]. On the other hand, an opposite observation is made in Al6061 alloy with 4% Gr and 8% SiC wherein tensile strength of 219MPa and yield strength of 185 MPa are respectively less than the values of 295 MPa and 271 MPa for base alloy [20]. As can be observed these strengths are less than the strength for any reinforcement in the present investigation Addition

of SiC has reduced % elongation continuously as shown in Fig-6. This is due to composites being harder on addition of SiC particulates as evidenced by the hardness values provided in Table-3. Addition of SiC has influence on hardness of composites similar to tensile yield strength and ultimate tensile strength as shown in Fig-6. This is due to SiC particulates which are naturally hard contributing for increased hardness of composites, the values of which increased continuously with SiC addition up to 8%. Identical observation is made in Al6061 alloy with 4% Gr and 8% SiC as presence of these reinforcements has increased hardness of composite compared to the alloy [20].

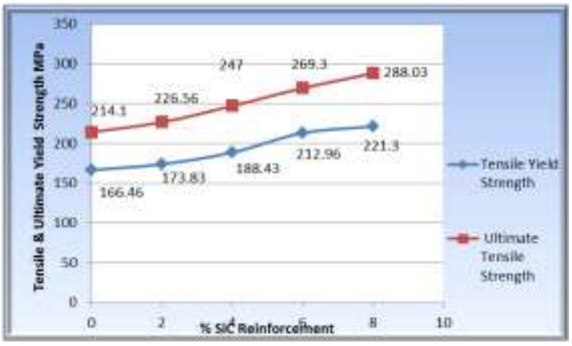


Fig-5: Plot of Tensile Yield Strength and Ultimate Tensile Strength with % SiC

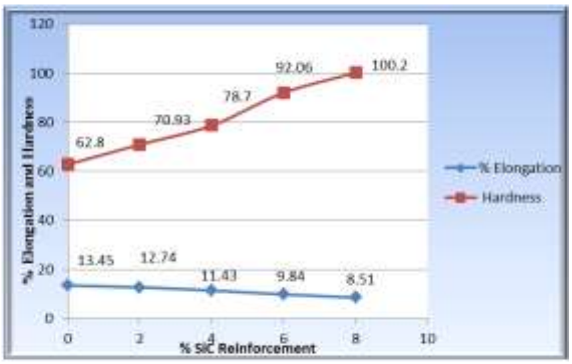


Fig-6: Plot of % Elongation and Brinell Hardness with % SiC

The values of cutting force (F), tool wear (W) and roughness of turned surface (Ra) which are measured as responses provided in Table-4 are analyzed using a software, MINITAB. Analysis of variance (ANOVA) is carried out for these measured responses considering the coded values of each test combinations of Table-4. Factors with p-value less than 0.05 are significant with a confidence limit of 95%. Results of analysis are separately discussed for each of the responses.

Cutting Force

Fig-7 shows turning of a particular composite during which the three components of cutting forces are measured. ANOVA results are given in Table-5 and it can be observed that only feed affects the cutting force. Increase of feed results in increase of cutting force. Identical observation is made while turning LM25 alloy with 10% Al2O3 using uncoated cemented carbide inserts wherein increase of feed increase the cutting forces [21]. Normal probability plot for cutting force is shown in Fig-8 wherein all the experimental values are normally distributed as their values are very close to the normal probability line. Contour plots for different combinations of factors provide more insight in to their effect on the cutting force by way of optimal combinations. Actual values of factors for contour plots for different % SiC and corresponding feed as per Table-2 are used for combination of speed and depth of cut. Fig-9 and Fig-10 respectively represent such plots for 4% SiC and 8% SiC. Table-6 provides the summary of optimal values of cutting forces also considering contour plots for other % SiC reinforcements. These plots are advantageous so that values of both %SiC and feed can be known by considering any combination of speed and depth of cut in the range so that the cutting force is minimum.

Fig-7: Turning of Composite

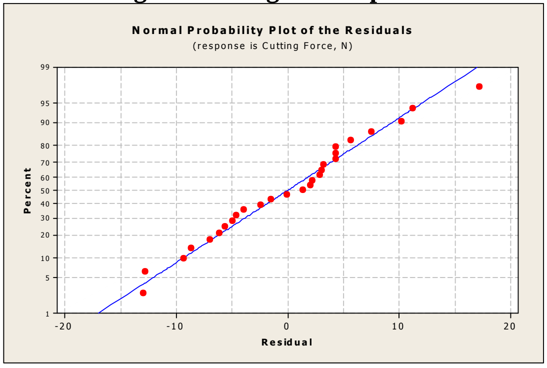


Fig-8: Normal Probability Plot

Table-5: ANOVA Results for Cutting Force of Al-Cu-SiC-Gr Composites

Term	Coefficient	P
Constant	54.6667	0.000
Speed, m/s	-3.7083	0.117
Depth of Cut, mm	2.8750	0.215
Feed, mm/rev	**10.2083**	**0.001**
% SiC	0.4583	0.838
Speed, m/s*Speed, m/s	2.3021	0.343
Depth of Cut, mm*Depth of Cut, mm	-1.0729	0.653
Feed, mm/rev*Feed, mm/rev	-0.8229	0.730
% SiC*% SiC	4.5521	0.075
Speed, m/s*Depth of Cut, mm	-2.1875	0.432
Speed, m/s*Feed, mm/rev	3.0625	0.277

Speed, m/s*% SiC	1.0625	0.700
Depth of Cut, mm*Feed, mm/rev	5.8125	0.052
Depth of Cut, mm*% SiC	-2.1875	0.432
Feed, mm/rev*% SiC	-2.4375	0.383
Estimated Regression Coefficients for Cutting Force with R-Sq = 77.4%		

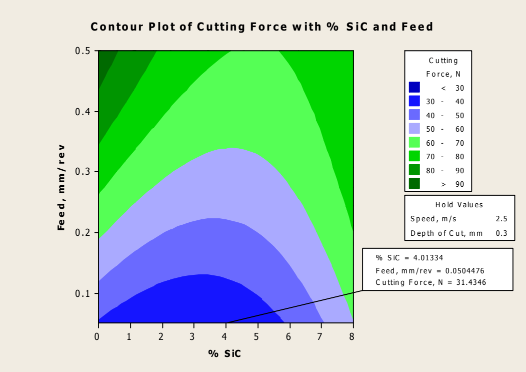


Fig-09: Contour Plot of Cutting Force with 2.5 m/s Speed and 0.3 mm Depth of Cut

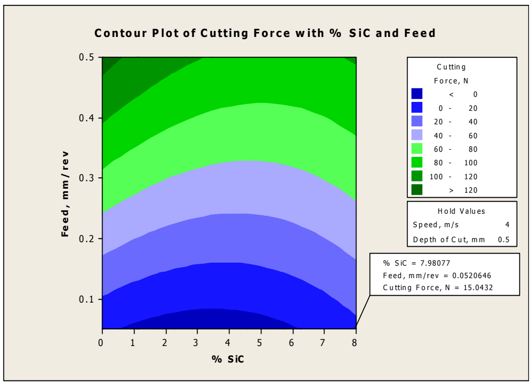


Fig-10: Contour Plot of Cutting Force with 4 m/s Speed and 0.5 mm Depth of Cut

Table-6: Optimal Combinations of Depth of Cut, Speed and Feed for minimum Cutting Force during Turning of Al-Cu-SiC-Gr Composites

% SiC	Depth of Cut, mm	Speed, m/s	Feed, mm/rev	Cutting Force, N
0	0.1	1	0.49	55.88
2	0.2	1.75	0.05	46.40
4	0.3	2.5	0.05	31.43
6	0.4	3.25	0.05	20.92
8	0.5	4	0.05	15.04

Tool Wear

Nikon Measure Scope 10 is used for measuring tool wear (W) and Fig-11 represents tool tip under the scope. ANOVA results for tool wear are given in Table-7 and it can be noticed that speed, depth of cut and feed are influencing tool wear such that increase of all these results in increase of tool wear. Fig-12 is the normal probability plot for tool wear and all the experimental values are normal distributed as they are very close to the normal probability line. Speed and % SiC as per Table-2 are used for combinations of feed and depth of cut and contour plots are drawn. Fig-13 and Fig-14 respectively represent these plots for 4% SiC and 8% SiC. Table-8 provides the optimal values of tool wear taking in to account the contour plots for other % SiC reinforcements. These plots have advantage similar to contour plots for cutting force, as it is possible to know feed and depth of cut yielding least tool wear for any combination of both speed and %SiC in the considered range.

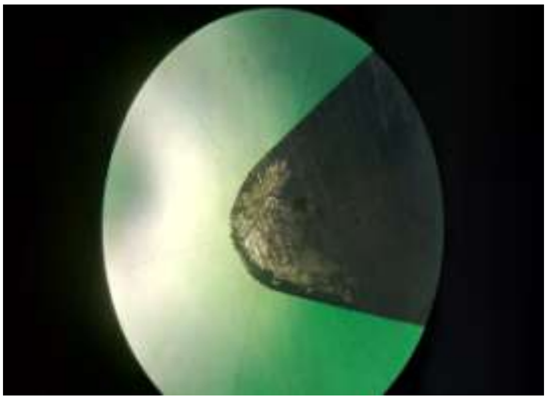


Fig-11: Tool Tip under Microscope

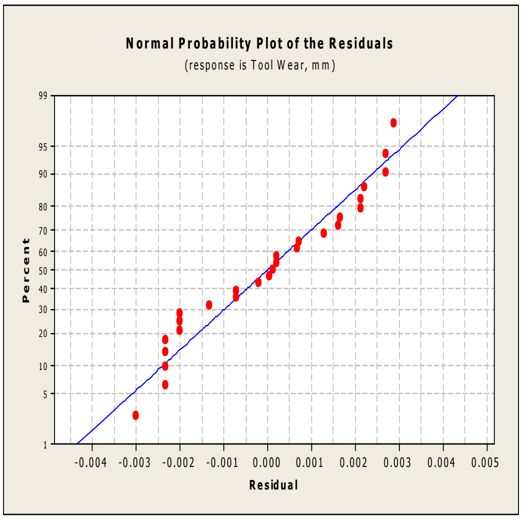


Fig-12: Normal Probability Plot

Table-7: ANOVA Results for Tool Wear of Al-Cu-SiC-Gr Composites

Term	**Coefficient**	**P**
Constant	0.011333	0.000
Speed, m/s	**0.001583**	**0.015**
Depth of Cut, mm	**0.001833**	**0.007**
Feed, mm/rev	**0.005667**	**0.000**
% SiC	0.001167	0.060
Speed, m/s*Speed, m/s	0.001208	0.065
Depth of Cut, mm*Depth of Cut, mm	0.000833	0.187
Feed, mm/rev*Feed, mm/rev	0.002583	0.001
% SiC*% SiC	0.003333	0.000
Speed, m/s*Depth of Cut, mm	-0.000125	0.859
Speed, m/s*Feed, mm/rev	-0.000125	0.859
Speed, m/s*% SiC	-0.000125	0.859
Depth of Cut, mm*Feed, mm/rev	-0.001375	0.068
Depth of Cut, mm*% SiC	0.000875	0.227
Feed, mm/rev*% SiC	0.000625	0.381
Estimated Regression Coefficients for Tool Wear with R-Sq = 93.5%		

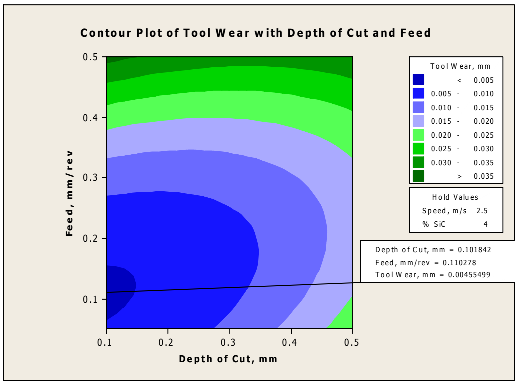


Fig-13: Contour Plot of Tool Wear with 4% SiC and 2.5 m/s Speed

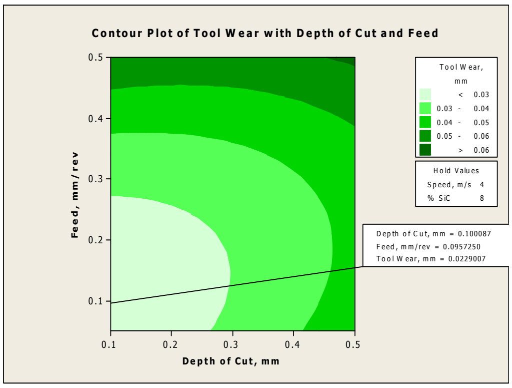


Fig-14: Contour Plot of Tool Wear with 8% SiC and 4 m/s Speed

Table-8: Optimal Combinations of Depth of Cut, Speed and Feed for minimum Tool Wear during Turning of Al-Cu-SiC-Gr Composites

% SiC	**Depth of Cut, mm**	**Speed, m/s**	**Feed, mm/rev**	**Tool Wear, mm**
0	0.18	1	0.15	0.0202
2	0.11	1.75	0.12	0.0082
4	0.10	2.5	0.11	0.0045
6	0.10	3.25	0.10	0.0094
8	0.10	4	0.09	0.0229

Surface Roughness

SURFCOM FLEX equipment as shown in Fig-15 is used for measuring surface roughness (Ra). ANOVA results are given in Table-9 and the normal probability plot for surface roughness as shown in Fig-16 indicates that all the experimental values are normal distributed as they are very close to the normal probability line. It is noticed form Table-9 that feed only affects the roughness of turned surface so that its increase results in increase of surface roughness of composites. Similar trend is noticed in turning LM25 alloy with 10% Al2O3 using uncoated cemented carbide inserts wherein increase of feed increases the surface roughness. A surface roughness of 1.5 is noticed at speed 1.75 m/s with feed 0.2 mm/rev [21]. This is more than the roughness of 0.652 in the present investigation under identical cutting condition. Increase of feed results in increased roughness of turned surface in Al356 alloy with 5% boron carbide and 5, 10, 15% SiC using coated carbide insert [22]. It is observed that surface roughness increases with feed in turning Al2024 alloy with 2, 4, 6% Al2O3 using both coated and uncoated carbide tool [23]. Values of Feed and % SiC as per Table-2 are used to prepare contour plots as shown in Fig-17 and Fig-18. Minimum surface roughness for different % SiC and corresponding combination of speed, feed and depth of cut can be known from these plots and Table-10 provides summary of these values. The optimal values of speed, feed and depth of cut for % SiC other than those in Table-2 also can be known from these plots.

Fig-15: Roughness Measurement of Composite

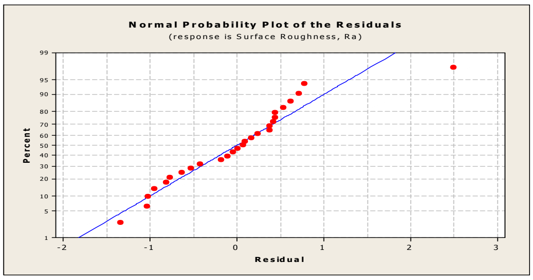


Fig-16: Normal Probability Plot

Table-9: ANOVA Results for Surface Roughness of Al-Cu-SiC-Gr Composites

Term	Coefficient	P
Constant	1.14333	0.111
Speed, m/s	0.05375	0.823
Depth of Cut, mm	0.21042	0.389
Feed, mm/rev	**0.70542**	**0.011**
% SiC	0.21792	0.373
Speed, m/s*Speed, m/s	-0.15073	0.557
Depth of Cut, mm*Depth of Cut, mm	-0.07698	0.763
Feed, mm/rev*Feed, mm/rev	0.50677	0.065
% SiC*% SiC	0.04927	0.847
Speed, m/s*Depth of Cut, mm	-0.00437	0.988
Speed, m/s*Feed, mm/rev	0.00937	0.975
Speed, m/s*% SiC	-0.06937	0.814
Depth of Cut, mm*Feed, mm/rev	0.22062	0.459
Depth of Cut, mm*% SiC	0.26938	0.368
Feed, mm/rev*% SiC	0.18562	0.532
Estimated Regression Coefficients for Surface Roughness with R-Sq = 61.5%		

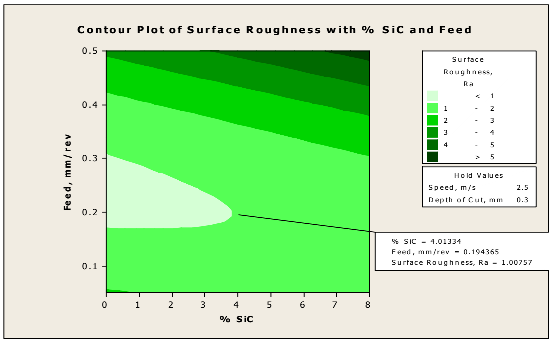


Fig-17: Contour Plot of Surface Roughness with 2.5 m/s Speed and 0.3 mm depth of Cut

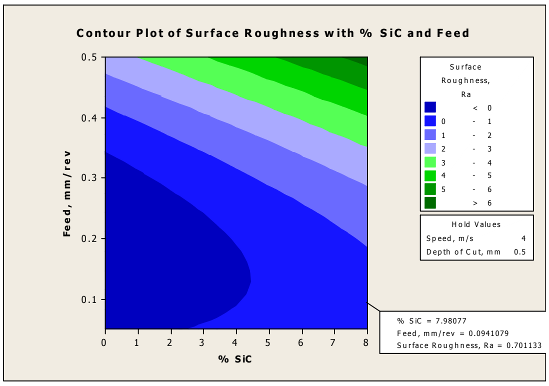


Fig-18: Contour Plot of Surface Roughness with 4 m/s Speed and 0.5 mm depth of Cut

Table-10: Optimal Combinations of Depth of Cut, Speed and Feed for minimum Surface Roughness during Turning of Al-Cu-SiC-Gr Composites

% SiC	Depth of Cut, mm	Speed, m/s	Feed, mm/rev	Surface Roughness Ra
0	0.1	1	0.25	0.002
2	0.2	1.75	0.24	0.652
4	0.3	2.5	0.19	1.007
6	0.4	3.25	0.14	1.024
8	0.5	4	0.09	0.701

Combinations of speed, feed and depth of cut in order to minimize cutting force and tool wear are respectively given in Table-6 and Table-8 for turning Al-Cu-Gr-SiC hybrid composites with 2, 4, 6 and 8 % SiC. But, Table-10 provides information which is more useful than that of the previous two due to the reason that it is important to know the combinations speed, feed and depth of cut which provide the minimum surface roughness in turning a hybrid composite with particular % SiC reinforcement from its application point of view. The very reason for this is that the quality of turned surface of a component made of a particular hybrid composite decides its suitability. Hence, contour plots for surface roughness are advantageous to turn hybrid composites of Al 2419 alloy with reinforcement of 1% Gr and 2, 4, 6, 8 % SiC.

V. CONCLUSIONS

Hybrid composites of Al 2419 alloy with reinforcement of 1% Gr and 2, 4, 6, 8 % SiC are fabricated by stir casting, tested for tensile, hardness and turning characteristics. Following are the conclusions.

- Central Composite Design of Experimental Technique is used to know percentage reinforcement of SiC, Speed, Feed and Depth of cut for investigation.
- Distribution of SiC particulates is ensured by SEM image.
- Addition of SiC by 2, 4, 6 and 8 % as improved Tensile Yield Strength, Ultimate Tensile Strength and Hardness of hybrid composites.
- Reinforcement of 2, 4, 6 and 8% SiC has decreased percentage elongation of the alloy.
- Feed alone affects cutting force so that its increase results in increased cutting force.
- Speed, depth of cut and feed affect the tool wear and increase of any one or all the three a increase tool wear.
- Surface roughness is influenced by feed such that its value increases with increase of feed.
- Charts providing combinations of speed, depth of cut and feed in the considered range are the outcome of investigation which are developed with the help of contour plots so that cutting force, tool wear and surface roughness are minimum.

REFRENCES

[1]. A.E. Al-Rawajfeh, S.M.A. Al Qawabah, Investigation of Copper Addition on the Mechanical Properties and Corrosion Resistance of Commercially Pure Aluminum, Emirates Journal for Engineering Research, 14 (1) (2009) 47-52.

[2]. Chinta Neelima Devi, V.Mahesh ,N.Selvaraj, Tensile and Impact behaviour of Al-Sic-Zn-Cu Metal Matrix Composite, Research Journal of Engineering Sciences, 3(2),(2014)17-22.

[3]. B Latha Shankar, K.C Anil ,Prasann, J Karabasappagol, A Study on Effect of Graphite Particles on Tensile,Hardness and Machinability of Aluminium 8011 Matrix Material, IOP Conf. Series: Materials Science and Engineering 149 (2016).

[4]. Mohammed Imran, A.R. Anwar Khan, Sadananda Megeri, Shoaib Sadik, Study of hardness and tensile strength of Aluminium-7075 percentage varying reinforced with graphite and bagasse-ash composites, Resource-Efficient Technologies 2 (2016) 81–88.

[5]. El-Sayed M. Sherif, A. A. Almajid, Fahamsyah Hamdan Latif, Harri Junaedi, Effects of Graphite on the Corrosion Behavior of Aluminum-Graphite Composite in Sodium Chloride Solutions, Int. J. Electrochem. Sci., 6 (2011) 1085 – 1099.

[6]. Saravana Bhavan K, Suresh S, Vettivel S C, Synthesis, Characterization and Mechanical Behaviorof Nickel Coated Graphite on Aluminum Matrix Composite, International Journal of Research in Engineering and Technology, 2 (11) (2013) 749-755.

[7]. K Karvanis, D Fasnakis, A Maropoulos, S Papanikolaou, Production and mechanical properties of Al-SiC metal matrix composites, IOP Conf. Series: Materials Science and Engineering 161 (2016).

[8]. K. L. Meena, Dr. A. Manna, Dr. S. S. Banwait, Dr. Jaswanti, An Analysis of Mechanical Properties of the Developed Al/SiC-MMC's. American Journal of Mechanical Engineering, 1(1) (2013) 14-19.

[9]. Sumesh Narayan, Ananthanarayanan Rajeshkannan, Hardness, tensile and impact behavior of hot forged aluminium metal matrix composites, Journal of Materials Research and Technology,6(3)(2017) 213 219.

[10]. Jokin Beristaina, Oscar Gonzaloa,, Alejandro Sandáa, Machinability of Al-SiC metal matrix composites using WC, PCD and MCD inserts, Metal. 50(1) (2014).

[11]. R.Venkatesh,A.M.Hariharan,.Muthukrishnan, Machinability Studies of Al/SiC/ (20p) MMC by Using PCD Insert (1300 grade). Proceedings of the World Congress on Engineering 2009 (2) (2009).

[12]. U. A. Dabade, M. R. Jadhav, Experimental study of surface integrity of Al/SiC particulate metal–matrix composites in hot machining, Procedia CIRP 41 (2016) 914 – 919.

[13]. M.Vamsi Krishna, Anthony.M.Xavior, An Investigation on the Mechanical Properties of Hybrid Metal Matrix Composites. Procedia Engineering 97 (2014) 918 – 924.

[14]. Radhika N, Subramanian, Sajith, Analysis of chip formation in machining aluminium hybrid composites, E3 Journal of Scientific Research, 2(1) (2014)9-15.

[15]. Anthony Xavior M, Ajith Kumar J P, Machinability of Hybrid Metal Matrix Composite - A Review, Procedia Engineering 174 (2017) 1110 – 1118.

[16]. Ch. Shoba, N. Ramanaiahb, D. Nageswara Rao, Effect of reinforcement on the cutting forces while machining metal matrix composites An experimental approach. Engineering Science and Technology, an International Journal 18 (2015) 658-663.
[17]. Soorya Prakash Kumarasamya, Kavimani Vijayananthb, Titus Thankachanb,Gopal Pudhupalayam Muthukuttiba, Investigations on mechanical and machinability behavior of aluminum/flyashcenosphere/Gr hybrid composites processed through compocasting. Journal of Applied Research and Technology 15 (2017) 430–441.
[18]. Ahmad T. Mayyas, Mohammad M. Hamasha, Abdalla Alrashdan, Adel M. Hassan, Mohammed T. Hayajneh, Effect of Copper and Silicon Carbide Content on the Corrosion Resistance of Al-Mg Alloys in Acidic and Alkaline Solutions, Journal of Minerals & Materials Characterization & Engineering, 11(4)(2012) 335-352
[19]. C. Velmurugan, R.Subramanian, S.Thirugnanam, B.Ananadavel, Experimental investigations on machining characteristics of Al 6061 hybrid metal matrix composites processed by electrical discharge machining, International Journal of Engineering, Science and Technology, 3(8) (2011) 87-101.
[20]. Devaraju Aruri, Kumar Adepu, Kumaraswamy Adepu, Kotiveerachari Bazavada, Wear and mechanical properties of 6061-T6 aluminum alloy surface hybrid composites [(SiC + Gr) and (SiC + Al2O3)] fabricated by friction stir processing, Journal of Materials Research and Technology, 2(4) (2013) 362- 369.
[21]. Srinivasan, A, R.M. Arunachalam, S. Ramesh ,J.S. Senthilkumaar, Machining Performance Study on Metal Matrix Composites-A Response Surface Methodology Approach, American Journal of Applied Sciences 9 (4)(2012) 478-483.
[22]. K. Venkatesan1, R. Ramanujam, J.Joel, P.Jeyapandiarajan, M.Vignesh, Darsh Jiten Tolia,R.Venkata Krishna, Study of Cutting force and Surface Roughness in machining of Al alloy Hybrid Composite and Optimized using Response Surface Methodology, Procedia Engineering 97 (2014) 677 – 686.
[23]. Puneet Bansal, Lokesh Upadhyay, Effect of Turning Parameters on Tool Wear, Surface Roughness and Metal Removal Rate of Alumina Reinforced Aluminum Composite, Procedia Technology 23 (2016) 304 – 310.

Lakshmi Narasimha Murthy "Mechanical Characterization and Optimization of Machinability Characteristics of Aluminium Copper Graphite Silicon Carbide Hybrid Composites "International Journal of Engineering Research and Applications (IJERA) , vol. 8, no.6, 2018, pp.01-10