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Fabrication of Aluminium Composite Using Stir Casting Process and Optimization of Machining Parameters

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Abstract – **In this study an attempt has been made to fabricate aluminium metal matrix composite with a composition of 5 wt% Silicon carbide and 4 wt% graphite using stir casting method. Silicon carbide has been added because it is well known for its hardness and its abrasive nature and graphite is a solid lubricant, result of its addition can change the surface roughness. The combined effect of four machining parameters including nose radius (R), cutting speed (s), feed rate (f), depth of cut (d) on the basis of single performance characteristic of surface roughness (Ra) were investigated. As Surface finish gives low co-efficient of friction and it shows the quality of the mechanical component. Optimal machining parameter has been calculated using design of analysis using Taguchi design or an orthogonal array.**

Keywords: **Al-MMC, Hybrid composite, Stir casting, Surface roughness, Taguchi's design**

I. Introduction

The necessity for engineering materials with the technological importance for the areas of aerospace and land vehicles has led to a rapid development of composite materials. Composites have an edge over monolithic materials because of their unique properties such as high specific strength and stiffness, increased wear resistance, corrosion resistance, enhanced temperature performance together with better thermal and fatigue and creep resistance [1]. Metal matrix composites are one of the main innovations in the development of advanced materials. Among the different matrix materials available, aluminum and its alloys are widely utilized in the fabrication of MMCs and have reached the industrial production stage. The emphasis has been given on improving affordable Al-based MMCs with different hard and soft reinforcements (SiC, Al_2O_3, graphite, and mica) because of the enhanced possibilities of these combinations in forming highly desirable composites [2]. Graphite, in the form of particulates, has long been identified as a high-strength, low-density material. Literature reveals that most of the previous work was done to reinforce SiCp in various aluminum matrix composites [1]. However, some information is available regarding Al2O3 particulates reinforced in various aluminum metal matrixes [3]. The effects of SiCp in Al-4.5% Cu-1.5% Mg alloy on mechanical properties of materials were investigated by Stefanos [4]. He prepared composite material using stir casting route and concludes positive response on fatigue and tensile strength in heat treated condition with addition of SiCp. The stir cast aluminum alloy matrix and process parameters were thoroughly investigated by Pai, *et. al.*[5] . They conclude from literature that stir casting process is relatively simple and less expansive as compared to other processing methods. The most economical manufacture of such composites is by stir casting. In order to discover the potential of using Al/graphite composites as structural materials, mechanical properties need to be improved by controlling the nature of the distribution of the graphite particles and the interface that exists between the graphite and the metal matrix. In addition to that the presence of graphite in the Al-SiC-graphite alloy made it highly machinable and wear resistant because of the presence of graphite. Also presence of graphite gives lower density than Al-SiC MMCs castings.

II. Fabrication of Al/Sic-Graphite Metal Matrix Composites

Silicon Carbide and graphite reinforced particles of average particle size 75 microns respectively are used for casting of Al/SiC-Graphite MMCs by stir casting technique. Table 2 represents the chemical composition of commercially available aluminium used for manufacturing of MMC. In this study, commercially available aluminium is used as metal matrix reinforced with 5 wt% Silicon Carbide and 4 wt% graphite particulates. The melting was carried out in a steel crucible placed inside the resistance furnace. An induction resistance furnace with temperature regulator as well as indicator is used for melting of Al/SiC-graphite MMCs. The figure 1 shows an induction resistance furnace and temperature regulator as well as indicator respectively. SiC and graphite particulates were preheated at 800°C for 2 hours to improve the wetness properties by removing the absorbed hydroxide and other gases.

The furnace temperature was first raised above the melting temperature that is 800°C, to melt the matrix completely and then it was cooled down to just below the melting temperature to keep the slurry in a semi-solid state. At this stage the preheated SiC and graphite particles were added and mixed. A small amount of Magnesium is added in order to increase the wet ability of the composite. The composite slurry was then reheated to a fully liquid state and mechanical mixing was carried out for 20min at 400rpm average stirring speed. Moulds made of thick steel sheet were preheated to 200°C for 2 hours before pouring the molten Al/SiC – graphite MMC. Then fabrication of composite was followed by gravity casting. The molten material flows in to the cast iron mold and solidified.

Table I Stir Casting Process Parameters

Sl.No	Parameters	Values
1	Preheating chamber temperature	800°C
2	Furnace temperature	850°C
3	Core temperature	800°C
4	Voltage	440V
5	Frequency	50 Hz
6	Stirrer speed	400 rpm
7	Die preheating temperature	200°C

III. Machining of Composite

In the present experimental, the material to be machined is 6061 Al alloy reinforced with SiCp and graphite particles at a composition of 5%, 4% (mass fraction) and particle size of 50 micron. The experiments were performed on a lathe machine (turning operation). The dimensions of the specimens were 450 mm in length and 30mm in diameter. The composition of the 6061 Al alloy specimen is presented in Table II. The list of controllable factors influencing the surface roughness in turning process is

A. Nose radius

B. Cutting speed

C. Feed rate

D. Depth of cut

Table II Chemical Composition of Matrix Al 6061 T6

Al 6061 T6	Al	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	Others
% Composition	Balance	0.8-1.2	0.4-0.80	Max 0.70	0.15-0.40	Max 0.25	Max 0.150	Max 0.150	0.04-0.35	0.05

Table III Machining Parameters and Their Levels.

Process factors	Unit	Notation	Level		
			1	2	3
Tool Nose radius (TNMG)	mm	R	0.4	0.6	0.8
Cutting speed	mm/min	s	30	60	90
Feed rate	mm/rev	f	0.118	0.176	0.235
Depth of cut	mm	d	0.3	0.6	0.9

TABLE IV TAGUCHI L_9 ORTHOGONAL ARRAY AND SURFACE ROUGHNESS

LEVELS	NOSE RADIUS (mm)	CUTTING SPEED (mm/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	TRIAL (SURFACE ROUGHNESS) (µm)			
					R1	R2	R	Mean
1	1	1	1	1	3.104	3.395	4.39	3.62
2	1	2	2	2	2.877	2.69	2.746	2.77
3	1	3	3	3	1.86	1.52	1.62	1.66
4	2	1	2	3	2.89	3.42	3.67	2.55
5	2	2	3	1	1.789	1.68	1.89	1.78
6	2	3	1	2	3.317	3.34	3.31	3.32
7	3	1	3	2	1.688	2.08	1.49	1.75
8	3	2	1	3	2.601	2.481	2.607	2.56
9	3	3	2	1	3.278	3.103	3.68	3.35

TABLE V ANALYSIS OF VARIANCE

Source of variation	SS	DOF	MSS	% Contribution
Nose radius	4.15	2	2.075	24.7
Cutting speed	4.17	2	2.085	24.89
Feed rate	4.014	2	2.007	23.96
Depth of cut	3.065	2	1.5325	18.29
Error	1.35	-	-	8.16
Total	16.75	8		

IV. RESULTS AND DISCUSSION

Surface Roughness

In this experiment, the effect of SiCp and graphite reinforcement to LM6-MMC material at different ratios on surface roughness have been investigated at selected cutting speed and depth of cut and feed rate. The graph shows the relationship between surface roughness and cutting speed during dry turning at different depth of cut (0.3mm, 0.6mm, 0.9mm) and feed rate (i.e.0.118mm/rev, 0.176mm/rev & 0.235mm/rev) of 5 wt% and 4wt % SiCp-Graphite reinforced cast MMC material. The surface roughness is higher in case of samples having higher percentage of reinforcement compare to samples, which have relatively low percentage of reinforcement particles. This above results occurred might be due to the presence of extremely hard SiCp in the cast MMCs, during turning at low cutting speed the removed SiC particles has rolled over the machined surface and deteriorate the quality of the surface finish.

Evaluation of optimal parameters and Graphical representations

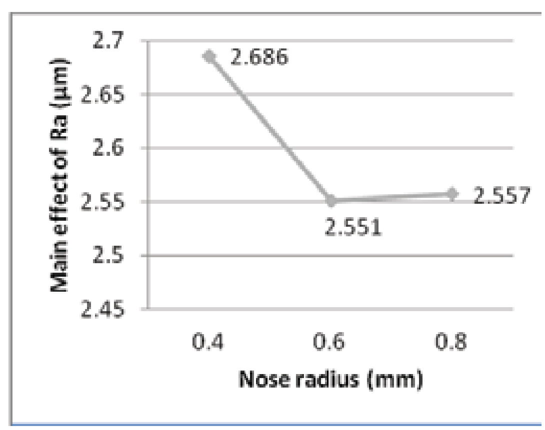

Fig.4 Plot for mean of mean vs nose radius of tool on surface roughness

From Figure 4 it has been observed that mean of mean decreases when nose radius increases. so the optimized machining parameter for better surface roughness is N3 (Nose radius) = 0.6mm

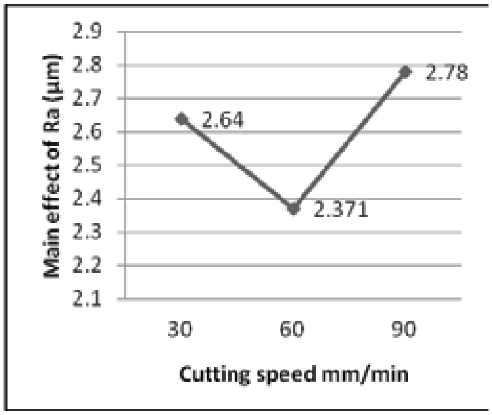

Fig.5.Plot for mean of mean vs cutting speed on surface roughness

From Figure 5 it has been observed that when cutting speed increase from 30 mm/min to 60 mm/min the mean of mean decreases, but it drastically increases from 60 mm/min to 90 mm/min, mean of mean drastically at 90mm/min than 30 mm/min. So the optimized machining parameter is S3 (cutting speed) = 60mm/min.

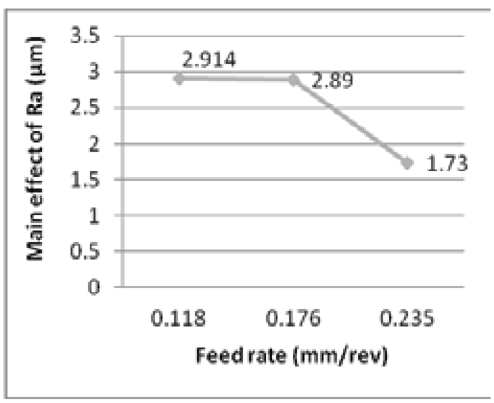

Fig.6 Plot for mean of mean vs feed rate on surface finish

From Figure 6 it has been observed that when feed rate increase from 0.118 mm/rev to 0.176 mm/min the mean of mean increases gradually, decreases of mean of mean at feed rate 0.235 mm/min. So the optimized machining parameter is F1 (Feed rate) = 0.235 mm/rev

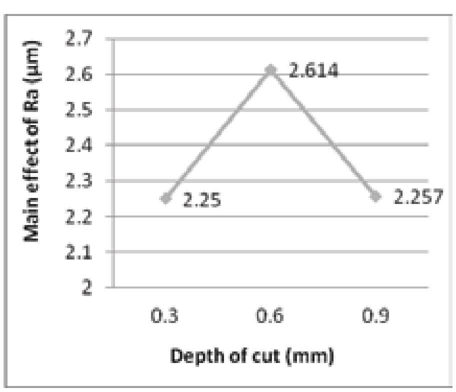

Fig.7 Plot for mean of mean vs depth of cut on surface finish

From Figure 7 it has been observed that when depth of cut increases mean of mean increases gradually, but it starts decreasing when depth of cut increases from 0.6mm to 0.9mm. So the graph the optimized machining parameter is DC1 (Depth of cut) = 0.3mm.

V. Conclusion

1. Taguchi's design and analysis (L_9 (3^4) orthogonal array) method is suitable to optimize the surface roughness in this work.
2. The percentage influence of significant factors in turning on surface finish is as follows
   - Nose radius (R) = 24.7%
   - Cutting speed (s) = 24.89%
   - Feed rate (f) = 23.96%
   - Depth of cut (d) = 18.29%3.
3. Using design of analysis the below optimized machining parameters are tabulated for better surface finish

Factors	Nose Radius (mm)	Cutting speed (mm/min)	Feed rate (mm/rev)	Depth of cut (mm)
Optimum value	0.6	60	0.235	0.3

In this present work solid lubricant graphite at 4 wt% is added to get good surface finish and the surface finish obtained in the turning process is without liquid lubricant. Further improvement in this paper can be done by varying the weight percentage of graphite and liquid lubricant can be applied during turning process to achieve considerable change in surface roughness.

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