International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 06 | June 2018 www.irjet.net p-ISSN: 2395-0072

FABRICATION AND CHARACTERIZATION OF HYBRID ALUMINIUM METAL MATRIX COMPOSITE

I. Joe michael[1], S. Jeya kumar[2]

[1] *PG student, Department of Mechanical Engineering, PSNA College of Engineering and Technology, Tamilnadu, India*
[2] *Assistant professor ,Department of Mechanical Engineering, PSNA College of Engineering and Technology, Tamilnadu, India*

---***---

Abstract – *The manufacturing of Aluminium alloy based hybrid metal matrix composite is one of the most economical process. Stir Casting Method or process is mainly used for manufacturing of particulate reinforced composites. The main objective of this is to combine matrix material AA6063 with reinforcement particles Silicon Carbide, Magnesium and fly ash to improve Wear rate loss of metal matrix composites from 5% to 15%. When machining the specimen the speed, percentage of composites and load are selected as process parameters for the investigation. In this process composite material to test ultimate tensile strength ,wear test ,compressive strength , hard ness test , microstructure test .In Design of Experiments Taguchi's Technique L9 Orthogonal Array, ANOVA table, and pooled ANOVA is obtained to reduce the wear rate loss of the composite materials. When machining the specimen the speed, percentage of composites and load are selected as process parameters for the investigation. The regression analysis is made to obtain the relationship between those process parameters. The optimum parameters are obtained to minimize the wear rate loss.*

***Key Words*: particulate composites, Taguchi method, Testing, wear test, mechanical testing.**

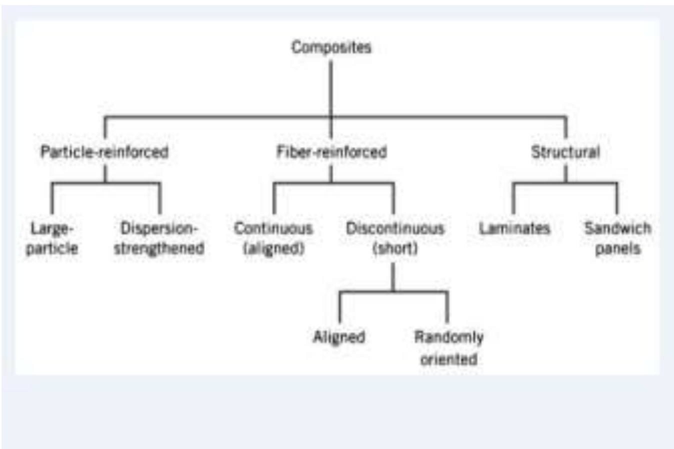
1. INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications

A Composite is a combination of two or more dissimilar materials joined together such that the properties of the resultant material are greater than the individual components. Composite material is composed of two or more constituent phase (i.e): matrix phase and reinforcement phase. A metal matrix composite is one of the types of composite in which the matrix phase is predominantly a metal or a metal alloy. The metal is the base material which constitutes the major part and the minor constituents are reinforcements that can be in the form of particles, whiskers, continuous and discontinuous fibers. The MMC consists of superior properties such as high strength, high stiffness, high electrical and thermal conductivity, greater resistance to corrosion, oxidation and wear when compared to the base material. A hybrid composite is one which involves more than two constituting materials.

Aluminium is an ideal material to be selected as a matrix as it consists of desirable properties like abundancy, low cost, low density, high strength-to-weight ratio, controlled co- efficient of thermal expansion, increased fatigue resistance and superior dimensional stability at elevated temperatures etc.

1.2 CLASSIFICATION OF COMPOSITES



2. LITERATURE REVIEW

J.Y. Hwang et al. studied the effect of Mg on the structure and properties of Type 319 aluminum casting alloys. The precipitation hardening behavior of a Type 319 aluminum alloy (Al–6.7 wt.% Si–3.75 wt.% Cu) with and without 0.45 wt.% Mg has been investigated. A considerably greater enhancement in UTS was observed after heat treating the alloys to their T6 condition. Specifically, there is an approximately 67% increase in the UTS of the Mg-containing alloy from 196 to 328 MPa upon ageing, while in the case of the Mg-free alloy, only a 30% increase in UTS was observed after the same heat treatment. Unfortunately, the Mg-containing material displays a significant decrease in ductility after ageing.

P. Apichai et al. studied the effect of Precipitation Hardening Temperatures and Times on Microstructure, Hardness and Tensile Properties of Cast Aluminium Alloy A319.At lower aging temperatures or shorter times, the hardness and tensile strength were decreased due to incomplete precipitation. However, at higher aging temperature or longer time, the hardness and tensile strength were decreased most probably due to precipitate coarsening and associated loss in coherency effects. A319 alloy is a hypoeutectic Al-Si alloy with two main solidification stages: the formation of primary aluminium rich (Al) dendrites followed by Al-Si eutectic. However, the presence of additional alloying elements such as Cu and Mg leads to a more complex solidification sequence and giving rise to other intermetallic eutectic phases such as Al_2Cu, Mg_2Si.

N. Crowell et al. studied Solution Treatment Effects in cast Al-Si-Cu alloys.Sr modification also reduces the number of Fe needles in alloys with high Fe content. The tensile properties of thee castings improve slowly with solution treatment time. Sr modification has a beneficial effect in improving the strength and elongation, further more modification also lowers the solution time necessary to attain the desired property level. At a Sr concentration of .005%, even after a solution time of 128hr the casting contain several highly angular Si particles. By comparison, at a Sr concentration of .014% nearly all the Si particles are highly spheroidized even for times less then 8-16hr.

J.Gauthier et al., studied the heat treatment of 319.2 aluminium automotive alloy part 1, solution treatment. Heat treatment is one of the important controlling factors used to enhance the mechanical properties of an alloy casting. This involves optimizing both the solution heat treatment and the ageing treatment given to the alloy. An alternative solution treatment is suggested consisting of solutionizing for a short period at 540^0C to allow for spheroidization of the Si particles and dissolution of a significant part of the Cu, followed by slow cooling to 515^0C, followed by quenching into water. This process is found to produce better ductility than the 8hr at 515^0C treatment, maintaining the same time high levels of yield and ultimate tensile strengths.

J.Gauthier et al., studied the heat treatment of 319.2 aluminium automotive alloy part 2, Ageing behavior. In this paper the hardening behavior upon artificial ageing in the range 155-220^0C for periods of up to 24hr has been investigated. Inclusion and oxides have a marginal effect on the yield strength; they deteriorate both UTS and %elongation to levels below those obtained in the as cast condition. The results show that peak ageing is achieved after 24hr at 150^0C or 5hr at 180^0C.

3. WORK PIECE MATERIAL DETAILS

3.1 AL6063 MATRIX MATERIALS

Aluminium is used as matrix in the synthesis of composite. Aluminium was cut from its ingot size into smaller pieces by an electric power saw in order to feed the crucible properly. Composition of matrix alloy was analyzed and the chemical composition of the matrix alloy. Aluminium alloy 6063 is an , aluminium alloy with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance.

Table 1. chemical composition of the Al6063matrix alloy

Cu	Mg	Ti	Sn	fe	Mn	sb	v
4.089	0.425	0.039	0.013	0.123	0.425	0.015	0.010

3.2 SILICON CARBIDE

Silicon Carbide magnesium and fly ash is composed of tetrahedra of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Silicon Carbide and magnesium and fly ashis not attacked by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. The high thermal conductivity coupled with low thermal expansion and high strength give this material exceptional thermal shock resistant qualities. Silicon Carbide and magnesium and fly ashceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. Chemical purity, resistance to chemical attack at temperature, and strength retention at high temperatures has made this material very popular as wafer tray supports and paddles in semiconductor furnaces. The electrical conduction of the material has leadto its use in resistance heating elements for electric furnaces, and as a key component in thermistors (temperature variable resistors) and in varistors (voltage variable resistors).Silicon Carbide and magnesium and fly ashand Iron were used as reinforcement material. Particle size of Silicon Carbide and magnesium and fly ash was in the range between 50 μm and Iron was in the range between 50 μm The received reinforcement particles were sieved and required particle size were selected .

Table 2. chemical composition of the Silicon Carbide

Cu	Mg	Ti	Si	Fe	Ga	Sb	v
2.089	2.40	0.039	1.12	0.123	1.43	0.75	0.83

3.3 MAGNESIUM

Magnesium-base products are available in a wide range of mechanical properties. As with metal manufactures in general, the tensile and other properties of the magnesium materials depend upon the composition, condition (whether cast or wrought), details of fabrication, heat treatment, and other factors. For the same composition, some mechanical properties vary considerably with the type of product. Accordingly, it is important to define the kind of material as well as the alloy composition. Also, the direction in which the test specimen is taken in relation to the direction of and the thickness of the product are factors which influence strength and other properties fabrication.

3.4 FLY ASH REINFORCEMENT

Fly Ash is a semimetals an electrical conductor. It is consequently, useful in such applications as arc lamp electrodes. **C** is the most stable form of carbon under standard conditions. Therefore, it is used in thermo chemistry as the standard state for defining the heat of carbon compounds. Fly Ash may be considered the highest grade of coal, just above anthracite and alternatively called meta-anthracite, although it is not normally used as fuel because it is difficult to ignite.

3.5 COMPOSITION OF SAMPLES

Aluminium 6063 was reinforce in Silicon Carbide magnesium and fly ash and 5% 10% and 15% table:3.10 show in mixed ratio in %

Table 3. Composition of sample

SAMPLE NO.	ALUMINIUM 6063 (GM)	REINFORCEMENT, SILICON CARBIDE AND MG IN (%) AND FLY ASH(GM)
1.	475	Silicon Carbide - 25%
2.	450	Silicon Carbide -25% mg- 25 %
3.	425	Silicon Carbide -25% mg- 25% fly -25%

4. EXPERIMENTAL METHOD

A stir casting setup (Figure 1), which consisted of a resistance furnace and a stirrer assembly, was used to synthesize the composite. The stirrer assembly consisted of a graphite turbine stirrer, which was connected to a variable speed vertical drilling machine (speed 0 to 890 rpm) by means of a steel shaft. The stirrer was made by cutting and shaping a graphite block to desired shape and size manually. The stirrer consisted of three blades at angles of 120° apart. Figure 1 show the photograph of the stirrer from two different angles. Clay graphite crucible of 1.5 Kg capacity was placed inside the furnace.

The stirrer assembly consisted of a graphite turbine stirrer fixed to a steel rod. Approximately 1Kg of alloy was then melted at 820°C in the resistance furnace of stir casting setup. Preheating of Silicon Nitride, Aluminium Nitride, and Zirconium Boride mixture at 800°C was done For one hour to remove moisture and gases from the surface of the particulates. The stirrer was then lowered vertically up to 3 cm from the bottom of the crucible (total height of the melt was 9 cm). The speed of the stirrer was gradually raised to 800 rpm and the preheated Silicon and Iron particle was added with a spoon at the rate of 10- 20g/min into the melt.

The speed controller maintained a constant speed, as the stirrer speed got reduced by 50-60 rpm due to the increase in viscosity of the melt when particulates were added into the melt. After the addition of Aluminium alloy , Silicon and Iron particle, stirring was continued for 10 minutes for better distribution. The melt was kept in the crucible for one minute in static condition and it was then poured in the metal mould

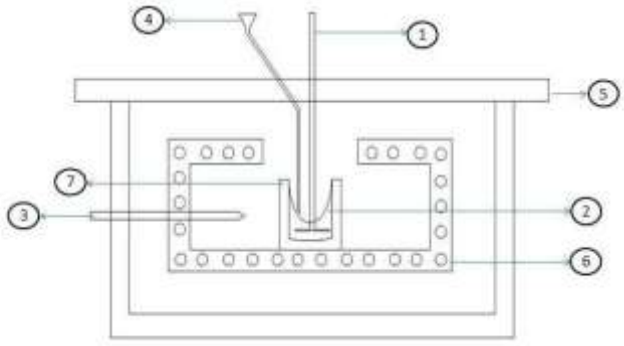


Fig 1. Stir casting setup

5. TAGUCHI DESIGN OF EXPERIMENT

Taguchi design method with L_9 orthogonal array was implemented to optimize the wear rate. In S/N ratio, the smaller the better criteria was selected and formula detailed in the literature [5,8].

The following order of plan to optimize the process parameters for wear rate are detailed below:

1. Determination of critical process control parameters
2. Selecting the levels of the process control parameters
3. Selection of the experimental design matrix
4. Conducting the experiments a s per the design matrix and recording of responses
5. Calculate the signal to noise (S/N) ratios
6. Analysis of variance (ANOVA)
7. Pooled ANOVA
8. Confirmatory test to check the optimized process parameters

Table 4. process parameters and their levels

Parameters	Units	Notation	levels					
			original			Coded		
			1	2	3	1	2	3
composite	**%**	A	5	10	15	1	2	3
speed	**RPM**	B	60 0	900	1200	1	2	3
load	**N**	C	30	45	60	1	2	3

Table 5. Experimental layout using L9 orthogonal array with coded and original level values

Trial no	Parameters/factors					
	composite (%)		SPEED (RPM)		LOAD (N)	
	Original value	Coded value	Original value	Coded value	Original value	Coded value
1	5	1	600	1	30	1
2	5	1	900	2	45	2
3	5	1	1200	3	60	3
4	10	2	600	1	45	2
5	10	2	900	2	60	3

6	10	2	1200	3	30	1
7	15	3	600	1	60	3
8	15	3	900	2	30	1
9	15	3	1200	3	45	2

Table 6. Experimental results and corresponding S/N ratios and Wear Rate

Trial no	Process parameters			Responses	S/N ratio (dB)
	composite (%)	speed (rpm)	load (N)	wear rate	
1	5	600	30	0.0001303	77.70
2	5	900	45	0.0001387	77.15
3	5	1200	60	0.0001392	77.12
4	10	600	45	0.0000955	80.39
5	10	900	60	0.0000993	80.06
6	10	1200	30	0.0001086	79.28
7	15	600	60	0.0000706	83.02
8	15	900	30	0.0000769	82.28
9	15	1200	45	0.0000898	80.93
Average S/N ratio					79.73

Table 7. S/N response table for Wear Rate

PARAMETERS	CHARACTER	LEVEL 1	LEVEL 2	LEVEL 3	DELTA =MAXIMUM-MINIMUM	RANK
composite (%)	**A**	**77.3**	79.9	82.07	4.77	1
speed (rpm)	**B**	80.25	79.83	**79.11**	1.44	2
load (N)	**C**	**79.37**	79.75	80.06	0.31	3

Table 8. Result of ANOVA for wear rate

Character	parameters	Degree of freedom	Sum of squares (ss)	variance	Corrected sum of squares	Contribution (%)

A	composite (%)	2	226.406	113.203	104.03	2.80
B	speed (RPM)	2	159.421	79.712	37.045	0.99
C	load (N)	(2)	(122.3)	pooled	-	-
Error		2	122.376	61.188		96.20
Total		6	508.203			100

Character	Parameters	Degree of freedom	Sum of squares (ss)	Variance	Corrected sum of squares	contribution (%)	Rank
A	composite (%)	2	226.40	113.203	226.40	6.10	1
B	Speed (rpm)	2	159.421	79.712	159.421	4.30	2
C	Load (N)	2	122.3	61.18	122.3	3.30	3
Error		0	0	0	0		
Total		6	508.20				

Table 9. pooled ANOVA for wear rate

Table 10. Evaluation of the predicted wear rate with the experimental results of the confirmation experiment using optimal condition

Parameter	A	B	C	S/N ratio		Performance values of wear rate	
	% of composite	Speed	load				
				Prediction	Experiment	Prediction	experiment
Optimum coded value	1	3	1	76.52	77.32	0.000076	0.00013
Opti mum Original value	5	1200	30				

EQUIPMENT USED : METALLURGICAL MICROSCOPE- METSCOPE-1A	
COMPOSITE(6063ALUMINUM REINFORCED SILICON CARBIDE MAGNESIUM AND FLY ASH)	HVI KG
SAMPLE 5%	120, 122,124 Avg : 122
SAMPLE 10%	138, 140,142 Avg : 140

SAMPLE 15%	142,144,146 Avg : 144

Table 11. Hardness test result

TABLE 12. ULTIMATE TENSILE STRENGTH

EQUIPMENT USED :UTM.MAKE : FIE. MODEL UTN 40. SR NO: 11/98 – 2450.			
COMPOSITE (6063 ALUMINUM REINFORCED SILICON CARBIDE MAGNESIUM AND FLY ASH)	5%	10%	15%
TENSILE STRENGTH IN MPA	221.45	229.7	246.57
YIELD STRESS IN MPA	426	447	477
ELONGATION	10.26 %	14.56 %	15.86%

5.1 HARDNESS TEST

The hardness of the 6063 Aluminum Alloy Reinforced with Silicon Carbide Magnesium And Fly Ash 5%, 10%, and 15%specimen were carried out. In this test the 6063 Aluminum Alloy samples of the size 40 mm length and 18 mm diameter were applied a load of 10kg for 5 to 10 sec. The values are calculated as shown in figure 6063 Aluminum Alloy specimen with different treated conditions used for measuring hardness.

5.2. ULTIMATE TENSILE STRENGTH TEST

The Ultimate Tensile Strength of the 6063 Aluminum Alloy Reinforced with Silicon Carbide Magnesium And Fly Ash in 5%, 10%, and 15%specimen were carried out. In this test the 6063 Aluminum Alloy samples of the size 40 mm length and 18 mm diameter were applied a load of 10kg for 5 to 10 sec. The values are calculated as shown in figure 6063 Aluminum Alloy specimen with different treated conditions used for measuring ultimate tensile strength.

5.3 STATISTICAL ANALYSIS

The mathematical relationship between response and process parameters were established using multiple linear regression analysis by using MINITAB 16.

wear loss = 3.766 x 10-4 – 5.97 x 10-6 % of reinforcement + 2.295 x 10-9 speed -7.173 x 10-9 load .

6. CONCLUSION

In this study, stir casting method process parameters were optimized for wear rate to obtain the minimum wear loss and the results were analysed in detail. Analysis of variance (ANOVA) and pooled (ANOVA) techniques were used to examine the most significant factor. We can draw the following conclusions

1. To investigate the results the test conducted are wear test, tensile test, compressive test, hardness test, microstructure

2. The % of composite is the predominant factor that affects the wear loss in stir casting process.

3. The optimum condition for wear rate achieved at % of reinforcement of 5 % , speed of 1200 rpm, load of 30 N, at minimum wear loss value 0.00013 . further scope to maintain the % of reinforcement, speed, load to control the wear rate loss.

4. Finally multiple linear regression modeling also done. The multiple linear regression equation of wear loss = 3.766 x 10-4 – 5.97 x 10-6 % of reinforcement + 2.295 x 10-9 speed -7.173 x 10-9 load .

REFERENCES

[1] JIANG, L., JIANG, Y. L., YU, L., SU, N., & DING, Y. D. (2012). Experimental study and numerical analysis on dry friction and wear performance of co-continuous SiC/Fe–40Cr against SiC/2618 Al alloy composites. Transactions of Nonferrous Metals Society of China, 22(12), 2913-2924.

[2] Das, D. K., Mishra, P. C., Singh, S., &Pattanaik, S. (2014). Fabrication and heat treatment of ceramic-reinforced aluminium matrix composites-a review. International Journal of Mechanical and Materials Engineering, 9(1), 1-15.

[3] Dinaharan, I., Kumar, G. A., Vijay, S. J., &Murugan, N. (2014). Development of Al< sub> 3</sub> Ti and Al< sub> 3</sub>Zr intermetallic particulate reinforced aluminum alloy AA6063 in situ composites using friction stir processing. Materials & Design, 63, 213-222.

[4] Kumar, S., Panwar, R. S., & Pandey, O. P. (2013a). Effect of dual reinforced ceramic particles on high temperature tribological properties of aluminum composites. Ceramics International, 39(6), 6333-6342.

[5] Kumar, S., Panwar, R. S., & Pandey, O. P. (2013b). Wear Behavior at High Temperature of Dual-Particle Size Zircon-Sand-Reinforced Aluminum Alloy Composite. Metallurgical and Materials Transactions A, 44(3), 1548-1565.

[9] Characterization and Engineering Vol.8 No.10, 2009.

[10] G. B. Veeresh Kumar, C. S. P. Rao and N. Selvaraj: "Mechanical and Tribological Behaviour of

[6] Rajan., Ramabalan., Dinaharan., Vijay (2014). Effect of TiB2 content and temperature on sliding wear behaviour of AA7075/TiB2 in situ aluminum cast composites. Archives of Civil and mechanical engineering, 14(1), 72-79.

[7] Rajaneesh N. Marigoudar and Kanakuppi Sadashivappa: "Dry Sliding Wear Behaviour of SiC Particles Reinforced Mos2 -Aluminium (ZA43) Alloy Metal Matrix Composites", Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.5, pp.419-425, 2011.

[8] Manoj Singla, Lakhvir Singh and Vikas Chawla: "Study of Wear Properties of Al-Sic Composites", Journal of Minerals and Materials

Particulate Reinforced Aluminium Metal Matrix Composites – a review", Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.1, pp.59-91, 2011.

AUTHORS PROFILE

I. Joe Michael received his M.E-Engineering design from PSNA college of Engineering and Technology, Tamilnadu

S. JeyaKumar He is working at assistant professor, Department of Mechanical Engineering, PSNA College of Engineering and technology, Dindigul, tamilnadu..