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Investigation of Mechanical Properties of Al- TiO_2-Graphite Hybrid Composite Fabricated Using Squeeze Casting Process

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Abstract: In this study TiO_2 particles and Graphite particles reinforced with Al1100 to form a metal matrix composite, which is more commonly used in aerospace, marine, military and automotive applications. Al 1100 an variable weight fractions of 2, 4 % titanium dioxide and 1,3 % percentage of graphite were fabricated through stir casting. Subsequent analysis on wear and mechanical properties such as microhardness, tensile, corrosion tests were carried out. Results showed improved wear and improved mechanical characteristics for 2% of TiO_2 and 3 % of Graphite at reinforcement preheat temperature of 900 C.
Keywords: Squeeze casting, Al1100, Tensile test, Hardness test, Corrosion Test, Taguchi method.

I. INTRODUCTION

Aluminium is a ductile, silvery white colour material, hence these Al based Metal matrix composite are the area for the research which have emerged as major class of materials for various fields of engineering applications. On the other hand Al alloy matrix composites have better wear resistance, low density, higher toughness and corrosion resistance.

Various researches have been conducted by reinforcing Graphite, TiB_2, TiC, B_4C, Flyash on aluminium based metal matrix composites using different manufacturing processes. Nevertheless, the reinforcement of TiO_2 particles in Al1100 has got a greater importance because they possess higher hardness and good corrosion resistance properties.

Generally the incorpation of hard ceramic particles on the Aluminium matrix may improve the mechanical and tribological behaviour, but sometimes they may cause rapid wear on the surface and deteriorated machinability.

II. MATERIALS AND EXPERIMENTAL FABRICATION

A. Matrix Material

For this experimental investigation, Al1100 is used as the matrix material. The chemical composition of Al1100 is listed in table 1 below. Al1100 has excellent machinability. In Al1100 hot and cold forming can also be easily performed.

Table I Chemical composition of Al 1100

Mg	Cr	Cu	Fe	Mn	Si	Zn	Others
0.05 %	0.15 to 0.35 %	0.05-0.20 % max	0.95 % max	0.1 % max	0.95 % max	0.1 % max	0.15 % max

B. Reinforcement Material

Titanium di Oxide is chosen as the reinforcement material, since it is easy to blend with al alloys for improving strength and hardness.

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III. EXPERIMENTAL PROCEDURE

The experimental setup of squeeze casting essentially consists of an electric furnace and a mechanical stirrer. The electric furnace carries a crucible of capacity 2*Kg*. The maximum operating temperature of the furnace is 1000*°C*. The current rating of furnace is single phase 230V AC, 50*Hz*. The squeeze casting machine set up at GCT, Coimbatore is shown in Fig. 1.

Fig 1.Squeeze Casting Setup

A. *Experimental Plan*

The matrix material is aluminium alloy Al 1100. Samples are to be prepared using Al 1100 reinforced with Aluminium oxide TiO_2 (2%, 4%) and Graphite (1%,3%) by volume at various melting temperatures of 750°C, 825°C and reinforcement pre-heat temperatures as 850°C and 900°C. Experiments were conducted using Taguchi L_4 orthogonal design of experiments is shown in table II shows the various constituent levels of reinforcements added.

Table III Material Requirement

Sample No.	Al1100 (gm)	TiO_2(gm)	Graphite (gm)
1	1290.1	26.6	13.3
2	1236.9	53.2	39.9
3	1263.5	53.2	13.3
4	1263.5	26.6	39.9

An table III shows the material required for the fabrication of each sample.

Table III Material Requirement

Sample No	Melting temperature (°C)	Reinforcement preheat Temperature (°C)	Reinforcement (%)	
			TiO_2	Graphite
1.	750	850	2	1
2.	750	900	4	3
3.	825	850	4	1
4	825	900	2	3

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IV. MECHANICAL TESTS RESULTS

A. Tensile Test

The Casting were made according to the Parameters (squeeze pressure, melting temperature, squeeze time) selected in the Taguchi L4 orthogonal Array. Tensile testing, also known as tension testing is a test in which a sample is subjected to a tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under normal forces.

The Tensile test is carried out on the casting samples is shown in figure 2. The samples is loaded in the machine nd tensile load is given to test the specimens tensile strength. The unit of load measured is in N/mm^2. Figure 3 shows the specimen is after breaking of specimen by applied the tensile load on the specimen.

Fig 2 Tensile Test Sample preparation

Fig3 Tensile Tested Samples

The tensile test results are as shown in the table IV below.

Table IV Tensile Test Results

Sample No	Tensile Test N/mm^2	SNRA
1	124.88	41.16
2	117.63	40.90
3	119.81	41.56
4	121.81	41.82

The optimization of process parameter of tensile test is carried with minitab software the optimal values was shown in figure 4.

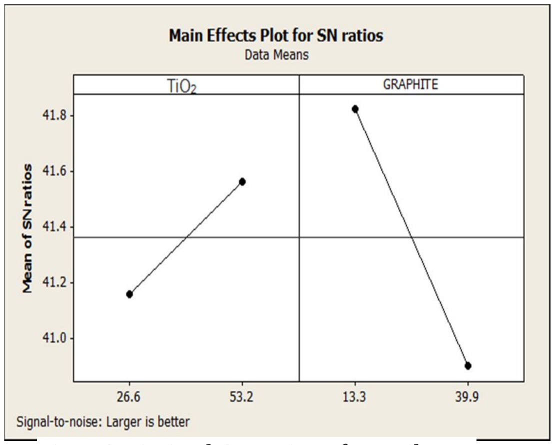

Fig 4 Optimized SN ratios of Tensile test

B. Hardness Test

Micro hardness test at various locations was carried out to know the effect of reinforced particulates on the alloy matrix as given in Table V. Vickers hardness measurement has been carried out on the embedded reinforcement particles as well as in the locality of particles and matrix.

Table V Microhardness Test results

Sample No	Trial 1 HV	Trial 2 HV	Average HV	SNRA
01	121.3	123.7	122.5	42.62
02	130.4	134	132.2	43.01
03	142.4	156	149.2	43.30
04	173.9	174.9	174.4	43.63

Fig 5 , 6 and 7 shows the indentation marked on the Vickers micro hardness tested samples, Vickers Microhardness tester and the machined samples on which the micro hardness tests were conducted.

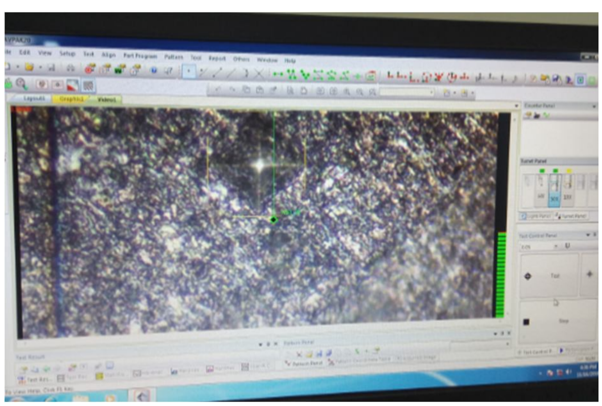

Fig 5 Indentation marked

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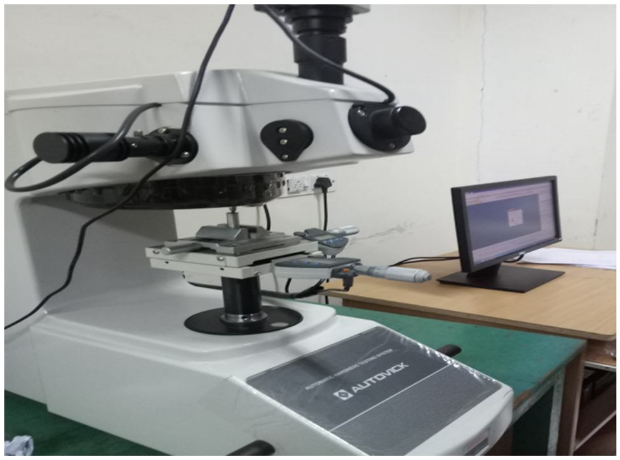

Fig 6 Vickers hardness tester

Fig 7 Micro hardness tested samples

C. Corrosion Test

Corrosion testing is a method used for evaluation of a materials ability to withstand specific environmental conditions. Corrosion in field conditions can be extremely slow, so different test methods have been followed to enable prediction of long-term corrosion behavior. Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases.Figure8 shows the samples on which corrosion test were conducted.

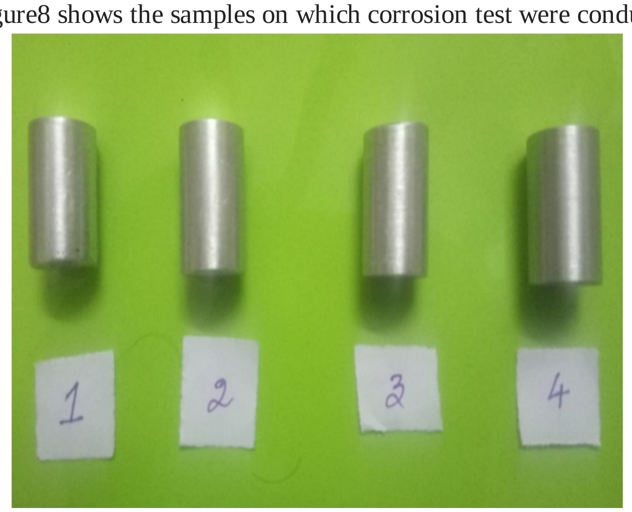

Fig 8 Corrosion tested samples

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The corrosion test is carried out on the casted and machined samples. The samples are machined, corrosion rate was calculated by weight loss method. The samples were weighted and immersed in 3.5% of NaCl solution for 10 days. After 10 days sample were collected and then weighted. the The corrosion test results are shown in the table VI. The corrosion resistance rate is high in level third of sample 4 addition of reinforcement percentage, squeezing time.

Table VI Corrosion test Values

Run Order	Area	Density	Before weight	After weight	Weight Loss	Corrosion Rate
	cm^2	g/cm^3	gm	gm	Gm	MPY
01	15.30	2.71	11.85	11.77	0.08	0.014
02	15.30	2.71	12.45	12.39	0.06	0.010
03	15.30	2.71	12.65	12.55	0.10	0.021
04	15.30	2.71	12.60	12.53	0.07	0.013

The optimized SN curve of ratio curve for corrosion test is as shown in figure 9.

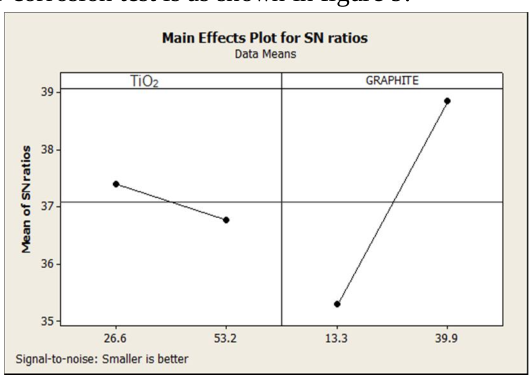

Fig 9 Optimized SN curve

Table VII shows the Response table for signal to noise ratios for corrosion tests.

Table VII Response Table for Signal to Noise Ratio for corrosion tests

Level	TiO_2	Graphite
	(2%, 4%)	(1%, 3%)
1	37.40	35.32
2	36.7	38.86
Delta	0.62	3.54
Rank	2	1

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V. ANOVA ANALYSIS

The inferences made from the above said graphs can be arrived at mathematically with the help of ANOVA.

Table VIII Anova table for Tensile test

Source	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
TiO_2	0.00004	53.55%	0.00004	0.000040	0.16	0.758
Graphite	0.00003	37.57%	0.00003	0.000030	1.44	0.442
Error	0.00002	8.08%	0.0000250	0.0000250		
Total	0.000650	100.00%				

The confidence limits are taken as 95% for all the factors. Factors with P-value less than 0.05 are considered to be significant. The table VIII shows the values obtained from tensile test ANOVA table. Table IX shows ANOVA table values for hardness test and Table X shows ANOVA table values for Corrosion test.

Table IX Anova table for hardness test

Source	Seq SS	Contribution	Adj SS	F-Value	Adj MS	P-Value
TiO_2	59	38.08%	59	0.05	59	0.860
Graphite	306	59.54%	306	0.26	306	0.700
Error	1183	6.37%	1183		1183	
Total	1549	100.00%				

Table X Anova table for Corrosion test

Source DF	Contribution	Adj SS	Adj MS		P-Value
TiO_2	24.86	64.52%	24.86	24.86	0.647
Graphite	149.84	25.67%	149.84	149.84	0.371
Error	64.96	8.81%	64.96	64.96	
Total	239.67	100.00%			

A. Conformation Experiments

The samples were prepared by optimum parametric setting. The optimized values of tensile, hardness, corrosion properties are shown in table XI, table XII,table XIII.

Table XI Optimized values for tensile test

Sample No	Weight of TiO_2+Graphite	Melting temperature	Squeeze time	Tensile test
	gm	*˚C*	*Minutes*	*N/mm^2*
4	26.6+39.9	750	10	121.89

Table XII Optimized values for hardness test

Sample No	Weight of TiO_2+Graphite	Melting temperature	Squeeze time	Hardness test
	Gm	˚C	Minutes	HV
4	26.6+39.9	750	10	174.4

Table XIII Optimized value for Corrosion test

Sample No	Weight of TiO_2+Graphite	Temperature	Squeeze time	Corrosion rate
	Gm	*° C*	*Min*	*MPY*
4	26.6+39.9	750	5	0.013

VI. CONCLUSION

The hybrid composite samples of Al 1100, TiO_2 and graphite as reinforcements were produced using squeeze casting process.The mechanical properties such as tensile strength, hardness and corrosion rate were investigated from the produced samples.

A. Composite having 2% TiO_2 ,3% graphite, squeeze time 10 mins and 95% Al- 1100 combination fabricated at melting temperature 825 °C and reinforcement pre-heat temperature 900°C has higher tensile strength 121.89 N/mm^2 and hardness 174.4 HV compared to other combinations.

B. The minimum Corrosion rate for Al 1100 composite is 0.013 Mpy in combination of 2% TiO_2, 3% graphite and squeeze time 5 mins. Whereas for others, the corrosion rate is maximum.

This hybrid composite can be explored for use in applications where higher strength and corrosion resistance is required.

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