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Synthesis and Characteristic of Aluminium-Graphite Composite

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Abstract: *It is known that aluminium and its alloys are of low modulus and medium strength. In order to improve the modulus and strength the composites are made by adding reinforcement in the aluminium and its alloys. Reinforcement can be in fibre form as well as in particulate form. Both have their own advantages. Fibers provide greater strength than particulate while particulate provide isotropic properties. In the present work. MMC has been prepared by reinforcing graphite particles of 50-350 ASTM size range into the base matrix alloy. The base matrix alloy (LM 11 alloy) has the composition as follows,*

Pb - 2.4%, Cu - 4.3%, Fe - 0.2%, Si - 0.4%, Al - remaining

The base alloy was melt in a vertical furnace. Melt was stirred and the preheated graphite powder (at 7000C) was added into it. The bottom pouring was done and then the melt was squeezed with 5 Tone load till it solidified. From the compocastings, samples were subsequently prepared for metallography examination, resistivity measurement, x-ray analysis, hardness and tensile test and deep drawing test.

Examination of the composites under optical microscope and SEM reveals that graphite particles are found to be uniformly distributed in aluminium alloy matrix. Quantitative metallography reveals that the composites produced have 5 and 20 volume % of graphite particles in the matrix. X-Ray analysis of the composites reveals the phases CuAl2 apart from Al & graphite.

Hardness of the composite material has reduces as compared to base alloy.

The tensile strength of the composite material has considerably improved as compared with the tensile strength of the base alloy.

The draw ability of the samples studied was very poor as compared to the base alloy. The resistively of the composite is found to be greater than base alloy.

keyword:*-Reinforcement, MMC,X-Ray Analysis, Tensile test, Deep drawing test, drawability.*

I. Introduction

Aluminium alloy graphite particulate composites are excellent bearing materials and it has been reported that they compare well with many copper alloy including lead. The major difficulty in the preparation of cast aluminium alloy - graphite particulate composites by a liquid metallurgy process is the apparent non wettability of graphite by liquid aluminium alloy and hence the rejection of graphite particles by the melt. The contact angle of aluminium with graphite is 1600 and it is reported to remain unwettable between the melting point of aluminium and 1080°C [1-2].

The dispersion of about 5-20 v % graphite particles in aluminium alloy matrix gives better adhesives wear resistance to the alloy [3]. The automotive pistons made out of these composites have shown about 5-7% fuel and lubrication oil saving [4]. The presence of graphite in the matrix improves its oil spread ability over the contact surface thus reducing the scoring tendency. The effects of size, shape and volume fraction of the disperssed graphite particles on the bearing properties of graphite composite [5]. The presence of graphite in the matrix gives° a tribo-induced thin film at the rubbing interface which prevents the scoring. It is necessary to maintain a continuous thin film to prevent scoring and for which about 5-20 vol % graphite in the matrix is used. The size range of graphite particle between 50-200 'um yields best result [6-7]. The coefficient of friction decreases with graphite percentage more than .2% of but below 20% [3]. The tensile properties of the composites come down sharply, when the graphite content in the matrix exceeds about 5 vol % [2-4].

In this investigation, the synthesis of graphite dispersed aluminium alloy matrix composites has been carried out by liquid metallurgy technique [7] 5-20 vol % of 50-350 µm size range surface treated graphite particles are added into matrix aluminium -copper alloy melt, kept stirred using an impeller [8-9].

The particle dispersed composite melt is then cast into ingots. The aluminium alloy - graphite composites are subjected to metallography studies under optical and scanning electron microscope. The phases present are identified by X-Ray diffraction. The mechanical testing to study the tensile properties, hardness and deep drawing characteristics are carried out. The resistively measurements of the composites are noted and compared with the base alloy.

II. Production Of Compocasting

The following equipments were used in the experimental work during casting. A batch type of setup, schematically shown in fig. 4.1 was used. The set up consists of a melting unit, a stirring arrangement, and a bottom pouring system.

Preparation of Furnace

A vertical muffle furnace having kanthal winding of dimensions 125 mm :(125 mm x 260 mm was used. A chromel-alumel thermocouple was used for the temperature control and its measurements. For melting of aluminium alloys, a graphite crucible having a bottom hole was placed inside the muffle furnace. The hole was plugged with a graphite stopper inserted through the hole in the bottom of the muffle furnace.

Design of Mould

A rectangular shaped permanent die steel mould of inner dimensions 9 x 9.5 x 10 cms was used. Their meeting surfaces were machined finally so that perfect contact was obtained. As the mould was in two parts, nut-bolt arrangement was provided. After joining the parts together with nut bolts, the spacing left at edges were covered with bentonite clay and mixture. It was properly dried to avoid explasion at the time of pouring of melt.

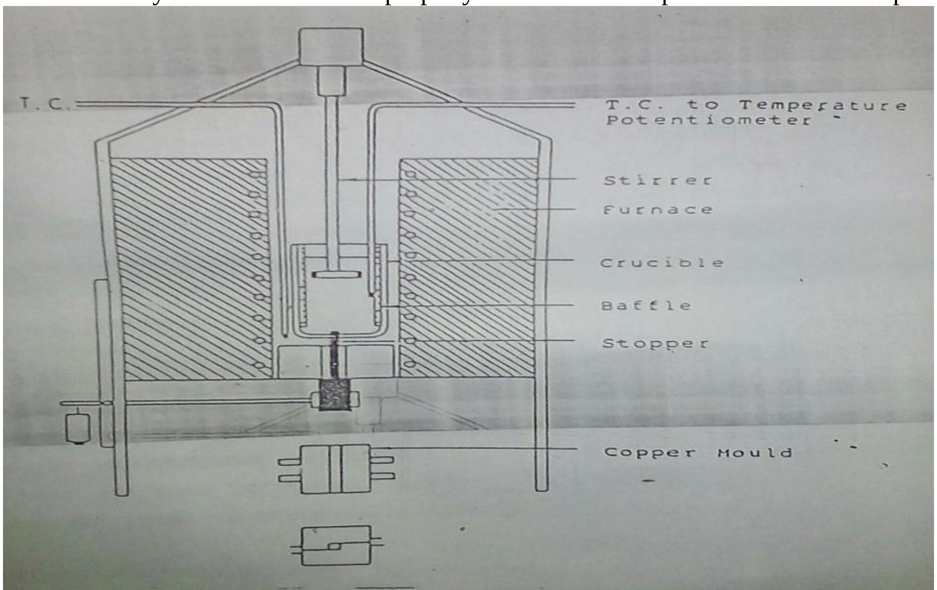

FIG. 4.1. : SCHEMATIC REPRESENTATION OF STIR CASTING UNIT (18)

FABRICATION OF CASTING

After the mould preparation, the mould was preheated to 4500C for 1 hr. At the same time, the powder was also preheated at 5000C for 1 hr. When the temperature of the vertical muffle furnace reached 750°C, suitable pieces of base alloy was kept in the crucible and then placed in the furnace for melting. Initially high temperature was necessary in order to minimize oxide formation. After the temperature reached 800°C, the base alloy is changed to molten state, a stirrer was inserted into the melt and stirred at 700 rpm for 5 minutes to enable the vortex formation.

Now, the preheated graphite powder was added at the rate of 4.5 gm/sec, in the vortex. After complete mixing. the melt was poured into the mould (450°C) in 40 seconds. Immediately, after pouring, the melt was taken to the press and with the help of plunger the melt was pressed at a pressure of 5 tones in the hydraulic press until it solidified.

CHARACTERIZATION OF THE COMPOSITES

For the characterization of the composite , vertical and horizontal surface were cut from the casting. Specimens for deep drawability of dimensions (70 x 70mm) with (2 mm thickness and 1 mm thickness) were prepared

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Table no.5.1-X-Ray diffraction details of Al-5 vol% graphite composite

Peak No.	2θ	d(ηλ=2dsinθ) (A^0)	I/I_0 (height wise)	A/A_0 (Area wise)	Phases Present
1	21^0	2.149	1	1	Al
2	31.4^0	1.486	0.4938	0.01	Pb, $CuAl_2$
3	36. ^{0}4	1.301	0.3210	0.2104	Graphite
4	39^0	1.234	0.3457	0.2575	Al
5	45^0	1.089	0.1111	0.0628	Al
6	52^0	0.993	0.1234	0.0392	$CuAl_2$
7	62^0	0.870	0.1342	0.0156	Graphite
8	64.4^0	0.849	0.1336	0.0143	Al
9	78.1^0	0.787	0.1520	0.020	Al
10	82^0	0.775	0.1545	0.025	Graphite

Table no-5.2 X-Ray diffraction details of Al-20 Vol % graphite Composite

Peak No.	2θ	d(ηλ=2dsinθ) (A^0)	I/I_0 (height wise)	A/A_0 (Area wise)	Phases Present
1	21^0	2.123	1	1	Al
2	31.4^0	1.478	0.4938	0.01	Pb, $CuAl_2$
3	36. ^{0}4	1.291	0.3210	0.2104	Graphite
4	39^0	1.224	0.3457	0.2575	Al
5	45^0	1.001	0.1111	0.0628	Al
6	52^0	0.985	0.1234	0.0392	$CuAl_2$
7	62^0	0.884	0.1342	0.0156	Graphite
8	64.4^0	0.854	0.1336	0.0143	Al
9	78.1^0	0.787	0.1520	0.020	Al
10	82^0	0.776	0.1545	0.025	Graphite

RESULTS OF QUANTITATIVE METALLOGRAPHY STUDY

For the purpose of measuring the retained volume fraction of the graphite particles in the base alloy matrix, quantitative metallography was done by using point counting technique. Chi the two surfaces, one horizontally other one vertically cut from the ingots of AliVol % graphite and A1-20 Vol % graphite, the above study was carried out.

Table no 3 : 5.3 : For point counting for specimen and horizontally and vertically

Filter	Value Fraction End Centre End	Average
Graphite Particles	11 10 9 9 7 8 10 11 11	9.56
Graphite Particles	Volume fraction 15 13 14 12 11 9	Average 12.56

Volume fraction variation can be seen in the table 5.3 of the vertically & horizontally cut samples. The volume fraction decreases to the top this is because oF the higher specific gravity of the graphite particles which tend to scatle. The average volume percentage 10.86. While we added 5-20% volume percentage of graphite powder in the casting. It shows that only 10.86% retention took place.

Deep Drawability Test Of Composite

Deep drawability test of Aluminium graphite composite samples yielded following results :
Erichsen no. of Al-5 vol% graphite composite sample. (composite thickness 1.08 mm) = 6.5 mm
Erichsen no. of A1-20 Vol% graphite composite sample. (composite thickness 0.6mm) = 8.8 mm
Erichsen no. of sample (Base alloy thickness 1.08 mm) = 7.78 mm Erichsen no. of sample (Pure aluminium_ thickness 2 mm) 14.25 mm
The Al-5 Vol% graphite and Al-20 vol% graphite are before and after deep drawabilit, tests are shown in Figs 5.6 and 5.7 respectively.

The deep drawability in Al-alloy-5 vol% graphite is observed to the
greatest in comparison of Al alloy-20 vol% graphite, because 5% graphite is more ductile. The results show that the drawability of composite samples are poorer than that of base alloy and pure aluminium samples. This is due to brittleness caused by incorporation of graphite particles in the matrix. The flowability of metal which is caused by the easily movement of dislocation is hindered by the graphite particles.

Tabele no 5.4 Viker hardness of Al-graphite composites and base alloy

S. No.	Sample specification	Diagonal length	Vickers hardness VHN	Mean hardness VHN
1	Al alloy-graphite	0.494	38.0	44
2	(20 Vol % graph)	0.453	45.2	
3		0.400	58.0	
4		0.471	41.8	
5		0.490	38.6	
1	Al alloy-graphite	0.407	56.0	48
2	(5 Vol % graph)	4.467	42.5	
3		0.467	42.5	
4		0.433	49.5	
5		0.447	46.4	
1	Al base	0.430	49.93	50

It can be seen that the hardness values of Composite materials are lower than that of base alloy. This is because of the presence of the softer graphite particles decrease. The increase in the volume fraction of graphite particles is reducing the hardness further.

Table no 5.5 Details of tensile specimens taken for study

Sample details	Gauge dia (mm)	Gauge length (mm)	Original Cross section area (mm^2)
Al-5 vol% graphite composite	3.43	20.1	9.26
Al-20 vol% graphite composite	4.00	20.5	12.57

Table no. 5.6 Details of tensile specimens after the tensile study along with the maximum and fracture loads

Sample details	Gauge dia (mm)	Gauge length (mm)	Final cross section area (mm^2)	Maximum load (Newton)	Fracture load (Newton)
Al-5 vol% graphite composite	3.20	21.3	8.05	1945	1050
Al-20 vol% graphite composite	3.70	22.2	10.98	1245	140

Table no.5.7 Tensile properties of Al-graphite composites and base alloy

Sample No. Specification	%Elongation	UTS N/mm^2	Fracture N/mm^2
Al-graphite (5% graphite)	9	210	130
Al-graphite (20% graphite)	8	99	12
Base alloy	20	62	8

Table no 5.8 Resistivity of the Al-Gr composites along with base alloy

Sample Specification	Thickness of samples (mm)	Current (mA)	Voltage (mV)	ρ_o = V x2□ □ S I (ohm-mm)	G_7 (W/S)	$\rho=\rho_o/G_7$ (W/S) (ohm-mm)
Al-5 vol % Graphite	1.877	200	0.002	0.0001256	1.402	$0.1090x10^{-3}$
Al-20 vol % Graphite	2.250	200	0.002	0.0001256	1.363	$0.0631x10^{-3}$
Aluminium alloy	1.400	200	0.002	0.0001256	2.140	$0.05869x10^{-3}$

III. Conclusions

The following conclusions are drawn on the basis of the study carried out :

i. Examination of the composites under optical microscope and SEM reveals that graphite particles are found to be uniformly distributed in aluminium alloy matrix.
ii. Quantitative metallography reveals that, the composites produced have 5 and volume % of graphite particles in the matrix.
iii. X-Ray analysis of the composites reveals the phases $CuAl_2$ apart from Al & graphite.
iv. Hardness of the composite material has reduced as compared to base alloy.
v. The tensile strength of the composite material has considerably improved as compared with the tensile strength of the base alloy..
vi. The drawability of the samples studied was very poor as compared to the base alloy.
vii. The resistivity of the composite is found to be greater than the base alloy.

SUGGESTIONS FOR FUTURE WORK

The work carried out can be modified by including the following suggestions :

1. The graphite particles size range should be lowered so that a uniform distribution of particles is obtained which could probably increase the strength of the composite.

2. To enhance the wettability the wetting agents as Mg, MgO could be added.
3. The same work can be carried out using other reinforcement materials as Al_2O_3. etc.
4. Correlation of deep drawability with other parameters such as conductivity can be studied.

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