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Fabrication and Study of the Mechanical Properties of AA7129 Alloy Reinforced with B4C &TiC

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ABSTRACT
In the present work Al7129 metal matrix reinforced with Titanium carbide (TiC) and Boron carbide (B4C) powder is fabricated through stir casting route. Metal matrix composites were manufactured by altering percent weight fraction 5 to 25 wt. % in steps of 5%weight with average particle size. The importance of composites as engineering materials is considered by the fact that out of over 1600 engineering materials available in the market today consists of 200 composites. These composites initially to many experiments and the wear behavior of these composites were traversed to a maximum extent and were reported by number of research scholars for the past 25 years. In the present study based on the literature review, the effect Carbide on Stir Cast Aluminum Metal Matrix Composites is discussed. aluminum hybrid composites are a new generation of metal matrix composites that have the potentials of satisfying the demands of advanced engineering applications such as in used in the aircraft manufacturing sector, aerospace, automobile, space, underwater and transportation applications. This is mainly due to upgraded mechanical and tribological properties like stiff, strong, abrasion and impact resistant and is not easily corroded. This paper attempts to review the different combination and configuration of reinforcing materials used in processing of hybrid aluminum matrix composites and how it effects the mechanical, corrosion and wear performance of the materials.

KEYWORDS: *AA7129, B4C &TiC, Fabrication, Mechanical Properties*

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1. INTRODUCTION
In various fields and applications like aerospace, defence, automobiles and other important structural applications, ceramic reinforced metal matrix composites have been used extensively asthese material possesses important properties i.e. high strength to weight ratio making them very important material in these fields [1]. These materials are customized materials, which consistof matrix phase reinforced with ceramic reinforcements havingvery hard and brittle nature. Common reinforcement used areBoron Carbide (B4C), Aluminium Oxide (Al2O3), Silicon Carbide (SiC), Titanium Carbide (TiC) to fabricate metal matrix composites (MMC) materials [2]. MMC's possesses improved physical andmechanical properties achieved through combined effect of softalloy matrix and hard, brittle reinforcement. Depending upon type of reinforcement used and its volume fraction in metal matrix, aluminiummetal matrix composites (AMC's) are able to achieve largervalues of strength, rigidity, resistance to wear, fatigue, resistance to corrosion and creep.

Narender Panwar et al. [3] compared stir casting with Compo Casting, Squeeze casting, Friction stir processing, Spray casting etc. processes highlighting sir casting as simple and cost effective technique providing a fairly uniform distribution of particles in metal matrix to manufacture metal matrix composites. Rajesh Kumar et al. [4] used aluminium as matrix and Silicon Carbide (SiC), Graphite, Aluminium Oxide (Al2O3) as reinforcements and discussed about stir casting method, working parameters involved in it by varying proportion of reinforcement and showed that processing parameters, type of reinforcement and its fraction plays important role in imparting physical properties to metal matrix composites. Uppada Rama et al. [5] reinforced Aluminium 7075 matrix with fly ash in constant weight percentage and Silicon Carbide (SiC) in distinct weight percentages and reported uniform presence and diffusion of fly ash and silicon carbide particles throughout the matrix through microstructure studies whereas the grain size reinforcement is observed in EBSD analysis. Balaji et al. [6] in their studies regarding microstructure of composites, uniformly distributed. Ritesh Raj et al. [7] fabricated Al6061-B4Ccomposites containing 5–20 wt% of B4C particles in increment of5% by weight using stir casting technique. Microstructural characterization showed that the distribution of Boron Carbide (B4C) particulatesin the matrix was almost uniform and at some locations minute agglomeration and accumulation of particles were observed. Bhaskar Chandra et al. [8] in their study reported betterment of mechanical properties such as tensile strength and hardness with increase of weight percentage of Silicon Carbide (SiC) reinforcement and keeping weight percentage of fly ash constant in aluminium matrix.

This work predominantly focuses on examination of microstructure of metal matrix composites and grain refinement of particle reinforced composites where Alumnium 7129 (Al7129) is considered as a matrix material by varying the percentage by weight fraction of reinforcement Titanium carbide (TiC) and Boran carbide (B_4C) powder this work focuses mainly on micro structural aspects of fabricated metal matrix composites through stir casting.

2. MATERIALS & METHODOLOGY

In current study, Aluminium 7129 (Al7129) has been used as matrix phase and Titanium carbide (TiC) and Boran carbide (B_4C) powder as reinforcement phase. The chemical composition of the base metal and its physical properties are shown in Tables 1 & 2 respectively. While the chemical compositions and physical properties reinforcement are shown in Tables 3 & 4 respectively. The availability of literature has helped in finding out the composition of Titanium carbide (TiC) and Boran carbide (B_4C) powder to be reinforced in Al 7129 matrix. For current study, Al7129 matrix has been reinforced with 5 to 25 wt. % in steps of 5%weight fraction of Titanium carbide (TiC) and Boran carbide (B_4C) powder reinforcement and metal matrix composites are prepared by stir casting technique.

The following table 1 shows the chemical composition of aluminium / aluminum 7129 alloy.

Element	Content (%)
Aluminum, al	90.9 - 94
Zinc, zn	4.2 - 5.2
Magnesium, mg	1.3 - 2
Copper, cu	0.50 - 0.90
Iron, fe	≤ 0.30
Titanium, ti	≤ 0.050
Vanadium, v	≤ 0.050
Gallium, ga	≤ 0.030
Silicon, si	≤ 0.15
Chromium, cr	≤ 0.10
Manganese, mn	≤ 0.10
Remainder (each)	≤ 0.050
Remainder (total)	≤ 0.15

Table2: Physical properties of aluminium / aluminum 7129 alloy.:

Property Value Melting point Approx = 580˚C

Modulus of Elasticity =70-80 GPa

Poisson's Ratio =0.33

Density =2.7 g/cm3

Co-Efficient of Thermal Expansion = (20-100˚C) 24.3 µm/m˚C

Thermal Conductivity =173 W/mK

Table 3- Titanum carbide properites

Compound formula	N/a
Molecular weight	59.89
Appearance	Powder or solid in various forms
Melting point	3160 °c, 3433 k, 5720 °f
Boiling point	4820 °c, 5093 k, 8708 °f
Density	4.93 g/cm^3
Exact mass	59.947946
Monoisotopic mass	59.947946

Table 4- Boron carbide properties

Property	Value
Density (g.cm^{-3})	2.52
Melting Point (°C)	2445
Hardness (Knoop 100 g) (kg.mm^{-2})	2900 - 3580
Fracture Toughness (MPa.m$^{-½}$)	2.9 - 3.7
Young's Modulus (GPa)	450 - 470
Electrical Conductivity (at 25 °C) (S)	140
Thermal Conductivity (at 25 °C) (W/m.K)	30 - 42
Thermal Expansion Co-eff. x10^{-6} (°C)	5
Thermal neutron capture cross section (barn)	600

3. METAL MATRIX COMPOSITE PREPARATION

Fig. 1 represents the stir casting set up used to manufacture composites with Aluminium 7129 (Al7129) as base alloy whichhas been reinforced with Titanium carbide (TiC) and Boran carbide (B_4C) powder. In this method the matrix material, Al7129 is placed inside a electric furnace and heated at 850^{0}C. Heating at such a high temperature causes melting of base metal which is then stirred vigorously by using a mechanical stainless steel stirrer. This vigorous stirring action results in formation a vortex at the surface of melt. After formation of vortex, the reinforcement material, preheated Titanium carbide (TiC) and Boran carbide (B_4C) powder is then added from the side of the formed vortex. The process parameters used here are pouring temperature of 850^{0}C, speed of stirring 200–250 rpm, preheating silicon carbide reinforcement at 350^{0}C. The amount of Titanium carbide (TiC) and Boran carbide (B_4C) reinforcement is varied percent weight fraction 5 to 25 wt. % in steps of 5%weight weight to manufacture metal matrix composites. To assist wettability of with Titanium carbide (TiC) and Boran carbide (B_4C) powder aluminium matrix.

Fig.1. Stir Casting Setup

Stir casting is a liquid state method of composite materials fabrication, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

3.1. Required % of compositions:

To fabricate the composite the configuration is decided by taking consideration the previous literature carried out by different researchers. The weight percentage of titanium carbide and boron carbide is decided to take by weight each in the composite because this is the optimum amount of these reinforcements to achieve impressive properties of composites, while the amount of copper is varied by weight %.

Compositions	Material	AL7129	Tic	B_4C
1	A_1	97%	1%	2%
2	A_2	95%	3%	2%
3	A_3	93%	5%	2%

Table 5- % of varying composition

3.2. Experimentation:

The experimental arrangement has been assembled by the coupling gear box motor and mild steel four blade stirrer used. The melting of the aluminium(97%) billet material and tic(1%) & b4c(2%) is carried out in the graphite crucible into the coal fired furnace.

Compositions	Material	AA	Tic	B_4C	TOTAL WEIGTH
1	A_1	97% (1940 grams)	1% (20 grams)	2% (40 grams)	2000 grams
2	A_2	95% (1900 grams)	3% (60 grams)	2% (40 grams)	2000 grams
3	A_3	93% (1860 grams)	5% (100 grams)	2% (40 grams)	2000 grams

Table 6- % varying & weighting of materials

Finally we prepared the three types varying samples including round bars & square plates. These final samples are now ready for further testing process of hardness, impact, tensile, & compression tests

Figure 2- Molten metal pouring into dies

3.3. Machining of composites:

Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. The processes that have this common theme, controlled material removal, are today collectively known as subtractive manufacturing, in distinction from processes of controlled material addition, which are known as additive manufacturing.

Figure3. Lathe machining operations

3.4. After machining process composite materials:

The composite materials completely machining process the required sizes and shape can be performed in machining process.

4. RESULTS AND DISCUSSIONS

Ultimate tensile strength table:

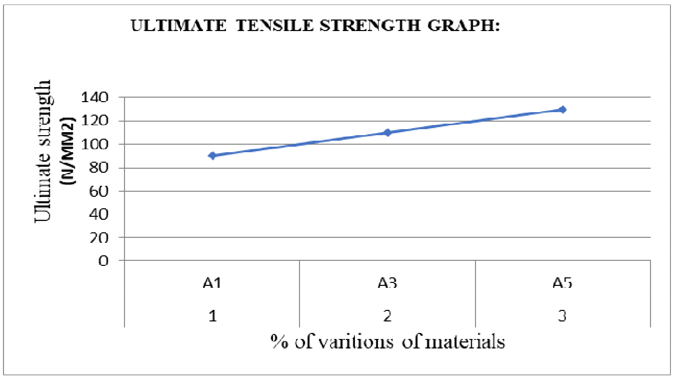
S. No	Material	Gauge length (mm0)	Diameter2r (mm)	Ultimate load (kgf)	Ultimate strength
1	**A1**	24	5	180	**89.93**
2	**A2**	22	5	220	**109.91**
3	**A3**	23	5	260	**129.90**

Formula Used:

$$out = \frac{\text{ultimate load}}{\text{cross sectional area}}$$

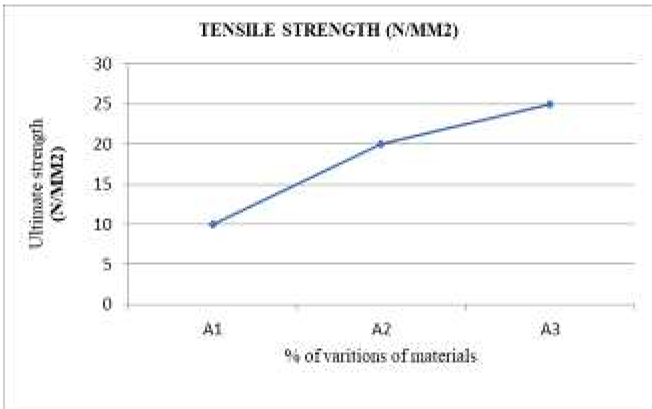
Cross sectional area of the specimen is $A = \pi r^2$=πr^2 = $\pi * 2.5^2$ π*2.5^2= **19.6364 mm2.**

r = radius of the circular cross section =**2.5 mm**



Tensile strength table:

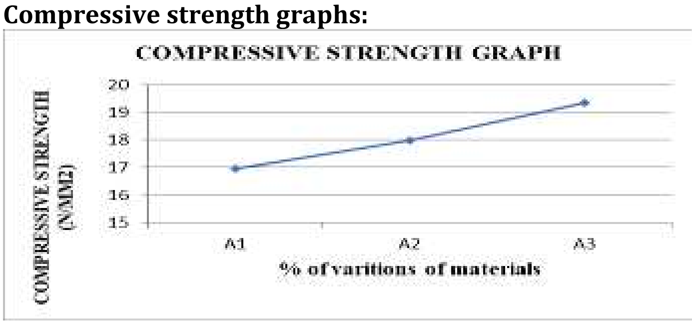
S. No	Material	Gauge Length (Mm)	Diameter (Mm)	Ultimate Load (Kgf)	Ultimate Strength (N/Mm²)
1	A1	24	5	20	**9.9992**
2	A2	22	5	40	**19.984**
3	A3	23	5	50	**24.981**



Compression test table:

Material	Diameter And Length (Mm)	Area A(Mm²)	Load (P)Kn	Compressive Strength (N/Mm²)
A1	10mm 20mm	200	169.5	**16.95**
A2	10mm 20mm	200	179.76	**17.976**
A3	10mm 20mm	200	193.33	**19.35**

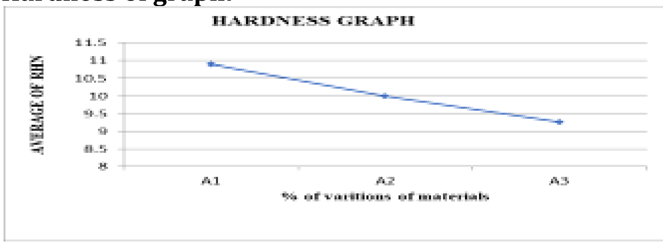
Compressive strength graphs:



Hardness test table:

Material	Load Applied (Kgf)	Trial 1	Trial 2	Trail 3	Trail 4	Trial 5	Average Of RHN
A1	100	9	12	12	11	10.5	**10.9**
A2	100	10	9	11	8	12	**10**
A3	100	10	9.5	9	8.8	9	**9.27**

Hardness of graph:



IMPACT TEST;

Observations of impact testing machine;
One division on scale = 2J
Charpy scale range = 0-300J
Angle drop of pendulum = 1400
Effective weight of pendulum = 20.59 kg

Impact Test Table

S. No	material	Energy (j)
1	A1	40
2	A2	50
3	A3	30

Picture view of all testing machines and Specimens:








Tensile and Compression Test

The tensile and Compression test is conducted by using Universal Testing Machine and the samples are cut as per the ASTM standard. The three samples were compared to evaluate the mechanical properties. The comparison of break load, maximum displacement and percentage elongation were carried out and observes as, the sample 3 (pure Al alloy) has maximum break load values, maximum displacement and maximum percentage elongation. Whereas sample 1 has greater break load than sample 2 and sample 1 has maximum percentage elongation which is equal to sample 3, and sample 1 has less displacement when compared with sample 2 because variation in mechanical properties of three samples changes with the variation in the proportions of reinforcements added to molted metal.

Impact Strength

The Charry Impact test is performed by preparing the samples as per IS 1757 standard. It was observed that sample 2 observes more energy to resist the impact force when compared to sample 1 and sample 3, because the high content which makes the sample 2 turn out to be into high strength.

Brinell Hardness Test

The Brinell Hardness Test is carried out on the three samples and three trials are conducted. The ball shape indenter made of hardened is used for this test. The diameter of ball shaped indenter is 5mm and the load applied is 100kgf. The test resulted as, the value of sample 1 has the maximum hardness followed by sample 2 and sample 3 in all the 3 trials, because of the high content makes the sample 1 more harden.

5. CONCLUSION

This paper presents the different combination of reinforcements used in the synthesis of hybrid AMC's and how it influences their mechanical properties.

1. It has been observed that the tensile strength of sample 3 is marginally higher than the samples 1,2 because of its Aluminum content, but the sample 1 has higher tensile strength than sample 2.
2. The impact strength of sample 2 is greater than the other 2 samples, because carbon content makes the sample 2 more strengthen component. Brinell hardness test concludes that, the sample 2 has high hardness value when compared to sample 1 and sample 3.
3. Finally, it is observed that the fabrication of Hybrid Metal Matrix Composites results in advancement of mechanical properties such as low density, mechanical compatibility, high elastic modulus, low thermal expansion, high compression and tensile strength etc…
4. With the advancement in mechanical properties this Al alloy- hybrid composite can be widely used in various areas such as marine applications, automotive industries, space applications etc.
5. It was noticed that hardness of the composite will be increased depending upon the added reinforcement fraction or by reducing the particle size of reinforcement however, the porosity in the composites affects hardness adversely. The hardness of ceramic reinforced composites will be improved by ageing time heat treatment and ageing temperature.
6. yield stress, Young's modulus, breaking (fracture) stress and ultimate tensile stress of ceramic-reinforced Aluminum matrix composites were higher than monolithic alloys and increased with the reinforcement fraction of ceramic materials however, the ductility of the composites is reduced.
7. It is hard to attain a perfectly homogeneous phase of composites through reinforced particles in the matrix phase, when the Aluminum matrix composites were fabricated through liquid metallurgy or stir casting method.
8. Stir casting technique has been sucessfully adpted in preparation of Al7129 metal matrix reinforced with Titanium carbide (TiC) and Boran carbide (B_4C) reinforcement.
9. According to results with the increase of reinforcement mechanical properties has been increased except compression strength. In compression test at the average value of reinforcement the compression strength has been increased.

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