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INFLUENCE OF REINFORCEMENT TYPES ON MECHANICAL PROPERTIES OF HYBRID ALUMINUM ALLOY

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Abstract: This paper presents the results of the qualified study of mechanical properties - yield strength, ultimate strength, elastic modulus, hardness, toughness, ductility and flexural strength - of different wt% of Al_2O_3, SiC and B_4C reinforced with Al6061 T6 matrix. These composites were prepared through stir casting process which is a liquid state fabrication technique. The experimental study evaluates fairly uniform distribution of reinforcements with spherical shaped and with clustering in few regions. It was observed that there was a good interface bonding between the reinforcements and matrix resulting very good mechanical properties.
Keywords: Metal Matrix Composites, mechanical properties, Stir casting

1. INTRODUCTION

Higher temperature materials, higher solidarity to-weight proportion materials, very erosion safe materials have pulled in a lot of consideration from researchers and specialists everywhere throughout the world. Aluminum Composite materials have been considered the "material of decision" in certain uses of the car and flying machine.[1] Improvement of mechanical and tribological properties of aluminum can be accomplished through making half breed composites with at least two kinds of reinforcements.[2] Micro shrinkage or scattered porosity in the composite can be limited by reasonable area of chills. An improvement in the tribological properties of Aluminum HMMCs has been effectively accomplished by presenting reinforcement particles, for example, SiC, B_4C, Al_2O_3 and TiC, [3-4] using different way of approaches such as squeeze casting, stir casting, powder metallurgy and in-situ technique.[5-6-7] Composite of aluminum compound mixed with alumina and graphite by rheo casting process. Examination demonstrated an expanding pattern in hardness and effect qualities with increment in weight portion of alumina. Be that as it may, nearness of carbon lessens mechanical properties, thus Garnet strengthened which is one of the hardest normally accessible fired material.[8-10] Researchers have shifted their focus from monolithic to composites because there is a huge change in mechanical properties when employed unconventional methods.[11] Among these composite materials, metal grid composites are the most broadly utilized. MMCs join high quality, pliability and high temperature opposition properties of metals together with the solid, however fragile character of earthenware production.

2. EXPERIMENTAL WORK - MATERIALS AND PREPARATION OF COMPOSITES

In this study, Si and Mg majorly contained Al 6061 T6 alloy is used as the matrix material and 325 mesh size SiC, Al_2O_3 and B_4C particles were used as the reinforcements. Table 1 presented the chemical composition of the matrix material. Melting of matrix material is done in Stir Casting Furnace with graphite crucible. Initially Al 6061 alloy ingots were charged into crucible and heated up to 750°C till the entire alloy is melted to semi solid state. The ceramic particles were preheated to 450°C for two hours before incorporation into the melt. The preheated Al_2O_3, SiC and B_4C were added to the matrix at uniform rate in a three stage mixing process.

During the incorporation of reinforcements, the melt was stirred with graphite stirrer at the speed of 500 rpm for 5 minutes. After the matrix alloy fully melted a small amount of degasser known as hexachloroethane was added to minimize the presence of moisture. Stirring was done uniformly to improve the wettability.

Table 1. Composition of matrix alloy Al6061

Si	Fe	Cu	Mn	Mg	Cr
0.4-08	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35
Zn	Ti	Others each	Others total	AL 6061	
0.25	0.15	0.05	0.15	Reminder	

3. MECHANICAL PROPERTY TEST

Tensile test on the samples was done on Instron 8.1, computerized universal testing machine. Tensile specimens were prepared in dog bone shape as per ASTM E8 standard at a maximum diameter of 12 mm and minimum diameter of 10mm and gauge length as 50mm. After machining the samples were polished using 400 and 6-00 grained emery papers to remove scratches and machining marks. Three Composites were tested and compared with the base matrix sample. The 0.2% proof stress, ultimate tensile strength (UTS), elastic modulus (E) and percentage elongation (%EL) were determined using stress- strain curves of the tested samples. Brinell hardness at a load of 500 kgf was carried out on the composite samples. For hardness measurement at least 3 indentations have been made on the sample and the average reading of the indentation gives the hardness of the respective samples.

Flexural test gives the stress in the material just before it yields. Transverse bending test was employed when a sample have circular or rectangular cross section and is bent until the sample undergoes yielding under a 3-point flexural test. Test was done on conventional UTM. Maximum deflection and point break load of the respective samples were determined from numerical method. Charpy Impact test results the toughness of the samples withstanding at sudden applied load. Samples were machined as per ASTM 370 standard with dimensions 55 mm length and 10mm thickness and 8mm width under the marking portion. This test evaluates the energy absorbed by the sample during application of load and toughness is calculated from the value of energy absorption and vice versa.

Table 2. Representation of composition of reinforcements in alloy matrix

Samples	Al-6061	SiC	Al2O3	B4C
1	94%	2%	2%	2%
2	94%	3%	3%	-
3	94%	-	-	6%
4	100%	-	-	-

4. POROSITY MEASUREMENT

In a composite, the extents of the framework and reinforcement are communicated either as the weight division (w), which is pertinent to creation, or the volume part (v), which is ordinarily utilized in property computations. By relating weight and volume parts by means of thickness (ρ), the accompanying articulation is acquired, where c= composite, r= reinforcements and m= matrix.

$$\rho_c = \rho_r V_r + \rho_m V_m \qquad [16]$$

In this study the theoretical density of the samples was obtained from rule of mixtures and the experimental densities were determined from Archimedes principle of weighing small pieces chopped from the composite samples and place first in air and later in water to calculate the differences. Then the porosity of the composites was determined by using theoretical and experimental densities, as per the equation below. Where d_t stands for theoretical density and d_e stands for experimental density.

$$\text{Porosity} = \frac{d_t - d_e}{d_t} \qquad [17]$$

5. RESULTS AND DISCUSSION

— Analysis on mechanical properties

From the test's such as tensile, flexural, hardness and impact strength done on the samples mechanical properties have been revealed and are listed below.

— Ultimate Tensile Strength (UTS)

It has been seen that UTS for sample 1 is high when contrasted and other 3 examples. In test 1 three reinforcements are added at 2% weight proportion to the grid which brings about augmentation of

Table 3. UTS for samples

	Sample	UTS (MPa)
1	(3 reinforcements hybrid sample)	365.85
2	(Al_2O_3, SiC reinforced hybrid sample)	314.71
3	(B4C reinforced composite)	354.89
4	(Al6061 alloy)	232.62

solidarity and decrement in weight. In sample 3 where just B4C is added at 6% weight part to the Al lattice and this example remains in the second spot on account of its high burden to break limit.

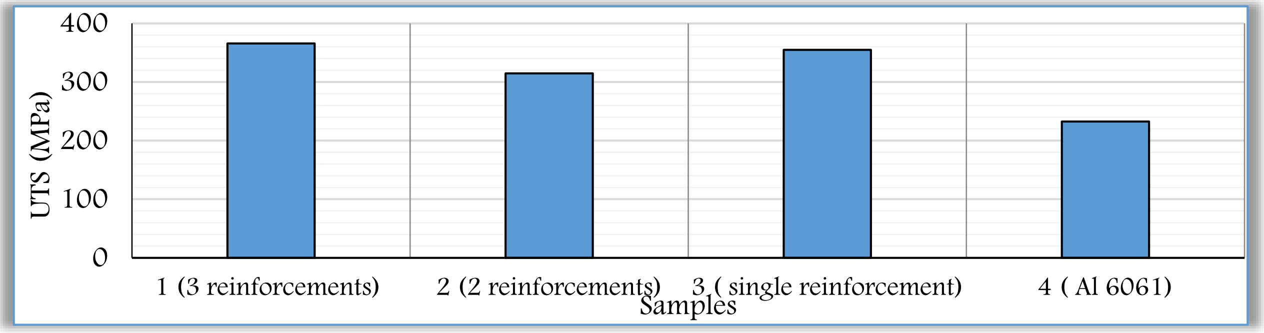

Figure 1. Pictorial representation of UTS in samples

— Flexural Strength

Flexural quality is a material property where the example fizzles at a specific burden where it surpasses its yield point and the heap at where the sample breaks is known as point break load. As saw from test half breed composite, example 1 have higher flexural quality followed by the composite example 3.

Table 4. Flexural Strength of Samples

	Sample	Flexural Strength (MPa)
1	(3 reinforcements hybrid sample)	201.883
2	(Al_2O_3, SiC reinforced hybrid sample)	167.415
3	(B4C reinforced composite)	185.880
4	(Al6061 alloy)	113.251

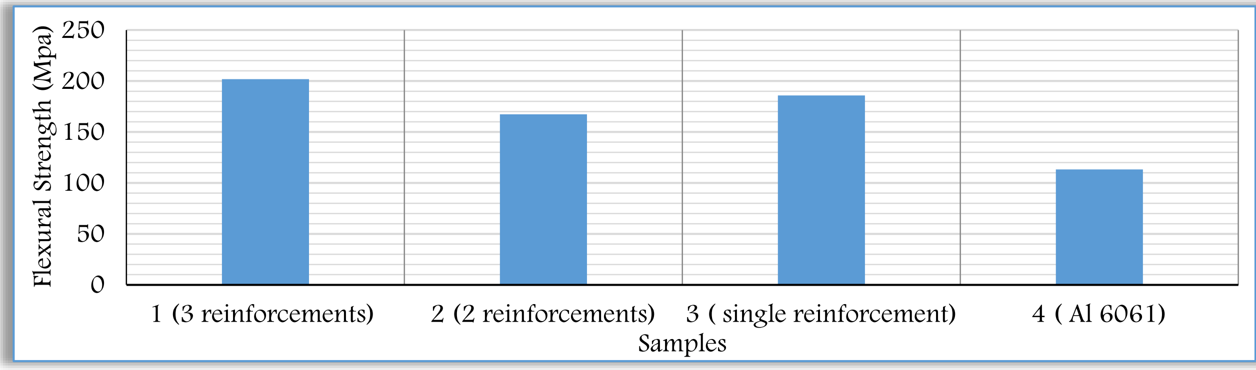

Figure 2. Pictorial representation of flexural strength in samples

— Young's Modulus (E)

Young's Modulus otherwise called Modulus of Elasticity, it very well may be seen when there is protection from changes in measurements under length shrewd augmentation or pressure. From malleable test it was seen that E for test 1 has lower an incentive because of blending of three reinforcements because of bringing down to weight however expanding in quality.

Table 5. Young's Modulus for samples

	Sample	Young's modulus-E (MPa)
1	(3 reinforcements hybrid sample)	27981.43
2	(Al_2O_3, SiC reinforced hybrid sample)	31150.97
3	(B4C reinforced composite)	29451.32
4	(Al6061 alloy)	32681.84

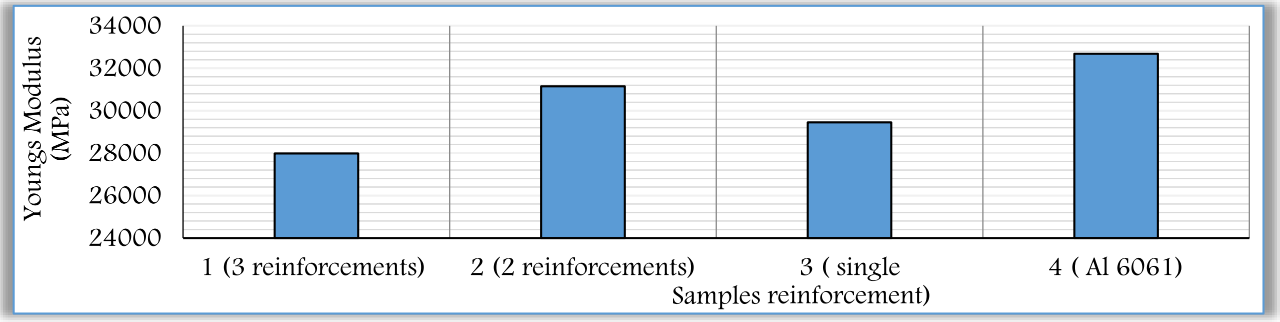

Figure 3. Pictorial representation of Young's Modulus in samples

— **Hardness**

It can be represented by resistance to plastic deformation with mechanical indentation pressure. The average of three indentations of individual samples gives the hardness values and from the results it is observed that hardness for sample 1 is high followed by sample 3 and then sample 2 in the next place. Since B_4C is the hardest material than the other 2 reinforcements sample 3 has the highest value than sample 2.

Table 6. Hardness Values of samples

	Sample	Hardness from B.H.N formula (Kgf/mm^2)
1	(3 reinforcements hybrid sample)	62.6619
2	(Al_2O_3, SiC reinforced hybrid sample)	62.4319
3	(B4C reinforced composite)	62.6090
4	(Al6061 alloy)	62.3631

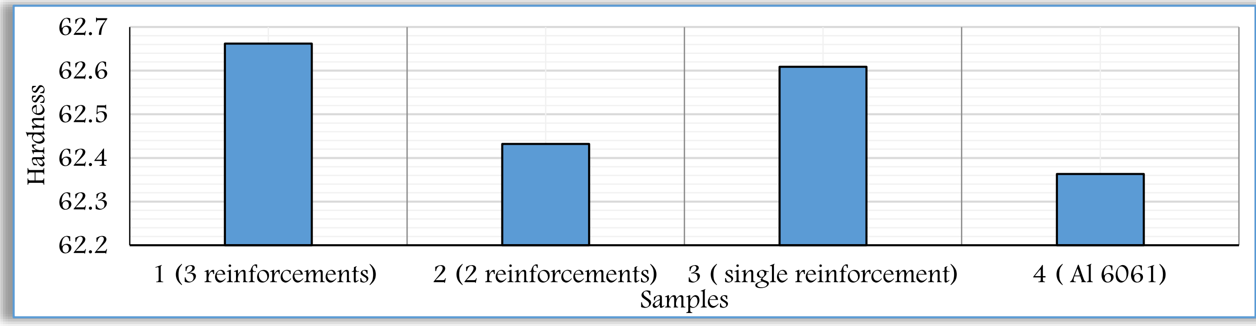

Figure 4. Pictorial representation of Hardness in samples

— **Toughness**

Toughness is the capacity of the material to assimilate the unexpected effect vitality and abstain from bursting while at the same time having plastic deforming. As the initial 2 sample are half and half composite and 3 example is a composite, the 3 samples have higher durability esteem with increment in their opposition and engrossing nature of vitality.

Table 7. Toughness of the samples

	Sample	Toughness (J/mm^2)
1	(3 reinforcements hybrid sample)	3.325
2	(Al_2O_3, SiC reinforced hybrid sample)	2.762
3	(B_4C reinforced composite)	2.625
4	(Al6061 alloy)	2.512

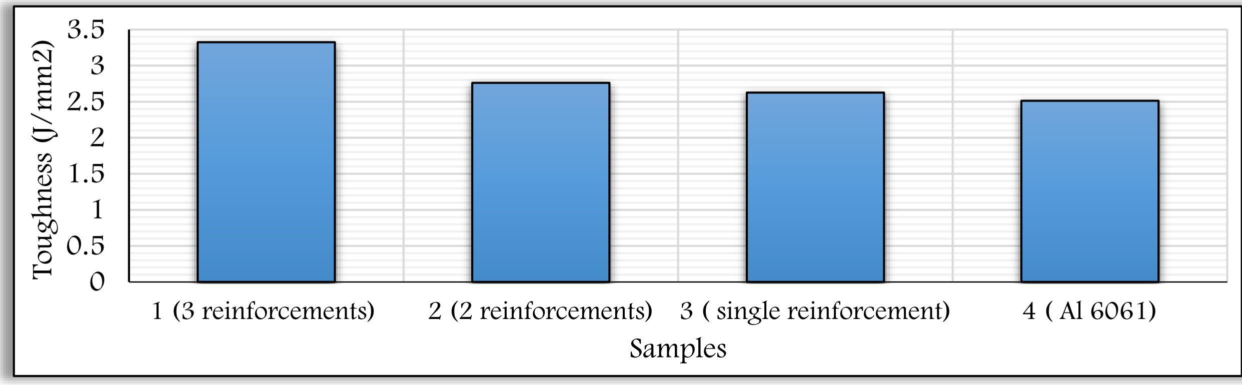

Figure 5. Pictorial representation of Toughness in samples

— **Deflection**

It is a term estimated when the structure is uprooted under a heap. The removal can be estimated as far as length and degree.

Table 8. Deflection values for samples

No.	Sample	Maximum deflection (mm)
1.	(3 reinforcements hybrid sample)	0.0490
2.	(Al_2O_3, SiC reinforced hybrid sample)	0.0893
3.	(B_4C reinforced composite)	0.0760
4.	(Al6061 alloy)	0.1021

Higher the slant gives higher the avoidance and the most extreme dislodging shows the less flexural quality. From the flexural test it has been seen that sample 4 and 2 have higher redirection in light of their flexibility nature, henceforth they can ingest more burden before breaking.

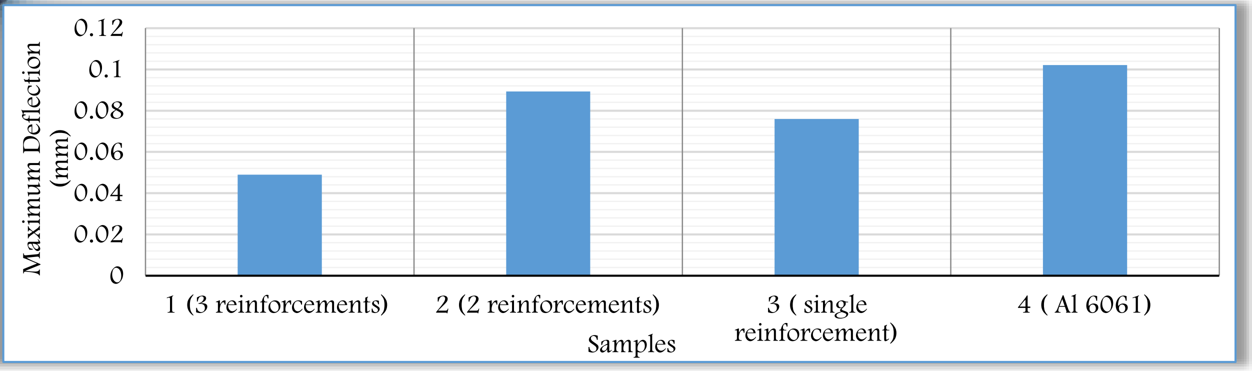

Figure 6. Pictorial representation of Deflection in samples

— **Ductility**

It tends to be spoken to in term of level of stretching and can be characterized as the materials capacity to experience plastic disfigurement and changes in measurements before cracking. As from tests it is seen that sample 2 and 4 has high level of prolongation when contrasted with other 2 examples. Since sample 4 which is an uncovered Al combination it is flexible essentially and shows progressively plastic twisting before bursting. From sample 2, which is a half and half composite stands in runner up having greater malleability nature in light of its silicon content.

— **Density**

Density of the composites were calculated by using rule of mixture and experimental density was calculated by Archimedes' principle. From results density of the sample 1and sample 2 which are hybrid composites have low densities with higher strength because of their extra added contents during casting. Sample 3 also have greater strength but stands in third place because of its less contaminated parent material which gives high mass to volume ratio.

6. CONCLUSIONS

From the present study the following conclusions have been drawn.

- 2 wt% of Al_2O_3, SiC and B_4c reinforced hybrid composite sample 1 and 3 wt% of Al_2O_3 and SiC reinforced hybrid composite sample 2 and 6 wt% of B_4C reinforced composite sample 3 were successfully produced through stir casting process.
- It was found that increasing the silicon carbide content within the aluminum matrix results in observable increase in ductility.
- It was observed that UTS, flexural strength, Young's modulus, toughness, hardness values increased in the sample 1 because of imported properties due to the addition of reinforcements.
- The properties of the cast Al6061 composites significantly improved by varying the amount of B_4C. It was found that increasing the B_4C content within the matrix material, resulted in significant improvement in the mechanical properties like hardness, tensile strength, young's modulus etc., and at a cost of reduced ductility.

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