RESEARCH ARTICLE

Effect of Hybrid Reinforcement on Mechanical Properties of Al6082 Metal Matrix Composite for Automobile Application

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The mechanical behavior of AMMC based reinforced hybrid composites with various volume fractions of Sic (3, 6, 9, 12, 15) and Gr (1, 2, 3, 4, 5) was studied. The Stir casting method was adapted for manufacturing the various samples. The analysis reveals the increase in strength and hardness of the samples with greater percentage compositions of reinforcements. The study was performed to analyze the micro structural properties of the composites based on the addition of reinforcements. The hardness, tensile strength and impact strength were analyzed. The addition of Sic and Gr proved to enhance density to an optimal range to improve the structural and mechanical property of the reinforced AMCs. The composite with enhanced mechanical property was identified and the test results were verified to establish the alignment of the composite with a wide range of industrial and automotive applications.

Introduction

Aluminium is widely used in the automobile and aerospace sectors for its low cost, flexibility, lighter weight and machinability it is referred to as universal material because of its strength corrosion resistance and stiffness. Despite its great metallurgical properties it is ill suited for engineering applications due to reduced compressive strength and hardness. The use of aluminium composites can improve its mechanical properties and make it useful for industrial applications. There are a variety of techniques to make these aluminium composites such as powder metallurgy, spray deposition, casting etc. Casting is the best suited for aluminium composites manufacturing [**1**]. Stir casting has its own advantages for manufacturing of composites as it is simple method yet provides good results [**2, 3**]. The flexibility and robustness associated with stir casting makes it best suited for mass manufacturing and adding Si Cu and Mg as reinforcements help in improving the strengths, aspect ratios and thermo mechanical properties [**4, 5**]. These improved properties of aluminum composites over metal aluminum can be altered to suit specific industrial applications. On manufacturing the aluminum composites are subjected to compressive tests in UTM and hardness is validated by Vickers hardness tester.

Ceramic has also been used to reinforce aluminum alloys to improve their physical properties [**6**] in many works. The hardness of the (AMC) Aluminum Matrix Composites is mainly dependent on the Gr particles, as there was decrease in hardness when the percentage composition of graphite contents increased [**7-9**]. The AMC main constituents of aluminum alloy is called the matrix phase and they are reinforced with non-metallic compounds like Sic and Al2O3. The additions of these reinforcements tend to decrease the matrix materials ductility and toughness. This can be overcome by analyzing the composites microstructure dislocation generation and precipitation during aging (D.L. Mc Danels *et al.* 1985).

When the AMCs are reinforced with Silicon Carbide particles they tend to have increased modulus of elasticity and wear resistance as well as a significant increase in Yield strength when compared to the non-reinforced AMCs thus increasing the potential of reinforced AMCs replacing steel and aluminum being used widely [**10**]. A mechanical stir casting with different sizes (75µm, 50µm and 25 µm) of reinforcements in AMC was studied by Dwivedi *et al.* (2014). The resulting AMC was subjected to Macro-structural analysis, tensile test, hardness test and impact test. The test results revealed the 25 micron sized Sic particle has reduced porosity, improved tensile strength and toughness indicating the importance of size and its influence on mechanical properties of AMC. There has been very few work based on the microstructure of AMCs reinforced with Gr. Most works emphasize on the wear and mechanical properties predominantly hardness of the AMCs reinforced with Gr particles. This work focuses on the study of the microstructure of AA6082 metal matrix reinforced with Gr and Sic reinforcements with varying proportions. The reinforced AMCs are manufactured using a relatively cost effective and efficient process of stir casting. Stir casting chosen not only for its low cost but also for its flexibility and wide range of material composition for volumetric fractions of reinforcements [**11-17**]. Along with these advantages stir casting facilitates better bonding of the AMCs with the reinforcements and hence is considered the manufacturing process in this work.

Research methodology

The Al6082/Sic/Gr composites were obtained using Stir casting, the considered parameters for the manufacturing procedure are listed in **Table 1**. The Micro structural analysis reveals the percentage constituents of the composite and is listed in **Table 2**. The properties of the contents of the AMC composites and reinforcements are tabulated in **Table 3**. **Table 4** lists out the ratio of mixtures of the AMC and the reinforcement in the composite. Magnesium was added before the start of Stirring of the molten metal with its main purpose being the enhancement of wettability of the particles. A proper Homogenous mixture distribution is obtained by constant stirring with the reinforcements blending with the AMC contents in a uniform manner the usage of mechanical stirrer to stir the molten aluminum results in the formation of a finer vortex [**18, 19**]. The reinforcement particles were heated prior to melting and pouring to have their surfaces oxidized. Once the Stirring process of the molten AMCs and their reinforcements is over the molten mixture is poured into a permanent mould. The oxidization of the molten particles was contained by the introduction of Argon gas during the manufacturing process. All the ratios of mixtures were manufactured by same process and were allowed to naturally cool to the atmospheric environment and solidify. The cast specimens were polished using abrasive papers and subjected to etching. Microstructure analysis on the samples were carried out, where they were subjected to scanning electron micrographic (SEM) study with elemental mapping. The hardness of the composites was measured on a Vickers hardness tester. A universal testing machine UTM was used for tensile analysis. The different elements that were present in the manufactured composites were analyzed using XRD analysis.

Table 1. Process parameters of stir casting.

S.No.	Process Parameter	Value
1	Stirring temperature	1000^0c
2	Stirring speed	300rpm
3	Stirring time	10min
4	Preheat temperature of reinforcement particles	800^0c
5	Preheat temperature of permanent mould	300^0c

Table 2. Chemical composition of Aluminium 6082.

Consti-tuent	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
Content %	0.7 to 1.3	0.5	0.1	0.4 to 1.0	0.6 to 1.2	0.2	0.1	0.25	Balance

Table 3. Physical properties of base material and reinforcement material.

Property	Al 6082	Sic (15µm)	Gr (22µm)
Density (g/cm^3)	2.70	3.1	2.23
Modulus of Elasticity (GPa)	70	410	27.6
Poisson ratio	0.3	0.14	0.23
Melting Point (°C)	555	2248	3526
Tensile Strength (MPa)	241	336	76

Table 4. Various composition of sample.

Sample	Composition (wt.%)		
	Al6082	Sic	Gr
1	100	0	0
2	96	3	1
3	92	6	2
4	88	9	3
5	84	12	4
6	80	15	5

Fig. 1. Methodology flow diagram.

Result and discussion

Effect of reinforcement on hardness strength

The hardness of the reinforced AMCs with volumetric fractions is listed in the **Table 5** and are plotted in the Graph 1. It can be noted that the hardness value of the mixture with highest content of Sic and Gr is more than the others. The average hardness of the mixture containing 20% reinforcements (15% Sic and 5% Gr) is 78.07 with the hardness value reducing as the percentage of reinforcement ratio reduces. This shows that the hardness of the AMC reinforced composite is directly proportional to the percentage of reinforcements present due to presence of Sic in the composition. This is because the Sic-Gr reinforcements possess a high material hardness property.

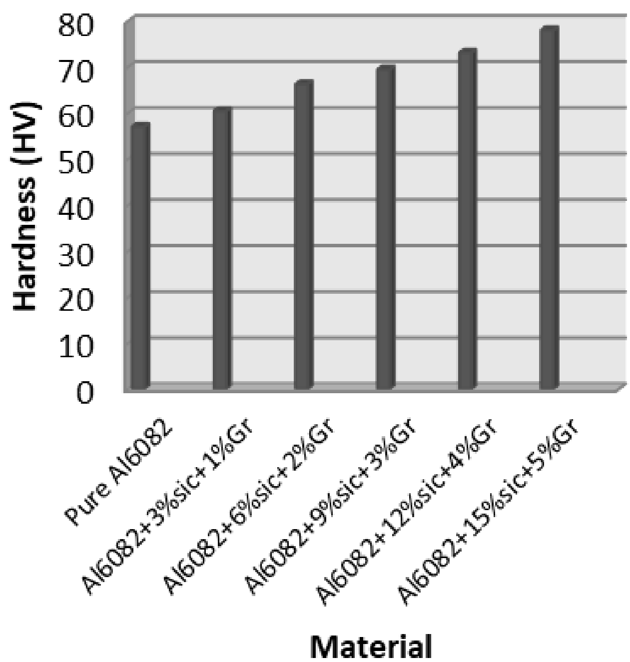

Fig. 2. Micro hardness Vs different composition of Al/Sic/Gr hybrid composite.

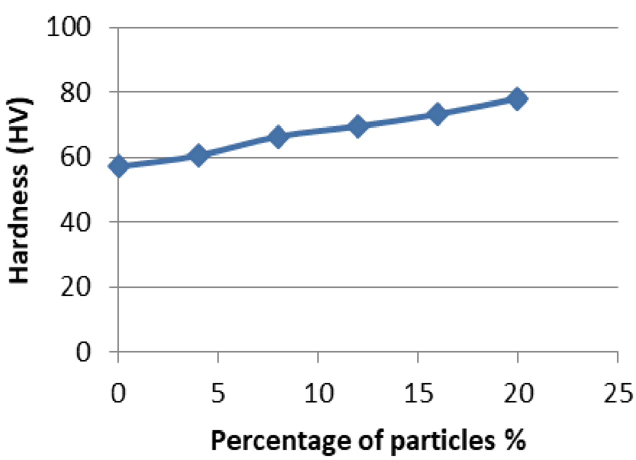

Fig. 3. Hardness Vs Percentage composition.

Effect of reinforcement on tensile strength

The tensile strength is measured in a Universal testing machine for all the percentage compositions of AMCs and reinforcements. It can be noted from **Table 6** that the composite with 20% reinforcement has the highest Tensile strength (197 MPa) in addition to highest break load of 22.4 KN along with highest yield strength of 159.2 MPa apart from having the least Strain of only 2.71 % which make this mixture relatively superior to other percentage composites. The tensile strength, yield strength and Break load values for the composites with 0% Sic-Gr reinforcements is seen to be the least. This can be attributed to the enhancement of elastic moduli of the reinforcements. The increase in strength of the composites is due to the tensile strength attributes of the Sic-Gr composition.

Properties	Wt. % of SiC +Gr with Al 6082					
	0	4	8	12	16	20
Tensile Strength (MPa)	171.21	177.42	184.10	189.43	194.81	197.61
Ultimate Break Load (KN)	16.83	18.10	19.54	20.24	22.30	22.43
Yield Strength (MPa)	135.62	139.24	143.65	148.45	154.31	159.20
Strain (%)	8.2	6.7	5.1	4.4	3.93	2.71

Properties	Locations	Volume Fraction % of SiC & Graphite with Al 6082					
		0%	4%	8%	12%	16%	20%
H.V. @ 0.5 Kg load.	1	59.3	66.7	56.4	71.3	68.4	71.6
	2	61.9	54.9	67.8	62.4	72.6	79.5
	3	48.6	58.4	72.7	69.6	77.3	82.6
	4	58.6	62.2	68.5	74.7	74.6	78.6
Average	1	57.1	60.5	66.35	69.5	73.2	78.07

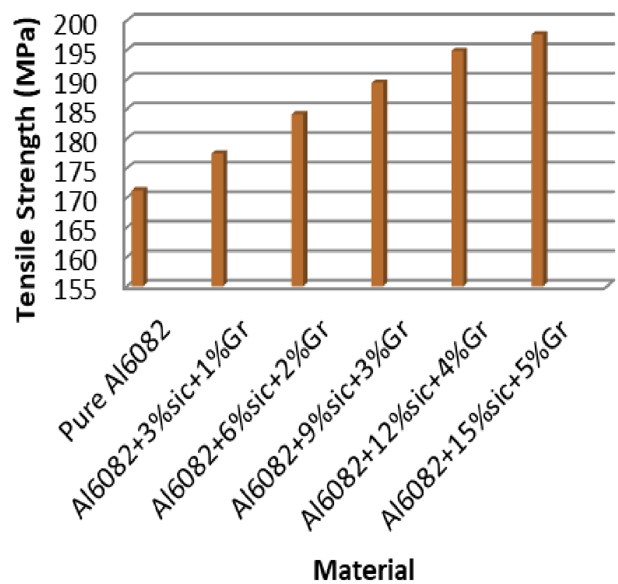

Fig. 4. Tensile strength Vs different composition of Al/Sic/Gr hybrid composite.

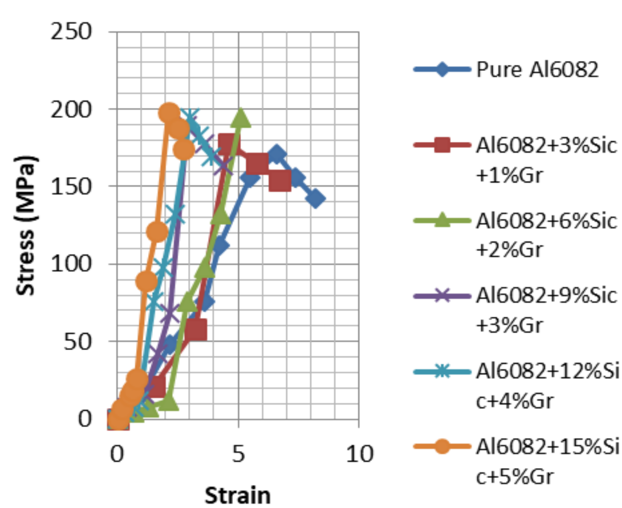

Fig. 5. Stress Vs strain.

Effect of reinforcement on impact strength

The Impact strength of the compositions are measured and tabulated in **Table 7**. The table reveals that the impact strength increases as the percentage of reinforcements increase. The highest impact strength is achieved for the composite with highest percentage of reinforcement (20% Sic & Gr). The tabulations confirm that the Sic-Gr reinforcements tend to increase the impact strength by around 15% as we can see the composite with 20% Sic-Gr reinforcements have an impact strength of 11.61 J, whereas the ones with 0% Sic-Gr contents have an impact strength of 10.2 J. As the percentage composition of Sic-Gr increases the impact strength is seen to increase this is due to the mechanical attributes such as ductility and bonding of the Sic-Gr content composition.

Properties	**Wt. % of Sic and Gr with Al 6082**					
	0	4	8	12	16	20
Impact strength (J)	10.2	10.45	10.72	10.96	11.27	11.61

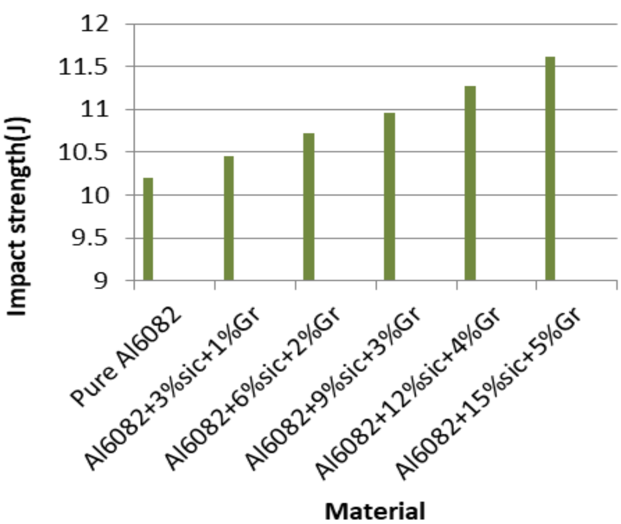

Fig. 6. Impact strength Vs different composition of Al/Sic/Gr hybrid composite.

Effect of reinforcement on density

The density of the AMC reinforced composites are measured as it is revealed that the reinforced AMC with 20% composition of Sic and Gr are the densest. The density decreases with the decrease in percentage of reinforcement added to AMCs. It can be seen that the density of reinforced aluminum composite with highest Sic and Gr content has a density of 2754 (Kg/m^3) whereas the composite with 0 % Sic-Gr content is the least dense with 2700 (Kg/m^3). This demonstrates the effect of reinforcements to provide uniform distribution in the composition and optimizing the density of the composites.

Properties	**Wt. % of SiC +Gr with Al 6082**					
	0	4	8	12	16	20
Density (Kg/m^3)	2700	2709	2719	2730	2742	2754

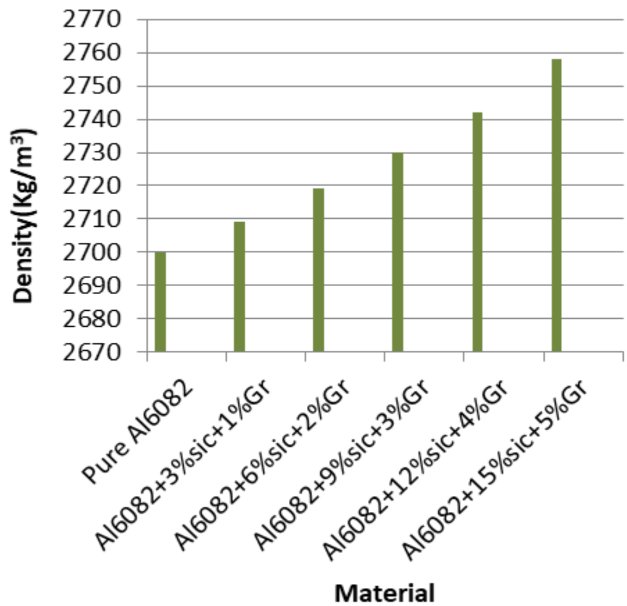

Fig. 7. Density Vs different composition of Al/Sic/Gr hybrid composite.

The composite specimen was subjected to various mechanical tests and the microstructure analysis was carried out to study the properties of the composition. The SEM was used for high magnification whereas the A-ray diffraction (XRD) was used to establish lattice structure of the composite. It was revealed that the reinforcement particles were uniformly distributed within the matrix alloy and this has helped the particle cluster reduction. The presence Gr particles in a finer form, tends to abrade with surface preparation of the component and provide enhanced hardness and elasticity. The micrograph seems to suggest the reinforced AMCs are free for cracks and large sized craters. The results seem to suggest a homogeneous structure of the hybrid composite was obtained with marginal peaks of Al contents at high angles and increased wt% of Gr particles was apparent in the XRD pattern.

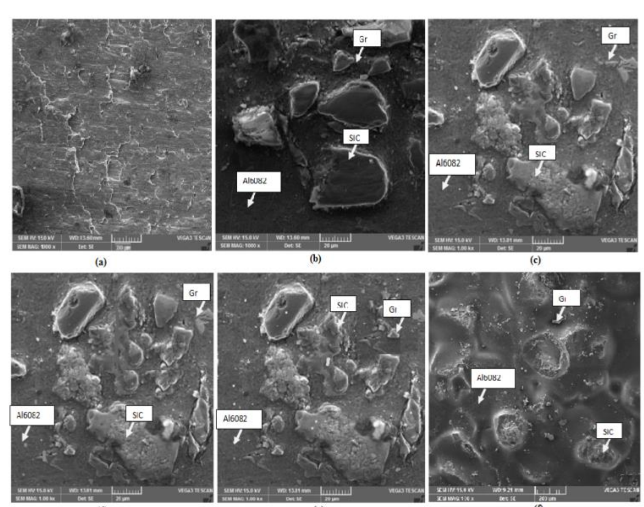

Fig. 8. SEM images of (a) Pure Al6082, (b) Al6082 + 3%SIC + 1% Gr, (c) Al6082 + 6% SIC + 2% Gr, (d) Al6082 + 9% SIC + 3% Gr, (e) Al6082 + 12% SIC + 4%Gr, (f) Al6082 + 15% SIC + 5% Gr.

The sample with the highest concentration of Sic and Gr particles seem to exhibit enhanced material property. The composition of AMC reinforced with 20 % reinforcements in the ratio of 15% SiC and 5% Gr seems to be the hardest, most tensile with higher load withstanding capacity and is also uniformly distributed in its particulate content. This mixture can be used for a wide variety of automotive applications owing to its strength, flexibility, durability, cost effectiveness and ease of manufacturing.

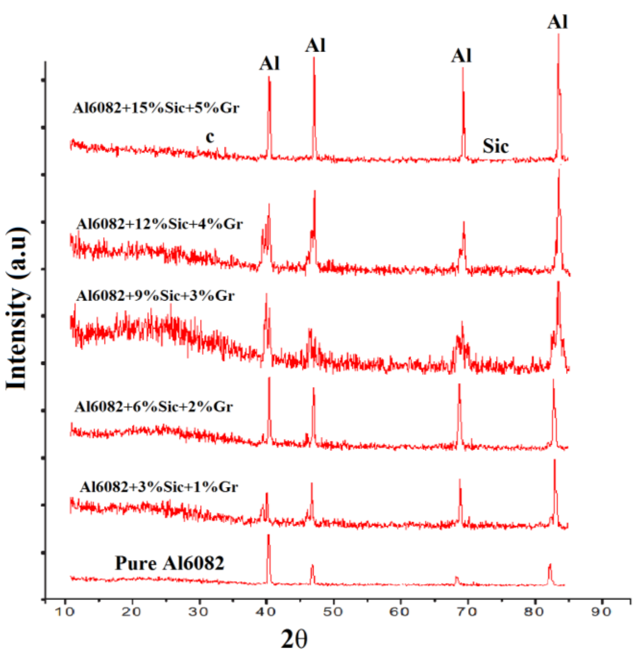

Fig. 9. XRD patterns for the developed Al/SiC/Gr composites with different compositions.

Conclusion

The AMMC of AL 6082 reinforced with Sic-Gr with various percentage composition has been manufactured using Stir Casting technique. The cast samples were subjected to mechanical analysis with the help of UTM and Vickers hardness measurement techniques. The outcomes of the tests are summarized as follows:

- The sir casting process seems to be optimal in providing good bonding between the composites and has enhanced compositional consistency.
- The mechanical properties of the Composites are hugely improved and this can be attributed to the addition of Sic-Gr reinforcements. The improvement in tensile strength, yield strength and impact strength are mainly due to the addition of the Sic-Gr reinforcements.
- The density and distribution consistency of the AMMC has been enhanced due to the bonding nature of the Sic-Gr reinforcements.
- The composition with 5% Gr and 15% Sic seems to have superior mechanical and physical properties compared to the other ratios. This makes the reinforced aluminum matrix much suited for automotive and Industrial applications.

Keywords

AMMC, stir casting, structural and mechanical property, automotive applications, hybrid composites.

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