RP Current Trends In Engineering and Technology
Vol. 3, No. 1 (January – March 2024) pp. 8–12
e-ISSN: 2583-5491

Cite this article: B. Roshan, B. Ravi Teja, U. Krishna Prasad, K. Sahith, R. Venkateswara Rao, Y.V.S.S.S.V. Prasada Rao, Effect of reinforced particulates on mechanical properties of AA5059 Al-based metal matrix composites, *RP Cur. Tr. Eng. Tech.* **3** (2024) 8–12.

Original Research Article

Effect of reinforced particulates on mechanical properties of AA5059 Al-based metal matrix composites

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ARTICLE HISTORY
Received: 12 Dec. 2023
Revised: 20 Jan. 2024
Accepted: 21 Jan. 2024
Published online: 22 Jan. 2024

KEYWORDS
AA5059; Stir casting technique; Mechanical properties; Microstructure.

ABSTRACT
The aluminum-based composites are demanded in the aerospace, marine and automobile industries, due to their good mechanical properties and high strength to weight ratio. The present work is aimed to develop the AA5059 based composite with SiC, B_4C and Al_2O_3 as a reinforcement and evaluate the mechanical properties. The composites are prepared using the stir casting technique, in which reinforcements are mixed to the AA5059 matrix in different compositions. The composites are subjected to microscopic analysis to know the porosity and distribution of the reinforced particles in the composites. Hardness and tensile test were performed on the prepared samples to find the mechanical properties of the composites. The maximum tensile strength is measured as 180 MPa of sample 2at cast condition.

1. Introduction

Composites are the new class of engineered materials manufactured from two or more different elements having different properties. Currently lightweight materials have thehuge demand in various fields of industrial applications, especially Al-based metal matrix composites (AMMCs) are the ideal composite materials due to their excellent properties like, high strength, stiffness, toughness and corrosion resistance [1-4]. In the composites the key elements are the reinforcements, which are define the microstructure and mechanical properties of the metal matrix composites (MMCs) [5-7]. The influence of multiple reinforcements on composites was critically analyzed, the results concluded that hybrid composites with multiple reinforcements have superior properties than single reinforcement [8].The impact of SiC on Al microstructure was addresses at different weight fractions was studied and results revealed that at 25% of weight fraction of SiC exhibit the maximum impact strength and hardness [9]. The hybrid Al-MMCs were made with -SiC-fly ash composition of 10% of each and the results revealed that at this composition the density and hardness values are observed as different [10].

The hybrid Al-MMCs were made with a SiC and fly ash composition of each 10%, and the results revealed that at this composition, the density and hardness values were observed to be different [11]. Aluminum reinforced with conventional ceramic materials and oxides was used to produce the sound composites [12-13]. The impact of SiC and preheated B_4C on Al-alloys was studied, and the composites were fabricated in a low-temperature environment [14-15]. The effect of various additives on the mechanical and surface properties of aluminum MMC's was addressed [16]. The influence of rice husk ash at different mass fractions was useful in analyzing the structure-property relationship of the AA6061 composite [17]. The composites fabricated with red mud and SiC particles exhibit higher tensile strength than the AA 2024 alloy [18].

The impact of 12% graphite on the AA6082 composite was discussed, and the results revealed that the microstructure shows that non-uniformly distributed graphite particles were observed [19-20]. The effect of reinforced Al_2O_3 powders on the structural properties of composites was studied [21-22]. The developed Al-Zn-Mg/SiCp hybrid composites exhibit superior properties after processing with the different techniques [23-24]. Work reported on the impact of Al_2O_3 and SiC-reinforced particle behavior on the wear properties of Al-based composites was studied [25].

The Al-SiC-based MMCs were developed with a casting process that was studied, where a volume portion of SiC composition ranging from 5–10% was used to examine the wear behavior of composites [26-28]. Many researchers have used SiC particles as reinforcement in the Al metal matrix composites. The composites have good wettability between Al 6061 and SiC particles. SiC particles have low density, good hardness, strength, thermal conductivity, and excellent chemical inertness with low thermal expansion [29-30]. From the available literature, it was known that a huge amount of research work was found in the manufacturing of MMCs using the stir casting method. Mainly, the present work focused on critically analyzing and establishing the structure-property relationship of hybrid composites made with Al alloy AA5059 reinforced with SiC, B_4C an Al_2O_3 at different compositions that were melted in vibration-assisted induction furnaces (VAIF). This method is well suited to produce composites with less porosity and good structural uniformity.

2. Materials and methods

2.1 Materials

The aluminium alloys that are belongs to the 5xxx series is also known as aluminium magnesium alloys, it contains the magnesium as a primary alloying element. The chemical composition of the AA5059 is tabulated in Table 1, and composition of the reinforcements are reported in Table 2.

Table 1: Chemical composition of AA5059 Al-alloy

Element	Mg %	Mn %	Si %	Fe %	Zn %	Al %
Composition	5.02	1.02	0.15	0.05	0.13	balance

2.2 Composite fabrication

AA5059 based hybrid composites were fabricated by VAIF. Initially, reinforcements are kept in the induction furnace (175kw) at 700^{o}C and preheated for 3 hours to oxidized the surfaces and aluminium alloy is heated about 950^{o}C for 30 minutes. The calculated amounts of matrix and reinforcements were placed in graphite clay crucible for producing the composites under inert gas environment.

Table 2: Composition of reinforcements.

No of specimens	SiC	B_4C	Al_2O_3
Specimen 1	5%	5%	5%
Specimen 2	6%	6%	6%
Specimen 3	7%	7%	7%

During the process necessary care has been taken manufacturing the composites without porosity by adopting de-oxidation process. It was famous that the SiC particles were entrapped by primaryAA5059 alloy during the composite solidification process. The casted samples were made as per the ASTM standards for perform the different tests to evaluate the characteristics of composites. The experimental setup was shown in Figure 1 (a-e) with schematic view of VAIF.

Figure 1: (a) casting set up (b) SiC (c) Fly Ash (d) AA6061 (e) casted specimens.

The weight of MMC'S should then be calculated using the percentages of SiC, Al_2O_3, B_4C (5, 6 and 7). After melting, reinforcements are added to the molten aluminium during stirring at a speed of 1500–3000 rpm for 5–10 minutes.

3. Results and discussion

3.1 Mechanical properties

The mechanical properties of aluminium MMC's vary due to non-uniform reinforcement particle distribution, reinforced element qualities, porosity between the reinforced element and metal matrix, and other factors. The detailed experimental composites test results are reported in Table 3.

Table 3: Tested results of the composites

Sr. No.	Sample details	Tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	Hardness (HV)
1.	AA5059 + 5% SiC + 5% Al_2O_3 + 5% B_4C	145	128	13.40	48.56
2.	AA5059 + 6% SiC + 6% Al_2O_3 + 6% B_4C	180	162	15.36	44.83
3.	AA5059 + 7% SiC + 7% Al_2O_3 + 7% B_4C	172	136	14.20	49.56

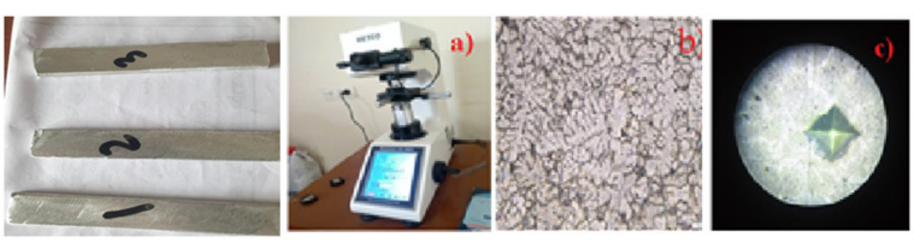

Figure 2: Hardness test image

Table 4: Hardness test results

Sample ID		1st value	2nd value	3rd value	Avg value
AA5059 + 5% SiC + 5% Al_2O_3 + 5% B_4C	Core	47.4	44.4	54.8	48.86
	Case	50.2	45.5	48.5	48.06
AA5059 + 6% SiC + 6% Al_2O_3 + 6% B_4C	Core	46.8	45.4	42.3	44.83
	Case	46.7	42.5	43.3	44.16
AA5059 + 7% SiC + 7% Al_2O_3 + 7% B_4C	Core	52.3	49.6	46.8	49.56
	Case	46.2	48.1	47.7	47.33

3.1.1 Hardness

The test results shows that the reinforced AA5059 has less hardness compared to the base AA5059 material without the reinforcement. The measured hardness values are listed in Table 4. The Hardness determination is shown in Figure 2. The sample 3 exhibits the nearly 50 HV as the highest hardness compared to other samples.

3.1.2 Tensile test

The mechanical properties are evaluated using UTM at natural environment conditions via. 0.2% offset yield strength, ultimate tensile strength and % elongation. The samples were prepared as per the ASTM-E8 [31],and the test sample specifications were shown in the Figure 3.

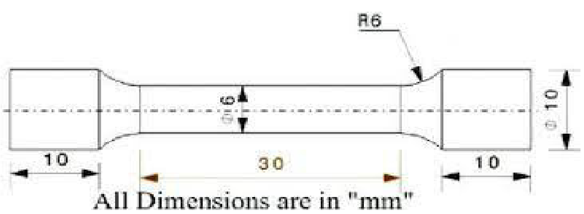

Figure 3: ASTM E8 tensile test specimen specification.

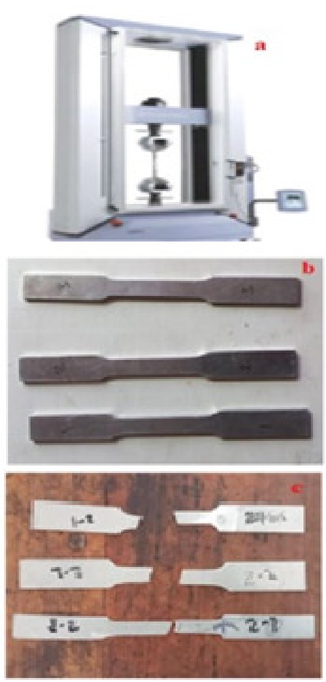

Figure 4: Tensile test conducted samples.

The tensile test is conducted on Universal Testing Machine and failure samples were shown in Figure 4.The test results shows that the reinforced AA5059 has relatively low tensile strength, yield strength, elongation compared to the base AA5059 material without the reinforcement. The work reported the variation of % Elongation with respectively to the B_4C and graphite reinforcements for different MMCs. [32].

These values are increasing with the increase of graphite and B_4C percentages but variation in the values is nominal. It is due to the fact that the B_4C and graphite reinforcement exhibits a good bonding with AA5059 matrix phase. Table 3 shows the variation of yield tensile strength with respectively to the B_4C and graphite reinforcements for different MMCs. These values are increasing with the increase of graphite and B_4C percentages but variation in the values is nominal. The sample 2 exhibits the highest tensile strength as compared to other composition composites.

3.1.3 % of elongation

With the improved UTS, percentage elongation of the SiC reinforced composite was reduced. High strength of SiC composite had reduced the ductility of the prepared composite [33]. Beyond 6 wt% of SiC content, the ductility was significantly decreased. The reduction of percent elongation is given in Table 3Al 5059/5wt%SiC composite had maximum reduced elongation and failure state of this sample 1 is shown in Figure 5.

Figure 5: Tensile strength of a reinforced composite.

3.2 Microstructure

The weld cross sections are subjected metallographically to explore the macro and microstructure details at the weld location. The weld surfaces are initially polished with different grided emery papers and metallurgically etched with standard Keller's reagent to reveal the grain structures in the weld area [34]. The microstructures are captured using computerized colour image microscopy, model METZ-778 (Make: METZR). The microstructure of sample 1, 2&3 in a polished which are randomly distributed all over the aluminium matrix. Microstructures of casted and etched samples are shown in Figure 6.

The microstructural images proved that the B_4C and graphite reinforcement exhibits a good bonding with AA 5059 matrix phase. The MMCs were formed with uniform grain distribution with boron carbide and graphite particles with some voids, and it shows best ductility, elongation, strength and hardness values. Sample 2 exhibits the high tensile strength as compared to other samples casted at different conditions shown in Figure 6.

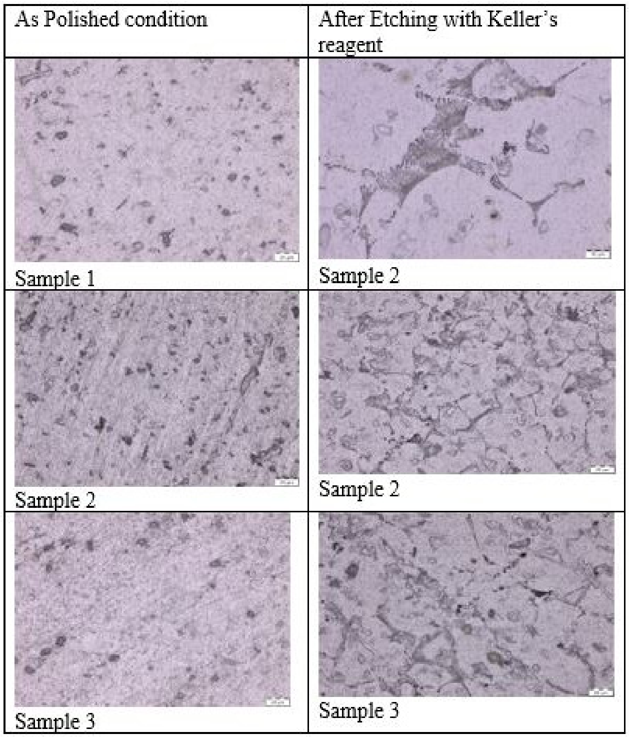

Figure 6: Microstructure of casted samples.

4. Conclusions

AA 5059 MMCs were produced with the help of vibration assisted casting method with SiC, Al_2O_3, B_4C nano-particles as reinforcements. The matrix AA5059 alloy microstructure compared with the composite microstructure, it clearly observed that the grain refinement occur red due to presence of reinforcements like SiC, Al_2O_3, B_4C particles. The composite properties are varied with the variations of reinforcements compositions. The microstructure images of the composite is revealed that SiC, Al_2O_3, B_4C powders are distributed regularly throughout the composite. The highest strength of compositesis measured as1 8 0 M P a . The sample 2 exhibits the better properties than other samples.

Acknowledgements

The authors are thankful to the Management of Vignana Bharathi Institute of Technology for providing support and facilities for the research work.

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