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Effect of Reinforment of Particles on the Mechanical Properties of Al6065-SiC, Al6065- Al_2O_3, Hybrid Composites by Modified Stir Casting Method

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ABSTRACT

Aluminum and its alloys are the most essential considerations as base metal in metal matrix composites. The aluminum alloys are reasonably attracted by various researchers owing to their decrease in weight, high quality corrosion resistance, maximum thermal and electrical conductivity, and on precipitation, they exhibit higher strength and superior damping capacity. The strong requirement for weight reduction in automobile and aerospace industries insists on the optimization of the design of products to make use of less weight materials. MMCs production has numerous challenges like porosity formation, attainment of good wettability and inappropriate distribution of reinforcement. Homogenous distribution of reinforcement in the metal matrix composites is the most important challenge among the other parameters and obtained by two-step stir casting method. In this present research work Al6065 & Hybrid composites with four different reinforcement particles such as SiC, alumina, SiC-fly ash, alumina-fly ash in three different weight fractions (2, 4, and 6 %) were fabricated by modified stir casting method. The mechanical properties of the Al6065 & hybrid composites and unreinforced alloy have been investigated. The enhancement in the mechanical properties of Al6065 composites due to the reinforcement of particles is obtained.

Keywords: ARNF; Hybrid; Precipitation; Homogenous; Mechanical; Stir casting.

INTRODUCTION

In the last two decades, there was a transition of research from conventional materials to composite materials to match the universal need for better performance, less weight, high strength, environmental friendly, wear and corrosion resistant materials. Metal Matrix Composites (MMCs) are suitable for the above demand requiring lower density. Aluminum alloys have the property that is light in weight can be used as replacement for the conventional materials. Composites are manufactured by dispersing the reinforcements in the metal matrix. The addition of reinforcement improves the mechanical properties and other properties of the base metal. Among the different base metals, aluminum and its alloys have attracted more attention as base metal by most researchers. Aluminum metal matrix composites are the most proficient material in the industrial world. For the past few years, researchers finding alternate material to meet the better properties and production methods by adding various reinforcements. Among the different reinforcements, fly ash is one of the cheapest available reinforcement and it enhances the tensile strength. Vivek Babu et al found that Fly ash and e-glass fiber can be effectively implemented to fabricate hybrid composite using stir casting method. The tensile, compressive and hardness increased with increase in wt. % of fly ash [1]. Fly ash and e-glass fiber can be effectively employed to fabricate hybrid composite using stir casting method. The various mechanical properties like tensile, compressive strength and hardness increased with increase in wt. % of fly ash were analyzed by Siva Kumar et al. [2], while decreasing the particle size of fly ash increases the mechanical properties [3][4]. Balasivanandha Prabu et al. [5], investigated that the density of the composites decreased with increasing fly ash content. Therefore, these lightweight composites can be used where weight plays major part like aerospace and aeronautical industries [6]. Hybrid matrix composites could be considered as an outstanding material than singe reinforcement material where enhanced properties are required. Sanjeev kumar et al. [7] analyzed that when the size of the fly ash increases the mechanical properties of the composites increases [8]. According to Vishal Sharma et al. [9], fiber reinforced composites are often characterized by their high specific strength and specific modulus parameters (*i.e.*, strength to weight ratios), and are

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widely used for applications in low weight components. Metals reinforced by short-fiber, have the advantage of being machinable and workable using conventional processing techniques, especially short fiber reinforcements have more favorable influence on the stiffness and elastic-plastic tensile properties. If good fiber alignment is obtained the tensile properties are much improved. Fiber alignment is often obtained during processing by using either contracting flow or expanding flow in the extrusion. The mechanism of strengthening and the mechanical properties of metal matrix composites have attracted a considerable number of investigations. Prasad [10] investigated the fabrication of MMCs by casting processes is very promising for manufacturing near net shape components at a relatively low cost. Al-fly ash MMCs are extensively used in automobile applications due to its higher tensile, hardness, compression and wear resistance. Al-alloy reinforced fly ash reveals superior damping characteristics and increases mechanical properties. Addition of fly ash decreases erosive wear but increases corrosion. Squeeze cast of Al-fly ash is limited by many authors and compared gravity cast with squeeze casting of Al-fly ash reinforcement and stated that advantageous of squeeze cast for obtaining higher structural homogeneity with minimum porosity level, uniform distribution of fly ash and good interfacial bonding between matrix and fly ash. Anil Kumar et al. [11] stated that fly ash particles are irregular dispersoids in the form of consecrate spherical in shape used in composites, because they are with low density and low-cost reinforcement available in huge quantities as a waste in thermal power plants. Al-alloy reinforced SiC particulates by squeeze casting is a promising composite accelerates hardness, tensile and fracture toughness, fatigue strength, flexural, stiffness and wear resistance with low CTE and higher thermal conductivity [12]. Very little literature is available on mechanical properties of fiber reinforced metal matrix composites. Most of the published data pertain to the mechanical properties of particulate-reinforced MMCs deal with tensile properties while only a relatively small amount of data has been obtained dealing with compression properties, although it is generally known that the compressive strength of an MMC is invariably higher than its UTS. Hence, in the present investigation, importance is also given to the compressive properties of the MMCs, together with the tensile properties such as the UTS, ductility, hardness and Young’s modulus. The mechanical properties of MMCs are also affected by the residual stresses, which form because of the differences in the thermal expansion coefficients between the matrix and reinforcement. The present research has been focused on the utilization of different Particles reinforcement in useful manner by dispersing it into aluminum 6065 to produce composites by the modified stir casting method to overcome the cost barrier and improvement in mechanical properties is obtained.

MATERIALS AND METHODS

Materials

Al6065 was used as the matrix material and four different particles SiC, alumina, SiC+flyash; alumina+flyash were used as reinforcement to produce composites by modified stir casting method. Composites were produced with (2, 4, and 6%) weight fraction of reinforcement.

Stir casting method

The metal matrix composite used in the present work was fabricated by the two-step stir casting method. Al alloys were used in the form of ingots. The cleaned metal was melted to the preferred super heating temperature of 730^{0}C in graphite crucibles below a cover of flux in order to minimize the oxidation of the molten metal. The temperature of the furnace was controlled by the three-phase electrical resistance. 300 - 400g of alloy was used for each melting. The superheated molten metal was degassed at a temperature of 760^{0}C. The reinforcement particulates were preheated to around 300^{0}C, then added to the molten metal at 720^{0}C and continuously stirred at 300 rpm by the mechanical stirrer. The stirring time was between 5 to 8 minutes. During stirring, small amount of magnesium was added to increase the wettability of reinforcement particles. After cooling to room temperature, the molten metal matrix was again heated to 720^{0}C and stirred by the mechanical stirrer at 200 rpm for 5 minutes.

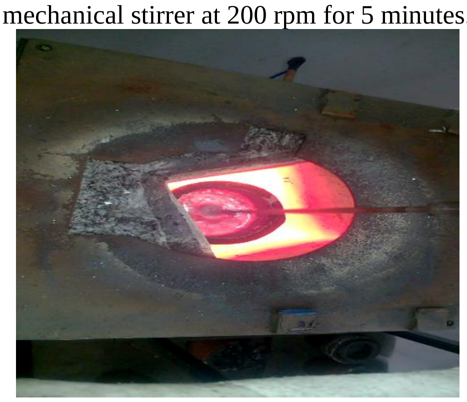

Fig.1: Stirring of the reinforcement

The melt, with the reinforced particulates, was poured into the dried, coated, cylindrical permanent metallic moulds 80 mm in diameter and 175 mm high. The pouring temperature was maintained at 670^{0}C. The same molten metal matrix mixture was poured into strip. The melt was allowed to solidify in the moulds. Similarly, the mould was prepared for the other weight percentages. For the comparison, the unreinforced alloy was casted under similar processing conditions.

Mechanical properties

Tensile strength

As per the ASTM E-10 standards, tensile strength tests were carried out on Al6065 alloy, Al6065-SiC, Al6065- Al_2O_3 Al6065- SiC-Fly ash and Al6065- Al_2O_3-Fly ash composites using a computerized UTM testing machine. Three samples were taken and tested for each composition and average value was taken as the tensile strength.

Fig.2: Tested tensile test samples

Hardness

Brinell hardness testing machine was used to evaluate the hardness of unreinforced Al6065 alloy, Al6065- SiC, Al6065- Al_2O_3 Al6065- SiC-Fly ash and Al6065- Al_2O_3-Fly ash composites specimens. The testing conditions were 5mm diameter ball indenter with the load of 250 kgf for a period of 10 seconds. Three readings were taken on each specimen to check repeatability and to eliminate possibility of error and mean value was taken as the hardness of the composite.

Fig.3 Tested hardness test sample

Toughness

Impact test were conducted on the Al6065 alloy, Al6065- SiC, Al6065- Al_2O_3, Al6065- SiC-Fly ash and Al6065- Al_2O_3-Fly ash composites using charpy impact test method. The specimen was made to standard impact test specimen of 10x10x55 mm dimensions, a 45-degree V notch of 2 mm depth and a 0.25 mm root radius. The specimen is made to resist the pendulum notch, which is released from a certain height from the opposite end, and fracture samples were collected. Tests were conducted on the samples for three times and average of three readings determines the toughness of the composites.

Fig.4: Tested impact test samples

RESULTS AND DISCUSSIONS

Tensile test

Fig.5 shows tensile test results of Al6065 composites. From the chart it is clear that there is a rapid transition in yield strength from 115 MPa to 148 MPa while the % of alumina reinforcement increasing up to 6%. The yield strength of Al6065-6wt. % SiC-was observed to be 156 MPa which was 35% higher than the unreinforced alloy.

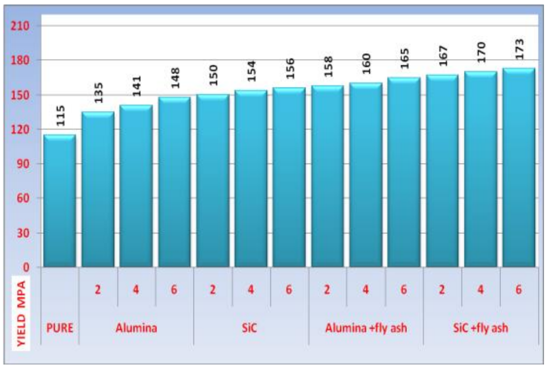

Fig.5: Yield strength of Al6065- SiC, Al6065- Al_2O_3, Al6065-Hybrid composites

The increase in weight fraction of SiC increases the yield strength, which indicates that SiC was harder than the alumina particles. It was observed that the value of yield strength for Al6065-2wt. % SiC-fly ash was 167 MPa, 170 MPa for Al6065-4wt. %SiC-fly ash and 173 MPa for Al6065-6wt. %SiC that shows increase in yield strength when compared to alumina & fly ash reinforcement. SiC-fly ash provides better bonding and load withstanding capacity than the other composites.

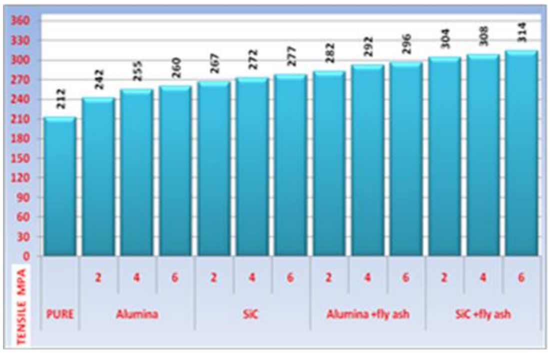

Fig.6: Tensile strength of Al6065- SiC, Al6065- Al_2O_3, Al6065-Hybrid composites

From Figure 6, it is observed that composites exhibit higher tensile strength than the pure Aluminum 6065.Al6065 unreinforced alloy exhibit tensile strength of 212 MPa and the value increased for Al6065-6wt. % SiC-fly ash composites to 314 MPa which was 46% higher than the pure alloy. Correspondingly 277 MPa for Al 6065-6wt. % SiC increase of 31 % was observed when compared to the Al6065 alloy.

Hardness test

From Figure.7, it could be observed that the hardness of the composites increases for all weight percentages 2%, 4% and 6wt.% of SiC reinforcement.

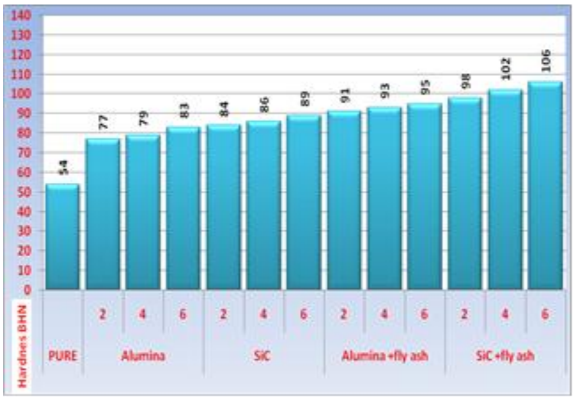

Fig.7: Hardness of Al6065- SiC, Al6065- Al_2O_3, Al6065-Hybrid composites

Table 1: Mechanical Properties of Composites

SI. No	Material	Hardness (BHN)	Yield strength (MPa)	Tensile Strength (MPa)	Toughness (Joules)
1	Al6065	54	115	212	1.4
2	Al6065-2%alumina	77	135	242	1.9
3	Al6065-4%alumina	79	141	255	2.1
4	Al6065-6%alumina	83	148	260	2.3
5	Al6065-2%SiC	84	150	267	2.5
6	Al6065-4%SiC	86	154	272	2.6
7	Al6065-6%SiC	89	156	277	2.6
8	Al6065-2% (alumina &flyash)	91	158	282	2.9
9	Al6065-4% (alumina &flyash)	93	160	292	3.1
10	Al6065-6% (alumina &flyash)	95	165	296	3.2
11	Al6065-2% (SiC &flyash)	98	167	304	3.4
12	Al6065-4% (SiC &flyash)	102	170	308	3.5
13	Al6065-6% (SiC &flyash)	106	173	314	3.6

Hardness of 89 BHN was observed for 6% weight fraction of, Al6065-SiC composites which was 7% more than Al6065-alumina for 6% weight fraction (83 BHN) and 64% more than the unreinforced alloy (54 BHN). Hard SiC particles act as an obstruction to the applied load. Hardness of the Al6065-SiC-fly ash composites was greater than the other composites because of the hard nature of SiC particles. The accumulation of hard SiC particles increases the bulk hardness of the aluminum alloy. Al6065-SiC-fly ash (6%. Wt) reinforcement exhibit superior hardness than the Al6065-alumina-fly ash (6%. Wt), Al6065-SiC (6%. Wt) and Al6065-alumina (6%. Wt). This result was due to the enhanced bonding of fly ash with SiC than the alumina particles.

Toughness test

As shown in Figure.8, the maximum toughness of 3.6 Joules was observed for Al6065-6% (SiC-fly ash).

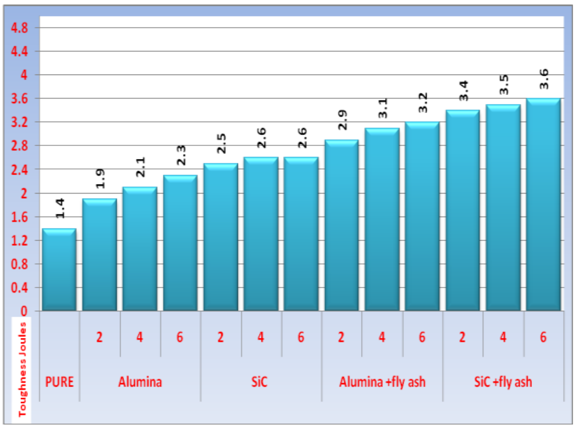

Fig.8: Toughness of Al6065- SiC, Al6065- Al_2O_3, Al6065-Hybrid composites

Al6065-alumina-fly ash (6wt. %) exhibit toughness of 3.2 Joules, Similarly 2.6 Joules for Al6065-6 wt. % SiC. However, the toughness decreases for the decrease in weight percentage reinforcement particles.

SEM images

Figure 10 shows a micrograph of Al6065-SiC composites produced by modified two-stage stir casting method. The composites produced with the modified two stage stir casting resulted in a much more homogeneous microstructure (Figure 9) than the actual stirring casting method (Figure 10) with the SiC being distributed more uniformly throughout the whole volume of the specimen. Thus, it could be concluded that the modified two-stage stir casting method is certainly advantageous since it helps in achieving a uniform distribution of SiC particles in the matrix. It can be seen that the fracture surface of Al6065-SiC composites (Figure 11) shows a ductile fracture characteristic, consisting of numerous cracks.

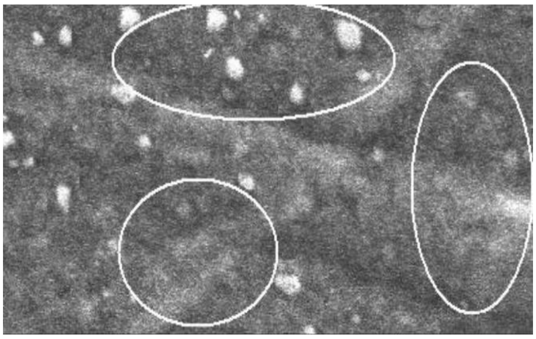

Fig.9 SEM micrograph of Al6065 –SiC composites produced by actual stir casting method

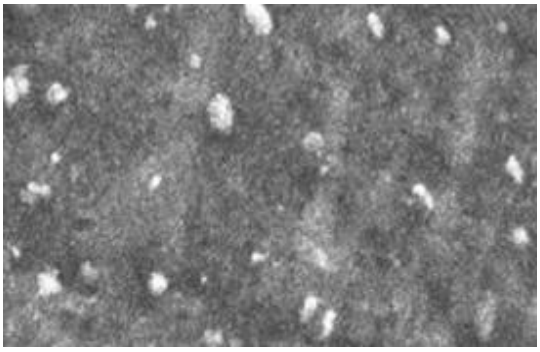

Fig.10 SEM micrograph of Al6065 –SiC composites by modified two-step stir casting method

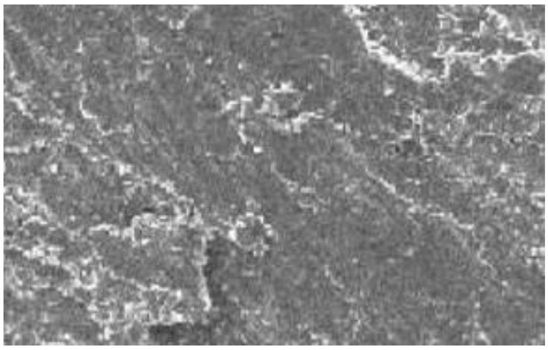

Fig.11: Fracture surfaces of Al6065-SiC-Flyash (6% Wt) tensile test specimens

In addition to these cracks, the fracture surface of the composites also reveals fragmentation and decohesion of the SiC particles from the matrix, leading to a reduction in ductility. In composites reinforced SiC reinforcements, the energy consumption for voiding, debonding or separation between the reinforcements and surrounding matrix becomes larger accounting high fracture toughness of the SiC particle reinforced composites

CONCLUSION

The fabrication of Al 6065-SiC, Al 6065-alumina, Al 6065-Hybrid Composites were successfully manufactured by the modified stir casting method and uniform distribution of reinforcement particles in the Al6065 matrix was achieved. From the results of test conducted the following conclusions have been drawn.

1. Hardness increased with the increase in addition of SiC particles. The highest hardness (106 BHN) was obtained for 6wt. % SiC particle and fly ash reinforced composites. The hardness was more for the composites reinforced with SiC when compared to alumina particles. The same was obtained in the behavior of hybrid composites.

2. The Al6065-alumina and Al6065-alumina-fly ash has lesser yield strength and tensile strength. The highest amount of yield strength and tensile strength were 173 MPa, 314 MPa for the sample containing Al6065-SiC-fly ash (6wt. %) composites.

3. Toughness increased with the increase in reinforcement of Sic for 2%, 4% and 6wt. % reinforced composites. The highest amount of toughness was 3.6 Joules for the sample containing 6wt. % SiC & fly ash reinforced with Al6065.

When the weight percentage of SiC increases hardness, yield strength, tensile strength, toughness increases. Al6065-SiC-fly ash composites exhibit superior mechanical property than the Al6065-alumina and the Al6065-alumina-fly ash composites. SiC provides to be the best reinforcement than the alumina for the reinforcement of Al6065.

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