Fabrication and Characterization ofAluminum Metal Matrix Composite

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ABSTRACT
Metal matrix composite materials increasingly replace traditional materials used in building engineering, aeronautics, mechanical engineering and in many other domains. It is related to a possibility of obtaining practically any combination of beneficial properties of the material, e.g. high vibration damping coefficient, high abrasion resistance, and high value of the Young's modulus, low specific gravity and low coefficient of thermal expansion. In the present investigation, Al 6351/Al_2O_3 metal matrix composite was fabricated by stir casting technique. Microstructure characteristics wereobserved on metallurgical microscope to observe the distribution of reinforcement in matrix alloy. Uniform distribution was observed in all samples.

KEYWORDS: Aluminium alloy (6351), Alumina (Al_2O_3).

1. INTRODUCTION

Metal matrix composites (MMCs) usually consist of a low-density metal, such as aluminum or magnesium, reinforced with particulate or fibers of a ceramic material, such as silicon carbide or graphite. Compared with unreinforced metals, MMCs offer higher specific strength and stiffness, higher operating temperature, and greater wear resistance, as well as the opportunity to tailor these properties for a particular application. However, MMCs also have some disadvantages compared with metals. Chief among these are the higher cost of fabrication for high-performance MMCs, lower ductility and toughness. Presently, MMCs tend to cluster around two extreme types. One consists of very high performance composites reinforced with expensive continuous fibers and requiring expensive processing methods. The other consists of relatively low-cost and low-performance composites reinforced with relatively inexpensive particulate or fibers. The cost of the first type is too high for any but military or space applications, whereas the cost/benefit advantages of the second type over unreinforced metal alloys remain in doubt.The application of response surface methodology (RSM) and central composite design (CCD) for modeling, optimization, and an analysis of the influences of dominant machining parameters on thrust force, surface roughness and burr height in the drilling of hybrid metal matrix composites produced through stir casting route[1]. Many factors which influence the effect of viscosity during Al–SiC MMC production. Processing periods (up to 65 min), stirring speeds (50–500 rpm), and reinforcement sizes (13–100 µm) for two different viscosity levels (1 and 300 mPa-s) were investigated [2]. Particulate metal matrix composites (PMMCs) have attracted interest for application in numerous fields [3]. The wear rate of spray formed composites is significantly lower than the base alloy and stir cast composite under same sliding condition [4] .Comparing with the Newtonian case, the couple stress effects of fluids containing suspensions provide an enhancement in the load capacity, as well as a reduction in the attitude angle and the friction parameter. AA6063 aluminium matrix composite billets reinforced with SiC particles (Al/SiCp) were prepared by stir casting method for extrusion process. The results show that the die wear is affected differently by the SiC particle size[5].Optical microscopy of the conventional cast and stir cast hypereutectic alloy has shown that stir casting causes refinement of primary silicon particles and modification of eutectic silicon compared to conventional cast alloy[6].The formation of TiB_2 particles occurred via diffusion of Boron atoms through TiAl3 particles interface, thereby reacting to form fine TiB2 particles [7].The use of aluminium-based particulate reinforced MMCs for automotive components and aircraft structures have been shown to be highly advantageous over their unreinforced alloys, due to their high specific strength and stiffness and superior wear resistance in a wide temperature range. SEM analyses of the fracture surfaces of the tensile specimens showed substantially similar morphologies for the as-cast and forged composites, both at room and high temperature. The mechanism of damage was mainly decohesion at the matrix–particle interface [8]. Rheological properties of aqueous concentrated aluminium nitride (AlN) suspensions have been investigated in the presence of a sintering aid, deffloculant, binder and plasticizers, in order to screen the most suitable experimental conditions to obtain a good rheological behavior for tape casting thick and non-cracked tapes with good flexibility[9].The wear rate of all heat-treated specimens is less than that of the specimens in the as-cast condition. The main reason for this improvement is clearly related to the hardness enhancement after the aging treatment [10].The wear resistance of the as-cast Al–Si alloy and composites was decreased with increasing sliding distance, while the wear resistance of Al–Si alloy matrix composites has increased with increasing wt% of Al_2O_3 particles. This is due to higher load-carrying capacity of the hard reinforcement Al_2O_3 particles, which limits the amount ofplastic deformation of the matrix [11].Literature survey did not reveal any systematic study of Al 6351/Al_2O_3metal matrix composites. Objective of the present work Fabrication of Al 6351/Al_2O_3 metal matrix composites with different percentage of reinforcement by stir carting method.Microstructure observation of all fabricated samples to observe distribution of reinforcement. Investigation of mechanical properties of all samples.

2. EXPERIMENTATION

MATRIX MATERIAL

Most of the aerospace structures and its allied infrastructure are made of aluminum alloy. In this context considering Al 6351 which was used for making pressure vessel cylinders is now testing for aircraft structures. Al 6351 has high corrosion resistance and can be seen in forms of extruded rod bar and wire and extruded shapes. It is easily machinable and can have a wide variety of surface finishes. It also has good electrical and thermal conductivities and is highly reflective to heat and light. Due to the superior corrosion resistance, Al 6351 offers extremely low maintenance. The experimental results were found satisfactory to propose the alternative alloy for aircraft structures. The mechanical and physical properties of aluminum alloy (6351) have been reviewed from literature data for the purpose of characterizing the mechanical for manufacturing process in engineering application. Aluminum alloys are used in many applications in which the combination of high strength and low weight is attractive in air frame in which the low weight can be significant value. Al 6351 is known for its light weight (density $= 2.7 g/cm^3$) and good corrosion resistance to air, water, oils and many chemicals. Thermal and electrical conductivity is four times greater than steels. The chemical composition of alloy is follows

Table 1: Properties of aluminum alloy (Al 6351) [12]

aluminum alloy	Cu	magnesium	Silicon	iron	Manganese	Others	Remaining
Al 6351	0.1 %	0.4-1.2%	0.6-1.3%	0.6%	0.4-1.0%	0.3%	Al

It has higher strength amongst the 6000 series alloys. Alloy Al 6351 is known as a structural alloy, in plate form. This alloy is most commonly used for machining.

REINFORCEMENT MATERIAL

Aluminum oxide (Al_2O_3) is widely used as the reinforcement in the metal matrix composites.The mechanical and physical properties of alumina (Al_2O_3) have been reviewed from literature data for the purpose of characterizing the mechanical properties of alumina for manufacturing process in engineering application.

Table 2: Mechanical properties of (Al_2O_3)

Alumina (Al_2O_3)	Grade	pH value	Mesh size
Neutral(1344-28-1)	Brockman 1 or 2	6.5-7.5	100

Metal–matrix composites (MMCs) are most promising in achieving enhanced mechanical properties such as: hardness, toughness and ultimate tensile strength due to the presence of micro-sized reinforcement particles into the matrix. Generally, regards to the mechanical properties, the reinforcements result in higher strength and hardness, often at the expense of some ductility. Aluminum-matrix composites (AMCs) reinforced with particles and whiskers are widely used for high performance applications such as in automotive, military, aerospace and electricity industries because of their improved physical and mechanical properties. In the composites relatively soft alloy like aluminum can be made highly resistant by introducing predominantly hard but brittle particles such as Al_2O_3 and SiC.

EXPERIMENTAL PROCEDURE

The materials used in the present work are aluminium alloy (Al 6351) and aluminium oxide (Al_2O_3 as reinforcement). These materials are chosen due to their easily mixable property and gives good mechanical properties. The aluminium alloy (Al 6351) is heated up to its melting temperature 600^0C in a mufflefurnace. Temperature measurement is done with help of K-type thermocouple. Preheatedaluminium oxide at 100^0Cis mixed slowly in molten aluminium alloy with the help of stirrer. The material is left for cool down in the crucible in which it was melted and mixed.There are three samples in different ratios which are prepared for testing mechanical properties. The ratios are shown below in the Table 3.

Table 3: Composition selection

Material	Sample 1	Sample 2	Sample 3
(Al 6351)	97.5%	95%	92.5%
(Al_2O_3)	2.5%	5.0%	7.5%

Figure 1 a. Muffle furnace Figure 1 b. Preparation of sample by stir casting

Now the mixed composite after cooling and solidification is cut into desired shapes for testing mechanical properties on the band saw machine. The machine is an electrically driven machine which is used to cut the hard composites. The MMC samples prepared are shown in figures given below.

Figure 2: MMC (Al 6351+2.5% of Al_2O_3)

Figure 3: MMC (Al 6351+ 5% of Al_2O_3)

Figure 4: MMC (Al 6351+7.5% of Al_2O_3)

Figure 5: MMC sample prepared for hardness test

Figure 6: MMC sample for tensile test

Figure 7: MMC sample prepared for toughness test

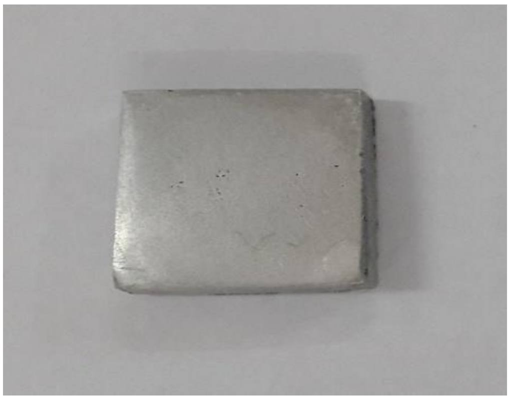


Figure 8: MMC sample prepared for microstructure

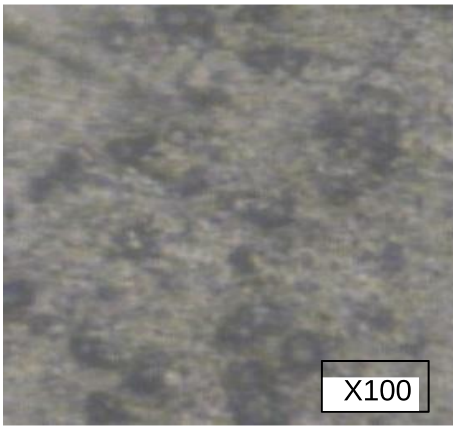
Grinding/polishing

The cut samples prepared above had an uneven surface. So, the cut samples were then taken for grinding/polishing operation. The sample was first held over a grinding machine with a moving belt to obtain a smooth surface. The grinding was done in such a way so that all the scratches are in the same direction and the grinded surface becomes flat. After this the samples were polished using different grits of emery papers. Because the samples being aluminium alloy composites it is rubbed over the emery paper for a small time. It was rubbed over an emery paper of 400, 600, 800, 1000 grit and then over a very fine emery paper of 1200, 1600,2000 grit for a considerable time in order to get a smooth and clear surface of the samples.

3.RESULTS AND DISCUSSION

Analysis of Microstructure

The microstructures of the MMC samples are seen using metallurgical microscope. The term 'microstructure' in metal matrix composites is used to describe the appearance of the reinforcement material. Microstructure shows that the Al_2O_3 reinforcement distributed uniformly throughout the casted component. Here Al_2O_3 distribution did not show any segregation.Uniform distribution was observed of all selected composition as shown in figure 9.



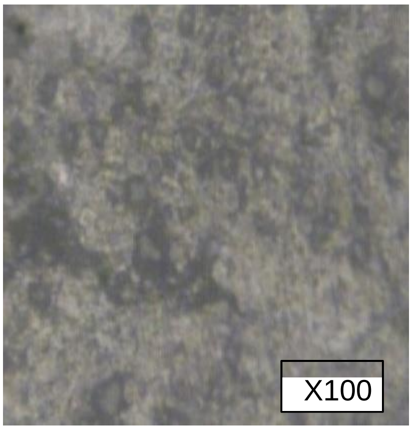
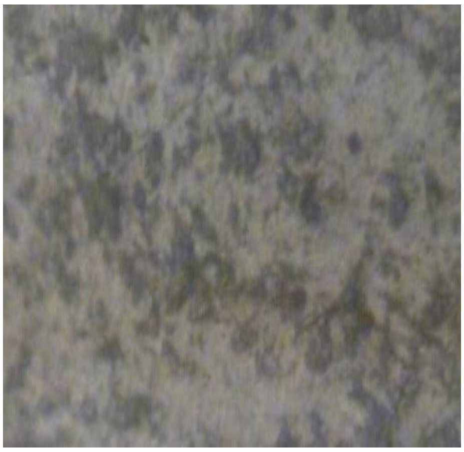


Figure 9: (a) Al 6351+2.5 % Al_2O_3 reinforcement (b) Al 6351+5 %Al_2O_3 reinforcement



X100

(c) Al 6351+7.5 % Al_2O_3 reinforcement

Analyses of Tensile Strength

Tensile tests are used to determine the elastic limit, elongation, tensile strength, yield strength and reduction in area. Tensile tests were carried out at room temperature using computerized universal testing machine with a capacity of 40 KN. The specimens were tested according to ASTM E8M-01 standard. Specimens of sub sized sample are length of 100 mm, width of 6 mm and gauge length is 36 mm.The ultimate tensile strength, percentage elongation was calculated for each prepared sample.

Table 4: Tensile Test of Al 6351+Al_2O_3 MMC

Samples (of Al_2O_3)	Ultimate strength(N)	Elongation (mm)	Break load (N)	Break Elongation (mm)	True UTS (N/ sq mm)	Area (sq. mm)
2.5%	698.3	0.52	146.1	0.62	26	27.341
5.0%	642.5	0.51	209.9	0.69	21.4	24.453
7.5%	1531.1	2.42	1315	3.23	67.2	26

Analysis of Toughness Test

In these MMC specimens toughness is tested by breaking it with impact force of a hammer weighing 21 kg. The Hammer is leaved from 140 degree of angle with the initial energy of 300 J. According to ASTM E-23, standard specimen, sizes are 10 mm x 10 mm x 55 mm. for charpy impact test analysis. The table shows the results while testing as follows:

Table 5: Toughness of Al6351+Al_2O_3 MMC

Sample No.	Composite Sample Name	Trial			Average Energy (Joule) (A+B+C) / 3
		A	B	C	
1	Al6351+2.5 % Al_2O_3	14	16	18	16.00
2	Al6351+5 % Al_2O_3	12	14	14	12.66
3	Al6351+7.5 % Al_2O_3	10	10	12	10.66

ANALYSIS OF HARDNESS TEST

The hardness test was carried on Rockwell Hardness testing method. For hardness testing, the samples of Al6351/2.5, 5, 7.5% wt. Al_2O_3 composite were prepared as per dimension (10 mm x 10 mm x 25 mm) as ASTM E18-05, standard.

Figure 10: MMC sample after indentation on hardness testing machine.

Table 6: Hardness of MMC

Sample No.	Composite Sample Name	Rockwell Hardness at (HRC) scale			Mean Hardness
		Trial 1	Trial 2	Trial 3	
1	Al6351+2.5 % Al_2O_3	42	45	51	46
2	Al6351+5 % Al_2O_3	50	51.5	53	51.5
3	Al6351+7.5 % Al_2O_3	57	58.4	60	58.4

CONCLUSION

The following conclusions are arrived based on the experimental investigation on the distribution of Al_2O_3 in themechanical stir casting and its effect on mechanical properties of the as cast MMCs at different weight fraction of Al_2O_3.

1. In the present investigation, it was observed that maximum mechanical properties were obtained for Al 6351/7.5% Al_2O_3.
2. The tensile strength of the as cast composites increases on increasing the weight fraction of Al_2O_3.
3. The hardness of the MMCs is higher than the unreinforced matrix metal and the hardness of the cast composites increases linearly with increasing the weight fraction of Al_2O_3.
4. Microstructural observation suggests that stirring action produces MMC with smaller grain size and there is a good particulate matrix interface bonding.
5. The increase in Al_2O_3 constituent toughness decreases with respect to base metal. This is due to increase in brittleness between the alloy Al6351 and Al_2O_3 interfaces.

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