A Comparative Study of Mechanical Properties Of As Cast And Heat Treated Al6063-MWCNT Composite Fabricated By Stir Casting Process

1Arun Joshi, 2Kumaraswamy H S, 3Anilkumar, 4A Mithun Reddy, 5Ashwin Raj

1 Assistant professor Department of ME, BNMIT Bangalore, India.
2, 3, 4 Under Graduate Students, Department of Mechanical Engineering, BNMIT Bangalore, India.
5 Department of ME, BNMIT Bangalore, India.

E-Mail: arun.joshi013@gmail.com

Abstract
The Expansion of manufacturing industries has somewhere led to the increase in the use of composite materials. Metal Matrix Composites (MMC) are the advanced and new age materials that find application in sectors like automotive, aerospace, rail components, defense etc. because of their light weight, high strength, good corrosion, wear resistance and low thermal coefficient of expansion. Among the different methods of manufacturing MMCs, Stir casting process is one of the most important and economical method. The present work is about the preparation of aluminium Matrix Composite by stir casting technique, where Al 6063 is the matrix or the base metal and 2% by Weight of multiwalled carbon nanotubes (MWCNT) in powder form is the reinforcement material. Microstructure analysis will be done in order to observe the distribution of CNT particles in the Al matrix. The specimens will also be subjected to heat treatment before being tested. The ASTM standard specimens will then be tested for wear, tensile, compression, Impact and hardness to compare the results. The major objective of this work is to compare the mechanical properties of both As-cast and heat treated test samples for the aluminium 6063-MWCNT composite fabricated by means of stir casting process and hence compare the results.

Keywords: Al-6063, MWCNT, Stir casting, Heat treatment, Mechanical Characteristics

1. Introduction

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fibre includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large coefficient of thermal expansion and thermal and electrical conductivities of metals can be reduced by the addition of fibres such as silicon carbide, MWCNT, Al2O3, silicon oxide, graphite and other such reinforcements.

Jamaluddin Hindi et.al [1] have studied that the addition of refractory reinforcement generally improves the hardness, tensile strength and high temperature properties of the material. Accordingly 200-300 micron size SiC (silicon carbide) reinforced Aluminium alloy composite was prepared in
laboratory condition. In the present work, Al 6063-SiC composite of 2, 4 & 6 wt% as reinforcement were manufactured using conventional stir casting technique. Specimens were prepared as per the international standards and tensile, hardness and impact tests are performed. Five trials are performed in each test and the averages of three closer readings are taken in hardness, tensile and impact strength tests. Microstructure reveals better dispersion of reinforcement in the matrix. It was found that hardness increases with increase in wt% of SiC reinforcement. Hardness and tensile strength of 6wt% SiC composite is found to be higher than 2 & 4 wt% of SiC. Ductility was found to decrease with increase in SiC addition. Impact strength variation was marginal with the increase in wt% of SiC. K.K. Alaneme, A.O. Aluko [2] have investigated the tensile and fracture behaviour of ascast and age-hardened aluminium (6063), silicon carbide particulate composites produced, using borax additive and a two-step stir casting method. Al (6063)-SiC composites having 3, 6, 9, and 12 volume % of SiC were produced, and sample representatives of each composition were subjected to age-hardening treatment at 180°C for 3 hours. Experimental results showed that the ageing treatment resulted in little improvement in the tensile strength of the composites. The tensile strength and yield strength increased almost the same magnitude with an increase in SiC volume percentage for both as-cast and age-hardened conditions. The fracture toughness was found to improve significantly with ageing treatment. Overall, Al (6063) alloy could be considered as a suitable matrix for the development of SiC reinforced Aluminium based composites. B Demudu Naidu and K R Satyanarayana [3] have studied the fabrication and characterization of Al6063 with reinforcement Nano γ-alumina (Al2O3) metal matrix composites produced by stir casting process. Various test specimens were produced with different wt% (0.5%, 1%, 2%, 3%) of reinforcement material. Age hardening process was done in order to improve the mechanical properties of the composite (strength and hardness). The microstructure analysis gave the proper mixing of Nano Al2O3 in Al6063. The Nano composite exhibited better properties after ageing than before ageing. The hardness was found to be higher for the Nano composite due to the grain reinforcement observed in the Nano composite. The tensile strength of the specimen increased with increase in the addition of reinforcements. Bharath V et.al [4] have synthesized a metal matrix composite using 6061Al as matrix material reinforced with ceramic Al2O3 particulates using liquid metallurgy route in particular stir casting technique. The addition level of reinforcement was being varied from 6 - 12wt% in steps of 3wt%. Hardness and tensile properties of the prepared composite were determined before and after addition of Al2O3 particulates to note the extent of improvement. It was observed that the microstructure of the composites contained the primary alpha-Al dendrites and eutectic silicon. While Al2O3 particles were separated at inter dendritic regions and in the eutectic silicon. The hardness and tensile properties were higher in case of composites when compared to unreinforced 6061Al matrix, also increasing addition level of reinforcement had resulted in further increase in both hardness and tensile strength. Maximum weight loss was observed in as cast 6061Al alloy and minimum weight loss was observed in 6061Al+12 wt% Al2O3 composites at a constant load of 19.62 N and speed of 300 rpm and as a part of wear test. The main aim of this work is to develop aluminum metal matrix composite using stir casting Set up and also compared the mechanical & tribological characteristics of AMMC with and without heat treatment process. Al-6063 used as a matrix material and MWCNT as reinforcement with a volume fraction of 2%
2. Materials and Experimentations

The furnace is heated to a certain temperature and a SiC crucible (melting pot) is place at the centre of the furnace. This procedure involved is known as "pit furnace process fuelled by coke." Once the crucible is placed in its required position, sufficient quantity of air is supplied from the bottom of the furnace to top in order to heat the coke. Once the crucible is heated to a red hot stage, the required quantity of aluminium (3.938Kg) and silicon (0.038Kg) is added to it. Once the mixture is heated sufficiently, magnesium (0.024Kg) is added into the crucible and stirred well as shown in figures 2.1 and 2.2. The temperature at which this takes place is around 750°C. The molten metal of Al-6063 is then poured into the required size of the die in required quantity. The mixture is then cooled at room temperature and hence the required aluminium alloy (Al 6063) is prepared. The molten metal of Al-6063 is then poured into the required size of the die in required quantity.

![Fig.2.1 Melting of Al + Mg + Si](image1)

![Fig.2.2 Al heated in furnace at nearly 750 °C](image2)

MWCNT (by 2wt %) is measured as per requirement. Measured CNT is added to the crucible and mixed well. Now the stirring process is carried out wherein a temperature of about 850oC is maintained. Mechanical stirring is done for about 10 minutes in order to mix the alloy and the reinforcement. The molten mixture of the composite is then poured into the required size of the die and is allowed to solidify as shown in figures 2.3. By this method the required Al6063-MWCNT composite is prepared as shown in the figure 2.4. Furthermore the prepared composite is machined to the required specifications according to the tests to be performed using lathe and milling operation.

![Fig.2.3Molten metal poured in to metallic mould](image3)

![Fig.2.4Final Cast products](image4)

Solution heat treatment is done by raising the alloy temperature to about 560oC and holding it there for about an hour. The purpose of this is to dissolve all the alloying elements in a solid solution within the aluminum. The alloy is then quenched in water. The purpose of quenching is to cool it rapidly enough to prevent the alloying elements from precipitating on cooling. So this provides a solid solution of magnesium, silicon in aluminum at room temperature. This material is then heat treated at a temperature of 160oC for time duration of about 3 hours in the furnace. This heat treatment is called aging, which results in material with a T6 temper. The main purpose of this procedure is to improve the yield strength and compressive strength of the aluminium (6063) alloy and the composite and compare its properties with that of the un-heat treated samples.
3. Results and Discussions
Microstructure Analysis:
Microstructural characterization studies were conducted on unreinforced and reinforced samples using metallurgical microscope with a maximum image resolution of 500X. The composite samples were fine polished prior to examination. It is first belted grinded followed by fine polishing with different grades of emery papers (80, 120, 400 and 600). It was washed and polished in clothes and finally fine polished using alumina powder before placing it for the microscopic analysis. The above figures 3.1 and 3.2 represent the microstructures of As-cast Al6063 with 0wt% of MWCNT at 100X and 400X respectively. The figures 3.3 and 3.4 represent the microstructures of As-cast Al6063 with 2wt% of MWCNT at 100X and 400X respectively. Micrographs clearly indicate the homogeneity in the distribution of Carbon Nano Tubes particulates through the matrix alloy. The microstructure of the carbon Nano tubes reinforced composite showed a reasonably uniform distribution of particles and good interracial bonding of dispersed particles with Al6063 matrix alloy. There is a good interfacial bonding between Al6063 alloy and carbon nanotube metal matrix which improves the hardness, yield strength and also the wear behaviour of the composites.

4. Tensile strength tests & Compression Test
The tensile test set up involves placing the test specimen in the universal testing machine as shown in Fig.4.1 and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. The data is manipulated so that it is not specific to the geometry of the test sample. The force measurement is used to calculate the engineering stress. Finally the data points are graphed into a stress strain curve. In the present work, in order to investigate the mechanical behavior of the test samples the tensile test is to be carried out on the tensile test
specimens prepared according to ASTM E8M-04 using universal testing machine (UTM). The tensile properties, such as, tensile strength, yield strength and % elongation will be extracted from the experimentation. The specimens after fracture are shown in the figure 4.1.
In the present work, the compression test set up involves the collection of data regarding the applied load, resultant deformation and condition of the specimen using a UTM. For ductile materials such as Aluminium 6063 which is used in the testing, the compressive strength is generally based on an arbitrary deformation value. They tend to buckle and "barrel out". From the experimentation the maximum compressive load and maximum compressive stress of the composite material is determined. The compression test specimens were prepared according to ASTM E9 standards and shown in figure 4.2.

The graph depicts an increase in the ultimate strength of heat treated samples over un-heat treated samples and also the samples with 2 wt% of MWCNT had increased ultimate strength over samples with 0 wt% of MWCNT.

Graph 4.1 Yield strength v/s wt. % of composition.
The graph 4.1 depicts an increase in the maximum compression load of heat treated samples over un-heat treated samples and also the samples with 2 wt% of MWCNT had increased value of maximum compression load over samples with 0 wt% of MWCNT.
Impact strength

A pendulum type single blow impact testing equipment as shown in figure 4.3 is used in which the specimen, usually notched, is fixed at one end and free at other end. Specimen is broken by a falling pendulum. The energy is determined from the decrease in the swing of the pendulum. The specimen required for the test is prepared according to ASTM E23 – 07a standards. The test specimens after fracture are as shown in the figure 4.4.

Graph 4.2 Maximum compression load v/s wt. % of composition

The graph 4.3 depicts an increase in the value of impact strength of heat treated samples over unheat treated samples and also the samples with 2 wt% of MWCNT had increased value of impact strength over samples with 0 wt% of MWCNT.
Graph 4.3 Impact strength v/s Wt % of composition.

Conclusion

- The composites containing Al6063 with 2wt% of MWCNT particulates were successfully synthesized by stirring method using a pit furnace fuelled by coke.
- Micrographs clearly indicate the homogeneity in the distribution of Carbon Nano Tubes particulates through the matrix alloy. The microstructure of the carbon Nano tubes reinforced composite showed a reasonably uniform distribution of particles and good interracial bonding of dispersed particles with Al6063 matrix alloy.
- The tensile tests revealed an increase in the yield strength and ultimate strength of the heat treated Al6063 samples (0wt% and 2wt% MWCNT) over the un-heat treated samples. Also a comparison between Al6063 (2wt% MWCNT) of both as-cast and heat treated samples showed improved tensile properties over Al6063 (0wt% MWCNT).
- The compression tests revealed an increase in the compressive strength of the heat treated Al6063 samples (0wt% and 2wt% MWCNT) over the un-heat treated samples. Also a comparison between Al6063 (2wt% MWCNT) of both as-cast and heat treated samples showed improved properties over Al6063 (0wt% MWCNT).
- The impact test revealed an increase in the impact strength of the heat treated Al6063 samples (0wt% and 2wt% MWCNT) over the un-heat treated samples. Also a comparison between Al6063 (2wt% MWCNT) of both as-cast and heat treated samples showed increased value of impact strength over Al6063 (0wt% MWCNT).

References

[1]. Jamaluddin Hindi and U Achutha Kini 2015 Mechanical Characterization of Stir Cast Al6063 Matrix SiC Reinforced Metal Matrix Composites et.al
[2]. K K Alaneme and A O Aluko 2012 Fracture toughness and tensile properties of As-cast and age hardened aluminium (6063)-silicon carbide particulate composite, Scientia Iranica 19 (4) 992-996
[3]. B Demudu Naidu and K R Satyanarayana 2017 Fabrication and characterization of al6063 metal matrix nano-composites ISSN: 2277-9655 (Naidu et al., 6(2)); CODEN: IJESS7
[4]. Bharath V 2014 Preparation of 6061Al-Al2O3 MMcs by Stir Casting and Evaluationof Mechanical and Wear Properties, 3rd International Conference on Materials processing and Characterization (ICMPC)
[5]. G G Sozhamannan and S Balasivanandha Prabu 2012 , 2015 Effect of Processing Parameters on Metal Matrix Composites: Stir Casting Process, *Journal of Surface Engineered Materials and Advanced Technology*, 2012, 2, 11-15

[6]. B K Prasad 2007 Investigation into sliding wear performance of zinc-based alloyreinforced with SiC particles in dry and lubricated conditions *Wear* 262; 262–273

[7]. A R K Swamy, A Ramesha, G B Veeresh Kumar and J N Prakash 2011 Effect of Particulate Reinforcements on the Mechanical Properties of Al6061-WC and Al6061-GrMMCs *Journal of Minerals & Materials Characterization & Engineering*, ,Vol.10, No.12, pp11411152

[8]. H S Arora & H Singh & B K 2012 Dhindaw Composite fabrication using friction stir processing—a review, *Int J Adv Manuf Technol* 61:1043–1055

[9]. Vikas Bhoria , N M Suri and Sumankant Effect on Mechanical Properties of Aluminium6063 Reinforced with Silicon Carbide – Graphite Hybrid Composites, *IJSRD – International Journal for Scientific Research & Development* | Vol. 4, Issue 05, 2016 | ISSN (online): 2321-0613

[10]. Al Faizal, Amarnath T S ,Roshan T Ninan,2014 An Investigation of Mechanical Properties of Aluminium 6063-T6 after Friction Welding Process, *International Journal of Engineering Trends and Technology (IJETT) – Volume 17*

[11]. K Uttarask, S Ngernbamrung and N Sirikulrat 2007 Microstructures and Mechanical Properties of Heat Treated Aluminium Alloy 6063, *33nd Congress on Science & Technology of Thailand*, 18-20

[12]. E Tan and B Gel 2007 Influence of Heat Treatment on the Mechanical Properties AA6066Alloy *Turkish Journal of Engineering and Environmental Sciences*, Vol. 31, pp 53-60.

[13]. G Al-Marahleh 2006 Effect of Heat Treatment Parameters on Distribution and Volume Fraction of Mg2Si in the Structural Al 6063 Alloy *American Journal of Applied Sciences* Vol. 3, No. 5, 2006, pp 1819-1823. doi:10.3844/ajassp.1819.1823

[14]. L P Troeger and E A Starke 2000 Microstructural and Mechanical Characterization of a Superplastic 6xxx Aluminum Alloy *Materials Science and Engineering: A*, Vol. 277, No. 1,31 Elsevier Science Ltd pp 102-113.

[15]. S Padmavathy, G Sharmila Devi, T Keerthivasan, R Balamurugan 2017. Microstructure analysis and mechanical behaviors of Al6063 reinforced with B4C and red soil metal matrix composite, *JCHPS Special Issue 3*. 