Synthesis of Al-TiC Particulate Composites by Stir Casting Technique and Estimation of Microstructure and Mechanical Properties

Manjunatha G[1], Anjan Babu V A[2] ,Harishanand K S[3], Jayasheel I Harti[4]
[1]PostGraduate Scholar, Department of Mechanical Engineering, EPCET- Bangalore-560049
[2]Assistant Professor, Department of Mechanical Engineering, EPCET- Bangalore-560049
[3]Professor & Head, Department of Mechanical Engineering, EPCET- Bangalore-560049
[4]Assistant Professor, Department of Mechanical Engineering, EPCET- Bangalore-560049

Abstract -Metal matrix composites improves mechanical properties such as ultimate tensile strength, hardness and yield strength, and wear properties when compared with base materials. At the same time there is a reduction in density and percentage of elongation of the metal matrix composite. Metal matrix composites (MMC) are progressively becoming eye-catching materials for advanced aerospace, automobile industries due to the light weight, economic cost, easy fabrication and machinability, and ever increasing engineering demands for modern technology.The specific modulus and specific strength of Aluminium alloys could be considerably enhanced by developing composites based on these alloys. The particle-reinforced Aluminium based metal matrix composites are of interest due to their ease of fabrication, lower costs and isotropic properties. There are a number of processing routes available such as powder metallurgy, spray deposition and various casting techniques, which offer different combinations of price and extent of processing defects. The choice of processing route could be made depending on the potential for economic savings from replacement of conventional material by composite for different applications. Casting is one of the most inexpensive methods of producing MMCs and lends itself to the production of large ingots, which can be further worked by extrusion, hot rolling or forging. In the present work The Al2219-TiC Composites is fabricated by using Bottom pouring stir casting techniques with weight % of 3, 6 & 9 and 2 wt. % of magnesium is added in order to increase the wettability of the composites and Microstructure and Mechanical properties like Hardness and Tensile Properties are evaluated according to ASTM Standards.

Keywords –Al2219, TiC Particles, Hardness, Ultimate Tensile Strength, Yield Strength, Elongation.

1. INTRODUCTION

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. A material which is composed of two or more materials at a microscopic scale and have chemically distinct phases. Heterogeneous at a microscopic scale but statically homogeneous at macroscopic scale. Constituent materials have significantly different properties. Metal matrix composites are combination of base material with the addition of small percentage of one or more reinforcement particulate. Due to the high resistivity, good corrosiveness at elevated temperatures of the metal matrix composites are used in advanced aircraft and jets. The other advantages application of the metal matrix composites are light weight, economical ,harder, fuel efficient, noise pollution control and energy savings etc.In common, metal matrix composites usually develop the properties of both the matrix (light weight, good thermal conductivity, ductility) and of the reinforcement usually ceramic (high stiffness, high wear resistance, low coefficient of thermal expansion).

Aluminium and its alloys, apart from their low density (one third of steel), have good damping characteristics, dimensional stability and excellent machinability, characterized by low power requirements, excellent surface evenness and small fragmented chips. Further, aluminium is the third abundantly available metal in the earth crust and available at relatively low cost. It is easy to fabricate this metal and its alloys by a number of conventional techniques. As the automotive and aerospace industries uses more and more lightweight materials to improve their fuel efficiency and reduce their emissions, the demand for aluminum alloys is growing rapidly.

For the metal matrix composites the reinforcement particulate materials are WC, B_4C, TiC, Al_2O_3, graphite, mica are in the form of fibres and whiskers.

Hard reinforcement materials like Silicon carbide, fly ash, alumina and soft particles likegraphite and talc reveals the results of improvement in mechanical and thermal properties of the metal matrix composites. The reinforcement material namely WC, TiC, Al_2O_3etc and graphite when fabricated with base material shows improvements in mechanical properties like ultimate tensile strength, hardness and yield strength, and wear properties. At the same time there is a decrease in density and percentage of elongation of the metal matrix composite.

Particle-reinforced metal matrix composites is isotropic discontinuously reinforced compositeswhich have either hard or soft particles or their mixtures embedded in a ductile metal or alloy matrix in order to reinforce the desired matrix properties. The PMMCs are of particular interest due to their ease of fabrication by conventional methods at lower costs. PMMCs combine metallic properties (ductility and toughness) with the special characteristics of particle reinforcements, often leading to greater strength, higher wear resistance and higher elevated temperature properties depending on the nature of particles.

Stir-casting techniques are currently the simplest and most commercial method of production of MMCs. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mould prior to complete solidification. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal. Non-homogenous Microstructure can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Non-homogeneity in reinforcement distribution in the cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. This process has major advantage that the production costs of MMCs are very low.

2. LITERATURE SURVEY

Anand Kumar et al [1] studied the properties of the Al-Cu alloy (2014 aluminum alloy series) as a matrix and reinforced with TiC by means of an in situ route. The percentage growth in yield and tensile strength was recorded to be around 15% and 24%, and the Vickers hardness was improved by almost 35% relative to base metal Al -2014. The higher the hardness value, the more TiC particles contribute to the hardness of the matrix. The fracture surface of the tensile specimen of the composite indicates the occurrence of a dimpled surface, thus signifying a fracture of the ductile type. In the fabrication of composite materials, intermetallic particles such as Al3Ti, Al2Cu and Al3C4 in metal matrix composites are recognized in different shapes and sizes.

M. AzeemDafedar et al [2] synthesized a composite material having Aluminium (Al) as matrix, Titanium Oxide (TiO2), and Titanium Carbide (TiC) as reinforcements which are manufactured by means of powder metallurgy having the weight %. of 2 and 4. The phase composition and morphology of material will be assessed from hardness test. From his work he showed that the mechanical properties will not only depend on reinforcements but also on compaction pressure and processing parameters also used while developing the composites.

G. Baskaran et al [3] studied the wear behaviour of composites synthesized by powder metallurgy with aluminium matrix and TiC and TiO2 as reinforcements. The outcomes shows that the wear rate of composite material obtained by wear test performed at sliding distance of 500m and at load level of 5, 10, 15 and 20N with sliding speeds of 3.14 m/s. For all these combinations the rate of wear is 0.22, 0.24, and 0.27mm respectively, and for sliding distance of 1000m with same level of other input parameter the rate of wear obtained by wear test is 0.23, 0.25, and 0.28 mm respectively, for 1500m sliding distance with same level of other input parameters the rate of wear is 0.24, 0.27, and 0.28mm respectively. From the result it is noted that the sliding distance is the greatest inducing parameter in wear rate of prepared aluminium composite material.

S Raghu et al. [4] showed the effect of Nano Particles on the Composites which is synthesized by using bottom pouring Stir Casting method. The LM0 Al Alloy is used as Matrix and Nano TiO2 Particles are used as reinforcement with wt% of 0, 4 8 and 12. The Microstructure study reveals the uniform distribution of TiO2 Particles, as the percentage increases clustering and agglomeration are seen. Hardness and Tensile properties have been increased nearly 15 to 20% compared to the same composition of Micron Sized Particulate Composites.

PattanshettyBasavaraja [5] revealed the evaluation of mechanical properties of Al2219-SiC-graphite reinforced hybrid composite. It was revealed from the optical microphotographs uniform distribution of SiC and graphite with no clustering. Further it was investigated that the improvements in ultimate tensile strength as the weight percentage of reinforced particulate was increased. Further the hardness was also increased and superior to other composite materials.

Vijaya Ramnath et al. [6] discussed about the mechanical properties of aluminum alloy reinforced with alumina and boron carbide metal matrix composites. Composites were fabricated by stir casting method and test samples were prepared and tested to find the various mechanical properties like tensile, flexural, impact and hardness. The results shows the improvement in overall properties compared with the base metal alloy. The internal structure of the prepared composite was observed by using scanning electron microscopy.

3. EXPERIMENTAL SET UPS & METHODS

Processing of Al2219-TiC Particulate Composites by Using Bottom Pouring Stir Casting Furnace:

A stir casting furnace cum bottom pouring set-up has been used in this research work for solidification processing of all the different Al2219-TiC composites with a maximum melting capacity of 1 kg. The schematic diagram of the experimental set-up is as shown in Fig. 1.

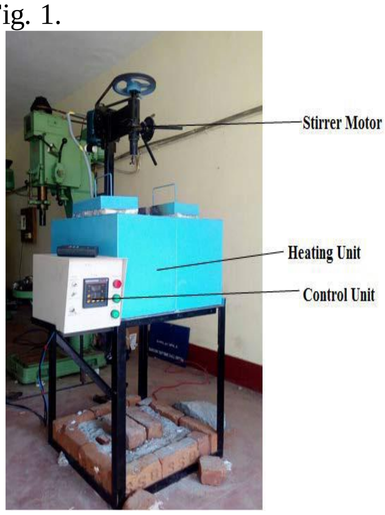

Fig. 1: Schematic diagram showing experimental set-up for stir casting used for solidification processing of cast composites and unreinforced base alloys.

Approximately 1000g of Al2219 aluminium was melted to a preferred processing temperature in a clay-graphite crucible inside the muffle furnace. Before any addition, the surface of the melt was cleaned by skimming. The weighed amounts of elemental TiC particles were preheated to about 400°C and the rate of addition of particles was controlled at an approximate rate of 0.2-0.3 g/s. A four pitched blade stirrer (45° pitch angle) was used to disperse the TiC particles in the melt. The speed of the stirrer was kept constant at 500 rpm. The temperature of the melt was measured by using a digital temperature indicator connected to a chromel-alumel thermocouple placed at a depth of 15-20 mm inside the melt. During stirring, the temperature of the slurry was maintained within ±10°C of the processing temperature. A magnesium lump of 3 wt% was enclosed in aluminium foil and charged into the melt-particle slurry before the addition of TiC particles. When thepreferred time of the stirring elapsed, the stirrer was stopped and taken out from the crucible. Then, the graphite plug at the bottom of the furnace was removed and the slurry of melt-particle was poured into a pre-heated permanent type mold of split type, having a size of 40x40x 150 mm kept below the plug. The cast composite ingot was immediately cooled by immersion in to water bath.

Titanium Carbide as a Reinforcement Material:

The reinforcement particulate used is titanium carbide powder for the metal matrix composite the particle size of reinforcement material is 50 microns. It is a ceramic particle type having hardness similar to that of the tungsten carbide reinforcement particle. The colour of the particulate is black in colour. In most of the industries for machining of the steel parts at the higher speeds it is used as cermets. With addition of about 30% of the titanium carbide to tungsten carbide material there will be tremendous improvements for the machining tool in terms of wear corrosiveness. It is used as an abrasion-resistant surface coating on metal parts for the tool bits and also for watch mechanism.

Al2219 Alloy as a Matrix Material:

The major alloying elements of the Al2219 are copper. The Al2219 has very good fracture toughness, high corrosion resistance, self-healing capacity, high elevated temperatures.Al2219 applications in many industrial, automotive, Service industry and aerospace research work. The common application are transport applications, marine, rock climbing equipment, bicycle components, in line skating-frames and mobile equipment, and other high stressed parts.

Scanning Electron Microscopy:

Metallography is the study of the microstructure of materials. Analysis of the microstructure of the material determines whether the material has been properly processed and the mechanical properties depend on how the TiC particles are distributed in the composite and therefore constitute a crucial step in determining the reliability of the product and determining the reason for failure of material. Field emission scanning electron microscopy (FE-SEM), Carl Zeiss, German model: Neon 40.

Hardness Testing:

The Brinell hardness test method as used to determine BHN, as defined in ASTM E10, the hardness of prepared nano composites are assessed using ball indenter of diameter 10mm at an applied load of 500kg. The Brinell hardness of the cast composites and cast unreinforced alloys were studied on the samples. The load was applied with a ball indenter for about 180 seconds on a sample and then the diameter of indentation was measured with the help of travelling microscope. For each indentation, an average of two diameters measured perpendicular to each other was used to find the corresponding hardness. On each sample, at least three indentations for hardness measurement were made at different locations and the average of these readings is reported as the hardness value of the material. The formula used to calculate BHN is given by: $BHN= 2P/(D-\sqrt{D^2-d^2})$.

Where,

P= Load Applied in Kg.

D= Steel Ball Indenter diameter in mm.

d= Impression made by steel ball indenter in mm.

Tensile Testing:

The tensile tests were carried out at ambient temperature for the cast unreinforced alloy, composites. The shape and dimension of the tensile specimens, conforming to ASTM–E8M specification, is shown schematically in Fig. 2. At least four tensile specimens machined out from each segment of each cast composite and unreinforced alloy, were tested under uniaxial tension in a UTM and the average of ultimate tensile strength, yield strength and percentage elongation is reported as the tensile property of the material.

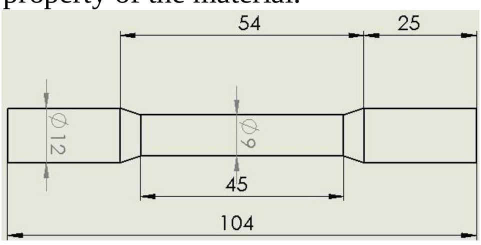

Fig. 2: The Tensile Specimen.

4. RESULTS & DISCUSSIONS

Microstructure Analysis:

Figure 3 (a) - (d) shows the Scanning Electron Microscope micrographs of as cast Al2219 alloy and its composites. The microstructure clearly shows the uniform distribution of the TiC particles in the developed composites. The porosity was less in the developed composites because of good wettability between the matrix and reinforcement particles which are observed from the SEM images. The dark black areas in the SEM picture indicate to some extent the presence of porosity in the composite. The typical microstructure consists of primary aluminum matrix (dark gray) and TiC particles (black color). The SEM image shows that for the 9 wt. % composite has more clustering and agglomeration than the 3 and 6 Wt. % composites.

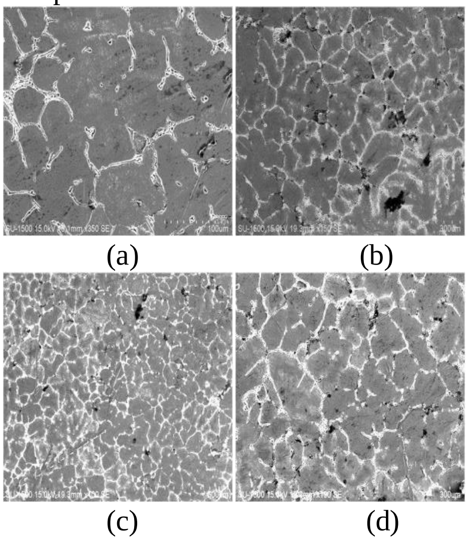

Fig.3: Showing the SEM microphotographs of (a) as cast Al2219 alloy (b) Al2219-3 wt. % TiC (c) Al2219-6 wt. % TiC (d) Al2219-9 wt. % TiC

Hardness:

The hardness increases gradually as the TiC particles increases in the composites. In fact, the hardness of a composite depends on the hardness of the reinforcement and matrix. The increase in hardness is principally owed to the fact that the coefficient of thermal expansion (CTE) of the ceramic particles is lesser than the coefficient of thermal expansion of the aluminum alloy and because of sudden quenching with water. Therefore, a large quantity of dislocations is produced at the particle-matrix interface during solidification, which further increases the matrix hardness. The greater the amount of particle-matrix interface, the more is the hardening owing to dislocations. The brittle nature of TiC particles increases the hardness in the composites. The hardness value of Al2219 with 3 wt. % TiC is nearly 14% increased as compared with the unreinforced alloy Al-2219, respectively for Al2219 with 6% TiC and Al-2219 with 9% TiC the increase in hardness is 34.2% and 46.4% with Al-2219 alloy.

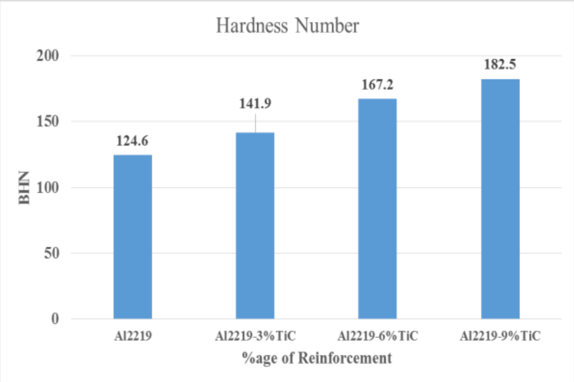

Fig.4: Variation in Hardness of Al2219 with wt. % of TiC particulates Composites.

Tensile Properties:

The average tensile properties i.e. yield strength, ultimate tensile strength and percentage elongation of synthesized composites have been measured and compared with those observed Al-2219 aluminium alloy. The variations of yield strength, ultimate tensile strength and percentage elongation with increasing TiC particle content are shown in Figs.5, 6, and 7 respectively. In cast composites, the yield stress increases from 127.18 MPa in Al-2219 aluminium alloy to 161.25, 188.71 and 212.8 MPa in composite containing about 3, 6 and 9 Wt. % of TiC particles but beyond this particle content, the yield strength remains more or less the same irrespective of the increase in TiC particle. UTS also enhances monotonically with increasing TiC particle content in cast composite, UTS for Al-2219 alloy is 157.45 to 183.4, 207.28 and 238.9 MPa in composite containing about 3, 6 and 9 Wt. % of TiC particles. The ductility of cast composites decreases with increasing TiC content which can be seen in figure 7 because of the brittle nature of the TiC particles.

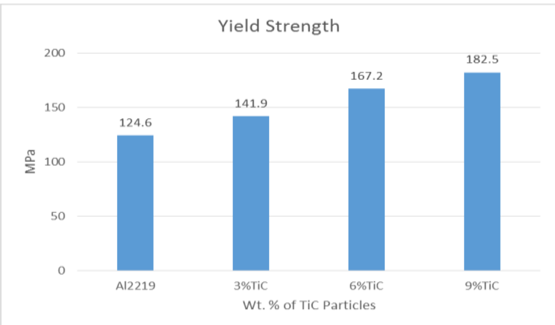

Fig.5: Yield Strength of the Developed TiC Particulate Composites.

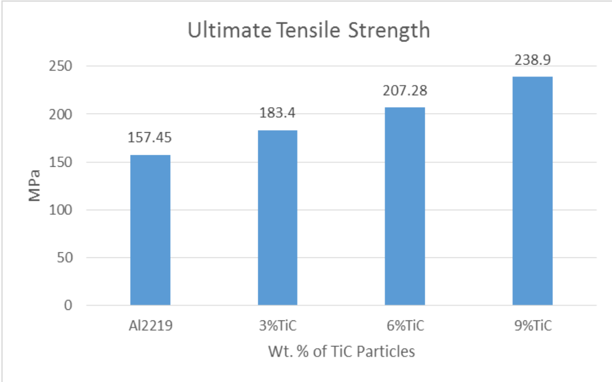

Fig.6: Ultimate Tensile Strength of the Developed TiC Particulate Composites.

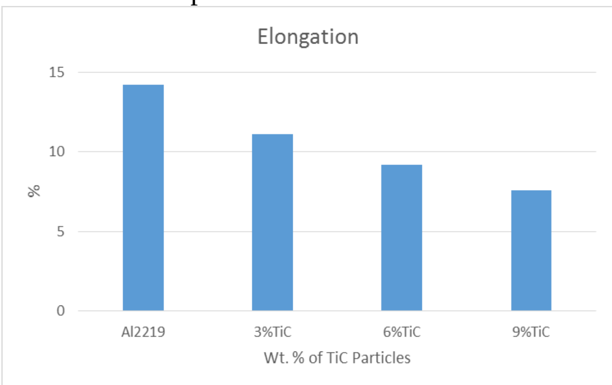

Fig.7: Percentage Elongation of the Developed TiC Particulate Composites.

5. CONCLUSIONS

i. The microstructure analysis displays that TiC particulate have been uniformly distributed in the composites but care has to be taken for increasing TiC wt. %age to minimize agglomeration and clustering.

ii. The Brinell hardness increases with increase in TiC particles in the composites.

iii. The Yield Strength and Ultimate Tensile Strength will also increase as the TiC particles increases in the composites due to progressive bonding of particles to matrix during plastic deformation and the TiC particles will act as barriers which prevent plastic deformation of the matrix.

iv. The ductility decreases as the wt. % of TiC particles increases in the composites compared to unreinforced composites.

REFERENCES

1. Anand Kumar, Manas Mohan Mahapatra and Pradeep Kumar Jha, "Fabrication and Characterizations of Mechanical Properties of Al-4.5%Cu/10TiC Compositeby In-Situ Method." Journal of Minerals and Materials Characterization and Engineering, Year 2012, Volume 11, pp.1075-1080.
2. M AzeemDafedar, Rahul Bhandari and T R Vijayaram, "Processing and Characterization of Titanium Carbide and Titanium Oxide Particulate Reinforced Aluminium Metal Matrix Composite for Aerospace Applications." International Journal of Scientific and Engineering Research, Year 2014, Volume 5, Issue 10, ISSN 2229-5518.
3. G Baskaran, I Daniel Lawrence, C Ramesh Kannan and B Stalin, "Characterization of Aluminium Based Metal Matrix Composite Reinforced with TiC and TiO2." International Journal of Applied Engineering Research, Year 2015, Volume 10, Issue 51, ISSN 0973-4562.
4. Raghu. S, H. M. Nanjundaswamy, Savitha. M and M. Sreenivasa, "Synthesis and Characterization of Mechanical Properties of Nano TiO2 Particle Reinforced Al-MMMC." International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), ISSN (P): 2249-6890; ISSN (E): 2249-8001 Vol. 8, Issue 2, Apr 2018, 981-988
5. PattanashettyBasavaraja, MadevaNagaral, Vidyashankar S., V. Auradi, "Evaluation of Mechanical properties of Al2219-SiC-Graphite reinforced hybrid Composites", International Journal of Applied Engineering Research, 10, 9, 2015.
6. B. VijayaRamnath, C. Elanchezhian, M. Jaivignesh, S. Rajesh, C. Parswajinan, Siddique Ahmed Ghias, "Evaluation of mechanical properties of aluminium alloy–alumina–Boron carbide metal matrix composites", Materials and Design, 58, pp. 332–338, 2014.
7. Raghu S, H M Nanjundaswamy, M Sreenivasa, "Impact of Different Nano-Sized TiO2 Particles on LM0 Al-Alloy on Mechanical Behaviour of Nano Metal Matrix Composites." Solid State Technology, Volume 63, Issue 1, Sept 2020.
8. Himanshu Kala, Mer K. K. S. and Sandeep Kumar, "A review on mechanical and tribological behavior of stir cast aluminium matrix composites", Procedia Materials Science, 6, 1951-1960, 2014.