Aluminium metal matrix composites and effect of reinforcements – A Review

Ch.Saikrupa1,2, G Chandra Mohan Reddy3 and Sriram Venkatesh4

1Research scholar, Department of Mechanical Engineering, Osmania University, Hyderabad, India.
2Assistant Professor, Department of Mechanical Engineering, Vignan Institute of Technology and Science, Hyderabad, India.
3Professor, Department of Mechanical Engineering, Chaitanya Bharathi Institute of Technology, Hyderabad, India.
4Professor, Department of Mechanical Engineering, Osmania University, Hyderabad, India.

Email: gcreddy_mech@cbit.ac.in

Abstract. A composite is a fusion of two or more different material chemically and unsolvable phases; its properties and structural concept are greater the ingredients performing homogeneous phases. ceramics and Metals, as well, can be implanted with particles, to advances their property; these mixtures are known as MMCs. Aluminum alloy compose a significant engineering material generally engaged in the aerospace industries for the production of dissimilar parts and equipments. It is due to its more strength to density fraction that it a sought after MMCs. A variety of processing technique and mechanical properties testing’s available for manufacturing the Aluminium matrix composites. The mutual reinforcement’s effect on Aluminium Metal Matrix composites with individual and multiple particulate reinforcements like Hybrid Metal matrix composites are finding better applications in aerospace industries, automobile industries, underwater, and transportation. In the current situation, a bunch of research activities were on pipeline. This review particularly directs the engineers and researchers towards right reinforcement materials selection especially hybrid composites by their properties in the appropriate field and diverse technique involved in production of metal matrix composites.

1. Introduction

Metal matrix composites are mixtures of more than two materials where customized properties are attained by efficient blending of different ingredients. Metal matrix composites consisting of discontinuous fibers or else continuous fibers in a molten metal get mixture of specific modulus and very high strength. From the last few decades in much industrial application concentrate on MMCs due to their specific properties like ratio of strength to weight and also cost effectiveness. Here we discussed about reviews of the research papers relevant to Al MMCs. Before going to the discussion, we are required to know the variation between the composites and alloy. The alloys are made by mingling of more than two metallic elements, especially to give greater strength or resistance to corrosion properties etc. The composites (MMCs) are metallic elements combined with non-metals give their significant properties for specific application this called MMCs.
Aluminium alloys are one of favored engineering application used for various industries like automobile, aerospace and mineral processing unit due to their lesser weight and tremendous thermal conductivity property. These composites are superior in nature for elevated temperature application when reinforced with addition of ceramic particle. Among some series of aluminium alloys, 6000 series aluminium alloy are heat treatable Al6060, Al6061 Al6063A, Al6065, Al6081, Al6082, Al6105, Al6162 and Al6951 are greatly explored, among them Al6061 alloy are high corrosion resistant, exhibits reasonable strength and locates a lot of application in the fields of constructional work and automobile applications. Aluminum alloys 7075 possess more high strength, high toughness and are preferred in aerospace industry and automobile industry. Generally aluminium alloys and MMCs are wide use due to their higher strength, stiffness, wear resistance, fracture toughness [1-3].

2. Fabrication of Metal Matrix Composites

2.1 Stir casting
Stir casting process, mixture of pure metals with a molten metal pool as a result of mechanical stirring. In a current scenario, this method improved by motorized stirring used in the mixing process. The material matrix is heated toward over its red hot temperature so that the entire metal is completely melted. Then the molten pool is cooled down and kept in a semi solid state. At this phase, the preheated reinforcements are additionally included in the molten pool and mixed. The semi-solid molten metal is once more heated to its required liquid phase completely and mixed systematically. The above effective process methodology is creates the ability to rupture the surrounding gas around the particle circumstance [4, 5].

2.2. Stir casting process parameter

Whereas fabricating the MMC through stir casting. The subsequent changeable factors are to be considered, [4, 5]

2.2.1. Rotation Speed: The successful rotation speed control is more important for fabrication of casting in required condition and also influences the casting shape. When adding reinforcement to the matrix it is need to increase of speed for refinement and slow up the process speed results in unsteadiness of the liquid mass.

2.2.2. Stirring speed: One of the significant parameter is stirring speed for wettability i.e. bonding quality stack between reinforcement & matrix. The stirring speed is openly controlled the molten metal flow pattern. When observed most of the research work carried out by maintaining Stirring speed range between 300 and 600 rpm for better fabrication. The wettability percentage increase the solidifying rate also increase directly [5].

2.2.3. Stirring temperature: The Stirring temperature is very important in the Al MMCs for fabrication due to its viscosity condition. The distribution of particle in the MMCs is subject to change of viscosity of the molten metal. The stirring holding time increased along with increase the processing temperature result in decrease in the molten viscosity. The Stirring temperature also plays a vital role in the chemical reaction acceleration among the matrixes and reinforcements. When observed most of the research work carried out by maintaining Stirring temperature in the fabrication keeps at 630°C for Al (6061) in semisolid condition [5].

2.2.4. Pre-heat temperature of Reinforcement: One of the research works describes the reinforcement materials are preheated at 500°C temperature for 30 minutes. It helps to clean the unwanted moisture or surrounding gases present over it [6].
2.2.5. Stirring time: The Stirring time is very significant impact on homogeneous circulation of the reinforcement particle in the MMCs.

2.2.6. Pouring temperature range: Based on the parts dimension, the pour temperature plays most important role in the solidification process. The pouring temperature is low and study mode results in maximum grain refinement. Even as elevated temperature promote columnar growth in lots of alloys. Still, the choice is restricted in realistic scenario. To make sure suitable metal flow temperature avoid the coarse structures formation, the pouring temperature should be adequately high.

2.2.7. Temperature of the Mould: To avoid tearing or die expansion the mould should be maintain some suitable temperature via preheating. Generally the temperature of mould must neither be very lesser or to be very higher, in non ferrous casting. Based on cast weight mould should be as a minimum 25 mm thick.

2.3 Compo-casting technique
Compo-casting technique is a liquid phase process in which particles reinforcements are added to a molten metal pool while being strongly disturbed. It has been exposed that the principal solid particle previously produced in the semi solid phase slurry can be added in the reinforcing particles, avoid their gravity separation and decrease their cluster. These will end result in enhanced distribution of the particles reinforcement. The lesser porosity observed in the castings product has been recognized to the improved the ability of observed moisture between particles reinforcement and the matrix [7].

2.4 Squeeze casting
Liquid forging, moreover it called squeeze casting, is a fusion metal forming method that combination of fixed mold casting through die forging method. The first step, a specific amount of molten phase matrix metal alloy is poured into a lubricated die in preheated condition and the next step under pressure condition the forging and solidification process were done.

2.5 Spray Deposition
Spray forming another name is spray casting; spray deposition is a technique of casting close to net profile MMCs work piece with uniform microstructures through the deposition of half - frozen sprayed droplet. This method normally consists of foil-coated fibers coil winding from drum and spraying metal pool onto them to prepare a mono tape [8].

3. Reinforcement materials
Based on the physical factors of reinforcement (fiber or granular particle) like type, size and weight fraction gives the better properties to the MMCs, and the reinforcement’s chemical nature reacted with matrix material to influence their physical properties like microstructure. The MMCs fabrication process, creation of well-built chemical bonds between matrix and reinforcement is good for the reinforcement wetting in the matrix molten pool. The wettability is minimum it creates the oxide films on the reinforcement surface in the metal pool. It affects the composite properties because of reinforcement adsorbed contaminant. Reinforcement’s metallic coverings, like calcium, titanium and magnesium to the metal pool and before the addition of particles, it needs to do the heat treatment. Its improve reinforcement– Matrix wettability [4, 5]. Reinforcements based on ceramics are used normally carbides or oxides or borides such as Al2O3, TiB2, TiO2, SiC, TiC, B4C, etc are used in the Aluminum matrix composites (AMCs).

Based on the above review, so many processes are engaged in the fabricating of Metal framework composites. Among the all strategies, mix projecting assumes a huge function because of its elite
particulars. In this procedure, the particles fortifying are added to the liquid pool with stirred systematically for uniform combination with the MMCs.

4. Literature survey
This research paper Pradeep et al. delivers details about grade 7075 Aluminium alloy MMC mixed by different mass percentages of Al/Red-Mud and Silicon Carbide. The following composition are used in this investigation SiC(8%)+Al-7075, SiC(6%)+Red-mud(2%)+Al-7075, SiC(4%)+Red-mud(4%)+Al-7075, SiC(2%)+Red-mud(6%)+Al-7075, Red-mud(8%)+Al-7075/Red-mud and SiC particles via stir casting method. The investigational outcome discloses to the mixture of Al-matrix with strengthening particles of Red-mud and SiC, get better material properties like hardness, compressive strength, tensile strength and yield strength [6]. These researches work Ravichandran et al. manufactures the Al-MMCs using liquid powder metallurgy method. The mechanical properties like tensile strength and hardness are tested into the Al-MMCs mixed with TiO$_2$ reinforcements. The matrix elements and reinforcement elements were confirmed by metallurgical characterization. Finally the better mechanical properties got in this study, the mixture of pure aluminium with TiO$_2$ (5% weight) [7]. Izadi et al. examines Friction stir Technique of Al/SiC composites produced via powder metallurgy method and has got improvement in the micro hardness in this MMCs. The material distribution in the stir zone for the duration of Friction Stir (FS) processing was doing well in homogeneously dispensing the Silicon carbide particles. Nevertheless, when the samples were tested with 16-vol% (SiC) reinforcements, the results observed lack of consolidation with residual pores. After (FS) processing of all samples was taken into characterisation. The results observed hardness was increases for the reason of improvement in particle distribution and also porosity was eliminated [8]. Keshavamurthy et al. investigated about Al-10%Ti and Al-3%Br in-situ composite, developed through stir casting method using commercially obtainable Al7075 alloy. Both matrix (Al7075) and MMCs (Al-10%Ti and Al-3%Br) be subjected to the microstructure examination. The grain size average were calculated of the Al-MMCs, it shows good than the pure Al7075 matrix. Mechanical properties like extreme rigidity, yield strength and miniature hardness also studied for Al7075-TiB$_2$ MMCs, are significantly superior while compared among pure Al7075 matrix [9, 10]. Uvaraja et al. Compared the mechanical properties of hybrid Al-MMCs (Al7075 alloy and Al6061 alloy) with B$_4$C reinforcement and SiC reinforcement. The results shows improved properties with low cost Al-MMCs compared with conventional composites. In 1980s at Toyota Motor industries started the Hybridization in the MMCs. Generally Hybrid metal matrix composites are prepared by mixing more than two reinforcing materials with metal matrix for improve strength to weight ratio, improve wear resistance, better fatigue nature and structural stability at high temperatures. The hybrid Al Metal Matrix composites used for aircraft manufacturing industries and automotive spares parts like shafts, engine cylinders, pistons assembly and rotors brake [11]. Anand Kumar et al. fabricated Al (series of 2014 Aluminium alloy)-MMCs by In-Situ technique and mechanical properties were confirmed by characterizations. The Al-matrix added with Cu (4.5%) and TiC (10) reinforcements for improving the properties like yield strength, and ultimate strength, hardness as measure up to Al-matrix added with Cu (4.5%). In the current investigation, In-situ technique Aluminium matrix with the reinforcement of Titanium Carbide (TiC) ceramic phase is well chosen compare with the Ex-situ technique. In this investigation report says yield strength and ultimate tensile strengths were increased Percentage increases 15% as well as 24% correspondingly while Vickers hardness improved by 35% and above. The upper values of hardness specify that the TiC reinforcement particles added to enhance the hardness of matrix [12]. Hartaj Singh et al. examined the crash behavior of Al-MMCs reinforced with Silicon Carbide particle under diverse temperature circumstances. The impact behavior of compound was exaggerated by particles clustering, fragile MMCs bonding and cracking of particle with reinforcement. The special effects of the examination temperature on the crash behavior of all materials were not very important [13, 14]. Rama rao et al. studied the Al-alloy matrix reinforced with boron carbide to fabricated Al-MMCs via liquid metallurgy method with various reinforcement weight fractions like follows 2.5, 5 and 7.5. Boron carbide Phase
was identified through x-ray diffraction method. The microstructure examination has been done by SEM. The mechanical properties compression and hardness were studied. The result proves that, the density of the Al-MMCs reduced while the hardness was improved. While compressive strength for Al-MMCs was amplifies by boost in the weight proportion of the boron carbide reinforcement in the composites [15]. Ravichandran et al. manufactured the Al-based MMCs. The pure Aluminium mixed with TiO2 and they were synthesized different types of MMCs like Al-5wt%TiO2, Al-5wt%TiO2-2wt%Gr, and Al-5wt%TiO2-4wt%Gr using powder metallurgic method and their forming characteristics were studied for the period of cold upsetting condition. The experimental results shows the mixing of reinforcements TiO2 and Gr together, it shrink the densification. The SEM was used for microstructure Investigation of the sintered MMCs and cold upset forged specimens also were carried out [16].

Balasivanandha prabu et al. was created the Two-dimensional microstructure based finite element analysis models to learn the stress–strain mechanical properties of MMC. The microstructure random particles arrangement and particle clusters influence the mechanical properties. The microstructures have been transformed into CAD format in ANSYS-7 for the FEA-analysis. The particles arrangement (clustered and non-clustered microstructures) effect lying on the failure such as particle fracture, matrix yielding interface de cohesion, and mechanisms have been analyzed [17]. Sozhamanan et al. was analyzed the failures of PRMMC. This analysis is based on elastic-plastic finite element model. This type of methodology is used to forecast the malfunction of 2-D microstructure patterns below the tensile loading environment. Therefore analysis used to determine the effect on strength and failure mechanisms of random and clustered microstructure particles. The SEM images were used for generating FEA models in ANSYS [18]. Rohatgi et al. were fabricated Al-MMCs. The MMCs mixing of A356 matrix and reinforcement of loose beds of unfilled fly ash particles through pressure infiltrated with dissolved to MMC syntactic spume, with applied pressure up to 275 kPa. The reinforcement size fractions of fly ash particles in between the MMC are ranges of 20–65%. The parameters particles size, integrated gas pressure, and melt temperature of fly ash. The material and mechanical properties of the synthesized MMCs were characterized. The result shows plateau stress, Young's modulus, and yield stress with an increase in the density. The MMCs compressive properties various in the current study when compared with further type of foam materials [19]. Radhia et al. studied tribological activities Al-MMCs reinforced with alumina and graphite made-up by stir casting Technique the wear properties tested by pin-on-disc wear experiment using dry sliding wear Procedure for hybrid MMCs. Experiments data were analyzed based on taguchi 27-orthogonal array. This examination was discovering the significance for wear rate, sliding distance and friction coefficient. The consequences prove that the sliding distance has the maximum control followed by sliding speed and load. In conclusion, proof test were conceded out to confirm the investigational outcome and SEM studies were completed on the wear surfaces. The inclusion of graphite as main support amplify the wear resistance of MMCs by structure a defensive coating between counter face and alumina inclusion as a minor reinforcement also has a considerable effect on the wear manners. The equation of regression produced to the current model was used to forecast the rate of wear and friction coefficient of HMMC for intermediate circumstances with sensible precision [20, 21]. Mahendra Boopathi et al. tested the progress of metal matrix composites mixture has turn into a significant region of examine notice in materials science. In sight of this, the current investigation is expected to evaluate the material belongings of 2024-aluminum in the existence of fly ash, SiC and its combinations. The portrayal was finished by x-beam diffraction study and visual microscopy was utilized for the miniature primary examinations. The mix projecting Technique was utilized for the manufacture of Al-MMC. This Al-MMCs combination was to improve the strength and toughness of the MMCs. To attain the advantageous properties not available in any single predictable material [22, 23].

Anilkumar et al. Experimented the Ak12 composites, it’s including of fly ash particles that microstructure characteristics of Al-MMCs, obtained by gravity and compress costing method, rust
kinetics and pitting rust behavior are conversed. In the similarity between squeeze casting and gravity casting technology Method was done. It was found that beneficial for gaining the superior structural homogeneity with least feasible porosity levels. The high-quality interfacial connection and fairly a standardized sharing of reinforcement, the next one the fly ash particles direct to an improved pitting corrosion of the Ak12/9% flyash composite in evaluation with unreinforced matrix and the next one. the incidence of nobler subsequent stage of particles, cast imperfection similar to pores, and superior silicon substance produced as a effect of response among aluminum and silica in Ak12 alloy and aluminum fly ash composite decide the pitting corrosion behavior and belongings to oxide film outlining on the corrode surface [24, 25]. These survey that related to mechanical possessions of fly ash reinforced Al-alloy (Al 6061) composites made-up through stir casting Technique. They are 3-sets of combination with fly ash element sizes of 4-25, 45-50 and 75-100μm were utilized. Both set have 3-types of fused samples with the strengthening fraction of weight of 10, 15 and 20%. The properties of mechanical like the hardness, compressive strength, tensile strength, and ductility were studied. Pure Al-6061 test sample also mechanical properties tested. It was found that the tensile strength, compressive strength, and hardness of the Al-alloy composites reduced with the added to fly ash size of particle reinforcement. Amplify the fractions of weight of the fly ash particles the compressive strength, ultimate tensile strength, hardness and diminishes the composite ductility. The SEM indicated the sample does not have any voids, because the fly ash distribution in the samples uniform of particles in the matrix. Investigation hard work set in position to determine these troubles are frequently guided on the way to choosing the correct option of reinforcing materials. This is a suggestion that the strengthen materials participate considerable position in determining the overall presentation of the composites. Allowing for the number of published articles studying while arranging this evaluation, it was studied that three types of diverse methods have been implemented to get better the DRAMCs performance. The first method engages to find another and cost effective reinforcements in the improvement of DRAMCs. This is expected at on condition that answers to the problems posed by increasing cost and limited availability of usual ceramic reinforcements [26-28]. Agro waste and their derivatives and Industrial wastes are choice of the reinforcing materials that have been examined [29-30]. Compared to the unreinforced alloy, the alternative reinforcements implemented alloys having important improvement in the properties of the composites during the last studies. Conversely, they hold substandard property when compared to conventional artificial reinforcements [31-33]. This article discussed about FEA methods and also discussed high temperature oxidation behavior of SS316 using Al2O3 coating [34, 35].

5. Summary and Discussion

The recent literature papers make known that wide-range of job has been described to get better the properties of diverse composites based on aluminium by manufacturing their MMC being reinforced with a variety of materials for example TiB2, TiO2, TiC Al2O3, SiC, and B4C etc., and also articles provided the information of diverse mixture of reinforcements material used in the blend of mixture aluminum based composites and how it impacts its performance.

- It has been observed that in literature stir casting process is cost effective method compare to other produced MMC.
- It has been observed that the solid reinforcement of ceramic supplementary to the material of matrix increases the composite density.
- It has been observed that performance of mixture composites under solid particle erosion is one more open end for the significant research.
- It has been observed that properties of hardness increased up to 30% of chance in MMC. Tensile strength properties almost increased double the time of base aluminium alloy.
- It has been experiential results described that the couple of times the man-made ceramics reinforced mixture of AMCs performing superior tribological and mechanical properties compare
to the unmodified alloys. Even though it required testing at different corrosion condition to check
the corrosion nature of AMCs.

✓ For the current research, the agriculture waste and waste from industry and their byproducts are
used as reinforcement material in MMCs. It actually gives some improved properties in the
MMCs. The new generation of hybrid composites still showed some limitation. So, the future
scope is still available for current researchers.

From this literatures survey the manufacturing practice parameters of Al-MMC acting an essential role on
improve the properties of Al-MMC. For using stir casting to fabricate the Al-MMC. In essential to
maintained the process parameters like pouring temperature, stirring temperature, stirring rate, material
quality etc., for attaining enhanced properties of Al-MMC. Also so many fabrication methods available for
manufacturing the Al-MMC, one of the methods are powder metallurgy (solid state processes). The
friction stir process, vapor deposition techniques and diffusion bonding process are used in Al-MMC
fabrication domain. If the procedure are accurately controlled, there is chance to guide to the enhanced
properties in Al-MMC material of composite.

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