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ALUMINIUM ALLOY METAL MATRIX COMPOSITE: A REVIEW

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Abstract

Aluminium metal matrix composites (AMMCs) have received extensive attention for practical as well as fundamental reasons. Aluminium alloys in recent years has found application in vast area of Engineering, particularly in the automobile industries, due to low weight, density, coefficient of thermal expansion, and high strength, wear resistance. Aluminium alloys and Aluminium-based metal matrix composites (AMMCs) have found applications in the manufacture of various automotive engine components such as crankshaft and connect rod. Many composite materials are used in home and industrial production. This review paper discuss recent composite technology and performance behaviour of Metal Matrix Composite, based on their fabrication techniques to achieve desired properties.

keyword; Aluminium alloys, Fabrication, Technique,composite

INTRODUCTION

A composite is made of several part or element but only combined different materials not a non-metal. The main mixed material most probably like aluminium alloy and then it group, silicon carbide fly ash, graphite, boron carbide, fly ash cenospehere, silicon nitride, silicon carbide, etc. In engineering, there has been a great demand since decades in synthesizing materials to attain certain properties to enhance efficiency and cost savings in the manufacturing sector. In fulfilling this demand, a certain dimension has been followed, the materials presently been used is for improvement through known methods of alloy additions, heat treatment, grain modification, and the like. Once the limit is reached through these methods, either due to economic constraint, difficulty in mass production, or further improvement is ruled out, a new line of thought emerges in further improving the properties or decreasing cost and increasing efficiency. A completely new system takes over, like was done around three decades back when metal matrix composites (MMCs) were conceived. Among Metal Matrix Composites (MMCs), Al-alloy-based composites were always on the forefront of research. MMCs composites took a lead compared to the other processes when the cost and ease of fabrication were compared. The other methods changed track and choose for themselves different areas of application and Al-based metal matrix composites (AMMCs) remained as the most potential candidate to be researched on for making engineering components viable.(Ramarao et al.,2012) [1]

Worldwide research in the area of AMMCs established beyond doubt the advantages of Aluminium-based metal matrix composites (AMMCs) over the other base alloys . As time goes on the demands moved ahead and engineering components were demanded from AMMCs. When the industrial application of these were targeted, the question of viability arose and from the different methods adopted for making AMMCs ., The liquid metallurgy route was considered to be ahead due to its ease of fabrication. Although the other routes were more efficient regarding property attainment and microstructural features, still the ease of fabrication added to the cost economics made the liquid metallurgy route a competitive and viable method for bigger sized components. This was clearly shown from the different results published from across the globe for two decades in the area of AMMCs that the application needs to be kept in mind before adopting a material and a process of fabrication. This is because the cost factors, ease of fabrication, second phase's nature, shape, size, distribution, wettability between matrix alloy and second phase must be considered before making a final choice depending on the component selected, mainly its working conditions for the engineering component to be fabricated.

In the last decade though research continues in this field yet the results obtained were a mere confirmation of the previously attained results, and a plateau in the possible improvement has been reached. Also attempts are being made to make engineering components from the AMMCs but still there is no mass utility of these composites especially those made from the liquid metallurgy route. Some areas where research is still needed before these versatile materials see the light of the day as engineering components include machining, joining, repeatability of properties on mass production, and effect of secondary processing. The difficulty in meeting the industry's demand can be easily seen from the lesser number of research publications since the millennium, and old researchers were finding it difficult to answer questions related to the engineering potential of these composites. The material with better property needs to be converted to a component with better properties than presently available and here lies the challenge, like (i) cast AMMCs will seldom find use as engineering components, (ii) advantages accrued in cast composites do not always hold good when processed, (iii) moreover secondary processing of composites has its own set of challenges, and (iv) only selected alloying elements and second phase dispersions can withstand the rigours and give meaningful results.

However, components that have seen the light of the day from AMMCs include Swash plate, tennis racket, transfer bench, foot rest, and a few automobile components like brake drum, casings, head light combos, mining equipment, and a few components for structural applications, with an intention to replace either cast iron products or Al-alloy products presently used especially aimed at weight reduction, strength, stiffness, and energy efficiency. However, the aerospace industries, automobile and railway sectors are keenly observing the composite research development.

The enormous amount of research and development that has gone into Al-based MMCs of every possible alloy with different dispersoids establishing beyond doubt the usefulness of making composites but a choice has to be made with both the base alloy selection and dispersoid size and volume percentage for making engineering components. All engineering components will undergo some wear related degradation with use even in an otherwise non- wear environment. The Al-Cu and Al-Zn-based alloys are commonly used for making engineering components used in non-wear environment.Based on the process

LITERATURE REVIEW

2.0 Aluminiun manufactured based on stir casting

. Balasivanandha prabu et al.,2006, [2] studied better stir process and stir time. The high silicon content aluminium alloy –silicon carbide MMC material, with 10% SiC by using a variance stirring speeds and stirring times. The microstructure of the produced composite was examined by optical microscope and scanning electron microscope. The results shows that stirring speed and stirring time influenced the microstructure and the hardness of composite. Also that at lower stirring speed with lower stirring time, the particle group was more. Increase in stirring time and speed resulted in better distribution of particles. The mechanical test results also comfirmed that stirring speed and stirring time have their effect on the hardness of the composite. The uniform hardness valued was achieved at 600 rpm with 10min stirring.

Radhia et al 2011[3], investigated the tribological behaviour of aluminium alloy reinforced with alumina and graphite fabricated by stir casting process. The wear and frictional properties of the hybrid metal matrix composites was studied by performing dry sliding wear test using a pin – on- test wear test. Experiments were conducted based on the plan of experiments generated through taguchi’s technique. AL 27 orthogonal array was selected for analysis of the data.To investigate the influence of wear rate sliding speed applied load sliding distance, as well as the coefficient of friction. The results shows that sliding distance has the highest influence followed by load and sliding speed. Finally confirmation test were carried out to verify the experimental results and scanning electrons microscopic studies were done on the wear surfaces. The use of graphite as primary reinforcement increases the wear resistance of composites by forming a protective layer between pin counter face and the inclusion of alumina as a secondary reinforcement also has an appreciable effect on the wear behaviour. The regression equation generated for the model was used to predict the wear rate and coefficient of friction of HMMC for intermediate conditions with reasonable accuracy.

Mahendra boopathi et al 2013, [4] investigated hybrid metal matrix composites. The study was aimed at evaluating the physical properties of aluminium 2024 in the presence of fly ash, silicon carbide and its combinations. Consequently, aluminium MMC combination the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties that cannot be achieved in any single conventional material. Stir casting method was used for the fabrication of aluminium MMC. Structural characterization was carried out on MMC by x-ray diffraction studies and optical microscopy was used for the micro structural studies. The mechanical behaviour of MMC like density, elongation, hardness, yield strength and tensile test were done by carrying out laboratory experiments that replicate as nearly as possible the service conditions. In the presence of fly ash and silicon carbide [sic (5%) + fly ash (10%) and fly ash (10%) +sic (10%)] with aluminium, the result shows that the decreasing the density with increasing harness and tensile strength was also observed but elongation of the hybrid MMC in comparison with unreinforced aluminium was decreased. The hybrid metal matrix composites significantly differed in all of the properties measured. Aluminium in the presence of sic (10%)-fly ash (10%) was the hardest.

Anilkumar et al., 2011[5], investigated the mechanical properties of fly ash reinforced aluminium alloy (Al 6061) composites fabricated by stir casting. They are three sets of composites with fly ash particle sizes of 75-100, 45-50 and 4- 25 µm were used. Each set had three types of composite samples with the reinforcement weight fractions of 10, 15 and 20%. The mechanical properties studied were the compressive strength, tensile strength, ductility and hardness. Unreinforced Al6061 samples also tested the mechanical properties. It was found that the compressive strength, tensile strength and hardness of the aluminium alloy composites decreased with the increase in particle size of reinforced fly ash. Increase in the weight fractions of the fly ash particles the ultimate tensile strength, compressive strength, hardness and decreases the ductility of the composite. The SEM of the samples indicated uniform distribution of the fly ash particles in the matrix without any voids.

Dora siva Prasad et al 2014[6], studied the Hybrid metal matrix composites with up to 8% rice husk ash and sic particles could be easily fabricated using double stir casting process. The uniform distribution of rice husk ash and SiC was observed in the matrix. The porosity and hardness increases with the increase in percentage of the reinforcement whereas the density of hybrid composites decreases, The yield strength and ultimate tensile strength increase with the increase in RHA and sic content. It was found that in comparison to that of base aluminium alloy, the precipitation kinetic was accelerated by adding the reinforcement. This effect obtaining the maximum hardness by the aging heat treatment at a reduced time.

Bienias et al., 2003[7] ,experiments that microstructure characteristics of aluminium matrix Ak12 composites containing of fly ash particles, obtained by gravity and squeeze costing techniques, pitting corrosion behaviour and corrosion kinetics are presented and discussed. It was found that one in the comparison with squeeze casting, gravity casting technology is advantageous for obtaining higher structural homogeneity with minimum possible porosity levels, good interfacial bonding and quite a uniform distribution of reinforcement, second one the fly ash particles lead to an enhanced potting corrosion of the Ak12/9%flyash (75-100 µm fraction) composite in comparison with unreinforced matrix (Ak12 alloy), and third one the presence of nobler second phase of fly ash particles, cast defects like pores, and higher silicon content formed as a result of reaction between aluminium and silica in Ak12 alloy and aluminium fly ash composite .

2.1 Liquid metallurgy technique.

Rama rao et al., 2012, [8] examined that aluminium alloy-boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5%). Phase identification was carried out on boron carbide by x-ray diffraction studies microstructure analysis was done with SEM a composites were characterized by hardness and compression tests. The results shows increase the amount of the boron carbide. The density of the composites decreased whereas the hardness is increased. Whereas the compressive strength of the composites was increased with increase in the weight percentage of the boron carbide in the composites.

Keshavamurthy et al., 2010[9], experiments Al6061 matrix composite reinforced with nickel coated silicon nitride particles were fabricated by liquid metallurgy. Microstructure and tribological properties of both matrix alloy and developed composites have been evaluated. Wear tests and dry sliding friction were carried out using pin on disk type machine over a load range of 20-100N and sliding velocities is 0.31-1.57m/s. Results shows that, coated of nickel in silicon nitride partical are uniformly distributed throughout the matrix alloy, lower wear rate and coefficient of friction compared to matrix alloy. The coefficient of friction decreased with increased in load up to 80N. Further increase in the load, also increases coefficient of friction and sliding velocity.

Rohatgi ,et al., 2006, [10] analyses that A356-fly ash cenosphere composites can be synthesized using gas pressure infiltration technique over a wide range of reinforcement volume fraction from 20 to 65%. The densities of Al356-fly ash cenosphere composites, made under various experimental conditions, are in the range of 1250-2180 kg/m3 corresponding to the volume fraction of cenosphere in the range 20-65%. The density of composites increased for the same cenosphere volume fraction with increasing size of particles, applied pressure and melt temperature. This appears to be related to a decrease in voids present near particles by and enhancement of the melt flow in a bed of cenosphere. The compressive strength and modulus of the composites increased with the composite density.

2.2 Powder metallurgy

Powder metallurgy is the process of blending fine powdered materials, pressing them into a desired shape or form (compacting), and then heating the compressed material in a controlled atmosphere to bond the material (sintering). The powder metallurgy process generally consists of four basic steps: powder manufacture, powder blending, compacting, and sintering. Compacting is generally performed at room temperature, and the elevated temperature process of sintering is usually conducted at atmospheric pressure. Optional secondary processing often follows to obtain special properties or enhanced precision. The use of powder metal technology bypasses the need to manufacture the resulting products by metal removal processes, thereby reducing costs.

Hrairi et al., 2009, [11] studied the use powder metallurgy route to develop A356–fly ash metal matrix composites. The samples of this experiment were made of A356 aluminium containing 0, 5, 10, 15, 20 and 30 wt.% fly ash. The result revealed improvement in mechanical properties as fly ash increases.

Senthilkumar and Omprakash 2011 [12], on his part synthesized Aluminum composites reinforced with varying percentages of titanium carbide particles (TiC) produced through the powder metallurgy route. The composites consisted of pure aluminium (45 m particle size) reinforced with 2.5% and 5% titanium carbide particles in as received condition from M/s Sigma Aldrich (fine size of 45 m), compacted to a pressure of 300 MPa and sintered at a temperature of 500°C for two hours in a tube furnace under argon atmosphere. Basic characterization studies such as microstructure, X-ray and XRD were obtained. It was found that mechanical properties significantly increase.

Cryomilling, a form of powder metallurgy method was used to combine boron carbide (B4C) with Al 5083 to form a nano-grained metal matrix powder(Vogt et al., 2009) [13] .The addition of ceramic particulate reinforcement via cryomilling was found to significantly increase the physical and mechanical properties of Al alloys. This powder was blended with unmilled Al 5083 to increase ductility and was then consolidated into plates by three methods: (1) hot isostatic pressing (HIPping) followed by high strain rate forging (HSRF), (2) HIPping followed by two-step quasi-isostatic forging (QIF), and (3) three-step QIF. The effects of process method on microstructure and mechanical behavior for the final consolidated nanocomposite plates were investigated.

Thixoforming was also reported by Ozdemir et al.2011, [14] composite powders were produced by high-energy ball milling (HEM) and then treated by semi-solid direct squeeze casting technique. Gas atomized AA 2017 aluminium alloy powders with a mesh size of ≤100µm were supplied as the starting matrix material for the processing route. The chemical composition of aluminium alloy matrix powder manufactured by gas atomization process is 3.9 Cu, 0.6 Mn, 0.7 Mg, bal. Al (wt.%). The aluminium matrix powder was mixed with volume fractions of 5 and 15% commercially available SiC or Al2O3 particles as reinforcement. The particle size ranges from 15 to 55µm for coarse reinforcements and from 0.2 to 2µm for fine reinforcements. Pre-mixed powders were milled by a laboratory scale high-energy ball milling within argon atmosphere using various rotation speeds (ranging from 600 to 800 rpm). The milling time was varied from 10 min to 3 h. The composite powders were cold pressed into a cylindrical shape and then heated up to a temperature range of 635–645^0 C in a permanent die, which is placed in an electrical furnace under an argon gas protective atmosphere. After the semi-solid state was achieved the material was finally solidified under a squeeze pressure of 100MPa to produce thixoformed samples. The samples were subjected to mechanical and metallographic tests.

Al/SiC MMC has aluminium matrix and the silicon carbide particles as reinforcements and exhibits many desirable mechanical properties. In this study, an attempt has been made to fabricate Al/SiC composite by powder metallurgy route as it homogenously distributes the reinforcement in the matrix with no interfacial chemical reaction and high localized residual porosity. SiC particles containing different weight fractions (10 and 15 wt. %) and mesh size (300 and 400) is used as reinforcement.

Gokce et al [15]. Investigated the mechanical and physical properties of sintered aluminum powders through powder metallurgy route. The study shows that green and theoretical density increased with the increment of compaction pressure. Good mechanical performance was recorded for both pressures during the transverse rupture (three point bending test) owing to enhanced diffusion in the mentioned sintering process.

Sujit Das et al [16]. Experimental Analysis of Density of Sintered SiCp Reinforced AMMCS Using the Response Surface Method. The paper study the fabrication of AlSiCp composites by powder metallurgy (P/M) processing route. An experimental investigation have been undertaken in order to understand the variation of density with respect to the variation of process parameters such as variation of silicon carbide proportion, compacting pressure and sintering time. The relation among the various process parameters with density has been studied. A mathematical model has been developed using second order response surface model (RSM) with central composite design (CCD) considering the above mentioned process parameters. The model shows increase in density due to change in wt% of SiCp (x1) and sintering time for compaction load from 40-93.63586 Ton at a fixed sintering time of 40 minutes and for a fixed value of compacting pressure (x2). The response variable, density (R1) shows linear increase when it is plotted against sintering time (x3) and compacting pressure (x2) for a fixed value of wt% of SiCp (x1) and the prediction of density variation from the mathematical model developed in this study matches closely with the observed data (R2 = 89.8 %). The microstructure shows the uniform distribution of particles.

Dinesh Kumar Koli et al [17]. Properties and Characterization of Al-Al2O3 Composites Processed Powder Metallurgy Routes. This paper shows the characterization of mechanical properties with production routes of powder metallurgy for aluminium matrixAl2O3composites.A uniform distribution of the Al2O3reinforcement phase in the Al matrix can be obtained by high-energy ball milling of Al– Al2O3blends. Nearly 92% increase in the hardness and 57% increase in the tensile strength were obtained in the nano-composites as compared to the commercially pure aluminium.

3.0 CONCLUSION

From literature review, we concluded that, the pure aluminium mixed with some other materials through the process like stir, liquid metallurgy, and powder metallurgy as fabrication procedure has significant effect on various properties of the material. Different processing methods were examining and the result of their experiment were discussed extensively to show improvement in various properties of aluminium metal matrix composite.

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