A Brief Review on Aluminum Metal Matrix Composite

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Abstract- *In recent years, Metal Matrix Composites (MMC) are gaining more popularity when compared with the conventional alloys especially in aerospace sectors, because MMCs possess higher hardness, better wear resistance, high strength and lower weight. Aluminium and its alloys are widely used as matrix material, in which several reinforced like Silicon carbide, Fly ash, boron carbide, aluminum oxide, zircon, fiber etc were used. The incorporation of reinforcement into the metal matrix improves the strength, stiffness, fatigue, wear and creep when compared conventional alloys. This paper highlights the overview of different processing methods of aluminum alloys. The advantages and applications of Al MMC.*

Keywords- Metal Matrix composites, Processing of MMC, Applications, Stir casting

I. INTRODUCTION

The composite material can be defined as the system of material consisting of a mixture of combination of two or more micro constituents (matrix phase and dispersed phase) insoluble in each other and differing in form and or in material composition. Composite materials are usually classified on the basis of the physical or chemical nature of the matrix phase, e.g., polymer matrix, metal-matrix and ceramic composites. This review highlights about Aluminum metal matrix composites. Al metal matrix composite consists of one of the constituent is aluminium/aluminium alloy, which forms percolating network and is termed as matrix phase. The other constituent is embedded in this aluminium/aluminium alloy matrix and serves as reinforcement, which is usually non-metallic and commonly ceramic such as boron carbide, silicon carbide, aluminum oxide, fly ash etc. The properties of Al MMC can be enhanced varying the nature of reinforcement and their volume fractions.[1]

The major advantages of Al MMC

Greater strength. Improved stiffness Reduced density (weight), Improved high temperature properties. Controlled thermal expansion coefficient. Thermal/heat management. Enhanced and tailored electrical performance. Improved abrasion and wear resistance. Control of mass (especially in reciprocating applications). Improved damping capabilities.

These advantages can be quantified for better appreciation. For example, elastic modulus of pure aluminium can be enhanced from 70GPa to 240GPa by reinforcing with 60 vol.% continuous aluminum fibre. On the other hand incorporation of 60 vol% alumina fibre in pure aluminium leads to decrease in the coefficient of expansion from 24 ppmoC to 7 ppmoC similarly it is possible to process Al-9% Si-20 vol% SiCp composites having wear resistance equivalent or better than that of grey cast iron. All these examples illustrate that it is possible to alter several technological properties of aluminium/aluminium alloy by more than two– three orders of magnitude by incorporating appropriate reinforcement in suitable volume fraction.[1]

II. TYPES OF AL MMC'S

AMCs can be classified into four types depending on the type of reinforcement.

(i) Particle-reinforced AMCs (PAMCs)
(ii) Whisker-or short fibre-reinforced AMCs (SFAMCs)
(iii) Continuous fibre-reinforced AMCs (CFAMCs)
(iv) Mono filament-reinforced AMCs (MFAMCs)

Particle reinforced aluminium matrix composites (PAMCs)

These composites generally contain equiaxed ceramic reinforcements with an aspect ratio less than about 5. Ceramic reinforcements are generally oxides or carbides or borides (Al_2O_3 or SiC or TiB_2) and present in volume fraction less than 30% when used for structural and wear resistance applications. However, in electronic packaging applications reinforcement volume fraction could be as high as 70%. In general, PAMCs are manufactured either by solid state (PM processing) or liquid state (stir casting, infiltration and in-situ) processes. PAMCs are less expensive compared to CFAMCs. Mechanical properties of PAMCs are inferior compared to whisker/short fibre/continuous fibre reinforced AMCs but far superior compared to unreinforced aluminium alloys.[1]

whisker-reinforced aluminium matrix composites (SFAMCs)

These contain reinforcements with an aspect ratio of greater than 5, but are not continuous.

Short alumina fibre reinforced aluminium matrix composites is one of the first and most popular

AMCs to be developed and used in pistons. These were produced by squeeze infiltration process. Figure 1b shows the microstructure of short fibre reinforced AMCs. Whisker reinforced composites are produced by either by PM processing or by infiltration route. Mechanical properties of whisker reinforced composites are superior compared to particle or short fibre reinforced composites.

Continuous fibre-reinforced aluminium matrix composites (CFAMCs)

Here, the reinforcements are in the form of continuous fibres (of alumina, SiC or carbon) with a diameter less than 20 _m. The fibres can either be parallel or pre woven, braided prior to the production of the composite. AMCs having fibre volume fraction upto 40% are produced by squeeze infiltration technique.

Mono filament reinforced aluminium matrix composites (MFAMCs)

Monofilaments are large diameter (100 to 150 _m) fibres, usually produced by chemical vapour deposition (CVD) of either SiC or B into a core of carbon fibre or W wire. Bending flexibility of monofilaments is low compared to multifilaments. Monofilament reinforced aluminium matrix composites are produced by diffusion bonding techniques, and is limited to super plastic forming aluminium alloy matrices.

III.PROCESSING OF AMCS

Primary processes for manufacturing of AMCs at industrial scale can be classified into two main groups.

(1) Solid state processes.
(2) Liquid state processes.

IV. LIQUID STATE PROCESSES

Stir casting: This involves incorporation of ceramic particulate into liquid aluminium melt and allowing the mixture to solidify. Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminium alloy melt. The simplest and most commercially used technique is known as vortex technique or stir-casting technique. The vortex technique involves the introduction of pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller. Lloyd (1999) reports that vortex-mixing technique for the preparation of ceramic particle dispersed aluminium matrix composites was originally developed by Surappa & Rohatgi (1981) at the Indian Institute of Science.[1]

Subsequently several aluminium companies further refined and modified the process which are currently employed to manufacture a variety of AMCs on commercial scale.

Microstructural inhomogeneties can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Inhomogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. Generally it is possible to incorporate upto 30% ceramic particles in the size range 5 to 100 _m in a variety of molten aluminium alloys. The melt–ceramic particle slurry 11 may be transferred directly to a shaped mould prior to complete solidification or it may be allowed to solidify in billet or rod shape so that it can be reheated to the slurry form for further processing by technique such as die casting, and investment casting. The process is not suitable for the incorporation of sub-micron size ceramic particles or whiskers. Another variant of stir casting process is compo-casting. Here, ceramic particles are incorporated into the alloy in the semi solid state.

Infiltration process: Liquid aluminium alloy is injected/infiltrated into the interstices of the porous preforms of continuous fibre/short fibre or whisker or particle to produce

AMCs. Depending on the nature of reinforcement and its volume fraction preform can be infiltrated, with or without the application of pressure or vacuum. AMC shaving reinforcement volume fraction ranging from 10 to 70% can be produced using a variety of infiltration techniques. In order for the preform to retain its integrity and shape, it is often necessary to use silica and alumina based mixtures as binder. Some level of porosity and local variations in the volume fractions of the reinforcement are often noticed in the AMCs processed by infiltration technique. The process is widely used to produce aluminium matrix composites having particle/whisker/short fibre/continuous fibre as reinforcement.

(c) Spray deposition: Spray deposition techniques fall into two distinct classes, depending whether the droplet stream is produced from a molten bath (Osprey process) or by continuous feeding of cold metal into a zone of rapid heat injection (thermal spray process). The spray process has been extensively explored for the production of AMCs by injecting ceramic particle/whisker/short fibre into the spray.

(d)In-situ processing (reactive processing): There are several different processes that would fall under this category including liquid-gas, liquid-solid, liquid-liquid and mixed salt reactions. In these processes refractory reinforcement are created in the aluminium alloy matrix. One of the examples is directional oxidation of aluminium also known as DIMOX process. In this process the alloy of Al–Mg is placed on the top of ceramic preform in a crucible. The entire assembly is heated to a suitable temperature in the atmosphere of free flowing nitrogen bearing gas mixture. Al–Mg alloy soon after melting infiltrates into the preform and composite is formed.[1]

V. APPLICATIONS OF AL MMC'S

AMCs now have a proven track record as successful "high-tech" materials in a range of applications.

AMC utilisation provides significant benefits including performance benefits (component lifetime, improved productivity), economic benefits (energy savings or lower maintenance cost) and environmental benefits (lower noise levels and fewer air-borne emissions).

(a) Particulates of SiC, Al_2O_3, TiC, TiB_2, B_4C have been used as reinforcements. PAMCs have been successfully used as components in automotive, aerospace, opto-mechanical assemblies and thermal management.
(b) In the wake of greater health risks associated with the handling of ceramic whiskers, of late production of whisker-reinforced aluminium composites has been very limited. However, with appropriate safety measures, SiC whisker-reinforced aluminium matrix composites have been produced and used as track shoes in advanced military tanks.
(c) Carbon fibre (continuous) reinforced Al matrix composites have been used as antenna wave guides for the Hubble Space Telescope. Here, composites provide high dimensional accuracy, high thermal and electrical conductivity with no outgassing oxidation resistance. 6061 Al-boron fibre (continuous) composites have been used as struts in main cargo bay of space Shuttle
(d) AMCs provide benefits in volume critical flywheel applications. Use of AMCs enable smaller flywheels compared to polymer composites.

VI. CONCLUSION

The Aluminum matrix composites is light, its specific weight is substantially lower than other common metals. Aluminum metal matrix composites are suitable for both solid state and liquid state processing

Science of primary processing of AMCs need to be understood more thoroughly, especially factors affecting the microstructural integrity including agglomerates in AMCs. There is need to improve the damage tolerant properties particularly fracture toughness and ductility in AMCs. Work should be done to produce high quality and lowcost reinforcements from industrial wastes and by-products. Efforts should be made on the development of AMCs based on non-standard aluminium alloys as matrices. There is a greater need to classify different grades of AMCs based on property profile and manufacturing cost. There is an urgent need to develop simple, economical and portable non-destructive kits to quantify undesirable defects in AMCs. Al MMC's has outstanding formability and can be processed in a variety of ways.

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