Development and Characterization of Aluminium Based Metal Matrix Composites: An Overview of challenges and opportunities

P.B.Pawar[#1], D.J.Jadhav[*2]

[#]Department of Mechanical Engineering, SVPM,s ITE Malegaon BK
Tal-Baramati, Pune MH India

[1]purushottampawar_07@rediffmail.com , djjadhav88@gmail.com

ABSTRACT : *MMCs are made by dispersing a reinforcing material into a metal matrix. They are prepared by powder metallurgy and casting, although several technical challenges exist with casting technology. Achieving a homogeneous distribution of reinforcement within the matrix is one such challenge, and this affects directly on the properties and quality of composite. The properties of aluminium metal matrix composite mostly depend on the processing method which is capable of producing good properties to comply the industry need. In case of increased silicon carbide content, the hardness, and material toughness are enhanced. In the last few years, AMCs have been utilised in high-tech structural and functional applications including aerospace, defence, automotive, and thermal management areas, as well as in sports and recreation. It is interesting to note that research on particle-reinforced cast AMCs took root in India during the 70's, attained industrial maturity in the developed world and is currently in the process of joining the mainstream of materials. This paper presents an overview of AMC material systems on aspects relating to processing, microstructure, properties and applications.*

Keywords-MMC, Aluminium Matrix, Sic, Hybrid composite

I. INTRODUCTION

Your Al/SiCp Metal Matrix Composites (MMCs) are the new class of materials and are rapidly replacing conventional materials in various applications industrial and aerospace applications. These materials are generally regarded as extremely difficult to machine, because of the abrasive characteristics of the reinforced particulates. Metal matrix composites (MMCs) form one group of the new engineering material that has received considerable research since 1980s. The most popular reinforcements are silicon carbide and alumina. Aluminum, titanium and magnesium alloys are commonly used as the matrix phase. Reinforcements have been used in the form of particulates, whiskers, or continuous fibers. AMCs can be classified into four types depending on the type of reinforcement.

(a) Particle-reinforced AMCs (PAMCs)
(b) Whisker-or short fibre-reinforced AMCs (SFAMCs)
(c) Continuous fibre-reinforced AMCs (CFAMCs)
(d) Mono filament-reinforced AMCs (MFAMCs)

The mechanical properties of a composite depend on many factors such type of reinforcement, quantity of reinforcement, shape, size etc.

The objective of developing metal matrix composite materials is to combine the desirable properties of metal and ceramics. The major advantages of aluminium matrix composites compared to unreinforced materials are greater strength, improved stiffness, reduced density, improved temperature properties, controlled thermal expansion and improved wear resistance **Short Fibre and Whisker Reinforced Aluminium Matrix Composites (SFAMCs).**

The characteristics exhibited by SFAMCs lies in between CFAMCs and PAMCs. The production of short fibre and whisker reinforced aluminium are done either by infiltration route or by PM (powder metallurgy) process. The mechanical characteristics of whisker reinforced AMCs surpass that of PAMCs. These type of composites are the very first composites to be used in pistons. **Mono Filament Reinforced Aluminium Matrix Composites (MFAMCs)**

The production of MFAMCs takes place by chemical vapour deposition also coined as CVD of either boron or SiC into the core of fibre made up of carbon or W wire. The size of fibres is as large 100 to 150µm diameter. The main purpose of aluminium matrix is the distribution and transferring of load. These types of composites are directional in nature. The bending flexibility in case of multifilament is more than that of monofilament. MFAMCs are generated by techniques such as diffusion bonding. The strength of composite is less when the orientation is perpendicular to the orientation of fibre. Maximum load is carried by the matrix due to the reinforcement. **Continuous Fibre Reinforced Aluminium Matrix Composites (CFAMCs)**

One of the detailed type of AMC is CFAMCs. It is widely used in practice. In this type of reinforcement, the fibres are continuous in nature. The reinforcements of these composites are of the form of SiC, carbon or alumina fibres. In size the diameter of CFAMCs is not more than 20µ. Fibres here can be either parallel or pre woven and these are braided before the production of the composite.

Particle Reinforced Aluminium Matrix Composites (PAMCs)

Particle reinforced aluminium matrix composites generally comprise of ceramic reinforcements which are equiaxed in nature with the aspect ratio does not exceeding 5. PAMCs are manufactured either by the liquid state or solid state methods. Processes such as stir casting, infiltration process and in situ reaction synthesis comes under the category of liquid state methods and Powder Metallurgy is one of the solid state methods [6]. The cost of PAMCs is less than CFAMCs. Considering the mechanical properties, they are inferior to SFAMCs and CFAMCs but much better than that of unreinforced aluminium alloys. They are generally borides, carbides or oxides. For e.g. Al2O3, SIC or TiB2. It is used for the application such as structural and resistance and hence is present in less than 30% of volume fraction.

Hybrid Aluminium Matrix Composites

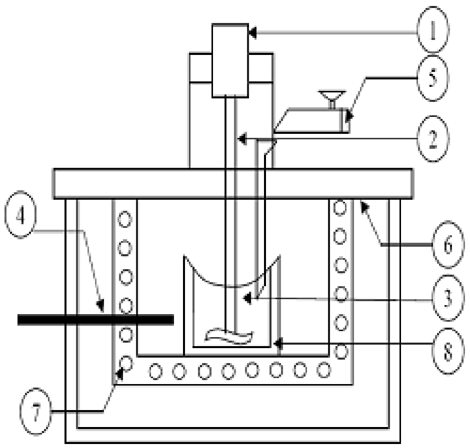
In recent times the latest development other than the above four AMCs is hybrid AMC. Hybrid composites are those in which reinforcements are of more than one type. For example mixture of CFAMCs and PAMCs.

Reinforcement materials

In Aluminum matrix composites (AMCs), the ceramic reinforcements are generally oxides or carbides or borides such as Al2O3, TiB2, TiO2,SiC, TiC, B4C, etc.

Preparation of Aluminium Based Metal Matrix Composite

Stir casting technique is one of the popular Liquid Metallurgy Route (LMR) and also known as a very promising route for manufacturing near net shape hybrid metal matrix composite components at a normal cost.



1. Motor 5. Particle injection chamber
2. Shaft 6. Insulation hard board
3. Molten aluminum 7. Furnace
4. Thermocouple 8. Graphite crucible

Fig.1 Schematic set up for Stir casting [5]

Challenges and opportunities

- 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.

Desirable properties of metal

Tensile strength

Tensile properties dictate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties. The main product of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve. Since both the engineering stress and the engineering strain are obtained by dividing the load and elongation by constant values (specimen geometry information), the load-elongation curve will have the same shape as the engineering stress-strain curve. The stress-strain curve relates the applied stress to the resulting strain and each material has its own unique stress-strain curve

Ultimate Tensile Strength

The ultimate tensile strength (UTS) or, more simply, the tensile strength, is the maximum engineering stress level reached in a tension test. For ductile metals the current design practice is to use the yield strength for sizing static components. However, since the UTS is easy to determine and quite reproducible, it is useful for the purposes of specifying a material and for quality control purposes. On the other hand, for brittle materials the design of a component may be based on the tensile strength of the material.

Hardness

Hardness is the resistance of a material to localized deformation. Hardness measurements are widely used for the quality control of materials because they are quick and considered to be non-destructive tests when the marks or indentations produced by the test are in low stress areas. There are a large variety of methods used for determining the hardness of a substance.

Toughness

The ability of a metal to deform plastically and to absorb energy in the process before fracture is termed toughness. There are several variables that have a profound influence on the toughness of a material. These variables are Strain rate (rate of loading), Temperature, Notch effect.

A metal may possess satisfactory toughness under static loads but may fail under dynamic loads or impact. As a rule ductility and, therefore, toughness decrease as the rate of loading increases. Temperature is the second variable to have a major influence on its toughness. As temperature is lowered, the ductility and toughness also decrease. The third variable is termed notch effect, has to do with the distribution of stress

Wear resistance

Wear occurs as a natural consequence when two surfaces with a relative motion interact with each other. Wear may be defined as the progressive loss of material from contacting surfaces in relative motion. We know that one third of our global energy consumption is consumed wastefully in friction. Wear causes an enormous annual expenditure by industry and consumers.

Corrosive Resistance

Corrosion is a slow, progressive or rapid deterioration of a metal's properties such as its appearance, its surface aspect, or its mechanical properties under the influence of the surrounding environment: atmosphere, water, sea water, various solutions, organic environments, etc. In the past, the term "oxidation" was frequently used to designate what is now a day's commonly called "corrosion". Nevertheless, the former was the right word because corrosion also is an electrochemical reaction during which the metal is oxidised, which usually implies its transformation into an oxide, i.e. into the state in which it existed in the mineral [6].

Process variables and their effects on properties

Speed of rotation

The control of speed is very important for successful production of casting. Rotational speed also influences the structure, the most common effect of increase in speed being
to promote refinement and instability of the liquid mass at very low speed. It is logical to use the highest speed consistent with the avoidance of tearing

Pouring temperature

Pouring temperature exerts a major role on the mode of solidification and needs to determine partly in relation to type of structure required. Low temperature is associated with maximum grain refinement and equiaxed structures while higher temperature promotes columnar growth in many alloys. However practical consideration limits the range. The pouring temperature must be sufficiently high to ensure satisfactory metal flow and freedom from cold laps whilst avoiding coarse structures

Pouring speed

This is governed primarily by the need to finish casting before the metal become sluggish. Although too high a rate can cause excessive turbulence and rejection. In practice slow pouring offers number advantages. Directional solidification and feeding are promoted whilst the slow development of full centrifugal pressure on the other solidification skin reduces and risk of tearing. Excessive slow pouring rate and low pouring temperature would lead to form surface lap

Mould coatings

Various types of coating materials are used. The coating material is sprayed on the inside of the metal mould. The purpose of the coating is to reduce the heat transfer to the mould. Defects like shrinkage and cracking that are likely to occur in metal moulds can be eliminated, thus increasing the die life. The role of coating and solidification can be adjusted to the optimum value for a particular alloy by varying the thickness of coating layer. For aluminium alloys, the coating is a mixture of Silicate and graphite in water.

CONCLUSION

Following conclusions can be drawn from the review carried out on Al based composites

- Particle distribution in the matrix material depends strongly on the stirring speed, stirring time, viscosity of slurry, heating temperature, particle wetting solidification rate, and minimizing of gas entrapment.
- Aluminium alloy matrix composites reinforced with Hybrid can be successfully synthesized by the stir casting method.

For synthesizing of hybrid composite by stir casting process, stirrer design and position, stirring speed and time, melting and pouring temperature, particle-preheating temperature, particle incorporation rate, mould type and size, and reinforcement particle size and amount are the important process parameters.

- In general, the Al-MMCs are found to have higher elastic modulus, tensile and fatigue strength over monolithic alloys In case of heat treatable Al-alloys and their composites, the yield strength of composites increase after heat treatment by reducing the cracking tendency and improving the precipitation hardening.

REFERENCE

[1] Pradeep K. Rohatgi "Metal-matrix Composites" Defence Science Journal, Vol 43, No 4, October 1993, pp 323-349

[2] Hashim, J.; Looney, L.; Hashmi, M.S.J. "Metal matrix composites: Production by the stir casting method" Journal of Materials Processing Technology 1999, 92 (93), 1–7.

[3]Manoj Singla1, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla, "Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite, 335.Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467, 2009

[4[J.Jenix Rino, D.Chandramohan, V.Daniel Jebin "Research Review On Corrosion Behaviour Of Metal Matrix Composites", ISSN: 0975-833X.

[5] D. J. Lloyd, " Particle reinforced aluminium and magnesium matrix composites ", International Materials Reviews 1994 Vol. 39 No.1.

[6[K. M. Shorowordi, T. Laoui, A. S. M. A. Haseeb, J. P. Celis and L. Froyen, "Microstructure and Interface Char-acteristics of B4C, SiC and Al2O3 Reinforced Al Matrix Composites: A Comparative Study," Journal of Materials Processing Technology, Vol. 142, 2003, pp.738-743.

[7] K. V. Mahendra and K. Radhakrishna, "Characterization of Stir Cast Al-Cu-(fly ash + SiC) Hybrid Metal Matrix Composites", Journal of Composite Materials, Vol. 0, No. 00/2009.

[8] Clyne T W, Withers P J 1993 *An introduction to metal matrix composites* (Cambridge: University Press)

[9] K.U. Kainer, Cast magnesium alloys reinforced by short Fibres, in: Proceedings of the International Conference on Magnesium Alloys and their Applications, Garmisch-Partenkirchen, DGM Informationsgessellschaft, Oberursel, 1992, pp. 415-422.

[10] Abhishek Kumar, Shyam Lal, Sudhir Kumar, "Fabrication and characterization of A359/Al2O3 metal matrix composite using electromagnetic stir casting method", j mater res technol. 2013;2(3):250–254.