Metal matrix composites- a review on synthesis and characterization

1*Ashish Kumar Srivastava, 2Yash Gupta, 2Saurabh Patel, 2Sachin Kumar Tiwari, 2Shubham Pandey, 1Associate Professor, G.L. Bajaj Institute of Technology and Management, Greater Noida, GB Nagar 2Under graduate student, G.L. Bajaj Institute of Technology and Management, Greater Noida, GB Nagar,
Email: ashish7185@gmail.com

Abstract. The manufacturing industries continuously demanded the new class of engineering materials for various applications. It results in improvement of metal matrix composites. Development of newer materials like MMCs are one of the keen area of research now a day’s. In this regard various literatures are available in open literature on development, characterization and application of MMCs. In this work an attempt is made to discuss the available literatures in terms of their output findings. The work also focuses on the area where the more attention is required to carry out the research work.

1. Introduction

There is continuous demand in aerospace industries to develop lighter weight materials which are more economical to produce and poses better mechanical and thermal properties than the regular Aluminium alloys [1]. This important need has led us to develop aluminium based metal matrix composites [2]. A composite material is a material consisting of two or more physically or chemically distinct phases. One component acts as a matrix in which the reinforcing phase is distributed, when the base material is metal it is called metal matrix composite [3]. Composites are not the same as alloys. Alloys are formed in a way that it is not possible to distinguish one component from the other [4]. Some examples of composite materials are fiberglass, concrete mud bricks, and natural composites such as rock and wood. There are mainly three types of metal matrix composites (MMCs): particle reinforced MMCs, short fiber or whisker reinforced MMCs, and continuous fiber or sheet reinforced MMCs [5]. The wings of HAL TEJAS aircraft are fabricated from aluminium-lithium alloys, carbon-fibre composites, and titanium alloys. Composite substances make up 45 % of the airframe through weight and 95 % by using floor region [6]. The F-22 raptor makes use of a composite pivot shaft hired with precise tooling procedures to comprise a composite structure in region of a titanium one in its horizontal stabilizers. The carbide drills used in drilling machines is a composite material made from cobalt as base metal and with tungsten used as reinforcement particles [7]. One of the common solid-state processing techniques for joining similar or dissimilar metals is diffusion bonding. The diffusion of atoms between clean metallic surfaces, in contact at high temperature leads to bonding [8]. Liquid state processing is the most common liquid state fabrication method. The base metal is heated to the molten state in the furnace at very high temperatures (800-900°C), then the reinforced particles are scattered on the molten slurry. The molten slurry is then mixed with the help of stirrer at varying RPM [9].
In this work, the detailed survey of studies available in open literature has been discussed. The work also includes the discussion on findings of various researchers in this field.

2. Literature Survey

There is a continuous effort to try to improve various mechanical and chemical properties of engineering materials. Aluminium based MMC processes very good mechanical properties as compared to regular aluminium based alloys. They can easily be moulded and fabricated in any shape and size as compared to regular aluminium alloys [10]. Some of the critical properties which composite materials possess are accelerated strength & better fatigue resistance, high corrosion resistant, high warmness resistant, higher wear resistant, stiffness, low weight and so on. In order to obtain the desired properties required for any specific applications metal matrix and reinforcements can be arranged in a particularly suitable manner. The analysis of metal matrix composite through development and testing by reinforcing SiC particles on Aluminium alloy was carried out by Idrisi and Deva [11] and they investigated its mechanical properties. Their mechanical properties were improved as the percentage of SiC was increased. In aluminium MMCs, base metal or matrix material is aluminium and very fine particles of SiC silicon carbide is used as reinforcement material. K Milos et al. [12] done analysis on the aluminium-based composite substances for the development use and transport approach and it became concluded that mechanical properties of the aluminium primarily based metal matrix composites relies upon weight percent and the size of Al2O3 and graphite. Al 5083 alloy was reinforced with SiC particle and further the testing and development of AL5083 was carried up by Idris et al [13]. Compressive strength and tensile strength was seen to increase with weight % of the SiC particle. Solid phase process is generally more expensive than liquid phase stir casting process. High temperature furnace is being used up in stir casting process. Good chemical reaction between molten aluminium and the SiC reinforcement is possible due to high temperature. SiC reinforced with Al6063 metal matrix composite was studied by K.L. Meena et al [14]. They speak about the method of stir casting and investigated their mechanical homes. The scale of reinforcement particles was varied and used 200 mesh, three hundred mesh, four hundred mesh with the special weight percent i.e. 5%, 10%, 15% and 20%.

Sijo MT [15] analysed up stir cast aluminium silicon carbide metal matrix composite and pronounced that wettability of reinforcement (sic) and clustering up of reinforcement debris in molten aluminium are the high subject in stir casting of composite material. A. Pramanik et al [16] found that fracture and fatigue existence evaluation of al-primarily based MMC’s machined at specific situations and located out that fatigue existence of MMC’s are an awful lot lower than that of corresponding matrix material. 

Ashok kumar et al [17] studied experimental investigations on mechanical and tribological residences of extruded aluminium A356/AL2O3 stir solid MMC’s and concluded the growth in tensile power with decrease in elongation while decreasing the dimensions of Al2O3 particulates. The nano-sized sic/7075 AMMC’s have been studied by way of Jufu Jiang and Ying Wang [18], they talk about mechanical property and microstructure of developed metal matrix composites. The ultrasonic assistance has been used with liquid stirring. R. Taherzadehmosaivi et al [19] investigated the fabrication of aluminium matrix composites which was reinforced with nano-to micro-sized silicon carbide particles. They said that the particle size of the coarse silicon carbide powders was found to reduce with increasing up of the milling time. Analysis on the mechanical and microstructural properties of Al/B4C developed by microwave sintering was done by EhsanGhasali et al [20]. The conclusion made was that at sintering temperature of 850°C and extra, the interfacial response between the Al and B4C had led to the formation of the Al3B4C. M. PenchalReddy et al [21] investigated the development of nano sized SiC reinforced with aluminium by microwave sintering and hot extrusion technique. They reported the increment in hardness and modulus of elasticity by increasing the percentage of SiC. Mohammed Imran, A.R. Anwar Khan [22] studied the development of MMCs with the use of waste materials like bagasse and flyash. They used stir casting method to develop the samples. They suggested that the ductility of the base material were decreases with increasing the percentage of reinforced materials.
3. Discussion
In this work the development and characterization of MMCs has been discussed in terms of their results and output findings. On the basis of literature survey it has been summarises that most of the authors have worked to develop MMCs by different processes like stir casting, solid state processing like powder metallurgy and microwave sintering technique. Diffusion bonding was also used to develop MMCs. Figure 1 shows the graph to show the contribution of various processes in development of MMCs on the basis of sampling. In most of the research work, the problem arises with clustering of reinforcements and its wettability in the molten slurry is the main problem for assessment. However, the characterization factors such as shape and size of reinforcement, cooling type and time are the other keen area of research describes by various authors. The base materials like aluminium, copper, magnesium etc are successfully used as a matrix material. Figure 2 shows the contribution of ductile materials used as a choice of matrix material for most of the research.

![Figure 1 Contribution of development processes in MMCs](image1)

![Figure 2 Contribution of Matrix materials](image2)
It is also to be noted that the mechanical characterization is one of the major parameters to select MMCs for most of the engineering applications. Tensile strength, hardness, impact strength, fatigue strength, ductility, percentage elongation are the key parameters of mechanical properties. Few of the researchers have worked on thermal behaviour of MMCs. Few experiments such as differential thermal analysis (DTA), thermal expansion are examined to suggest the thermal behaviour of developed MMCs. Table 1 shows the contribution by the various authors in their research work. It helps to make an idea about the characterization part of the MMCs.

**Table 1 Developments in MMCs**

| S.No. | Authors                        | Materials                        | Mechanical property                           | Contributions                                                                 |
|-------|--------------------------------|----------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------|
| 1     | Maninder Singh et al           | Al+SiO2                          | Weight Loss, decreases density and increase hardness | Hardness and wear resistance improved with addition of SiO2.                   |
| 2     | H.C. Anil kumar                | Al (6061)+fly ash (Al2O3, SiO2, Fe2O3) | Tensile strength was found to increase with the weight percentage increase of the fly ash, composite hardness was increased with weight fraction increase of fly ash particles. | The composite ductility decreased with the weight fraction increase of reinforced fly ash and decreased with the increasing up of fly ash particle size. |
| 3     | Shailendra Deva                | Al5083+SiC                       | Hardness was increased                        | Ultrasonic stir casting route has proven to be the leading composite manufacturing route. |
| 4     | D. Das                         | Al-6 wt. % SiC, Al-8 wt. % SiC, Al-17 wt % SiC | The ultimate tensile stress, and the young’s modulus, yield stress, breaking stress (fracture) of ceramic-reinforced aluminum matrix composites were found better than of their monolithic alloys. | It is possible to improve the hardness of aluminium matrix composites by reducing the particle size of the reinforcement or by increasing up of the reinforcement fraction. |
| 5     | A. Mazaffary and M. O.         | Al6061+SiC                       | Decreased porosity, hardness was increased    | Application of the heavy reduction (90%) during cold rolling process results in almost no porosity. |
| 6     | K. Milos et al                 | Al/A2O3                          | Contraction and surface elongation was found to deteriorate as hard particle content increased | MMC can be created without difficulties through powder metallurgy techniques, which is through extrusion. |
| 7     | A. Hidrissi et al              | Al5083+SiC                       | With increased wt of the SiC percentage., the compressive strength and tensile strength and increased. | Ultrasonic stir casting route has proven to be the leading composite manufacturing route. |
By increasing the milling time, the particle size of a coarse SiC powders was found to reduce.

The method of using a carrier agent was found to be profitable if the carrier agent was able to release the ceramic particles throughout stirring.

Due to the implementation of a higher sintering temp, XRD findings confirmed Al3BC phase was developed in microwave sintered samples.

It was founded that red mud and Al alloy composite gives good mechanical results.

The hybrid AMCs reinforced with agro - waste derivative products showed that higher performance levels in AMCs can be preserved at reduced production charges, even when synthetic reinforcement is replaced by agro - waste by around 50 percent.

Flexural strength increased. No catastrophic failure actions exhibited by both the SiC(SCS-6)/Ti / Ti3AlC2 composites, irrespective of the processing temperature.

4. Conclusion

Based on the above survey it is clear that the advantages of Metal Matrix Composites over conventional metal alloys are numerous such as high strength, high toughness, high temperature resistance, durability and stability. In most of the engineering applications substitution of metal matrix composite in place of other available materials offers improved performance, reduced weight and saves cost. However, the fabrication of metal matrix composite through stir casting offers various challenges and more research is needed to reduce the clustering problem of reinforcements in the molten matrix. Further the addition of reinforcement up to a certain degree enhances the mechanical properties, but after exceeding that particular level the property of base metal is lost. To realize full potential we choose an optimum amount of mixing. Some new techniques like friction stir processing are gives improved results in terms of defects arises due to liquid stirring.

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