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ISSN : 2348 - 5612 | Volume : 05 , Issue : 05 | May 2018

Review on Fabrication of Aluminium Metal Matrix Composite

[1]Kedar Narayan Bairwa, [2]Prof. (Dr.) Dinesh Shringi. [3]Raj Kumar

[1]Research Scholar, Department of ME, M.B.M. Engineering College Jodhpur (Raj.)

Jai Narayan Vyas University Jodhpur (Raj.)

[2]Professor, Department of ME, M.B.M. Engineering College Jodhpur (Raj.)

Jai Narayan Vyas University Jodhpur (Raj.)

Abstract

Engineering works are full of exploration and always seeking for the better material to build with. The properties that are shown by already existing pure materials have their own limitations in terms of strength to weight ratio. Thus, the composite materials are used in many engineering applications due to their excellent properties. The sandwich composite materials replace the metals owing to their excellent strength with low weight. This work gives an introduction about Metal Matrix Composite to fabricate the composite of Aluminium with other constituents. Fabrication is not the only part, further AMC (Aluminium Matrix Composite) is tested for different aspects to achieve the required tailored properties. Various tests refer to mechanical strength testing of the material and investigation of the matrix at micro level which is known as Micro Structural Investigation. SEM (Scanning Electron Microscope) and XRD (X-Ray Diffraction) are the test and analyses which are performed to obtain the best results in machining and smoothness in fabrication.

ISSN : 2348-5612 © URR
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Keywords: **MMC (Metal Matrix Composite), AMC (Aluminium Matrix Composite), Microstructural Investigation, SEM (Scanning Electron Microscope), XRD (X-Ray Diffraction)**

****Author for Correspondence*** E-mail: mailid@author, Tel:

INTRODUCTION

Current engineering applications require lighter as well as stronger materials i.e. major focus is given on strength to weight ratio. Modern manufacturing sector demands for materials with broad range of properties like high thermal resistance, minimum wear rate, good damping properties, high specific stiffness etc. Metal-matrix composites (MMCs) are engineered combinations of two or more materials (one of which is a metal) where tailored properties are achieved by systematic combinations of different constituents. Typically, a composite material is made of reinforcement and a matrix. The reinforcement material provides the mechanical strength and transfers loads in the composite. The matrix binds and maintains the alignment or spacing of the reinforcement material and protects the reinforcement from abrasion or the environment.

MMCs are classified into different categories depending upon the matrix materials. Some examples of most commonly used metallic matrix configurations are:

- Aluminium-based composites; aluminium as matrix can be either cast alloy or wrought alloy (i.e., Al Mg Si, Al Mg, Al Cu Si Mn, Al Zn Mg Cu, Al Cu, Al Si Cu Mg)
- Magnesium-based composites
- Titanium-based composites
- Copper-based composites

Aluminium Matrix Composite

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Alumina/aluminium MMCs are characterized by low weight, high temperature tensile and fatigue strength, low thermal conductivity and superior wear resistance. In automotive industry short–fiber Al_2O_3/aluminium MMCs have been used to replace cast iron components such as pistons, engine blocks, cylinder heads and brake calipers and rotors.

The processes root of manufacturing, shape, size, and chemical affinity with matrix material of reinforcement materials influence their microstructure, physical properties, tribological properties and other desirable properties of the composite. The formation of strong chemical bonds at the interface is favorable for the wetting of reinforcement by molten metal, which is considered as an important aspect in MMC synthesis. The lower wettability adversely affects the properties of the composite.

Automotive and marine industries are in need of better class of materials that need all versatile applications and also they should be environment friendly. The most important factor in fabricating of these laminates is to achieve better structure to automotive where aesthetics and weight play an important role.

Mechanical testing reveals the properties of a material under dynamic or static force. Mechanical testing of materials covers a wide variety of experimental approaches, ranging from a simple standard tensile test to more complex tests. These tests are tensile test, flexural test, impact test and hardness test.

MICRO STRUCTURAL INVESTIGATION

By using this analysis we can find the yield strength and ultimate tensile or compressive strength which are not as well established in the literature mainly due to the high hardness and the low ductility that makes the determination of reliable information of material as a challenging task. Microstructural investigation is used among the various industries to find the structure of the material at various stages of testing. This investigation can be carried out by using either optical microscope or Scanning Electron Microscope (SEM). In this study, SEM method is preferred over optical microscope.

SCANNING ELECTRON MICROSCOPY (SEM)

Scanning electron microscopy (SEM) has become a powerful and versatile tool for material characterization. SEMs use a specific set of coils to scan the beam in a raster-like pattern and use the electrons that are reflected or knocked off the near-surface region of a sample to form an image.

XRD Analysis

XRD analysis, by way of the study of the crystal structure, is used to identify the crystalline phases present in a material and thereby reveal chemical composition information. Identification of phases is achieved by comparison of the acquired data to that in reference databases.

SEMs use a specific set of coils to scan the beam in a raster-like pattern and use the electrons that are reflected or knocked off the near-surface region of a sample to form an image. Since the wavelength of electrons is much smaller than the wavelength of light, the resolution of SEMs is superior to that of a light microscope.This test method is performed by directing an x-ray beam at a sample and measuring the scattered intensity as a function of the outgoing direction. Once the beam is separated, the scatter, also called a diffraction pattern, indicates the sample's crystalline structure.

EDM (ELECTRIC DISCHARGE MACHINING)

The principle behind this process is the ability of controlled electric sparks to erode material. The workpiece and electrode do not touch during this process. In between is a gap that is roughly as thick as a human hair. The amount of removed material with a single spark is small, yet the discharge occurs roughly several 100,000 times a second.

Depending on the accuracy and surface finish needed, a part will either be one cut or it will be roughed and skimmed. On a one cut the wire ideally passes through a solid part and drops a slug or scrap piece when it is done. This will give adequate accuracy for some jobs, but most of the time, skimming is necessary.

LITERATURE REVIEW

Recent research of (Schmidt et al., 2018) [1] have shown that aluminium matrix composite (AMC) possesses desired potential properties such as high specific strength and stiffness, required wear resistance to withstand abrasive properties compared to monolithic materials which are demanded by automotive and aerospace industries for the tribological application.
Other researchers (Şenel, Gürbüz and Koç, 2017) [2], (Maleque, Radhi and Rahman, 2016) [3] showed that silicon carbide (SiC) is ideal reinforcement candidate for several matrix materials, including aluminium because of its significant ability to enhance the strength, modulus, thermal stability, and abrasive wear resistance of the matrix materials.
(Huang SJ, 2011) Reported that the wear resistance of AMCs with 3μm SiC particles is considerably lower compared to 20 μm SiC particles. This phenomenon is attributed to the tendency of finer reinforced particles to be easily gouged out and machined away by abrasive particles. (Bindumadhavan P, 2001) Studied the tribological behavior of a low volume fraction dual particle size (DPS) containing both small (47 μm) and large (120 μm) SiC particles reinforced composite and compared with a single particle size (SPS) of (47μm) reinforced composite. They found that the DPS composite exhibited better wear resistance and impact energy compared to the same volume fraction of SPS composite.
The tensile test is an excellent example of mechanical testing that may be used either to determine the yield strength of a material for use in design calculations or to ensure that the steel complies with a particular set of specifications. There are many types of testing machines. The most common are universal testing machines, which test materials in tension, compression or bending. The primary use of the testing machine is to create the stress-strain diagram. Once the diagram is generated, a pencil and straight edge or computer algorithm can be used to calculate yield strength, Young's Modulus, tensile strength or total elongation (M.Dinesh and R.Ravindran, 2016) [4].
(Madhukiran, Rao and Madhusudan, 2013) [5] Tensile test was carried out as described in American Standard Testing and Measurement (ASTM) method D638, using the associated universal testing machine (FIE) make at crosshead speed of 2.5mm/min using dumbbell test piece. In each case, five specimens were tested to obtain the average value. Each tensile specimen was positioned in the associated universal tester, as the specimen stretched the desired parameters and computer generated graph were recorded until the specimens fractures. A graph of tensile stress versus tensile strain was plotted automatically by the computer.
(Tamilarasan, Karunamoorthy and Palanikumar, 2015) [6]sandwich carbon fibre reinforced aluminium composite material is fabricated as explained above and it is cut into the required shape and dimension using a saw cutter. The edges of composite specimen are finished by using emery paper. The tensile test specimen is prepared according to the ASTM standard as used by many researchers. The process of tensile testing involves fixing the specimen in the machine using proper fixing equipment and the tensile load is applied till the fracture occurs. The tensile force is recorded with respect to the increase in gauge length. The tensile test is carried out on the universal testing machine (make: FIE 11/98-2450).
(Hamid et al., 2008) [7]Ten rectangular specimens were prepared in a split brass mould according to the ADA specification No. 27 for resin- based filling materials. Five specimens (25 ± 2 mm) x (2 ± 0.1 mm) x (2 ± 0.1 mm) were prepared for each material. The uncured materials were placed in the mould and covered by Mylar strips and topped by glass plates from both sides. The Mylar strip smooth finish was used to avoid discrepancies associated with using rotary finishing/polishing procedures. Pressure was applied in order to extrude excess material and produce a flat surface. Each specimen was cured with a visible light curing unit (Elipar ® Highlight, ESPE, curing unit, Germany, light intensity is approximately 800mw /cm_2 and wavelength of 400-500 nm)that was monitored before and after curing using the built-in light tester. Specimens were exposed to curing light for 20seconds according to manufacturer's instructions.
(Senthiil and Sirsshti, 2014) [8]flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed. Since the physical properties of many materials (especially thermoplastics) can vary depending on ambient temperature, it is appropriate to test materials at temperatures that simulate the intended end use environment.

(Mohan and Manoharan, 2015) [9]tensile and impact tests are performed on the aluminium metal matrix composite as per ASTM standard to find their mechanical properties. For tensile test, Universal testing machine is used and the test samples are prepared as per ASTM: B557M, while the samples are prepared as per IS: 1757 standard for carrying out impact test.

(Usman et al., 2014) [10]impact strength test was carried out by preparing the sample on a lathe machine and tested on a Hounsfield Balanced Impact Strength Testing Machine. The sample was inserted into the notch hole and the load was released to impact the specimen while the reading was taken from the scale reading on the machine.

(Venkatesan and Xavior, 2017b) [11]hardness tests were conducted by Brinell hardness tester in accordance to the ASTM E10 standard with the ball indenter diameter 10mm, load applied 500 kg and 20 seconds. The test were carried out in the room temperature atmosphere in the range of 30 to 32°C and measurements of hardness were obtained from five different places on each sample then considered as average hardness value.

(Senthilkumar and Kumar, 2015) [12]Vickers Hardness is a very popular test, which is characterized by a square based diamond pyramid indenter, exactly ground to a standard form with 136 degrees between opposite faces and used to leave a mark in metal under a precisely applied force by taking care to avoid impact: the diagonals of the impression have to be measured using a suitable microscope and the results are either calculated using a given formula (see at the end of this section) or looked up in Tables arranged for each of the forces (loads) used.

(Senthilkumar and Kumar, 2015) [12]The casted specimen is polished and etched as per the standard metallographic procedure. The microstructures of color etched specimens were observed using a scanning electron microscope (SEM). The microstructure of cast aluminum composites reinforced entrapped at the edges of silicon randomly. The presence of reinforced particles in the composite refined the primary silicon crystals while its morphology is relatively unaffected.

(Tamilarasan, Karunamoorthy and Palanikumar, 2015) [6]specimen used for the mechanical testing of carbon fiber reinforced sandwich composite is analyzed by using Scanning Electron Microscope (SEM) JEOL JSM-6480LD. The SEM image observed for the sample subjected to the tensile loading. analysis of the SEM images, it has been noticed that the fiber breakages, fuzzy surface, fiber de-bonding, fiber pull-out and pits are some of the defects, which are observed in the composite specimen. And this is due to the application of the load on the specimen.

(Krishna B and Rao V, 2013) [13] Aluminium reinforced with B_4C particulate composites are successfully fabricated by stir casting process. The optical micrographs of the fabricated AMCs with different particle sizes of B_4C and different wt% of reinforcement of 105µ size are shown. It is observed from the figure that B_4C particles are dispersed uniformly in the aluminium matrix for all particle sizes and for all wt%. This can be attributed to the effective stirring action and the use of appropriate process parameters. XRD analysis confirms the presence of B_4C reinforcement within the matrix.

(Şenel, Gürbüz and Koç, 2017) [2]SEM images and XRD analysis revealed the presence of Si_3N_4 and SiC reinforcement particles in the fabricated aluminum matrix composites. Also, bonding between the particles and a good neck formation were observed at Al-9%Si_3N_4 and Al-30%SiC composites. SiC and Si_3N_4particleswere detected along the aluminum grain boundaries. This approach is confirmed by SEM-EDX analysis.

(Yi et al., 2015) [14]the experimental factors of free variables and surface roughness is converted into matrix form through the test parameter transformation; then coefficient can be found byusing the least squares regression, so the multivariate regression empirical formula between surface roughness and cutting parameters is established. model is checked by using the analysis of variance (ANOVA) technique. As this technique, if the calculated value of the ratio of the developed model does exceed the standard tabulated value of ratio for a desired level of confidence (say 99%), then the model is considered to be adequate within the desired limit ANOVA.

(Anis Micheal Visu.A Nagarajan.A.M, 2014) [15]prepared the six types varying samples including rounded bars and square bars. These final samples are now ready for further testing processes of hardness test, surface roughness test and corrosion test surface roughness of the Al5034 and Al5034+MoO_3 composites was evaluated using surface roughness testing machine. The prepared composites machined in lathe machine. After that the surface roughness testing readings noted. Compare to the Al5034 value the composite have the good surface roughness values.

(Ay, Altunpak and Hartomacioğlu, 2017) [16] experiments were performed at different speeds of 3500, 4000 and 4500 rpm and at feed rates of 350, 400 and 450 mm/min (0.1, 0.13 and 0.16 mm/rev) as given in Table I. The experimental conditions were presented in detail in an earlier publication. Coolant was not used in any of the drilling tests. In the experiment design, there were three parameters at three levels. If the full factorial experimental design used, (3^3) 27 experiments must be conducted. To reduce the number of experiments, the Taguchi L9 orthogonal array was used.
(Bansal and Upadhyay, 2016) [17]observed that tool wear increases with increase in speed (rpm). This is because at higher speed tool- work piece interface temperature increases, softening the tool material. This promotes the abrasive, adhesive and diffusional wear. The tool wear increases with increasing the feed rate. This is because at higher feed rates, greater is the cutting force per unit area of chip-tool contact on the rake face and the work tool contact on the flank face. This increases the cutting temperature and mechanical shock thereby increasing the tool wear. Similarly tools wear increases with increasing the depth of cut. The area of contact increases with increase in depth of cut and accelerating the abrasive adhesive and diffusion type of tool wear.
(Gururaja, Ramulu and Pedersen, 2013) [18]Tool material is also known to affect the cutting forces observed. It observed that cut- ting forces were much larger for WC tools than for 10 mm PCD tools and that the difference increased significantly over tool life. This occurs mainly due to the tendency for WC tools to form a BUE unlike PCDs. Use of flood coolant helps prevent BUE to some extent. Cutting forces have been found to increase as the hardness of the alloy increases due to various heat treatments.

CONCLUSIONS

This review paper explains the present day scenario of the composites as why they are being preferred over natural materials. Number of literature works has been studied and the process is being understood from fabrication of the metal matrix composite to its final testing and analyzing the best out of different numbers. Various literature works explained the method of studying the microstructure of the material and some work showed the optimization technique of the result. Also aluminium composite has to be formed with different constituent particles with different percentages of weight in it. These will increase the number of samples for the particular metal and will give the best result.

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