An Overview on Development of Aluminium Metal Matrix Composites with Hybrid Reinforcement

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Abstract: ***Aluminum alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of applications both from scientific and technological viewpoints. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and Ceramics. This review article is written for initiating new researches on development of aluminium metal matrix composites with hybrid reinforcement.***

Key words: Hybrid reinforcement, Metal Matrix Composites, Desirable properties, Aluminium alloy.

1. Introduction

The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics. The addition of high strength, high modulus refractory particles to a ductile metal matrix produce a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement. [3] Aluminium is the most abundant metal in the Earth's crust, and the third most abundant element, after oxygen and silicon. It makes up about 8% by weight of the Earth's solid surface. Due to easy availability, High strength to weight ratio, easy machinability, durable, ductile and malleability Aluminium is the most widely used non-ferrous metal in 2005 was 31.9 million tonnes[4] .

2. Advantages of Aluminium

A. Light Weight, Strong and Long-lasting

Aluminium is a very light metal with a specific weight of 2.7 gm/cm3, about a third that of steel. For example the use of aluminium in vehicles reduces dead-weight and energy consumption while increasing load capacity. Its strength can be adapted to the application required by modifying the composition of its alloys [6].

B. Highly Corrosion Resistant

Aluminium naturally generates a protective oxide coating and is highly corrosion resistant.

It is particularly useful for applications where protection and conservation are required [6].

C. Excellent Heat and Electricity Conductor

Aluminium is an excellent heat and electricity conductor and in relation to its weight is almost twice as good a conductor as copper. This has made aluminium the most commonly used material in major power transmission lines[5].

D. Good Reflective Properties

Aluminium is a good reflector of visible light as well as heat, and that together with its low weight makes it an ideal material for reflectors, for example, light fittings or rescue blankets[5].

E. Very Ductile

Aluminium is ductile and has a low melting point and density. In a molten condition it can be processed in a number of ways. Its ductility allows products of aluminium to be basically formed close to the end of the product [5].

F. Completely Impermeable and Odourless

Aluminium foil, even when it is rolled to only 0.007 mm thickness, is still completely impermeable and let’s neither light aroma nor taste substances out. Moreover, the metal itself is non-toxic and releases no aroma or taste substance which makes it ideal for packaging sensitive products such as food or pharmaceuticals[5].

G. Totally Recyclable

Aluminium is 100 percent recyclable with no downgrading of its qualities. The re-melting of aluminium requires little energy: only about 5 percent of the energy required to produce the primary metal initially is needed in the recycling process. Pure Aluminium has also some limits according to properties so to enhance Aluminium properties aluminium alloys are used [6].

3. Aluminium Alloys

Selecting the right alloy for a given application entails considerations of its tensile strength, density, ductility, formability, workability, weld ability, and corrosion resistance. Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc.

There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminium alloys yield cost effective products due to its low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminium alloy system is Al-Si, where the high levels of silicon (4.0% to 13%) contribute to give good casting characteristics. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required. Wrought **aluminium** alloys are used in the shaping processes: rolling, forging, extrusion, pressing, stamping. Cast Aluminium alloys are comes after sand casting, permanent mould casting, die casting, investment casting, centrifugal casting, squeeze casting and continuous casting. Aluminium alloys are classified as shown in Figure 1[13].

Aluminum Alloy	*Common Use*
1050/1200	Food and Chemical Industry
2014	Airframes
5251/5052	Vehicle panelling, structures exposed to marine atmospheres, mine cages.
6063	Architectural extrusions (internal and external) window frames, irrigation pipes.
6061/6082	Stressed structural members, bridge cranes, roof trusses, beer barrels.
7075	Armoured vehicles, military bridges motor cycle and bicycle frames.

Table 1: Application of Aluminium alloys [7]

4. Desirable properties of metal

A. 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[8].

A typical engineering stress-strain curve is shown below Figure 1.18. If the true stress, based on the actual cross-sectional area of the specimen, is used, it is found that the stress-strain curve increases continuously up to fracture. They are tabulated for common materials such as alloys, composite materials, ceramics, plastics, and wood, tensile strength is measured as force per unit area[8].

a) Yield Point

In ductile materials, at some point, the stress-strain curve deviates from the straight-line relationship and Law no longer applies as the strain increases faster than the stress. From this point on in the tensile test, some permanent deformation occurs in the specimen and the material is said to react plastically to any further increase in load or stress. The material will not return to its original, unstressed condition when the load is removed. In brittle materials, little or no plastic deformation occurs and the material fractures near the end of the linear-elastic portion of the curve [8].

With most materials there is a gradual transition from elastic to plastic behaviour, and the exact point at which plastic deformation begins to occur is hard to determine. Therefore, various criteria for the initiation of yielding are used depending on the sensitivity of the strain measurements and the intended use of the data. For most engineering design and specification applications, the yield strength is used. The yield strength is defined as the stress required producing a small, amount of plastic deformation. The offset yield strength is the stress corresponding to the intersection of the stress-strain curve and a line parallel to the elastic part of the curve offset by a specified strain (in the US the offset is typically 0.2% for metals and 2% for plastics). To determine the yield strength using this offset, the point is found on the strain axis (x-axis) of 0.002, and then a line parallel to the stress-strain line is drawn. This line will intersect the stress-strain line slightly after it begins to curve, and that intersection is defined as the yield strength with a 0.2% offset. A good way of looking at offset yield strength is that after a specimen has been loaded to its 0.2 percent offset yield strength and then unloaded it will be 0.2 percent longer than before the test. Even though the yield strength is meant to represent the exact point at which the material becomes permanently deformed, 0.2% elongation is considered to be a tolerable amount of sacrifice for the ease it creates in defining the yield strength [8]. Some materials such as gray cast iron or soft copper exhibit essentially no linear-elastic behaviour. For these materials the usual practice is to define the yield strength as the stress required to produce some total amount of strain.

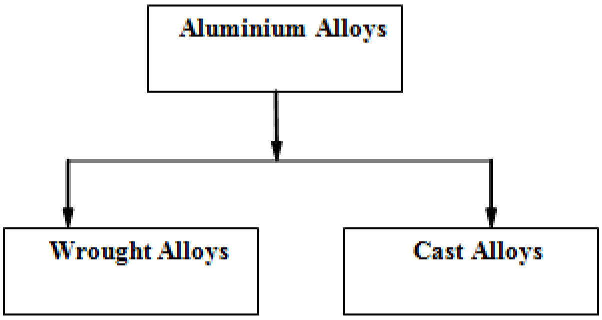

Figure 1: Classification of Alloys

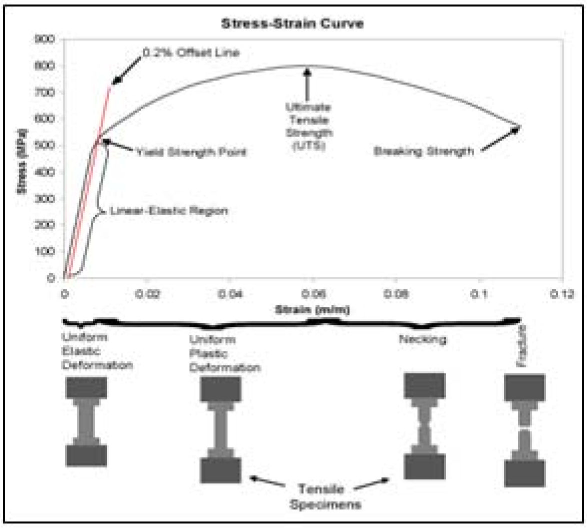

Figure 2: Stress Strain Curve [12]

True elastic limit is a very low value and is related to the motion of a few hundred dislocations. Micro strain measurements are required to detect strain on order of 2 x 10 -6 in/in.

Proportional limit is the highest stress at which stress is directly proportional to strain. It is obtained by observing the deviation from the straight-line portion of the stress-strain curve.

Elastic limit is the greatest stress the material can withstand without any measurable permanent strain remaining on the complete release of load. It is determined using a tedious incremental loading-unloading test procedure. With the sensitivity of strain measurements usually employed in engineering studies (10 - 4in/in), the elastic limit is greater than the proportional limit. With increasing sensitivity of strain measurement, the value of the elastic limit decreases until it eventually equals the true elastic limit determined from micro strain measurements.

Yield strength is the stress required to produce a small-specified amount of plastic deformation. The yield strength obtained by an offset method is commonly used for engineering purposes because it avoids the practical difficulties of measuring the elastic limit or proportional limit.[8]

b) 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. The strength of a material is its ability to withstand external forces without breaking. In brittle materials, the UTS will at the end of the linear-elastic portion of the stress-strain curve or close to the elastic limit. In ductile materials, the UTS will be well outside of the elastic portion into the plastic portion of the stress-strain curve. On the stress-strain curve above, the UTS is the highest point where the line is momentarily flat. Since the UTS is based on the engineering stress, it is often not the same as the breaking strength. In ductile materials strain hardening occurs and the stress will continue to increase until fracture occurs, but the engineering stress-strain curve may show a decline in the stress level before fracture occurs. This is the result of engineering stress being based on the original cross-section area and not accounting for the necking that commonly occurs in the test specimen. The UTS may not be completely representative of the highest level of stress that a material can support, but the value is not typically used in the design of components anyway [8].

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.

c) Measures of Ductility (Elongation and Reduction of Area)

The ductility of a material is a measure of the extent to which a material will deform before fracture. The amount of ductility is an important factor when considering forming operations such as rolling and extrusion. It also provides an indication of how visible overload damage to a component might become before the component fractures. Ductility is also used a quality control measure to assess the level of impurities and proper processing of a material.

The conventional measures of ductility are the engineering strain at fracture (usually called the elongation) and the reduction of area at fracture. Both of these properties are obtained by fitting the specimen back together after fracture and measuring the change in length and cross-sectional area. Fracture or breaking Point of ductile or brittle material is shown in Figure.3

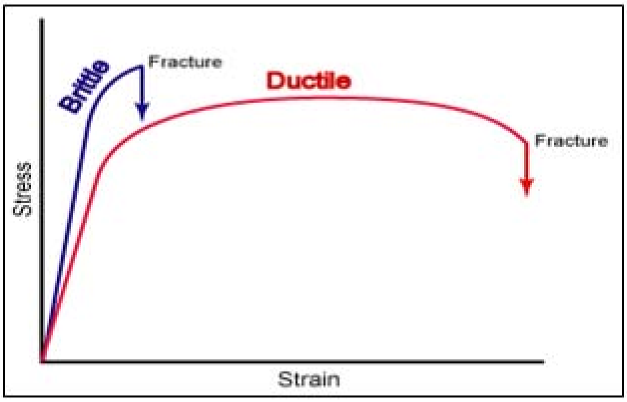

Figure 3: Fracture Point of Ductile and Brittle material[8]

Elongation is the change in axial length divided by the original length of the specimen or portion of the specimen. It is expressed as a percentage. Because an appreciable fraction of the plastic deformation will be concentrated in the necked region of the tensile specimen, the value of elongation will depend on the gage length over which the measurement is taken. The smaller the gage length the greater the large localized strain in the necked region will factor into the calculation. Therefore, when reporting values of elongation, the gage length should be given. One way to avoid the complication from necking is to base the elongation measurement on the uniform strain out to the point at which necking begins. This works well at times but some engineering stress-strain curve are often quite flat in the vicinity of maximum loading and it is difficult to precisely establish the strain when necking starts to occur. Reduction of area is the change in cross-sectional area divided by the original cross-sectional area. This change is measured in the necked down region of the specimen. Like elongation, it is usually expressed as a percentage. [8]

B. Hardness

Hardness is the resistance of a material to localized deformation. The term can apply to deformation from indentation, scratching, cutting or bending. In metals, ceramics and most polymers, the deformation considered is plastic deformation of the surface. For elastomers and some polymers, hardness is defined at the resistance to elastic deformation of the surface. The lack of a fundamental definition indicates that hardness is not be a basic property of a material, but rather a composite one with contributions from the yield strength, work hardening, true tensile strength, modulus, and others factors. 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. A few of the more common methods are introduced below[1].

C. Toughness

The ability of a metal to deform plastically and to absorb energy in the process before fracture is termed toughness. The emphasis of this definition should be placed on the ability to absorb energy before fracture. Recall that ductility is a measure of how much something deforms plastically before fracture, but just because a material is ductile does not make it tough. The key to toughness is a good combination of strength and ductility. A material with high strength and high ductility will have more toughness than a material with low strength and high ductility. Therefore, one way to measure toughness is by calculating the area under the stress strain curve from a tensile test. This value is simply called “material toughness” and it has units of energy per volume. Material toughness equates to a slow absorption of energy by the material.

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[14].

Impact Toughness of a material can be determined with a Charpy or Izod test. Impact properties are not directly used in fracture mechanics calculations, but the economical impact tests continue to be used as a quality control method to notch sensitivity and for comparing the relative toughness of engineering materials. For both tests, the specimen is broken by a single overload event due to the impact of the pendulum. A stop pointer is used to record how far the pendulum swings back up after fracturing the specimen. The impact toughness of a metal is determined by measuring the energy absorbed in the fracture of the specimen.

This is simply obtained by noting the height at which the pendulum is released and the height to which the pendulum swings after it has struck the specimen. The height of the pendulum times the weight of the pendulum produces the potential energy and the difference in potential energy of the pendulum at the start and the end of the test is equal to the absorbed energy. Since toughness is greatly affected by temperature, a Charpy or Izod test is often repeated numerous times with each specimen tested at a different temperature. This produces a graph of impact toughness for the material as a function of temperature.

Impact toughness versus temperature graph for steel is shown in the Figure 1.20. It can be seen that at low temperatures the material is more brittle and impact toughness is low. At high temperatures the material is more ductile and impact toughness is higher. Izod Charpy test machine is used in Figure.5 [16].

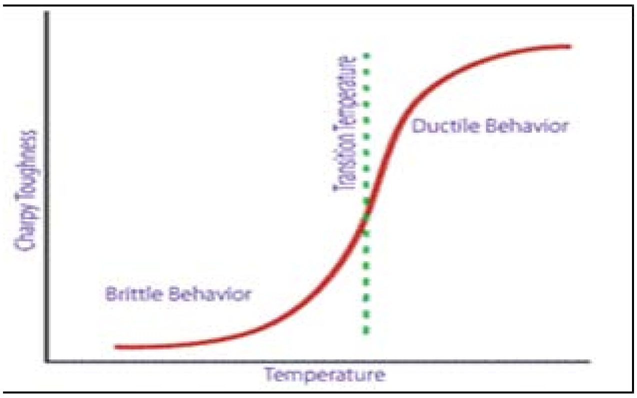

Figure 4: Temperature Vs Toughness Graph [16]

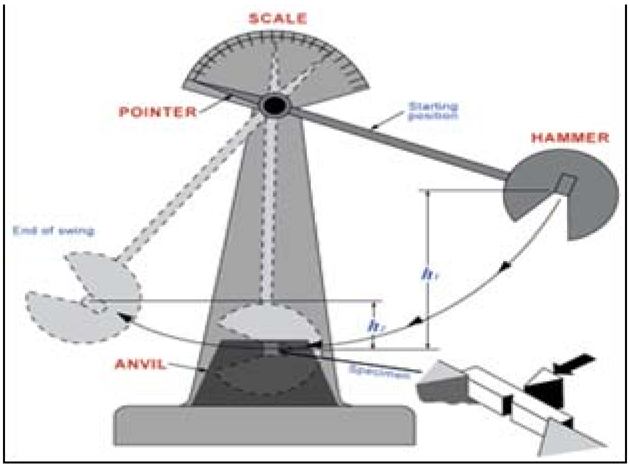

Figure 5: Izod Charpy Test Machine [16]

D. 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. Most of this is replacing or repairing equipment that has worn to the extent that it no longer performs a useful function. For many machine components this occurs after a very small percentage of the total volume has been worn away. For some industries, such as agriculture, as many as 40% of the components replaced on equipment have failed by abrasive wear. So, the effective decrease and control of wear of metals are always desired [14].

Types of Wear

In most basic wear studies where the problems of wear have been a primary concern, the so-called dry friction has been investigated to avoid the influences of fluid lubricants. Dry friction is defined as friction under not intentionally lubricated conditions but it is well known that it is friction under lubrication by atmospheric gases, especially by oxygen. There are generally five types of wear namely abrasive, adhesive, erosive, Surface fatigue and Corrosive[14].

E. 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].

5. Stir Casting Method of Fabrication of MMC

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring as shown in figure. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies[11].

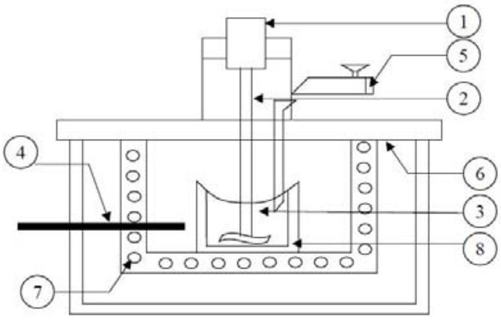

Figure6: Schematic view of setup for Fabrication of AMC via stir casting technique

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

Distribution of dispersed phase throughout the matrix is not perfectly homogeneous. There are local clouds (clusters) of the dispersed particles (fibers). There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase. The technology is relatively simple and low cost [11].

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 [11].

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 [11].

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 [17].

Mould temperature

The use of metal die produces marked refinement when compared with sand cast but mould temperature is only of secondary importance in relation to the structure formation. Its principal signification lies in the degree of expansion of the die with preheating. Expansion diminishes the risk of tearing in casting. In nonferrous castings, the mould temperature should neither be too low or too high. The mould should be at least 25 mm thick with the thickness increasing with size and weight of casting [17].

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.

Mould life

Metal mould in casting is subjected to thermal stresses due to continuous operation. This may lead to failure of the mould. The magnitude of the stresses depends on the mould thickness and thickness of the coating layer, both of which influence the production rate. Deterioration takes place faster in cast iron mould than in steel mould [17].

7. Wettability between Reinforcement and Matrix Alloy

Wettability can be defined as the ability of a liquid to spread on a solid surface. It also describes the extent of intimate contact between a liquid and a solid. Successful incorporation of solid ceramic particles into casting requires that the melt should wet the solid ceramic phase. The basic means used to improve wetting are

(a) Increasing the surface energies of the solid,
(b) Decreasing the surface tension of the liquid matrix alloy,
(c) Decreasing the solid-liquid interfacial energy at the particles-matrix

Several approaches have been taken to promote the wetting of the reinforcement particles with a molten matrix alloy, including the coating of the particles, the addition of alloying elements to the molten matrix alloy, the treatment of the particles, and ultrasonic irradiation of the melt. In general, the surface of non-metallic particles is not wetted by the metallic metal, regardless of the cleaning techniques carried out. Wetting has been achieved by coating with a wet table metal. Metal coating on ceramic particles increases the overall surface energy of the solid, and improves wetting by enhancing the contacting interface to metal-metal instead of metal-ceramic [13].

Nickel and copper are well wetted by many alloys and have been used for a number of low melting alloys. In general, these coatings are applied for three purposes, viz., to protect the reinforcement from damage in handling, to improve wetting, and to improve dispensability before addition to the matrix.

Heat treatment of the particles before dispersion into the melt aids their transfer by causing desorption of adsorbed gases from the particle surface. Heating Silicon Carbide particles to 900oC, for example, assists in removing surface impurities and in the desorption of gases, and alters the surface composition by forming an oxide layer on the surface. Hence a clean surface provides a better opportunity for melt-particles interaction, and thus, enhances wetting. Thus results in strong interfacial bonding [9].

8. Previous Research

S.V. Prasad et al.[14] developed affordable Al MMCs, reinforced with SiC and Al2O3, that reduced the weight and increase the engine efficiency, and thereby reduced fuel consumption and vehicle emissions. Considerable reduction in wear and friction is achieved by use of these particulates. Furthermore, increased cylinder pressures (and therefore, higher engine performance) are possible because Al MMCs can withstand high mechanical and thermal loads, and reduce heat losses by permitting closer fit that can be achieved because of lower thermal expansion coefficient of Aluminium MMCs.

G. B. Veeresh Kumar1 et al.[2] examined the base matrix and the reinforcing phase were AA 6061, AA 7075 and particles of Al2O3 and SiC of size 20 µm. It is observed that the densities of composites are higher than that of their base matrix, further the density increases with increased percentage of filler content in the composites. It is observed that the tensile strength of the composites is higher than that of their base matrix also it can be observed that the increase in the filler content contributes in increasing the tensile strength of the composite. In microstructure studies it is observed that, the distributions of reinforcements in the respective matrix are fairly uniform.

Sanjeev Kumar et al. [12] investigated the effects of Thermal Cycling on Cast Aluminium Composites Reinforced with Silicon Carbide and Fly Ash particles. During this investigation, dry fly ash was used with Aluminium reinforced with SiC and a composite was prepared using Liquid metal stir casting route with the reducing quantity of SiC. During the research, Thermal cycling was carried out on the samples prepared and effects on samples before and after thermal cycling were observed and found improvement.

Vishal Sharma et al.[18] investigated the effect of Al-4.5wt%Cu/ zircon sand/ SiC hybrid composite by stir casting route by controlling various casting parameters. The as-cast samples were observed under optical and scanning electron microscope. Micro structural observations of the as-cast hybrid composite, shows uniform distribution of reinforcement particles and also good interfacial bonding between the particles and the matrix. Micro hardness tester is employed to evaluate the interfacial bonding between the particles and the matrix by indenting the micro hardness indenter on the particle with the varying load (100 gm, 200 gm, and 300 gm) and time (10 sec, 15 sec, 20 sec and 25 sec). It has been concluded that by the variation in hardness at constant load varying time or at constant time varying load, the bond strength can be compared.

G.B.Veeresh Kumar et al.[2] this paper deals with the mechanical properties such as hardness, tensile strength and wear resistance etc. of Al6061-SiC and Al7075-Al2O3 composites. The composites are prepared using the liquid metallurgy technique, in which 2-6 wt. % of particulates was dispersed in the base matrix in steps of 2. The SiC and Al2O3 resulted in improving the hardness and density of their respective composites. Further, the increased %age of these reinforcements contributed in increased hardness and density of the composites. The microphotographs of the composites studied revealed the uniform distribution of the particles in the matrix system. The dispersed SiC in Al6061 alloy and Al2O3 in Al7075 alloy contributed in enhancing the tensile strength of the composites. The wear factor K obtained using computerized pin on disc wear tester with counter surface as EN31 steel disc (HRC60) and the composite pin as specimens, demonstrated the superior wear resistance property of the composites.

Sanjeev Das et al. [10] observed the effect of alumina and Zircon sand particles of different size and amount have been incorporated in Al-4.5 wt% Cu alloy by stir casting route. It is basically a comparative study on abrasive wear behaviour of aluminium metal matrix composite reinforced with alumina and zircon sand particles has been carried out. Microstructures of the composites in as-cast condition show uniform distribution of particles and reveal better bonding in the case of zircon particles reinforced composite compared to that in alumina particles reinforced composite also studied in this. Abrasive wear resistance of both the composites improves with the decrease in particle size. It is observed that the alumina particle reinforced composite shows relatively poor wear resistance property compared to zircon-reinforced composite.

9. Conclusion

The following conclusions can be drawn from the present review:

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. With the addition of hybrid reinforcement instead of single reinforcement the hardness, toughness, strength, corrosive and wear resistance of the composite will be increasing further increased.

References

[1] D Tabor, “The hardness of metals” Oxford University Press,1951

[2] G.B.Veeresh Kumar, “Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites”, Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, pp.43-55, 2010.

[3] Hashim J et al., “Metal matrix composites: production by the stir casting method”, Journal of Materials Processing Technology 92-93 (1999) 1-7.

[4] http://en.wikipedia.org/wiki/Aluminium.htm on date1/4/2011

[5] http://www.eaa.net/eaa/education/TALAT/index.htm on date6/5/2011.

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

[7] J. R. Davis, “Aluminium and aluminium alloys”, ASM International, 1993

[8] N.Chawla et al, “Tensile and fatigue fracture of Discontinuously Reinforced Aluminium” D, Advances in Fracture Research, (2001), pp. 1-6.

[9] Nigamanada ray, Dilipkumarkerketta, “Some Studies on Aluminium Matrix in Situ Composites Produced by Stir Casting Method”, ME Thesis NIT Rourkela, 2010.

[10] Sanjeev Das, Siddhartha Das, Karabi Das, “Abrasive wear of zircon sand and alumina reinforced Al–4.5 wt% Cu alloy matrix composites – A comparative study”, Journal of Science direct, pp. 746-751, June 2006.

[11] Sanjeev Das V. Udhayabanu S. Das K. Das, “Synthesis and characterization of Zircon Sand/Al-4.5 wt% Cu Composite produced by Stir Casting Route”, J Mater Sci (2006) 41:4668–4677.
[12] Sanjeev kumar and Bikramjit Sharma, “Effects of Thermal Cyclic loading on Cast Aluminium Composite Reinforced with Silicon Carbide and Fly Ash Particles”, M.E.Thesis, Thapar University, Patiala, India, July 2010.
[13] Seymour G. Epstein, “Aluminium and Its Alloys”, the Aluminium Association, Inc. 2001
[14] S.V. Prasad, “Aluminium metal–matrix composites for automotive applications: tribological considerations”, Tribology Letters, Vol. 17, No. 3, October 2004.
[15] Subhakantasarangi, Deepak kumar, “Fabrication and characterisation of Aluminium-fly Ash composite using Stir Casting method”, ME Thesis, NIT Rourkela, 2009.
[16] Toshiro Kobayashi,” Springer, 2004 - Technology & Engineering - 275 pages”
[17] T. P. D. Rajan, R.M. Pillai, B.C. Pai, K.G. Satyanarayana, P.K. Rohatgi, “Fabrication and characterisation of Al–7Si–0.35Mg/fly ash metal matrix composites processed by different stir casting routes”, Composites Science and Technology 67 (2007) 3369–3377.
[18] Vishal Sharma and Sanjeev Das, “Synthesis and Interfacial Characterization of Al- 4.5wt%Cu/ Zircon Sand/ Silicon Carbide Hybrid Composite”, Department of Physics and Materials Sciences, M.E. Thesis, Thapar University, Patiala, India, June 2007.

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